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Technical Memorandum 10.1

Groundwater Modeling Analysis

for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

18 April 2012

Prepared for

San Francisco Public Utilities Commission
525 Golden Gate Avenue, 10th Floor
San Francisco, CA 94102

K/J Project No. 0864001

Supplemental Explanation for Hydrographs - TM10.1

This supplemental explanation is prepared to address discrepancies on several graphs presented in TM 10.1.

First, the x-axis on several graphs showing model results was shifted. The x-axis is named Scenario Year which should correspond to a water year[1]. However, the graph template was plotted using a calendar year, so the intervals on the x-axis represent the period from January to December. The result is that the graph is shifted 3-months later relative to Scenario Year.

Second, the shaded area representing the Design Drought was added manually and because of this process, it was not presented consistently on the graphs. By definition per the PEIR, the 8.5-year Design Drought includes one Hold year before the 7.5-year Take period. In addition, the Design Drought needs to be shifted 3-months later for the x-axis issue to be consistent with the model output. The Design Drought should be shown as Scenario Years 35.5 to 44.0 on the shifted x-axis.

The following is a list of figures in TM 10.1 where the Design Drought shaded area is shown slightly different and does not match the correct display of the Design Drought. The figures should be viewed based on the correct representation of the Design Drought as explained above.

- Figures 10.1-6 through 10.1-13 (a total of eight figures) have the shifted x-axis. The Design Drought should be shown as Scenario Years 35.5 to 44.0 on the shifted x-axis.
- Attachment 10.1-B hydrographs with model simulated groundwater levels have the shifted x-axis. The Design Drought should be shown as Scenario Years 35.5 to 44.0 on the shifted x-axis.
- Attachment 10.1-G graphs showing model simulated lake levels have the shifted x-axis. The Design Drought should be shown as Scenario Years 35.5 to 44.0 on the shifted x-axis.

[1] A water year is October 1 of the previous year to September 30 of the current (named) year.

18 April 2012

Task 10.1 Technical Memorandum

San Francisco Public Utilities Commission

Groundwater Modeling Analysis for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

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1. Introduction

This Technical Memorandum (TM) was prepared to document work performed by Kennedy/Jenks Consultants (Kennedy/Jenks) for the San Francisco Public Utilities Commission (SFPUC) pursuant to the amended Task Order (TO) authorizations CUW30103-TO-1.12 of the Regional Groundwater Storage and Recovery (GSR) Project and CUW30102-TO-2.7 of the San Francisco Groundwater Supply (SFGW) Project. These projects are funded by the SFPUC's Water System Improvement Program (WSIP).

1.1. Purpose

The main purpose of this TM is to document the setup and application of the groundwater modeling analysis being prepared to evaluate groundwater issues for the GSR and SFGW Projects. For evaluating conditions at Lake Merced, the Lake Merced Lake-Level Model (refer to as the Lake-Level Model) was also used as the primary tool. The existing Westside Basin Groundwater-Flow Model (referred to as the Westside Basin Groundwater Model) (HydroFocus 2007, 2009, and 2011) was used as a quantitative tool to support analyses necessary for the groundwater issues that may occur during the implementation of the proposed GSR and SFGW Projects. The specific objectives of this TM are as follows:

- To provide a brief overview of the existing Westside Basin Groundwater Model and the Lake-Level Model
- To present the model scenario assumptions and modifications made to the model to develop the model scenarios
- To present and evaluate the results from the simulated model scenarios

This TM documents how the model was applied and provides an assessment for the application of the model results to specific groundwater issues that may result from the implementation of the proposed GSR and SFGW Projects. The evaluation of the model results with respect to these potential groundwater issues are presented in separate TMs listed below.

- Task 10.2 Assessment of Groundwater-Surface Water Interactions for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project
- Task 10.3 Assessment of Seawater Intrusion for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project
- Task 10.4 Changes in Groundwater Levels and Storage for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project
- Task 10.5 Assessment of Pumping Induced Land Subsidence for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project
- Task 10.6 Assessment of Changes in Groundwater Quality for the Regional Groundwater Storage and Recovery Project
- Task 10.7 Well Interference Analysis for the Regional Groundwater Storage and Recovery Project and Cumulative Analysis
- Task 10.8A Updated Analysis of Well Pumping Influences for the San Francisco Groundwater Supply Project and Cumulative Analysis

1.2. General Approach

The overall scope of Task 10.1 was to model scenarios by applying the previously-developed Westside Basin Groundwater Model, by HydroFocus (2007, 2009, and 2011), as a supporting tool to assess potential physical effects that may result from the GSR and SFGW Project operations. The Westside Basin Groundwater Model is a regional, basin-wide groundwater model of the Westside Groundwater Basin (Westside Basin) in western San Francisco and San Mateo County. The Westside Basin Groundwater Model developed by HydroFocus (2007, 2009, and 2011) for the City of Daly City (Daly City) was reviewed with assistance from the California Water Services Company (Cal Water), the City of San Bruno (San Bruno) and SFPUC, and the model was accepted for use in selected applications by all parties. Therefore, the Westside Basin Groundwater Model is a publicly available tool that is capable of supporting water resources planning and management on an ongoing basis (HydroFocus 2007, 2009, and 2011).

The Lake-Level Model is a spreadsheet based water balance model that has been used for evaluating conditions at Lake Merced. The model has been used for various studies of Lake Merced by EDAW, Inc., and Talavera & Richardson (2004), LSCE (2008), Kennedy/Jenks (2009a, and 2009b), and Jacobs Associates (2011a and 2011b).

The hydrogeological conceptual model that forms the basis for the Westside Basin Groundwater Model is based on the *Task 8B Technical Memorandum No.1 Hydrologic Setting of the Westside Basin* (TM#1) (LSCE, 2010). A summary of the hydrogeological conceptual model is presented in this TM to provide the context necessary for evaluating the model assumptions and setup.

Five model scenarios were constructed and simulated to evaluate potential groundwater and related hydrological effects from the GSR and SFGW Projects and from the cumulative scenario, which involves the GSR and SFGW Projects and other reasonably foreseeable future projects (e.g., the Vista Grande Drainage Basin Improvements Project as assessed by Jacobs Associates (2011a, 2011b) and the City of Daly City (2012)). The proposed GSR and SFGW Project pumping assumptions were incorporated into the groundwater model scenarios to evaluate the response of the model to projected pumping conditions under the proposed projects and the cumulative scenario and to analyze long-term regional basin-wide changes in groundwater levels and storage. The Lake-Level Model was applied to the five scenarios to evaluate potential groundwater-surface water interactions resulting from the proposed projects and the cumulative scenario.

The activities undertaken in Task 10.1 are summarized below:

- **Documentation of Model Scenario Assumptions** – The proposed five model scenarios simulated include Scenario 1 (also referred to as Existing Conditions without SFPUC Projects), Scenario 2 (GSR Project), Scenario 3a and Scenario 3b (SFGW Project), and Scenario 4 (Cumulative Scenario). Model assumptions for the five scenarios were developed. Potential model modifications to the recently updated Westside Groundwater Model were evaluated, particularly with respect to assumptions regarding pumping and recharge resulting from the hydrological data used in the model scenarios.
- **Model Scenario Simulations** – This included setting up, running, and post-processing the five proposed model scenarios using the Westside Basin Groundwater Model. The model setup and model assumptions used in the five model scenarios are described in Sections 5 and 6.

  During the development of the proposed future model scenarios, modeling assumptions and modifications were reviewed and approved by SFPUC prior to running the model scenarios. In addition, the major model assumptions that were used in the scenarios were presented to the Partner Agencies (PAs) for the GSR Project (Daly City, Cal Water, and San Bruno), and the San Francisco Planning Department, Environmental Planning Division (EP) for their review and approval prior to running the model for each scenario.
- **Lake Merced Lake-Level Model Scenario Simulations** – The Lake-Level Model has been developed by SFPUC and others for the purpose of evaluating the feasibility of potential future projects on maintaining lake level in Lake Merced. Because of this history of use, the Lake-Level Model was used as the primary tool to evaluate the effects of the GSR and SFGW Projects and other reasonably foreseeable future projects on Lake Merced. The Lake-Level Model is a spreadsheet-based water balance model and offers a more realistic conceptualization of the water balance of the lake than the MODFLOW model. The model has been calibrated to historical measured lake levels and applied in this analysis to simulate the five scenarios that involve the GSR and SFGW Project scenarios and other reasonably foreseeable future projects. The model development, assumptions, and modifications are described in Section 8.

A brief overview of the proposed GSR and SFGW Projects and the hydrogeologic setting in the Westside Basin are presented in Sections 2 and 3, respectively. The Westside Basin Groundwater Model is the primary tool used for evaluating the effects of the SFGW, GSR and other reasonably foreseeable future projects with respect to key groundwater issues. The discussion in Sections 4, 5, 6 and 7 focuses on the Westside Basin Groundwater Model. The Lake-Level Model is only used to evaluate the effects of the GSR and SFGW Projects and other reasonably foreseeable future projects on Lake Merced lake levels. Section 8 presents the development and application of the Lake-Level Model for easier reference.

2. GSR and SFGW Project Description

This section provides brief background information on the proposed projects that are considered as part of the model scenarios presented in this TM. The proposed projects include the GSR and SFGW Projects, and other reasonably foreseeable future projects that are considered as part of the Cumulative Scenario.

2.1. GSR Project

The GSR Project is a conjunctive use project that would increase groundwater supplies in the southern portion of the Westside Basin during periods of drought when SFPUC surface water supplies become limited (MWH, 2008). The GSR Project is based on the concept of providing available supplemental surface water from the SFPUC Regional Water System to the PAs. This water would be used by the PAs instead (or "in-lieu") of pumping groundwater from the Westside Basin, thereby increasing the amount of groundwater that would be stored in the aquifer. During periods of drought, both the PAs and SFPUC would pump groundwater from the Westside Basin. The SFPUC plans to install 16 new production wells for the GSR Project to recover the stored groundwater.

The GSR Project is sponsored by SFPUC in coordination with the PAs. The PAs historically have pumped groundwater from the southern portion of the Westside Basin (referred to as the South Westside Basin) for municipal purposes. Daly City and San Bruno serve municipal water demand in their respective cities. Cal Water serves South San Francisco, Colma, and a very small part of Daly City.

For SFPUC, the GSR Project will ultimately develop enough groundwater pumping capacity to produce 8,100 acre-feet per year (afy), or 7.2 million gallons per day (mgd), in addition to groundwater extraction from existing PA wells (MWH, 2008). The project will be designed to provide up to 60,500 acre-feet (af) of stored water from the GSR Project wells to meet SFPUC system demands during the last 7.5 years of SFPUC's Design Drought. The total duration of the Design Drought is 8.5 years. SFPUC anticipates that it will exercise its dry-year supplies after the first year of drought. Therefore, the storage is assumed to be used over the last 7.5 years of the Design Drought. The combined pumping rate (7.2 mgd) and duration (7.5 years) are consistent with the SFPUC's dry-year demands as described in the Urban Water Management Plan (SFPUC, 2010).

The SFPUC and PAs have developed the Draft GSR Project Operating Agreement (Draft GSR Operating Agreement) that is summarized in Attachment 10.1-A. The Draft GSR Operating Agreement can only be approved if the San Francisco Planning Commission certifies the Project Environmental Impact Report (EIR) and the SFPUC as the project sponsor approves the project. Following these actions, the SFPUC, Daly City, Cal Water, and San Bruno can then consider approval of the GSR Operating Agreement.

Under the Draft GSR Operating Agreement, the SFPUC would "store" water in the South Westside Basin through the mechanism of in-lieu recharge by providing supplemental surface water to the PAs as a substitute for the PAs groundwater pumping. The supplemental water deliveries would result in up to 60,500 af of "put" credits that would accrue to the SFPUC Storage Account. During shortages of SFPUC system water due to drought, emergencies or scheduled maintenance, or if the SFPUC Storage Account is at its full capacity of 60,500 af, the PAs would return to pumping from their existing wells. If a positive balance exists in the SFPUC Storage Account and there is a drought, then the SFPUC could also pump during this take period using the GSR Project wells installed by the SFPUC.

2.1.1. Put/Take/Hold Sequence

The GSR Project uses a “put/take/hold” sequence representing in-lieu groundwater recharge during wet years and groundwater extraction during dry years. The Hetch Hetchy and Local Simulation model (HH/LSM), which was used extensively for long term planning purposes in the SFPUC’s WSIP Program Environmental Impact Report (PEIR), outputs a put/take/hold sequence on a monthly basis together with a track of the volume of water stored in the SFPUC Storage Account (SFPUC, 2007; SFPUC, 2009a). As described below, the SFPUC Storage Account defines the amount of supplemental SFPUC system water that is stored in the groundwater basin, based on the amount of supplemental surface water deliveries to the PAs. The PEIR underpins the WSIP as a whole, and any individual WSIP project (including the GSR and SFGW Projects) must be as consistent with the PEIR as is practicable.

For reference, put/take/hold periods within the HH/LSM monthly sequence and this TM are defined as follows:

- A put period is a period where there are no water shortages and there is sufficient capacity in the SFPUC Storage Account for that account to be recharged. During put periods, the PAs would receive supplemental surface water from the SFPUC and reduce their groundwater pumping. As a result, the SFPUC surface water would be used “in-lieu” of groundwater pumping, and the reduced pumping would effectively increase the volume of groundwater in storage that would be available during dry years or an extended drought.
- A take period is a dry period when water shortages are triggered and water is taken from the SFPUC Storage Account. During these take periods, both the proposed GSR Project wells and the PA wells would extract groundwater. The SFPUC would recover groundwater that has already been “stored” or “banked” during put periods by pumping the proposed 16 GSR Project production wells in the South Westside Basin. In addition, the PAs would return to their typical groundwater pumping.
- A hold period is a period where there are no water shortages, but the SFPUC Storage Account is “full” and supplemental water deliveries do not occur. During hold periods, the PAs would return to their typical groundwater pumping, and the GSR Project wells would pump only small amounts to exercise the wells.
- In the PEIR, the put/take/hold conditions are defined as annual periods that run from July 1 to June 30 of the following calendar year. Therefore, the model scenarios start in July to simulate full annual put, take, or hold sequence.

2.1.2. SFPUC Storage Account

The SFPUC Storage Account represents the volume of water that is stored during put periods as defined by the amount of supplemental surface water deliveries made to the PAs. The in-lieu recharge is assumed to match the amount of supplemental water deliveries to the PAs with no losses in the SFPUC Storage Account except during take periods of groundwater pumping. Accruals in the SFPUC Storage Account would be recorded based on metered, in-lieu surface water deliveries and corresponding metered decreases in groundwater pumping below "designated quantities" agreed to by the PAs (Attachment 10.1-A).

A "Full SFPUC Storage Account" represents approximately 60,500 af of supplemental surface water deliveries to the PAs that are stored (or banked) in the basin in-lieu of groundwater pumping. This amount is based upon the designed operation of the GSR Project supplying an average of 7.2 mgd over the Design Drought (MWH, 2008). When 60,500 af of groundwater is stored in the basin, the SFPUC Storage Account would be considered full, and no additional supplemental water deliveries would occur.

The SFPUC has developed an 8.5-year Design Drought for planning purposes. Over this 8.5-year period, the SFPUC anticipates it will exercise its dry year supplies after the first year of the drought. Therefore, the 60,500 af of storage is assumed to be used over the 7.5 years of the Design Drought, with the GSR Project wells operating at a maximum capacity of 7.2 mgd.

The GSR Project and the Cumulative Scenario involve the Full SFPUC Storage Account of 60,500 af to maintain consistency of analysis with the PEIR studies and the assumptions made in the HH/LSM runs (SFPUC, 2007; SFPUC, 2009a). To achieve the Full SFPUC Storage Account, the model scenarios involving the GSR Project simulate the PA wells pumping at their reduced put period rates until the in-lieu recharge banked in the basin reaches the Full SFPUC Storage Account of 60,500 af. This amount includes the existing SFPUC Storage Account of approximately 20,000 af[1] at the beginning of the simulation (i.e., June 2009 initial conditions), and then adds approximately 40,500 af to the SFPUC Storage Account during the model simulation (assuming a put rate of 5.52 mgd by the PA wells that is equivalent to 80 percent of the total PA pumping of 6.9 mgd). Using the put rate of 5.52 mgd, it would take approximately 6.5 years (or 79 months) to reach the Full SFPUC Storage Account condition of 60,500 af[2].

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[1] The accrued volume in the SFPUC Storage Account at the start of the model scenarios is approximately 20,000 acre-feet (af) based on records of in-lieu exchange with the Partner Agencies (PAs) prior to July 2009.

[2] Assuming the initial SFPUC Storage Account of 20,000 af in June 2009 and the put rate of 5.52 mgd (or 6,182 afy), it would take 79 months, or approximately 6.5 years, to reach the Full SFPUC Storage Account of 60,500 af. This is equivalent to the difference in the Full SFPUC Storage Account and the initial SFPUC Storage Account (40,500 af = 60,500 af – 20,000 af) divided by the put rate (5.52 mgd = 6,182 afy).

2.2. SFGW Project

The SFGW Project would provide a reliable, local source of high-quality groundwater in the northern portion of the Westside Basin (North Westside Basin) to supplement the San Francisco municipal water system.

The SFGW Project would construct up to six wells and associated facilities in the western part of San Francisco and extract an annual average of up to 4.0 mgd of water from the North Westside Basin (SFPUC, 2009b). The extracted groundwater, which would be used both for regular and emergency water supply purposes, would be blended in small quantities with imported surface water before entering the municipal drinking water system for distribution. The SFGW Project includes two phases. Phase one would build four new groundwater wells at the Lake Merced Pump Station, West Sunset Playground, South Sunset Playground, and the Golden Gate Park Central Pump Station. Phase two would modify two existing irrigation wells (South Windmill Replacement and North Lake) in Golden Gate Park. With the future implementation of the Westside Recycled Water Project, North Lake and South Windmill Replacement wells in Golden Gate Park would be used to produce municipal supply as part of the SFGW Project, and irrigation pumping would be replaced with recycled water. If the Westside Recycled Water Project is not implemented, then phase two of SFGW Project would not occur.

2.3. Vista Grande Drainage Basin Improvement Project

The City of Daly City prepared the Vista Grande Drainage Basin Alternatives Analysis in 2011 based on the recommendations of the Vista Grande Watershed Plan (City of Daly City, 2012). The purpose of the alternatives analysis is to develop and evaluate alternatives that will reduce or eliminate flooding, reduce erosion along Lake Merced, and provide other potential benefits such as habitat enhancement and lake level augmentation. The recommended program outlined in the plan includes construction of a new stormwater tunnel, construction of a detention basin in Westlake Park, and potential for treatment wetlands in San Francisco to treat stormwater for diversion from the Vista Grande Canal to Lake Merced (Jacobs Associates, 2011a, 2011b; City of Daly City, 2012).

For the analysis of the GSR and SFGW Projects, the use of Lake Merced as part of the stormwater project for Daly City is considered to be one of the reasonably foreseeable future projects that are included as part of the Cumulative Scenario. Other cumulative projects are discussed in Section 5.4.

3. Physical Setting

Understanding the hydrogeological conceptual model is important in assessing the results of the numerical Westside Basin Groundwater Model and the Lake-Level Model. This section provides a brief overview of the physical conditions within the project areas of the proposed GSR and SFGW Projects to provide necessary context in evaluating the setup and application of the model scenarios. The hydrogeologic conditions described include the regional geologic setting, aquifer formations, and surface water features. In addition, a brief discussion of the historical and recent pumping conditions in the basin is provided. A more detailed description of the regional geologic setting can be found in *Technical Memorandum No. 1: Hydrologic Setting of the Westside Basin* (LSCE, 2010).

3.1. Westside Groundwater Basin

The groundwater basin beneath the western part of San Francisco from the vicinity of Golden Gate Park and extending southeasterly into San Mateo County is identified in the California Department of Water Resources (DWR) Bulletin 118 as both the Merced Valley Basin and the Westside Basin (DWR, 2003). Since it is more commonly known as the Westside Basin, this designation is used in this TM. In addition, more recent DWR initiatives use the Westside Basin name (e.g., California Statewide Groundwater Elevation Monitoring Program). Figure 10.1-1 shows the boundary of the Westside Basin.

For discussion purposes in this TM, the Westside Basin, which covers about 40 square miles in area, has been divided into northern and southern portions at the San Francisco County-San Mateo County line. This subdivision is a political division, which is not representative of a physical boundary, and is not meant to imply that there is any restriction of groundwater flow between the two areas. The portion of the basin that lies within San Francisco County is referred to as the North Westside Basin, which has an area of approximately 15 square miles (Figure 10.1-1). The portion of the basin that lies within San Mateo County is referred to as the South Westside Basin with an area of approximately 25 square miles underlying Daly City, Colma, South San Francisco, San Bruno, Millbrae, and Burlingame (Figure 10.1-1) (SFPUC, 2010).

The Westside Basin is bounded by bedrock highs in Golden Gate Park to the north and at Coyote Point to the south (DWR, 2003; Rogge, 2003; San Bruno, 2007). San Bruno Mountain and San Francisco Bay form the eastern boundary of the Basin (Cal Water, 2006). The San Andreas Fault and Pacific Ocean form the western boundary, and its southern limit is defined by a bedrock high that separates it from the San Mateo Plain Groundwater Basin (DWR, 2003; Rogge, 2003; San Bruno, 2007). The Westside Basin opens to the Pacific Ocean on the northwest and San Francisco Bay on the southeast. The major structural features include the San Andreas Fault system and the Serra Fault.

3.2. Aquifers

The Westside Basin includes five major geologic formations: Franciscan Complex, Merced Formation, Colma Formation, Dune Sands, and Bay Deposits (LSCE, 2010). Groundwater development in the Westside Basin primarily occurs in various aquifer units in the Colma and Merced Formations from the Golden Gate Park area, through Daly City and South San Francisco, to San Bruno. The Merced Formation is the primary water-producing aquifer in the Basin (LSCE, 2006). Within the two major water bearing zones in the Westside Basin, there are multiple smaller aquifer zones that are delineated vertically by different sand and clay layers within the Merced and Colma formations. The thickness and extent of these interbedded sand and clay layers vary spatially throughout the Westside Basin. The aquifer units in the Westside Basin are further described in TM#1 (LSCE, 2010).

All of the municipal groundwater extraction wells in Daly City, South San Francisco, and San Bruno are screened in the deeper, semi-confined to confined aquifers in the Merced Formation, where the water quality is better than in shallower aquifers (San Bruno, 2007). The Colma Formation is of interest because Lake Merced is incised within this formation (LSCE, 2006).

For discussion purposes, the aquifer units are informally designated as the Shallow Aquifer, the Primary Production Aquifer, and the Deep Aquifer. The Shallow Aquifer is limited to the vicinity of Lake Merced and the area north towards Golden Gate Park, and the Primary Production Aquifer is generally present throughout much of the Westside Basin (LSCE, 2010). In the North Westside Basin, aquifer units are separated by two distinctive fine-grained units, known as the -100-foot clay and the W-clay (LSCE, 2004). In the Daly City area, the -100-foot clay is absent, and the aquifer system is primarily composed of the Primary Production Aquifer overlying the W-Clay and the Deep Aquifer underlying the W-Clay. Further to the south in the South San Francisco area, the W-Clay is absent and the Primary Production Aquifer is split into shallow and deep units that are separated by a thick fine-grained unit at an elevation of approximately 300 feet below mean sea level (msl). The Primary Production Aquifer in the San Bruno area is located at an elevation less than -200 feet, and it underlies a thick, surficial predominantly fine-grained unit comprised of clay, sandy clay, and sand beds (LSCE, 2010).

3.3. Groundwater Flow

Groundwater levels and the general direction of groundwater flow vary in the Westside Basin. At the northern end of the Westside Basin, groundwater in the Shallow Aquifer tends to flow in a westerly direction towards the Pacific Ocean. From South San Francisco southward to Burlingame in the vicinity of San Francisco Bay, groundwater within shallow units overlying the Primary Production Aquifer generally flows east towards San Francisco Bay (Rogge, 2003; San Bruno, 2007). Groundwater from the vicinity of Lake Merced north to Stern Grove and Golden Gate Park is encountered at relatively shallow depths (ranging from approximately 5 to 60 feet), while south of Lake Merced the depth to groundwater can exceed 300 feet (LSCE, 2006).

Based on groundwater level data measured during spring and fall 2009 monitoring events, groundwater elevation contours were prepared for the Shallow Aquifer and the Primary

Production Aquifer and presented in the 2009 Westside Basin Groundwater Monitoring Report (SFPUC, 2010). The 2009 groundwater elevation contour maps also include data from three monitoring wells that were installed by SFPUC in 2009 in the South Westside Basin in Daly City, San Bruno, and Millbrae. The contours of groundwater elevation for the Shallow Aquifer exhibit westerly groundwater flow directions both in spring and fall 2009, with higher groundwater elevations in the eastern portion of the aquifer than the western portion near the Pacific Coast. No significant differences in flow directions were identified through the spring and fall 2009.

Based on the spring and fall 2009 monitoring events, the contours of groundwater elevation for the Primary Production Aquifer exhibit westerly groundwater flow directions in the North Westside Basin, similar to the Shallow Aquifer, and a southerly flow direction from the Lake Merced area towards Daly City and South San Francisco. The southerly groundwater flow gradient between Daly City and South San Francisco appears to be relatively flat as compared to the steep gradient between Lake Merced and Daly City (SFPUC, 2010; LSCE, 2010).

3.4. Lakes

The most notable surface water feature of the Westside Basin is Lake Merced, located in southwestern San Francisco (Figure 10.1-1). Lake Merced is a freshwater lake, bounded by Skyline Boulevard, Lake Merced Boulevard, and John Muir Boulevard, approximately 0.25 mile east of the Pacific Ocean. Lake Merced is a major natural habitat for many species of birds and waterfowl and a regional recreational venue offering fishing, boating, bicycling, and wildlife viewing. The lake, composed of four water bodies named North Lake, East Lake, South Lake, and Impound Lake, is incised within the upper portion of the Shallow Aquifer, representing a surface expression of groundwater table. In the early 1990s several investigations were conducted and have continued on a regular basis to investigate and monitor the lake levels and lake-aquifer interactions (LSCE, 2002, 2004, and 2010).

Pine Lake is a small, shallow lake approximately three acres in size, located north-northeast of Lake Merced in the westernmost portion of Stern Grove and Pine Lake Park. Groundwater produced by the Stern Grove well is used for maintaining water levels in Pine Lake (personal comm., Jeff Gilman, 2010).

Golden Gate Park, located in the North Westside Basin, contains several artificial lakes that are used for recreation and are lined with clay to minimize leakage; however, several of the lakes reportedly leak a considerable amount of water to the water table (Yates et al., 1990). Groundwater pumped from the three Golden Gate Park wells (Elk Glen, North Lake, and South Windmill Replacement wells) is used for irrigation and for maintaining the artificial lakes (personal comm., Jeff Gilman, 2011).

3.5. Groundwater Pumping

Groundwater pumping in the Westside Basin occurs for municipal, irrigation and other non-potable uses (golf courses, zoo, parks, and cemeteries). Groundwater pumping is the most significant groundwater outflow component for the Westside Basin. Almost all historical groundwater development in the Westside Basin has been in the South Westside Basin for municipal supply in Daly City, South San Francisco, and San Bruno and golf course and cemetery irrigation. Total municipal pumping in the Westside Basin was about 7,500 afy from the mid-1970s to the mid-1980s, and then ranged from 6,000 afy to 8,000 afy until 2001. From 2002 to 2007, total municipal pumping fluctuated greatly as a result of the In-Lieu Recharge Demonstration Study conducted by SFPUC, Daly City, Cal Water (in South San Francisco), and San Bruno (LSCE, 2005; LSCE, 2010). Historical trends and recent pumping conditions for municipal, irrigation, and other non-potable pumping are summarized below. Groundwater pumping in the Basin is described in detail in TM#1 (LSCE, 2010).

Daly City – Groundwater pumping by Daly City increased from about 1,000 afy to nearly 5,000 afy between 1950 and 1970. Since then, groundwater pumping has ranged between approximately 3,000 afy and 5,000 afy, where it remained until October 2002, when an increase in deliveries from SFPUC's Regional Water System were made available to replace the majority of Daly City's groundwater supply as part of the In-Lieu Recharge Demonstration Study (LSCE, 2005). Daly City pumping totaled about 3,600 af for 2008 (LSCE, 2010). Supplemental water deliveries by SFPUC to Daly City resumed in 2009. Daly City pumping was approximately 1,667 af in 2009 (SFPUC, 2010) and 1,743 af in 2010 (SFPUC, 2011). Based on the long-term pumping records from 1959 to 2009, the median pumping by Daly City is estimated to be 3.78 mgd (or approximately 4,235 af).

Cal Water – Groundwater pumping by Cal Water in South San Francisco has progressively declined from about 2,200 afy in 1947, to about 1,600 afy in 1969, to about 1,200 afy in 2002. The decreases in groundwater pumping have been offset by increases in SFPUC's Regional Water System deliveries. In early 2003, groundwater pumping in South San Francisco was discontinued as part of the In-Lieu Recharge Demonstration Study (LSCE, 2005) that ended in early 2005 in South San Francisco. Groundwater pumping for municipal supply in South San Francisco resumed on a limited basis in March 2008 and totaled 206 af during 2008 (LSCE, 2010). Groundwater pumping by Cal Water was 380 af in 2009 (SFPUC, 2010) and 453 af in 2010 (SFPUC, 2011). Based on the long-term pumping records from 1959 to 2009, the median pumping by Cal Water is estimated to be 1.18 mgd (or approximately 1,320 af).

San Bruno – Pumping in San Bruno ranged from approximately 1,000 afy to 2,300 afy from 1950 to the late 1990s and from 1,700 afy to 3,100 afy from the late 1990s through 2001. In 2002, San Bruno decreased groundwater pumping to approximately 1,240 af and further decreased groundwater production to about 550 af in 2003 and 2004 as part of the In-Lieu Recharge Demonstration Study (LSCE, 2005). San Bruno pumping resumed to about 1,800 afy to 2,300 afy after cessation of the In-Lieu Recharge Demonstration Study in early 2005 (LSCE, 2010). Groundwater pumping by San Bruno was 2,379 af in 2009 (SFPUC, 2010) and 2,364 af in 2010 (SFPUC, 2011). Based on the long-term pumping records from 1959 to 2009, the median pumping by San Bruno is estimated to be 1.88 mgd (or approximately 2,110 af).

Irrigation and Other Non-Potable Groundwater Pumping – Groundwater has historically been developed for irrigation supply and other non-potable uses in the Westside Basin, most notably on golf courses around Lake Merced, cemeteries in Colma, at the San Francisco Zoo, and in Golden Gate Park. In 2005, the delivery of recycled water for irrigation largely reduced groundwater use at the golf courses around Lake Merced, leaving the cemeteries, California Golf Club, San Francisco Zoo, and Golden Gate Park as the notable pumpers for irrigation and other non-potable uses at an estimated 3,000 afy (SFPUC, 2009c; Carollo, 2008).

Given the estimated historical irrigation pumping of about 6,000 afy, total combined pumping of groundwater for municipal and irrigation uses is estimated to have ranged from 12,000 afy to 14,000 afy from the mid-1980s through 2001. During the In-Lieu Recharge Demonstration Study conducted by SFPUC in coordination with the PAs from October 2002 to March 2005, municipal pumping by Daly City, Cal Water, and San Bruno was reduced as a result of SFPUC's supplemental surface water deliveries to the PAs in-lieu of municipal pumping by the PAs. Total pumping (municipal and irrigation) in 2005 was estimated to range from 5,500 af to 6,500 af. Total pumping between 2006 and 2010 remained below 9,000 af, ranging from 5,400 af in 2006 to 8,500 af in 2008. Total pumping in the Westside Basin in 2009 was estimated to be 6,800 af (SFPUC, 2010).

4. Westside Basin Groundwater Model

The Westside Basin Groundwater Model is a regional, basin-wide groundwater model of the Westside Groundwater Basin in western San Francisco and San Mateo County (Figure 10.1-2).

4.1. History of Model Development

The Westside Basin Groundwater Model was first developed through Daly City's 2002-2003 AB303-funded investigation of the Westside Groundwater Basin (City of Daly City, 2003). During the period 2003-2007, additional work funded by Daly City, San Bruno, Cal Water, and SFPUC further developed and calibrated the model (HydroFocus, 2007). In 2009, a revised groundwater model (version 2.1) was released that included several corrections and improvements to the model's historical pumping data set with no adjustments to the modeled aquifer parameter values (HydroFocus, 2009). The most recent modeling work (version 3.1) includes an updated historical calibration and a no-project scenario that is documented in detail by HydroFocus (2011). A brief summary of the 2011 updates includes the following:

- Historical Simulation – The updated Historical Simulation (version 3.1) simulates monthly hydrologic conditions during the period October 1958 through September 2009. The simulation period is discretized into monthly stress periods. The Historical Simulation was extended from 47 years to 51 years, with the extended model period covering December 2005 to September 2009.
- Updated Model Parameters – During model calibration, several corrections, modifications and improvements were made to the model structure, aquifer parameters and boundary conditions based on new data and from review of model performance. Modifications are noted in the following with more detailed discussion of the model in Section 4.2.
- 2008 No-Project Scenario – This scenario is based on a 47-year simulation period that uses the hydrologic conditions from October 1958 to December 2005 using the calibrated Historical Simulation version 3.1

The Historical Simulation calibration period of 51 years covers various types of hydrological events ranging from wet periods to droughts of different magnitude and duration, allowing adequate time for analyzing basin response under various hydrological conditions.

The 2008 No-Project Scenario assumes no new projects but includes new supply wells, planned operational changes in the magnitude and spatial distribution of pumping, and existing recycled water projects as of May 2008. The 2008 No-Project Scenario was used as the starting point for developing Scenario 1 (or the Existing Conditions) for this modeling analysis.

4.2. Model Overview

This section summarizes the model representation of the Westside Basin, including the model extent, model layer structure, aquifer properties used in the model, and model boundary conditions. This is intended as an overview of the detailed discussion of the model representation reported previously by HydroFocus (2007, 2009, and 2011). These aspects of the model remain the same and were not modified for the purposes of the modeling analysis documented in this TM.

4.2.1. Model Structure

The Westside Basin Groundwater Model was constructed using MODFLOW 2000, a finite-difference numerical modeling software developed by the United States Geological Survey (USGS) (Harbaugh et al., 2000). Model coordinates are based on the California State Plane Zone 3 coordinate system of the North American Datum of 1983 (NAD 83), in units of feet. The vertical datum is the National Geodetic Vertical Datum of 1929 (NGVD 29). All model inputs are based on English units for length (feet) and time (days) (HydroFocus, 2007).

The model domain is the geographical area covered by the numerical model. The model domain is mostly consistent with the extent of the Westside Basin and extends into the Pacific Ocean along the western boundary and San Francisco Bay along the eastern boundary, as shown in Figure 10.1-2.

The model grid provides the mathematical structure for developing and operating the numerical model. The Westside Basin Groundwater Model domain is divided into a set of grid cells (grid discretization), containing 189 rows and 126 columns. The cells in horizontal directions have variable dimensions ranging from 250 feet near Lake Merced to 1,000 feet near the model edges.

Model layers provide vertical resolution for the model to simulate variations in groundwater elevations and aquifer stresses with depth. In the vertical direction, the Westside Basin Groundwater Model is composed of five layers to characterize the conceptual basin geology. Figure 10.1-3 shows the representation of the model layering superimposed on the regional north-to-south subsurface cross-section. The upper surface of the model represents the land surface topography, and the bottom of Model Layer 5 represents the bedrock surface elevation. Land surface elevations were determined using digital elevation models (DEM) that specify land surface elevation at horizontal locations uniformly spaced about 90 feet apart (HydroFocus, 2007, 2009, and 2011).

For the Westside Basin Groundwater Model version 3.1, adjustments to the model layering were completed to incorporate new data. Top and bottom model layer elevations were updated using information from recently installed monitoring wells, new depth-to-bedrock information, and updated hydrogeologic sections (HydroFocus, 2011).

4.2.2. Aquifer Properties

Aquifer properties (e.g., horizontal and vertical hydraulic conductivity, specific storage, and specific yield) describe the physical characteristics of the aquifer and the hydraulic properties that control groundwater flow. The numerical model requires that these properties are defined for every active cell in the model. In the Westside Basin Groundwater Model version 3.1, adjustments were made to calibrate horizontal and vertical conductivity values in the parameter zones; no changes were made to specific yield or specific storage. These are discussed in greater detail in the HydroFocus report (2011).

In the Westside Basin Groundwater Model, Model Layer 1 was specified as convertible and Model Layers 2 through 5 were specified as confined. Under the convertible conditions, MODFLOW calculates the transmissivity of each model cell as the assigned hydraulic conductivity multiplied by the saturated thickness as defined by the simulated groundwater elevation and the bottom of the model layer, and the storage coefficient is the specific yield (Harbaugh et al., 2000). For the confined Model Layers 2 through 5, the transmissivity is the product of the layer thickness and hydraulic conductivity, and the storage coefficient is the product of layer thickness and specific storage.

Each model layer in the Westside Basin Groundwater Model was divided into subareas (also referred to as parameter zones) within which aquifer parameters are assumed to be uniform. The delineation of the parameter zones and calibrated aquifer parameters associated with the parameter zones as used in the updated Historical Simulation and the 2008 No-Project Scenario were described by HydroFocus (2007, 2009, and 2011). The parameter zones were modified in version 3.1 to account for updated geologic information and the spatial distribution of new monitoring well locations (HydroFocus, 2011).

4.2.3. Boundary Conditions

Model boundary conditions represent areas where groundwater enters and exits the model domain. Boundary condition data must be entered for each stress period at each boundary condition cell, other than no-flow cells. The model boundaries in the existing Historical Simulation and the 2008 No-Project Scenario are represented as follows:

- Groundwater pumpage in the model was represented using the well package. In the MODFLOW well package, the monthly groundwater pumping extraction rates are specified in the model cell and layer corresponding to each well location and for each stress period. A detailed description of the MODFLOW well package can be found elsewhere (Harbaugh et al., 2000).
- The MODFLOW drain package was included to represent shallow groundwater discharge from Model Layer 1 in the Bay Plain subarea. Evidence for shallow groundwater and seepage includes groundwater encountered in shallow monitoring wells (for example, at leaky underground storage tank sites), sustained baseflow in the Colma Creek gauging record (1 to 2 cubic feet per second (cfs)), and the visible presence of creek channels and ditches inland throughout the Bay Plain as far west as Highway 101 (HydroFocus, 2011).
- Lake Merced was simulated with the lake package (MODFLOW 2000 LAK3 package) to simulate the hydraulic interaction between Lake Merced and the adjoining groundwater system, and to estimate the amount of inflow and outflow across the lakebed. The lake package consists of several data sets (e.g., initial lake level, inflows to and outflows from

the lake such as rainfall, evaporation, runoff, lake additions, and withdrawals) to couple the groundwater flow system with the lake water budget and to calculate lake levels and inflow and outflow across the lakebed. Documentation of the MODFLOW LAK3 package can be found in Merritt and Konikow (2000).

- Rainfall, temperature, and municipal water use input data sets for the Soil Moisture Budget (SMB) model were extended to include the period January 2006 through September 2009. The SMB is used to estimate recharge from precipitation and return flows and is entered into the model using the MODFLOW recharge package. In version 3.1, changes were made to simulate rainfall and the spatial temperature distribution, which resulted in an about 7-percent decrease in average rainfall in the Westside Basin relative to version 2.1 over the historical model period from 1959 and 2009 (HydroFocus, 2011).
- The Serra Fault was represented as a no-flow boundary in the southwest and as a horizontal flow barrier in the northwest. The San Andreas Fault was represented as a no-flow boundary.
- Groundwater seepage from the lakes and ponds in Golden Gate Park was represented using the MODFLOW well package as a specified flux boundary that adds water to the aquifer at a constant rate equal to the measured leakage rate (HydroFocus, 2007). A seepage investigation found that total lake leakage was 627 acre-feet per year (SFRPD, 1994).
- San Francisco Bay and the Pacific Ocean were represented as constant head boundaries with head values of zero feet NGVD 29.
- No-flow boundaries were specified along the northern edge of the onshore part of the basin boundary near Golden Gate Park, near the eastern end of Golden Gate Park, the southern boundary, and the onshore part of the eastern boundary.

4.3. Summary of Model Strengths and Limitations

A calibrated numerical model, such as the Westside Basin Groundwater Model, is considered capable of reasonable simulation quality. However, when evaluating model results, it is important to consider the strengths and limitations of the model. This section summarizes the strengths and limitations of the Westside Basin Groundwater Model based on previous modeling analyses, reports, and documentation (HydroFocus, 2007, 2009, and 2011).

4.3.1. Version 3.1 Model Calibration

Simulated groundwater levels in version 3.1 were calibrated to the available measured groundwater elevations collected during the simulation period at various locations throughout the Basin (HydroFocus, 2011). After the model was recalibrated, the basin-wide root-mean-square-error (RMSE) was reduced from 25.8 to 18.9 feet. The RMSE is a statistical measure that evaluates the average difference (or residual) between modeled and observed groundwater levels and provides a measure of the overall error in the model. Therefore, the calibration results indicate that, on average, modeled groundwater levels are within about 19 feet of observed water levels. The RMSE represents about 4 percent of the total range in observed water levels across the model. This ratio shows how the model error relates to the overall hydraulic gradient across the model. Typically, a calibration is considered good when this ratio is below 15 percent (ESI, 2001).

Another calibration measure is the residual mean, which includes positive and negative residuals depending on whether the modeled results are higher or lower than the measured groundwater levels. The residual mean provides a measure of the average deviation between modeled and observed water levels. In version 3.1, the residual mean is fairly small and positive (1.6 feet) indicating simulated water levels are on average slightly higher than the observed water levels. These calibration results indicate that the updated model is a reasonable tool for basin-scale analyses and comparisons of water resources management alternatives. Some degree of difference or residual between the observed and model simulated groundwater elevations is expected because residuals may be due in part to localized effects or data quality issues.

4.3.2. Model Strengths

The Westside Basin Groundwater Model was developed to assist basin-wide data interpretation and system understanding and is considered a reliable data analysis tool for various purposes. The model provides a means to synthesize data and integrate processes that potentially influence groundwater conditions. It was developed over a period of several years under the oversight of several technical groups. The model input represents agreed-upon conceptual hydrogeologic and water use conditions as presently understood in the Westside Groundwater Basin. The model was calibrated using more than 2,000 observed monthly water levels in 125 wells representing a broad range of locations, depths and hydrologic conditions. The numerical model provides information and insights that cannot be obtained from available field measurements and/or analytical tools without the capability to synthesize and integrate all processes that potentially influence groundwater conditions (HydroFocus, 2011).

As suggested by HydroFocus (2007), the strongest predictive ability of the existing model is in relative changes over time, rather than absolute predictions of water levels. Therefore, this regional model is most capable of analyzing differences in water level rather than the actual groundwater elevation output by the model. In addition, HydroFocus (2007) states that the model is best suited for assessing groundwater levels and storage changes over large parameter zones, which vary in size from 476 acres to nearly 10,000 acres, as the Historical Simulation calibration was performed with the average conditions in these zones in mind. In other words, the model may not be able to re-create the groundwater elevations at local areas or at a single well correctly, but the composite statistics of that well and many others nearby are much more accurate and representative. As described by HydroFocus (2007), the model was initially developed as a tool to assist with the following types of evaluations and groundwater management scenarios:

- Regional (basin-wide) data interpretation and system understanding:
  - Basin management decisions.
  - Monitoring networks and existing data gaps.
- Regional water supply project operations (for example, conjunctive use and local groundwater water projects) by assessing the following types of changes due to changes in pumping rates and patterns:
  - Changes in water table and deeper groundwater elevations (magnitude and trends).
  - Changes in Lake Merced water levels (magnitude and trends).
  - Changes in the quantity of water stored in the basin.
  - Changes in the water budget and potential for saltwater (or seawater) intrusion.

For evaluating effects of a proposed future project, the Westside Basin Groundwater Model is considered useful in simulating the relative effect of possible conjunctive use or groundwater supply projects in the Westside Basin. As mentioned by HydroFocus (2007), planning analyses based on projected future conditions, such as the future modeling scenarios, are typically based on the relative differences between two projected conditions. The advantage of analyzing relative differences is that it minimizes the effects of model uncertainty. It is therefore preferable to employ the Westside Basin Groundwater Model to analyze relative changes (for example, compare the differences between simulated “no project” and “with project” scenarios) rather than using the model to predict absolute groundwater elevations, localized aquifer storage changes, or Lake Merced water levels.

4.3.3. Model Limitations

Overall, version 3.1 of the model is considered an appropriate quantitative tool for evaluating groundwater conditions in the Westside Basin. However, there are some specific areas of the weakness and/or limitations in the model and model calibration that are summarized below based on previous studies and modeling analysis by HydroFocus (2007, 2009, and 2011), and subsequently identified during this analysis.

Despite improvements in the historical calibration in version 3.1 (HydroFocus, 2011), the model subareas with the highest RMSE are the Colma and San Bruno subareas. This is attributed to historical water level measurement limitations, model scaling, and uncertainty in vertical hydraulic conductivity and vertical hydraulic gradients. Therefore, the model results should be evaluated with care to account for the higher potential uncertainty of model results in the San Bruno and Colma areas.

During the Historical Simulation calibration, the simulation of lake levels in Lake Merced improved slightly from version 2.1 to 3.1. The model generally reproduces the lake levels and trends during the period from 1972 to 1995. During the first 14 years (1958 to 1972) and the last 13 years of the simulation (1996 to 2009), simulated lake levels were consistently 2 to 3 feet higher than measured data, but with some differences as high as 7 feet. The model is considered useful in simulating the relative effect of possible regional groundwater supply projects on Lake Merced levels; however, the simulation of lake level management scenarios with the objective of projecting absolute lake levels is not recommended.

The MODFLOW lake package does not include a mechanism to simulate the control of a lake level via a spillway. Although not a large issue for the historical simulations, some of the future case scenarios have the potential for lake levels to increase to the level of the spillway. Without a spillway mechanism, MODFLOW will allow the lake levels to rise to levels that are not physically possible. This also could have an impact on shallow groundwater levels due to groundwater-surface water interactions with the lake. Scenarios where the lake level rises above the level of the spillway require an iterative process whereby the lake package inputs are adjusted until the lake levels remain below the level of the spillway. Because of these limitations, the Lake-Level Model discussed in Section 8 was used for evaluating the effects of the GSR and SFGW Projects, and other reasonably foreseeable future projects.

In reviewing the model structure in the Golden Gate Park area, it was found that the aquifer thickness in the model was substantially thinner than was found in the Golden Gate Park Central Pump Station test well. Based on this test well, it appears that the model does not account for data from deep exploratory borings drilled in January 2010 and presented in a geologic cross-section J-J' in *Task 8B Technical Memorandum No. 1: Hydrologic Setting of the Westside Basin* (LSCE, 2010). The model uses only Model Layer 1 in the central and eastern parts of Golden Gate Park, whereas pumping tests of production wells show confined aquifer behavior. In addition, compilation of pumping test results shows that the horizontal hydraulic conductivity (K_h) values used by the Westside Basin Groundwater Model in the North Westside Basin are lower than those obtained from measured data. It is recommended that future revisions to the model should include updating the model layer inputs in the Golden Gate Park area to be consistent with the existing hydrogeologic data. This is an important area for evaluating the SFGW Project; therefore, model results for Golden Gate Park will need to be evaluated with care because the model may overestimate the simulated drawdowns from the future proposed wells in this area.

In version 3.1, the MODFLOW drain package was used to reduce the degree to which simulated groundwater levels were above the topographic surface representing potential flooding situations. Flooded cells periodically occurred where the aquifer is thin or in areas characterized by a shallow water table, and these can often be ignored because the model resolution is not fine enough to capture the topographic pattern of the surface.

Other weaknesses that have been subsequently identified during this investigation relate to the boundary conditions where the model interacts with the Pacific Ocean and San Francisco Bay. These boundary conditions were set to a constant head of zero elevation in the existing Westside Basin Groundwater Model. This characterization does not handle the density difference between seawater and freshwater, or the wedged shape of possible seawater intrusion (see Task 10.3 TM). In addition, the constant head boundary condition is located on the landward side of the coast, rather than the seaward side; this prescription is overly rigid, preventing the near-ocean water levels from behaving dynamically. HydroFocus (2007) states that "model results should be interpreted with caution near constant head boundaries like the Pacific Ocean or San Francisco Bay."

As mentioned above, for evaluating effects of a future project compared to the conditions without the project, the model could help assess the relative differences between two projected conditions. However, it should be noted that because model scenario runs are a projection of assumed future hydrologic conditions relative to assumed no project conditions, it is always understood that the simulated relative changes in groundwater levels and aquifer storage may not equal the actual changes determined from future observed hydrologic conditions (HydroFocus, 2007).

5. Model Scenario Descriptions

A calibrated numerical model, such as the Westside Basin Groundwater Model, is considered capable of reasonable quality simulations. The numerical model can serve as a useful quantitative tool for future planning, management, and evaluation of technical issues related to groundwater resources.

Five model scenarios were set up and simulated under Task 10.1. Table 10.1-1 provides a summary of the model scenario descriptions. The main model assumptions in each scenario are described in the following subsections, and further details on the model setup and assumptions are provided in Section 6 below. The amount of groundwater pumping is the major model input that varies among the simulated MODFLOW model scenarios. Table 10.1-2 presents a summary of pumping assumptions used in each of the five model scenarios. The Lake-Level Model is the primary tool used to evaluate the effects of each of the five scenarios listed in Table 10.1-1. Section 8 provides a detailed description of Lake-Level Model development and assumptions and model results in evaluating the effects of the GSR and SFGW Projects and other reasonably foreseeable projects.

5.1. Scenario 1 – Existing Conditions

Scenario 1 was set up and simulated to represent the Existing Conditions and does not include the SFPUC Projects (both GSR and SFGW Projects). Scenario 1 is based on a new hydrologic sequence proposed by SFPUC over a 47.25-year simulation period and initial conditions representative of June 2009. Total pumping assumptions made under Scenario 1 are summarized in Table 10.1-2.

A detailed description of the model assumptions and modifications for Scenario 1 is provided in Section 6. The 2008 No-Project Scenario developed by HydroFocus (2011) was used as the starting point for the development of Scenario 1. However, there are some important differences between Scenario 1 and the HydroFocus 2008 No-Project Scenario. These differences are listed below:

- In order to allow all five model scenarios to be directly comparable, Scenario 1 uses a new hydrologic sequence. The HydroFocus 2008 No-Project Scenario used an exact repeat of the historical hydrology from October 1958 to December 2005. As described further in Section 6.3, the new hydrologic sequence has a period of 47.25 years. It was established by rearranging the historical monthly sequence of hydrologic conditions available from the HydroFocus modeling analysis (2011) and includes the 8.5-year Design Drought period for the GSR Project, consistent with the PEIR (SFPUC, 2007; SFPUC, 2009a).
- Initial conditions for groundwater levels and Lake Merced represent June 2009 conditions for Scenario 1, compared to September 2002 used in the 2008 No-Project Scenario. As described further in Section 6.4, the initial conditions are based on the June 2009 water levels from the updated calibrated Historical Simulation by HydroFocus

(2011). June 2009 groundwater levels as initial conditions represent the accrued SFPUC Storage Account of approximately 20,000 af at the start of the model scenarios.

- Pumping assumptions for the PA production wells were modified to incorporate the pumping assumptions representative of the Existing Conditions. Pumping by the PAs for the Existing Conditions is 6.84 mgd, compared to 6.9 mgd assumed in the 2008 No-Project Scenario. PA pumping under the Existing Conditions was derived from the median values of individual agency pumping over the historical period from 1959 to 2009. Under the Existing Conditions, the pumping distribution among each of the PA wells and the vertical distribution of pumping by model layers are essentially the same as in the HydroFocus 2008 No-Project Scenario (2011).
- In order to be consistent with the new hydrologic sequence, the SMB pre-processing model for estimating groundwater recharge and irrigation was revised. The SMB model uses precipitation, temperature, evapotranspiration and municipal water supply as inputs. As explained further in Section 6.5, the simulated monthly recharge resulting from municipal water use in municipal areas was revised based on the results of the revised SMB. Scenario 1 uses the same future municipal water use as projected in the 2008 No-Project Scenario, but that municipal water use was rearranged in order to reflect the new hydrologic sequence.
- Monthly irrigation pumping estimates were modified for the Existing Conditions as a result of the revised SMB to be consistent with the new hydrologic sequence. Monthly irrigation pumping in Scenario 1 is based on the results of the revised SMB. Further modification to the irrigation pumping simulated by the revised SMB was then made to account for actual pumping data for the following irrigation wells: Golden Gate Park irrigation wells (Elk Glen, North Lake, and South Windmill Replacement wells), California Golf Club No.2, Zoo No.5, Edgewood Development Center well, and Stern Grove well (Section 6.6).
- As a result of the revised SMB for the Existing Conditions, the Lake Merced lake package was modified consistent with the new hydrologic sequence, as explained further in Section 6.9. The modified lake package for Scenario 1 assumes no lake additions but accounts for water withdrawals from the lake when the lake levels are in excess of the lake spillway. In comparison, the HydroFocus 2008 No-Project Scenario assumes no Vista Grande stormwater diversions into Lake Merced and no other water additions to the lake.

5.2. Scenario 2 – GSR Project

Scenario 2 simulates the future operation of the GSR Project. The model was set up and simulated based on the new hydrologic sequence (Section 6.3) and identical assumptions for irrigation pumping as in Scenario 1, as presented in Table 10.1-2. The total PA pumping was assumed to be 6.9 mgd. This PA pumping rate is assumed to result in no appreciable storage change in the South Westside Basin (HydroFocus, 2011). For consistency with the PEIR, Scenario 2 was simulated based on the hydrologic sequence that also includes the GSR Project's Design Drought hydrology, as described below (SFPUC, 2007; SFPUC, 2009a). Descriptions of the hydrologic sequence and Design Drought hydrology are pertinent to all scenarios and are presented below in Section 6.3. Table 10.1-2 summarizes pumping assumptions made for the proposed GSR Project wells and the PA wells under Scenario 2. Irrigation pumping assumptions under Scenario 2 remain the same as in Scenario 1 (Existing Conditions), as further discussed in Section 6. The proposed GSR Project municipal well locations are shown in Figure 10.1-4. Table 10.1-3 provides a summary of pumping capacities for the proposed GSR Project municipal wells. GSR Project wells would pump at 7.23 mgd during take periods and at 0.04 mgd during put and hold years to exercise the wells.

5.2.1. Partner Agency Wells

Locations of the PA municipal wells are shown in Figure 10.1-4. Table 10.1-4 lists the PA municipal wells that are assumed to be pumping under the modeling scenarios and analysis.

As presented in the pumping summary in Table 10.1-2, total pumping by the PAs under Scenario 2 was assumed to be 6.9 mgd during take and hold years, based on the designated pumping amounts provided by the PAs to SFPUC as part of the GSR Project. The PA wells are planned to pump up to 20 percent of the take period volume during put periods to allow for well exercising and to avoid encrustation (MWH, 2008). As a result, the PA pumping during put periods would be reduced to 1.38 mgd, resulting in approximately 5.52 mgd of in-lieu stored water in the basin during a put year. Pumping by the PAs is consistent with the 2008 No-Project Scenario by HydroFocus (2011).

5.2.2. In-Lieu Recharge Demonstration Study

A brief overview of the In-Lieu Recharge Demonstration Study conducted by the SFPUC in coordination with the PAs from October 2002 to March 2005 is provided herein as this study is pertinent to the GSR Project, the accrued SFPUC Storage Account, and the initial conditions of June 2009 used for the model scenarios. The In-Lieu Recharge Demonstration Study involved delivery of supplemental surface water from SFPUC to reduce the PAs groundwater pumping. The reduced pumping effectively increased the volume of groundwater in storage (LSCE, 2005).

The purpose of the study was to evaluate the response of the Basin to the resultant in-lieu natural recharge resulting from reduced pumping. After the completion of the In-Lieu Recharge Demonstration Study, the SFPUC continued to deliver supplemental surface water to Cal Water through January 2007 and to Daly City through April 2007. The accrued volume in the SFPUC Storage Account at the start of the model scenarios in June 2009 is approximately 20,000 af based on records of in-lieu exchange with the PAs prior to July 2009. Table 10.1-5 presents the amount and timing of supplemental surface water deliveries to the PAs from October 2002 to April 2007, as provided by the SFPUC (personal comm., Greg Bartow, 2010). No supplemental deliveries were conducted from May 2007 to May 2009.

5.3. Scenarios 3a and 3b – SFGW Project

Scenarios 3a and 3b represent the SFGW Project scenarios and consist of the assumptions used for Scenario 1, with the added assumption of future operation of the SFGW Project. Two model scenarios were set up and simulated based on differing pumping assumptions for the proposed SFGW Project wells, as a result of the availability of recycled water to replace groundwater that is currently used for irrigation in Golden Gate Park.

Approximate locations of the proposed SFGW Project wells are shown in Figure 10.1-4. Table 10.1-6 lists the well identifications and proposed well pumping capacities for the SFGW Project municipal wells. As summarized in Table 10.1-2, Scenario 3a would pump four of the six proposed wells at 3.0 mgd, while the other two SFGW Project wells would remain as irrigation wells and their irrigation pumping rates would be the same as in Scenario 1 (Existing Conditions). Under Scenario 3b, the six proposed project wells would pump at the 4.0 mgd pumping target. Irrigation pumping assumptions at the other irrigation wells under Scenarios 3a and 3b remain the same as in the Existing Conditions, as further discussed in Section 6.6.

For the purpose of the SFGW Project modeling scenarios, the location of the Golden Gate Park Central Pump Station well for Scenarios 3a and 3b was slightly modified by relocating the well in the model to the adjacent model grid cell to the west, where the model layer becomes thicker and accommodates the assigned pumping by the well. As discussed earlier (Section 4.3.3), the aquifer thickness assigned by the model in the vicinity of this well was thinner than the data obtained from a test well and other nearby exploratory borings.

5.4. Scenario 4 – Cumulative Scenario

Scenario 4 is the Cumulative Scenario that includes the assumed operation of the GSR and SFGW Projects, projected pumping for the PAs and third party pumpers, and other reasonably foreseeable future projects. Reasonably foreseeable projects that are considered include (1) the Vista Grande Drainage Basin Improvements Project, and (2) the Holy Cross cemetery future build-out with its anticipated increase in irrigation pumping. The Cumulative Scenario assumes the same hydrologic sequence and initial conditions for groundwater levels and Lake Merced as Scenario 1. Total pumping assumptions for Scenario 4 are summarized in Table 10.1-2. As mentioned above, Scenario 4 assumes the operations of the GSR Project and SFGW Project; thus, it includes the combined pumping from both proposed projects. As presented in Table 10.1-2, the total PA pumping rates for each PA under Scenario 4 are the same as those under Scenario 2. Pumping assumptions by the PAs and locations of pumping wells account for reasonably foreseeable plans for future proposed wells by Daly City, Cal Water and San Bruno. For the SFGW Project, the pumping assumptions under Scenario 4 are the same as pumping assumptions under Scenario 3b (Table 10.1-2). A detailed description of pumping assumptions is provided in Section 6.7 for the GSR Project wells and the PA municipal wells and in Section 6.8 for the SFGW Project wells.

6. Westside Basin Groundwater Model Setup

Because of the complexity of a natural system, assumptions are necessary to define the model domain, aquifer properties and boundary conditions required for the numerical model. Therefore, a model is a simplification of the natural system. The quality of a model is highly dependent upon the accuracy of the conceptual understanding of the hydrogeology and the quality and quantity of the data.

This section presents a summary of the modeling assumptions that are common to all five model scenarios developed, modifications made to the model scenarios compared to the 2008 No-Project Scenario that was previously developed by HydroFocus (2011), and detailed pumping assumptions used for the PA municipal wells, the proposed GSR and SFGW Project municipal wells.

6.1. Common Modeling Assumptions

Modeling assumptions used in the five model scenarios that remain the same as in the 2008 No-Project Scenario are as follows:

- The model domain and grid discretization, model layer structure, and stress period setup are the same as in the 2008 No-Project Scenario (HydroFocus, 2011).
- All of the five model scenarios use the same boundary conditions (e.g., no-flow and constant-head boundary conditions) as in the 2008 No-Project Scenario (HydroFocus, 2011).
- The five modeling scenarios simulate the new hydrologic sequence that covers 47.25 years of monthly hydrologic conditions (a total of 567 monthly stress periods) by rearranging the historical hydrologic conditions available in the HydroFocus 2008 No-Project Scenario and Historical Simulation (2011).
- Land use conditions assumed in all of the future model scenarios are the same as in the 2008 No-Project Scenario, which simulates land use conditions as of May 2008. Therefore, land use zones and recharge zones used in all of the model scenario setups are the same as in the 2008 No-Project Scenario (HydroFocus, 2011).
- All five model scenarios simulate the hydraulic connection between Lake Merced and the surrounding groundwater system based on the lake and aquifer properties that were used in the 2008 No-Project Scenario (HydroFocus, 2011). The lake geometry and key variables used in the lake package remain the same as previously reported by HydroFocus (2007) (see Table 3 in the HydroFocus 2007 Report).
- All model scenarios assume ongoing pumping for the existing irrigation wells similar to the pumping assumptions in the 2008 No-Project Scenario. Modifications made to irrigation pumping assumptions are introduced in Section 6.2 and described further in Section 6.6.

6.2. Modifications to 2008 No-Project Scenario

Modifications to the 2008 No-Project Scenario were made to construct the model scenarios. The major modifications are listed below and described in the following sections:

- Hydrologic data based on the new hydrologic sequence (Section 6.3);
- Initial conditions used for groundwater levels (Section 6.4);
- Revised SMB analysis consistent with the hydrologic sequence and resulting modifications made to the recharge package (Section 6.5), the lake package (Section 6.9), and the irrigation pumping assumptions (Section 6.6);
- Pumping assumptions to incorporate the GSR Project (Section 6.7) and SFGW Project (Section 6.8). The 2008 No-Project Scenario (HydroFocus, 2011) assumes water use conditions as of May 2008 while the modeling scenarios presented here simulate water use conditions as of June 2009 as a representation of the publication of the Notice of Preparation (NOP) for the GSR Project in June 2009 and the NOP for the SFGW Project in December 2009; and
- Initial conditions for Lake Merced and modifications made for the lake spillways (Section 6.9).

The modifications made for the hydrologic sequence, initial conditions, and the revised SMB analysis are common to all five scenarios. Monthly irrigation pumping demand for the model scenarios was revised based on the results of the revised SMB analysis, to be consistent with the hydrologic sequence. The methodology developed by HydroFocus in the 2008 No-Project Scenario (2011) was used to revise the SMB and estimate the monthly irrigation demand for each irrigation well. Minor modifications were made to selected irrigation wells to update the irrigation demand estimated by the revised SMB to account for the actual data for those wells, as described in Section 6.6 as part of the irrigation pumping assumptions.

6.3. Hydrology

The five model scenarios use the same 47.25-year hydrologic sequence so that model scenario results are all directly comparable. This sequence is based on historical hydrological conditions and includes the 8.5-year Design Drought period used in the PEIR (SFPUC, 2007; SFPUC, 2009a). The 8.5-year Design Drought repeats the December 1975 to March 1978 drought period following the dry hydrologic conditions of July 1987 to November 1992. To incorporate the Design Drought, the historical hydrologic sequence was rearranged. The rearranged hydrologic sequence used for the five model scenarios presented in this analysis consists of the following:

- July 1996 to September 2003
- October 1958 to November 1992
- December 1975 to June 1978
- July 2003 to September 2006

The following is the rationale for developing the new hydrologic sequence and maintaining a consistency with the PEIR and the associated HH/LSM design drought run (SFPUC, 2007; SFPUC, 2009a).

As part of the initial conditions, the SFPUC Storage Account has approximately 20,000 af in storage in 2009 based on the past pilot program and agreed upon water exchanges. In order to identify a starting point for the rearranged hydrologic sequence that is consistent with the prior PEIR analyses for the GSR Project, the HH/LSM results were analyzed to identify a time when the simulated SFPUC Storage Account value was approximately 20,000 af. This was done in order to identify a starting condition that is equivalent to the actual SFPUC Storage Account value in July 2009. The analysis identified that this SFPUC Storage Account value occurs in the HH/LSM simulation at the beginning of July 1996 following the prolonged dry years (or take periods) during the 1987 to 1992 drought.

For the model scenarios involving the GSR Project (Scenarios 2 and 4), the Design Drought begins with the Full SFPUC Storage Account of 60,500 af in storage. This means that the SFPUC Storage Account must be “filled” from its 20,000 af initial condition to the “full” 60,500 af condition during the early part of the model simulation. The simplest way to accomplish this objective is to start the GSR Project and the Cumulative Scenario in put periods in order to simulate the filling of the SFPUC Storage Account. Filling of the SFPUC Storage Account therefore occurs during the first “block” of the rearranged hydrologic sequence (i.e., July 1996 to September 2003). Following the filling of the SFPUC Storage Account, the rearranged hydrologic sequence continues with October 1958 to November 1992. For this period, the put/take/hold conditions for the GSR Project are also based upon the HH/LSM output, and the SFPUC Storage Account is full at the beginning of the Design Drought.

The Design Drought is developed by repeating the period from December 1975 to March 1978 and incorporating it into the rearranged hydrologic sequence following November 1992. The PEIR design drought analysis ended in March 1978; however, the rearranged hydrologic sequence continues the Design Drought through June 1978 to maintain a complete rainfall year. To accommodate the Design Drought, the period from December 1992 to July 1995 is not included in the sequence, which is consistent with the PEIR analysis. Since the SFPUC Storage Account is depleted in 7.5 years, it does not cover the complete hydrologic year in the eighth year of the drought. Therefore, the final six months of the eighth year of the Design Drought (January to June 1978) are defined as hold months.

In the PEIR analysis, the Design Drought simulation ended at the end of the Design Drought. For these simulations, the Design Drought is followed by a period of put years. This period (from July 2003 to September 2006) is long enough to bring the SFPUC Storage Account back to 20,000 af at the end of the model scenarios. The July 2003 to September 2006 period is used because it is considered appropriate to keep a multi-year block of rainfall years together. Analysis of observed reservoir storage data was required in order to confirm that the period from July 2003 to September 2006 could be considered a put period. This analysis was necessary because the available HH/LSM simulations do not include this time period.

Rearranging the historical hydrologic sequence in the manner described above is justifiable because weather patterns are generally random. There is no reason that a historical hydrology sequence would repeat exactly in the future. For the rearrangement of the historical hydrologic sequence, the modified sequence was kept as simple as possible by maintaining long continuous blocks of the historical hydrologic sequences. Except for the Design Drought, individual rainfall years were kept together. The rearranged sequences start in either July or October in order to be consistent with the California climate.

The rearranged hydrologic sequence was evaluated with respect to the total rainfall at the Lake Merced precipitation station. This analysis examined the cumulative departure of total precipitation relative to the long-term average (Figure 10.1-5). The historic period of the original hydrologic sequence from October 1958 to December 2005 was near normal. The cumulative departure relative to the long-term average was less than 0.2 inch or 0.04 inch per year over the 47.25-year interval. For the rearranged hydrologic sequence, the cumulative departure is a deficit of 19.4 inches or 0.4 inch per year over the 47.25-year interval. The deficit is due to repeating the December 1975 to June 1978 drought period as part of the Design Drought. This repeat period replaces the December 1992 to June 1995 period, which has higher rainfall. Since most groundwater recharge is related to precipitation, this provides for a conservative evaluation of groundwater conditions during this period.

6.4. Initial Conditions

Initial conditions are the groundwater elevations assigned for each active model cell in each model layer at the beginning of model simulations. For all five model scenarios, model-simulated June 2009 groundwater levels from the HydroFocus Historical Simulation (2011) were used as the initial conditions. The MODFLOW model uses monthly time steps and the model is set to start in July 2009; therefore, June 2009 represents the month prior to model initiation. The calibrated model simulation of June 2009 represents the best characterization of groundwater elevations for the entire basin as is required for the model.

All five scenarios use the same June 2009 initial conditions in order to allow a direct comparison of the model scenario results. The initial condition of June 2009 represents the SFPUC Storage Account of 20,000 af that was stored between 2002 and 2009 (personal comm., Greg Bartow, 2010) during the In-Lieu Recharge Demonstration Study.

6.5. Recharge

For all five model scenarios, the recharge pre-processor SMB model was used to revise recharge consistent with the hydrologic sequence and revised results were entered into the model using the MODFLOW recharge package. This approach was based on the same pre- and post-processing approach developed by HydroFocus (2011). All five scenarios use the same revised recharge package.

In the Westside Basin Groundwater Model, pre-processing programs (e.g., SMB) were used to simulate the spatial and temporal distribution of groundwater recharge. Hydrologic processes simulated by the SMB model include municipal water deliveries, rainfall, runoff, infiltration, soil moisture storage, potential evapotranspiration, irrigation, pipe leaks, and deep percolation. The SMB model uses climate and water delivery data to calculate the temporal and spatial distribution of deep percolation. The final product generated by the SMB is a single model input data set representing monthly groundwater recharge time-series (recharge package) for input to the uppermost active model layer (Model Layer 1). In the Westside Basin Groundwater Model, recharge was distributed to recharge zones as delineated by HydroFocus. A detailed description of the pre-processing programs and the delineated recharge zones is previously reported by HydroFocus (2007, 2009, and 2011).

In the 2008 No-Project Scenario by HydroFocus, simulated monthly groundwater recharge in irrigated areas was also generated using the SMB model. As described earlier, the land use conditions and recharge zones assumed in Scenario 1 and the project model scenarios are the same as in the 2008 No-Project Scenario. However, altered hydrology in the new hydrologic sequence (including the Design Drought) leads to changes in the rate of groundwater recharge in irrigated areas. To account for the change in the monthly groundwater recharge model inputs, the MODFLOW recharge package in the 2008 No-Project Scenario was modified. It should be noted that in the 2008 No-Project Scenario, simulated monthly recharge in municipal areas is determined from both municipal water use and the historical temperature and rainfall data, as described by HydroFocus (2011). Municipal water use consists of both surface water and groundwater pumping for municipal use. For all five model scenarios, total municipal water use was assumed to remain the same as in the 2008 No-Project Scenario. Therefore, in all five model scenarios, monthly groundwater recharge that would result from municipal water use is essentially the same as in the 2008 No-Project Scenario, but altered according to the new hydrologic sequence.

6.6. Irrigation and Non-Potable Groundwater Pumping

This section describes modeling assumptions for irrigation and other non-potable pumping used in the model scenarios. The PA pumping assumptions and the project specific assumptions are presented separately in subsequent sections.

Irrigation and non-potable pumping assumptions were modified from the 2008 No-Project Scenario as a result of running the SMB model to be consistent with the new hydrologic sequence. A summary of the irrigation and non-potable pumping assumptions used in the model scenarios is presented in Table 10.1-2.

In the HydroFocus 2008 No-Project Scenario (2011), irrigation pumping for wells without metered data records was based on the monthly demand estimated by the SMB model. As mentioned earlier, rainfall, temperature, and municipal water use are input data sets for the SMB. As a result of changes in the hydrologic data used in the model scenarios, the SMB-estimated irrigation demand was updated to generate irrigation demand estimates that are consistent with the new hydrologic sequence. In the model scenarios, the SMB model was run with the input data sets that were rearranged according to the hydrologic sequence, following the same approach developed by HydroFocus (2011).

Minor modifications were made to the revised estimates of irrigation pumping resulting from the SMB model run to account for pumping data that are representative of actual pumping conditions, based on information provided by SFPUC. These modifications include the Golden Gate Park irrigation wells (Elk Glen, North Lake, and South Windmill Replacement), California Golf No.02, the Edgewood Development Center well, Zoo No.05, and the Stern Grove well, as described below:

- **Golden Gate Park Irrigation Wells** – The 2008 No-Project Scenario (HydroFocus, 2011) estimates Golden Gate Park irrigation at approximately 1.12 mgd (or 1,252 afy), based on metered data provided by SFPUC. For the Existing Conditions, irrigation pumping in Golden Gate Park was adjusted upward to approximately 1,280 afy to match 2008 meter data, which is the most recent and complete metered record that is representative of actual pumping. Pumping in each of the three individual wells was increased with the following pumping distribution among the wells to maintain the same proportion of total pumping as in the pumping distribution used in the 2008 No-Project Scenario.
    - Elk Glen – increased pumping from 0.011 to 0.081 mgd (from 12 to 91 afy).
    - North Lake – increased pumping from 0.302 to 0.563 mgd (338 to 631 afy).
    - South Windmill Replacement – decreased pumping from 0.805 to 0.498 mgd (902 to 558 afy).
- **California Golf Club No.02** – decreased pumping from 0.212 mgd to 0.192 mgd (from 237 to 215 afy), based on rates provided verbally by the California Golf Club (personal comm., Rick Kavakoff, 2009).
- **Zoo No.5** – decreased pumping from 0.404 to 0.321 mgd (from 452 to 360 afy), as provided by the SFPUC based on the average of 2005, 2006, 2007, and 2008 data (SFPUC, 2009c).
- **Edgewood Development Center** – increased pumping from 0.007 to 0.009 mgd (from 8 to 10 afy) (personal comm., Jeff Gilman, 2009).
- **Stern Grove Well** – reduced pumping from 0.042 to 0.0043 mgd (from 47 to 4.8 afy) to account for the new information available about the use of the well as a supplemental water source for Pine Lake (written comm., Jeff Gilman, 2010). The well is assumed to be pumped approximately four days per year, as needed, to maintain the water level in Pine Lake at 31.5 feet (City Datum).

6.6.1. SFGW Project Scenarios

Irrigation and non-potable pumping assumptions for Scenario 1 and Scenarios 3a and 3b are essentially the same, except changes described below.

- For Scenario 3a, the Stern Grove well irrigation pumping is increased from 0.0043 mgd to 0.012 mgd (from 4.8 to 13.6 afy) for Scenario 3a, which represents 0.008 mgd (8.8 af) more pumping than Scenario 1. Based on the monthly pumping assumptions provided by SFPUC, the Stern Grove well would pump seven months (January, May, June, July, August, September, and October) with pumping rates ranging from 1.1 af per month to 2.3 af per month.

- For Scenario 3b, the Stern Grove well irrigation pumping is increased from 0.0043 mgd to 0.013 mgd (from 4.8 to 14.8 afy) for Scenario 3b, which represents 0.009 mgd (10 af) more pumping than Scenario 1. Based on the monthly pumping assumptions provided by SFPUC, the Stern Grove well would pump seven months (January, May, June, July, August, September, and October) with pumping rates ranging from 1.2 af per month to 2.5 af per month.

The Stern Grove well pumping volumes under Scenarios 3a and 3b are based on the supplemental water needed to maintain the water level in Pine Lake at 31.5 feet (City Datum), based on information provided by SFPUC. Pumping of the Stern Grove well is proportional to the total pumping of the SFGW Project, in which the total pumping in Scenario 3a is less than the total pumping in Scenario 3b.

6.6.2. Cumulative Scenario

Irrigation and non-potable pumping assumptions for Scenario 3b and Scenario 4 are essentially the same, except changes described below.

- Based on the results of the revised SMB, the long-term average irrigation demand by Holy Cross cemetery was estimated at 0.19 mgd (212 afy) for Scenario 1 and the GSR and SFGW Project scenarios (Scenarios 2, 3a, and 3b). The Cumulative Scenario required further adjustments to take into account the planned future build-out in the Holy Cross cemetery. Based on the potential future build-out at the Holy Cross cemetery, additional pumping of 0.04 mgd (or 45 afy) was estimated for the Cumulative Scenario. The Holy Cross cemetery build-out was projected to be at a rate of about 1.5 acre per year from 2010 to 2030 (total of 30 acres over 20 years) (personal comm., Roger Appleby, 2010). With a conservative irrigation rate of 1.5 af per acre, the additional estimated future irrigation pumping rate was estimated to be 45 afy (or 0.04 mgd).

6.7. GSR Project

The GSR Project is sponsored by the SFPUC in collaboration with the three PAs (Cal Water, Daly City, and San Bruno), who operate their own municipal supply wells and purchase wholesale water from SFPUC's Regional (surface) Water System. The overall objective of the GSR Project is to develop a new dry-year groundwater supply that can be utilized at a rate of 7.2 mgd (or 8,100 afy) above the existing municipal groundwater pumping over a 7.5-year drought period. Water would be stored in the aquifer through in-lieu recharge equal to the reduction in pumping by the PAs made possible by supplemental SFPUC surface water supplies delivered in wet and normal years.

6.7.1. GSR Project Pumping

Figure 10.1-4 shows the locations of the proposed GSR Project municipal wells that were incorporated into the model scenarios involving the GSR Project. Table 10.1-7 shows the total pumping volumes assumed for the proposed GSR Project municipal wells during the put/take/hold sequence. The general assumption is that pumping in each GSR Project well would be reduced in duration to 4 hours per month for well exercising during put and hold periods. For the purpose of these modeling scenarios, month-to-month pumping was assumed to be constant, with no seasonal pumping variations.

Table 10.1-8 shows the assumed pumping distribution by model layers for each of the GSR Project wells. The general assumptions made to allocate the pumping vertically take into account the proposed well screen intervals in conjunction with the hydraulic conductivity differences in Model Layers 4 and 5. Where the W-clay is present, it was assumed that the screen footage in Model Layers 1 through 4 was given the double weighting above the W-clay that it is below the W-clay in Model Layer 5, except at TW-CUP-10A, where the proposed screen is only planned for the zone above the W-clay. For areas without the W-clay, e-logs were reviewed to determine how to allocate pumping (either equal weighting for all screens or double the weighting from the upper screen). The pumping allocation was based on the fact that the calibrated horizontal hydraulic conductivity (K_h) values are generally 8 feet/day in Model Layers 3 and 4 compared to 4 feet/day in Model Layer 5 (HydroFocus, 2011). Moreover, based on the conceptual understanding of the subsurface geology, review of the available well logs, analysis of footage of screen in various layers times weighting factors, it appears that the majority of pumping in practice is derived from depths corresponding to Model Layer 4.

6.7.2. Partner Agency Pumping

Figure 10.1-4 shows the locations of the PA municipal puping wells that were incorporated into the five model scenarios. The locations of the proposed wells were based on the information provided by Cal Water and Daly City to SFPUC.

The total pumping by the PAs for Scenario 2 is 6.9 mgd, compared to 6.84 mgd under Scenario 1 (Table 10.1-2). As shown in Table 10.1-1 and 10.1-2, the total PA pumping assumptions used for the GSR Project under Scenarios 2 and 4 are essentially the same, but the locations of the PA municipal pumping wells used for each scenario vary slightly, as shown in Table 10.1-7 and discussed below.

- **San Bruno** - Under Scenarios 2 and 4, San Bruno would continue to pump its existing five wells (SB-No.15, SB-No.16, SB-No.17, SB-No.18, and SB-No.20). As of early 2012, San Bruno was evaluating the potential to replace SB-No.15 and had identified several potential replacement sites. Since the GSR Project EIR modeling can only assume one location for the replacement of SB-No.15, it was agreed that the current location of SB-No.15 was reasonable to use because the current SB-No.15 location is the closest location to the proposed GSR Project wells and thus provides a conservative analysis by concentrating pumping in that area (i.e., the GSR Project proposed well at Golden Gate National Cemetery is about a quarter mile north of SB-No.15).

Another alternate location was about one mile northwest of the proposed GSR Project well at the SFPUC Millbrae Facility (CUP-M-1). However, CUP-M-1 is expected to have the lowest pumping rate (about 160 gpm as shown in Table 10.1-3) of all of the GSR Project wells because the saturated thickness at this location is less than areas where the proposed GSR Project wells to the north are located. Thus, it would not be conservative to use this as the replacement location for SB-No.15 for this analysis.

- **Daly City** – Under Scenario 2, Daly City plans to pump the five existing wells (Jefferson, Vale, Daly City No.4, Westlake, and Junipero Serra), but Scenario 4 accounts for Daly City's future plans to use two proposed wells (Daly City A Street Replacement well and Daly City No.4 Replacement well). Under Scenario 4, Daly City total pumping would be the same as Scenario 2, but using four existing wells (Jefferson, Vale, Westlake, and Junipero Serra) and the two proposed wells.
- **Cal Water** – Under Scenario 2, Cal Water proposes to pump five wells, including three of the existing wells (SSF1-19, SSF1-20, and SSF1-21) and two proposed wells (SSF1-22 and SSF1-23), based on the information provided by Cal Water to SFPUC. Under Scenario 2, three existing wells (SSF1-14, SSF1-17, and SSF1-18) were assumed to be out of production. Based on the documents provided by Cal Water, SSF1-14 and SSF1-17 were reported inactive, and SSF1-18 was reported to be replaced with the proposed well SSF1-23. The existing well SSF1-15 was assigned "zero" pumping based on the information from Cal Water that indicates the well will be destroyed due to age and contaminants. Under Scenario 4, Cal Water was assumed to be pumping the two existing wells (SSF1-20 and SSF1-21) and two proposed wells (SSF1-22 and SSF1-23). Based on the information provided by Cal Water, proposed wells SSF1-24 and SSF1-25 are considered redundant and no pumping was assigned to these wells for the purpose of the Cumulative Scenario.

Table 10.1-7 shows the total pumping at each PA municipal well during the put/take/hold sequence. Pumping during put periods was assumed to be 20 percent of the take period pumping in each well. For San Bruno wells, the pumping distribution among the individual wells and the monthly pumping distribution for each well are the same for Scenarios 1, 2 and 4, and they are assumed to be proportional to those in the 2008 No-Project Scenario (HydroFocus, 2011). Under Scenario 2, Daly City pumping distribution among the wells is the same as Scenario 1 and follows the same distribution as in the 2008 No-Project Scenario (HydroFocus, 2011). Under Scenario 4, total pumping by Daly City was distributed among the six wells evenly. Under Scenario 2, pumping among the individual Cal Water wells was determined based on the pumping rates provided by Cal Water and inputs from SFPUC. For Scenario 4, pumping among the individual Cal Water municipal wells was determined based on pumping rates provided by Cal Water for each well.

Table 10.1-8 presents the pumping distribution by model layers for each PA municipal well. For the existing PA municipal wells, vertical pumping distribution by model layers is the same as in the 2008 No-Project Scenario. The four Cal Water proposed wells (SSF1-22, SSF1-23, SSF1-24, and SSF1-25) would be similar in nature to the existing wells SSF1-20 and SSF1-21 and would be located in the vicinity of the existing wells, based on the information provided by Cal Water to SFPUC. In light of the estimated screen zones of 380 to 570 feet below ground surface (bgs) for the proposed wells, which are similar to existing wells SSF1-20 and SSF1-21, under Scenarios 2 and 4, the depth distribution of the Cal Water pumping by model layers for the proposed wells was assumed to be similar to that for the existing wells SSF1-20 and SSF1-21.

6.7.3. Put/Take/Hold Sequence

In the modeling scenarios involving the GSR Project (Scenarios 2 and 4), the hydrologic sequence follows the put/take/hold sequence to simulate in-lieu groundwater recharge during wet years and groundwater extraction during dry years. As described earlier, the HH/LSM, which was used extensively for long-term planning purposes in the SFPUC's PEIR, outputs a put/take/hold sequence on a monthly basis and tracks the volume of water stored in the SFPUC Storage Account (SFPUC, 2007; SFPUC, 2009a). The following is the description of the put/take/hold sequence used in the hydrologic sequence for the model scenarios, compared to the original put/take/hold in the HH/LSM run:

- The original HH/LSM put/take/hold sequence is based on the in-lieu recharge rate (or put rate) of 7.23 mgd. This put rate is equal to the rate of groundwater pumping during a take period in the HH/LSM simulation run. For the current modeling scenarios, on the other hand, the in-lieu recharge rate during a put year is 5.52 mgd and the rate of groundwater extracted during a take year is 7.23 mgd. The pumping rate of 5.52 mgd represents the 80 percent of total PA pumping of 6.9 mgd during a put period. As a result of the differences in the put rate, the hydro sequence has slightly longer put periods for the model scenarios compared to the original HH/LSM model outputs. The longer put periods are used in order to ensure the volume of put in the current modeling scenarios is not less than the volume of put in the HH/LSM outputs.
- In the PEIR, the put/take/hold conditions are defined as annual periods that run from July to June. The put/take/hold sequence used for the GSR Project under Scenario 2 and the Cumulative Scenario is consistent with this approach.
- The put/take/hold sequence used in the current modeling scenarios includes the Design Drought period as used in the SFPUC's PEIR.
- The put/take/hold sequence in the current modeling scenarios includes a recovery period (put period) following the Design Drought that brings the SFPUC Storage Account back to the same value as the initial condition (20,000 af). This allows a direct comparison of groundwater conditions with respect to the SFPUC Storage Account at the beginning and the end of the GSR Project under Scenario 2 and the Cumulative Scenario.

- The put/take/hold sequence used in the current modeling scenarios starts with a put condition for the GSR Project and the Cumulative Scenario. This is done in order to simulate the filling of the SFPUC Storage Account to the “full” condition (60,500 af) prior to the Design Drought.

The put/take/hold sequence used in the current modeling scenarios is presented in Table 10.1-9. The Design Drought is represented by the 7.5-year period of take months from Simulation Year 36 through 44.

6.8. SFGW Project

The SFGW Project consists of the development of up to 4.0 mgd of local San Francisco groundwater in the North Westside Basin as a regular and emergency drinking water supply. The WSIP primary level-of-service goal for the SFGW Project is to increase the long-term water supply available to the SFPUC.

As shown in Table 10.1-2, the PA pumping assumptions used for the SFGW Project scenarios (Scenarios 3a and 3b) are the same as Scenario 1. These assumptions are covered in Section 5.1 and are not discussed further in this section.

6.8.1. SFGW Project Pumping

Figure 10.1-4 shows the locations of the six proposed SFGW Project municipal wells that were incorporated into the model scenarios involving the SFGW Project. Table 10.1-6 shows the normal design and average pumping capacity for the SFGW Project municipal wells. Table 10.1-10 shows the percent pumping distribution for each well under Scenarios 3a and 3b. Pumping by each SFGW Project municipal well was estimated by distributing the total monthly pumping (combined pumping for the four wells for Scenario 3a and for the six wells for Scenario 3b) among the wells proportional to each well’s normal design pumping capacity.

The model layer-by-layer pumping distribution for the SFGW Project wells is presented in Table 10.1-8. Pumping among the model layers was distributed proportional to the layer thicknesses and the screened intervals of the wells (i.e., construction details) as provided by the SFPUC. In locations where the screened interval spans the entire model layer, pumping was distributed proportional to the layer thickness. When the well screen falls within only a portion of the model layer, pumping was distributed proportional to the length of well screen within that layer. Table 10.1-11 shows calculated monthly pumping by each SFGW Project well for Scenarios 3a and 3b. Monthly pumping varies, but total pumping remains the same annually (i.e., 3.0 mgd for Scenario 3a and 4.0 mgd for Scenario 3b).

Pumping assumptions for the three existing Golden Gate Park wells (Elk Glen, North Lake, and South Windmill Replacement wells) under Scenarios 3a and 3b are summarized in Tables 10.1-2, 10.1-6, and 10.1-10. If recycled water were available for irrigation, the Elk Glen well would not pump (Table 10.1-2), while the North Lake and South Windmill Replacement wells would pump at 0.50 mgd and 0.65 mgd, respectively, for municipal supply (Table 10.1-10). Without recycled water for irrigation, all three existing wells would pump at a total combined rate of approximately 1.14 mgd based on the monthly irrigation pumping assumptions used in the Existing Conditions (Table 10.1-2).

6.9. Lake Merced

Lake Merced is an important hydrological feature in the Westside Basin. It is simulated in the Westside Basin Groundwater Model using the MODFLOW Lake Package, generally following the conditions used for the 2008 No-Project Scenario. Details regarding the MODFLOW simulation of Lake Merced are discussed in Sections 6.9.1 through 6.9.3.

Lake Merced water levels are also simulated using the Lake-Level Model, as discussed in Section 6.9.5. Lake Merced level management operations are considered as a reasonably foreseeable future project under Scenario 4 (Cumulative Scenario) and discussed in Section 6.9.4. The current understanding of the Lake Merced management operations is that it will raise and maintain Lake Merced water levels up to an elevation of 9.5 feet (City Datum) (18.12 feet NGVD 29) with supplemental water derived from stormwater diverted from Daly City's Vista Grande Canal.

6.9.1. Model Modifications to Lake Package

For the model scenarios, monthly runoff entering Lake Merced from Harding Park Golf Course and nearby residential areas was estimated based on the results from the revised SMB model and revised results were imported into the model using the MODFLOW Lake Package (LAK3). In the 2008 No-Project Scenario, monthly runoff entering the lake is extracted from the SMB model. Following the same approach developed by HydroFocus (2011), the SMB model was revised to update the lake package consistent with the new hydrologic sequence. Similar to the 2008 No-Project Scenario, all five model scenarios, except the Cumulative Scenario, assume no Vista Grande stormwater diversions into Lake Merced and no other water additions to the lake.

The MODFLOW Lake Package was further modified for initial lake levels and lake spillway, compared with the 2008 No-Project Scenario, as described separately in the following subsections 6.9.2 and 6.9.3.

6.9.2. Initial Lake Condition

For all model scenarios, the initial Lake Merced water level was set to match the simulated June 2009 lake level from the version 3.1 Historical Simulation (HydroFocus, 2011). Simulated rather than measured (observed) Lake Merced lake levels are used because this change improves the model performance by ensuring that the lake levels are in equilibrium with groundwater conditions in the model. If this approach were not used, then there may be undesirable effects in the water balance and nearby groundwater levels as the model works to achieve a new equilibrium with the different initial lake condition. The initial lake level at South Lake was set to 17.95 feet (NGVD 29). The San Francisco City Datum (City Datum) is another reference datum commonly used for Lake Merced lake level measurements. Relative to the City Datum, the initial lake level at South Lake was set to 9.33 feet (City Datum).

6.9.3. Model Modifications for the Lake Spillway

The MODFLOW Lake Package does not include a mechanism to simulate the control of a lake level with a spillway. Without a spillway mechanism, MODFLOW would allow the lake levels to rise to levels that are not physically possible, which could affect the simulated shallow groundwater levels (due to groundwater-surface water interactions with the lake) and the overall Westside Basin water balance. For all five model scenarios, there were instances where the MODFLOW-simulated Lake Merced lake level was above the level of the spillway. Therefore, scenarios were run iteratively by adjusting the Lake Package input file to remove excess water from the lake (as lake spills) until the lake levels remained below the level of the spillway. This approach is different than the 2008 No-Project Scenario, which assumed no spills from the lake.

For Scenarios 1, 2, 3a and 3b, the existing Lake Merced water spillway elevation of 21.62 feet (NGVD 29, or 13.0 feet City Datum) was used. For Scenario 4, the projected modified spillway elevation of 18.12 feet (NGVD 29, or 9.5 feet City Datum) was used based on documentation for the Vista Grande Drainage Basin Alternatives Analysis project for Daly City (Brown and Caldwell, 2010, Jacobs Associates, 2011a, 2011b; City of Daly City, 2012).

The MODFLOW Lake Package uses a water balance method to calculate inflows and outflows from the lake outside of the groundwater contribution (e.g., precipitation, stormwater runoff, evaporation, and direct water additions and withdrawals). These values are defined in the Lake Package by the user prior to the model input files. The inflows and outflows from the groundwater contribution are calculated by MODFLOW.

To adjust for the spillway, the outflows that represent the lake spills (i.e., direct water withdrawals) in the Lake Package were increased iteratively until the MODFLOW-simulated lake levels stayed below the level of the spillway for consecutive months. A single month where the lake level was less than 0.1 foot above the spillway was allowed.

6.9.4. Cumulative Scenario

For the Cumulative Scenario (Scenario 4), the use of Lake Merced as part of the Vista Grande Drainage Basin Alternatives Analysis project for Daly City is considered to be a reasonably foreseeable future project. Daly City's Vista Grande Drainage Basin Alternatives Analysis recommended the alternative, in which stormwater flow from the Vista Grande Canal would be diverted to Lake Merced (Jacobs Associates, 2011a, 2011b; City of Daly City, 2012).

Daly City evaluated 24 potential scenarios for the Lake Merced Alternative for various flow configurations related to the presence or absence of a wetland and the level of the spillway (Brown and Caldwell, 2010). Given that the Lake Merced Alternative scenarios are still in the initial design stage, a scenario that provides an average flow to the lake is considered acceptable given that averages have been used for assumptions in other instances (e.g., the PA pumping assumptions). The 75 cfs Daly City scenario was selected for use in this modeling analysis. 75 cfs represents a cutoff volume, so that all flow down the Vista Grande Canal exceeding this cutoff volume would be diverted to Lake Merced (Brown and Caldwell, 2010). Stormwater discharges into Lake Merced occur when water flows in the Vista Grande Canal exceed the cutoff volume and are diverted into the Lake Merced. These flows occur periodically in response to large storms, and were calculated as part of the Vista Grande Drainage Basin Alternatives Analysis (Brown and Caldwell, 2010) based on historical precipitation data. Stormwater flows were calculated to occur as diversions to Lake Merced in every year, and range from 19 to 681 afy with an average of 207 afy (Brown and Caldwell, 2010). These flows were added to the MODFLOW Lake Package as an input into Lake Merced as stormwater discharges.

The Lake Merced Alternative scenarios also include provisions for an engineered wetland and modification of the Lake Merced spillway (Brown and Caldwell, 2010). In the 75 cfs scenario, the average baseflow in the Vista Grande Canal is assumed to be diverted into an engineered wetland for treatment and then discharged to Lake Merced on an ongoing basis. Baseflows have been estimated to range from 18 to 26 af per month (Kennedy/Jenks, 2009). These were also added to the MODFLOW Lake Package as an input into Lake Merced.

Finally, the 75 cfs scenario contains a provision to lower the spillway out of Lake Merced by 3.5 feet from an elevation of 21.62 to 18.12 feet (NGVD 29), or from 13.0 feet to 9.5 feet (City Datum). Spillway discharges at the lower spillway elevation were calculated using the methodology described in Section 6.9.3.

6.9.5. Use of Lake Merced Results

As mentioned in Section 4, the Westside Basin Groundwater Model has the ability to reproduce long-term trends in the Lake Merced lake levels as shown in the Historical Simulation by HydroFocus (2011), but there is uncertainty in estimating absolute lake levels. Comparisons between simulated and observed lake levels show differences that range from -2.0 to 7.0 feet. The model generally reproduces the trends and relative changes seen in the historical data for Lake Merced during the period from 1972 to 1995. During the first 14 years (1958 to 1972) and the last 13 years of the simulation (1996 to 2009), simulated lake levels were consistently 2 to 3 feet higher than measured data and show periods of divergence between historical and measured trends. The MODFLOW model is considered useful in simulating the relative effect of possible regional groundwater supply projects on Lake Merced levels; however, the simulation of lake level management scenarios with the objective of projecting absolute lake levels is not recommended.

Because of these issues with the MODFLOW representation of Lake Merced, the Lake-Level Model, discussed in Section 8, is also used to simulate the Lake Merced water levels for the five model scenarios.

7. MODFLOW Model Scenario Results

The results of MODFLOW model simulations for all five scenarios are presented in this section. The evaluation of these results with respect to specific groundwater issues is discussed in the following TMs:

- Task 10.2 for assessment of groundwater-surface water interactions
- Task 10.3 for assessment of seawater intrusion
- Task 10.4 for changes in groundwater levels and storage
- Task 10.5 for assessment of pumping induced land subsidence
- Task 10.6 for assessment of changes in groundwater quality

7.1. Documentation of Model Results

The model results are typically presented based on the water year (from October of the previous calendar year through September). The simulation period is 47 years and three months. The first three months of the simulation period from July 2009 to September 2009 are considered as Year Zero (0), and are excluded in the summary tables. This exclusion is made because the partial data would bias model result statistics (e.g., annual average, annual minimum, and annual maximum). The model results are presented for scenario years 1 through 47.

7.1.1. Hydrographs

The Westside Basin Groundwater Model can be used to report groundwater levels specific to each of the five model layers. To facilitate this analysis, model-simulated groundwater levels corresponding to Model Layers 1 and 4 are presented, because they are representative of the response of the unconfined and Primary Production aquifers, respectively.

Model-simulated hydrographs from selected key representative monitoring well locations were prepared across the entire groundwater basin. Twelve representative monitoring locations (shown in Figure 10.1-4) were used to show model-simulated groundwater elevations. This is a subset of the 125 observation wells present in the model.

Attachment 10.1-B presents hydrographs for the 12 selected well locations to demonstrate results from the individual model scenarios, and also to compare the results of the project model scenarios (Scenarios 2, 3a, 3b, and 4) relative to the Existing Conditions (Scenario 1). Attachment 10.1-B includes hydrographs of model-simulated absolute water levels at the 12 selected locations for Model Layers 1 through 5, and of the water levels from the five scenarios for Model Layers 1 and 4 relative to the Existing Conditions. These hydrographs are included to show how the pumping assumptions in the various scenarios result in changes in the hydrologic conditions of the Westside Basin. Model Layer 1 results provide information about expected changes to the Shallow Aquifer (where present) and to unconfined groundwater conditions; whereas, Model Layer 4 results give an indication of simulated groundwater level changes anticipated in the confined Primary Production Aquifer portion of the model. Model Layer 5 also encompasses portions of the Deep Aquifer, but it is not laterally continuous and thus not as well-suited for evaluation as is Model Layer 4 output.

7.1.2. Volumetric Water Budgets

Volumetric water budget graphs and tables were prepared for each of the five scenarios for the entire simulation period. The water budget (also referred to as water balance or hydrologic budget) presented in this TM shows the major components of inflows to and outflows from the Westside Basin. Water budget analysis was conducted at three different regional scales listed below and results are presented in the following subsections:

- Westside Basin
- North and South Westside Basins
- Five water budget zones that are collectively referred to as the “Developed Subbasin” by HydroFocus (2011)

7.1.2.1. Westside Basin Water Budget

Attachment 10.1-C presents annual water budget graphs and summary tables as well as annual and net changes in groundwater storage for each of the five scenarios for the entire Westside Basin. Average, maximum, and minimum annual inflows and outflows are summarized for each of the five scenarios in Table 10.1-12. The average values in the summary tables represent the average annual inflows and outflows for the simulation period based on the water year. As mentioned earlier, model results for the first partial year (July to September) are excluded in the summary tables. The minimum and maximum values represent the minimum and maximum annual inflows and outflows, respectively, for the simulation period. Results in Attachment 10.1-C are summarized on an annual basis to show the annual water balance itemized into individual major inflows and outflows. The annual change in groundwater storage is also tabulated and plotted. The negative values for the annual change in groundwater storage represent a decline in the groundwater storage, while the positive values represent an increase in groundwater storage. It should be noted that the net change in groundwater storage graphs represent values relative to the beginning of the simulation. Groundwater storage at the beginning of the simulation is set to zero (“0”); thus, changes in the basin storage are reported relative to the beginning storage. Since the model scenarios use the same initial conditions, the zero basin storage at the beginning of the simulation corresponds to the same basin storage values for the five model scenarios, each starting with the same June 2009 initial condition that is representative of the SFPUC Storage Account of 20,000 af.

7.1.2.2. North and South Westside Basin Water Budgets

A zone budget analysis was performed to summarize model results for the North Westside Basin and South Westside Basin separately. The U.S. Geological Survey post-processor ZONEBUDGET (Harbaugh, 1990) was used to extract the simulated volumetric water budget (summed over the five model layers). Two water budget zones are separated south of the San

Francisco-San Mateo County line to represent the North and South Westside Basins. As mentioned earlier, this division is not intended to represent a physical boundary, but is used merely for the convenience of representing the model results spatially. The model cells representing Lake Merced are all located in the North Westside Basin. Therefore, the flow between the lake and the surrounding aquifer system is accounted for as part of the North Westside Basin water budget only. Attachment 10.1-D presents volumetric water budget graphs and tables for the North and South Westside Basins separately, and are presented in the same way as for the entire Westside Basin. In addition to the water budget components (inflows and outflows), two components are presented to keep track of flow exchanges between the North and South Westside Basins, as shown in the summary tables and annual water balance graphs.

7.1.2.3. Developed Subbasin Water Budgets

Similar to the approach taken by HydroFocus (2011), a water budget zone analysis was conducted to summarize volumetric budgets for the five water budget zones that are collectively referred to as the “Developed Subbasin” by HydroFocus. The U.S. Geological Survey post-processor ZONEBUDGET (Harbaugh, 1990) was used to extract the simulated volumetric water budget (summed over the five model layers) for the San Francisco, Daly City, Colma, South San Francisco, and San Bruno water budget zones. These water budget zones encompass the inland area where all municipal water supply wells are located. The boundaries of the Developed Subbasin represent the institutional boundaries that coincide with the most intensely developed water use areas within the basin. This water budget zone analysis presents results for ten different sub-areas, including the aforementioned five zones in the Developed Subbasin and five adjacent sub-areas (beneath the Pacific Ocean, San Francisco Bay Plain, south of San Bruno in Millbrae and Burlingame areas, and across the Serra Fault). Attachment 10.1-E presents results of the water budget zone analyses for the ten sub-areas for each of the five scenarios. Each summary table presents the annual average inflows, outflows, and the net change (in units of afy) over the entire simulation period. The major inflows include recharge, seepage from Lake Merced and inflow from San Francisco Bay and the Pacific Ocean (represented by constant head). The major outflows include pumping, outflow to San Francisco Bay and Pacific Ocean, and seepage to Lake Merced. The summary tables also show the net flow to or from the Developed Subbasin and the adjacent sub-areas.

7.1.3. Groundwater Elevation Contour Maps

Contour maps of the model simulated groundwater elevation data were generated at selected key time periods. Model simulated groundwater elevation contour maps are presented in Attachment 10.1-F to show the model response to various pumping stresses and recovery periods, such as at the end of simulation (for all scenarios), and at the end of the Design Drought with the long-term take period (for Scenarios 2 and 4, each involving the GSR Project). These groundwater elevation contour maps demonstrate general and regional trends in groundwater flow directions and localized cones of depression around the primary pumping areas. Contour maps of the simulated groundwater elevation data were plotted for Model Layer 1 (for Scenarios 1, 3a, 3b, and 4) and Model Layer 4 (for Scenarios 1, 2, and 4) to represent the model response in the unconfined and deeper aquifers in the basin. Contour maps of the simulated groundwater elevation maps in Model Layer 1 were generated to demonstrate the model response in the SFGW Project area in the North Westside Basin where the Shallow Aquifer and unconfined groundwater conditions exist. Contour maps of the simulated groundwater elevation maps in Model Layer 4 generally represent the model response in the Primary Production Aquifer that is present in the GSR Project area in the South Westside Basin.

Dry cells shown on the contour maps for Model Layer 1 define areas where MODFLOW-simulated groundwater elevations are below the bottom of the layer. Dry cells do not necessarily imply dewatering the aquifer. During the model simulation, simulated heads can oscillate, in which cells convert from wet to dry and then convert back from dry to wet.

7.1.4. Lake Hydrographs

Hydrographs for Lake Merced water levels were prepared for all of the five model scenarios using the Lake-Level Model discussed in Section 8. A composite graph showing results of all scenarios on a single graph based on the Lake-Level Model is shown in Section 8.2. The lake hydrographs for each model scenario are also presented in Attachment 10.1-G. To be consistent with the datum used in the Westside Basin Groundwater Model and the groundwater elevation hydrograph results from that model, lake levels are shown using both the NGVD 29 datum and the City Datum. All five scenarios account for water removal from the lake to keep the lake levels below the spillway. As described earlier, the lake spillway is assumed to be 13 feet (City Datum) for Scenarios 1, 2, 3a, and 3b, and to be 9.5 feet (City Datum) for Scenario 4. Because of limitations in the MODFLOW Lake Package (Section 4.3.3), the results of the Lake-Level Model are considered the most appropriate for analysis of groundwater-surface water interactions at Lake Merced.

7.2. Model Scenario Assessment

Model results were reviewed to check that simulated results from individual scenarios are appropriate and consistent with model inputs. General trends observed in groundwater levels, water balances, and resulting changes in groundwater storage were checked for consistency among model scenarios.

7.2.1. Model Convergence

All of the future model scenarios met the mathematical convergence criteria specified in the existing Westside Groundwater Flow Model in all time steps. Therefore, the model-simulated results converged appropriately, and the resulting water balance was considered acceptable.

7.2.2. Assessment of Model Scenario Results

Groundwater pumping assumptions used to develop the model scenarios are the significant model inputs that differentiate one scenario from another and can be used as a measure to check consistency among scenarios. Simulated groundwater levels are expected to vary depending on the magnitude of pumping applied and the spatial and temporal distribution of pumping.

Figure 10.1-6 presents simulated groundwater levels for the model scenarios for Model Layer 1 at a monitoring well located in Golden Gate Park (SWM-GS). Figure 10.1-7 shows simulated differences in groundwater elevations at the same location relative to the Existing Conditions (Scenario 1). Given the proximity of this monitoring well to a proposed SFGW Project municipal well (South Windmill Replacement), groundwater levels in the vicinity of this well are expected to be most heavily influenced by the SFGW Project operations, while the GSR Project operations are not expected to have much effect. Therefore, Scenarios 3a, 3b, and 4 results are expected to be similar to each other throughout the simulation period. Since the SFGW Project pumping operations propose to produce additional year-round groundwater supply in the North Westside Basin compared to the Existing Conditions, groundwater levels resulting from Scenarios 3a, 3b, and 4 would be expected to be lower than those of the Existing Conditions in this area. The model results shown in Figures 10.1-6 and 10.1-7 are consistent with these expected results.

On the other hand, due to the large distance between the SWM-GS monitoring location and the GSR Project operations in the South Westside Basin, the overall effect of the GSR Project pumping on groundwater levels in Golden Gate Park area would be expected to be minor (i.e., groundwater levels for Scenario 2 would be similar to those for the Existing Conditions). As also shown in Figures 10.1-6 and 10.1-7, all hydrographs start at the same level, as expected, representing the same initial conditions used in all five scenarios. As the simulation time elapses, groundwater levels for Scenarios 1 and 2 behave in similar ways at the location of this monitoring well because of the minor effect of the GSR Project operations on this location. Similarly, as the simulation time progresses, Scenarios 3a, 3b, and 4 show similar trends since the results are more influenced by the SFGW Project operations at this location. The model results shown in Figures 10.1-6 and 10.1-7 are consistent with these expected results.

Figures 10.1-8 and 10.1-9 show the model-simulated groundwater elevations for Model Layer 4 in the Daly City area (DC-A St), which would be subject to influence from the proposed GSR Project operations and possibly to the proposed pumping for the SFGW Project . Because of its location, the effect of the GSR Project on groundwater levels at the DC-A St monitoring location would be expected to be greater compared to that of the SFGW Project. As expected, the SFGW Project alone would result in a small, incremental decline in groundwater levels as a result of the year-round additional pumping compared to Scenario 1, while the effects of the GSR Project would vary significantly depending on the timing of the put/take/hold sequence and the associated pumping assumptions. Figures 10.1-8 and 10.1-9 demonstrate the expected results, where the effect of the GSR Project would be more pronounced at this location. As expected, model–simulated groundwater levels decline during take periods, recover during put periods, and return to the trends seen in Scenario 1 during hold periods.

Figures 10.1-10 and 10.1-11 show the model-estimated aggregate change in groundwater storage and changes in groundwater storage relative to the Existing Conditions (Scenario 1). All five scenarios start with the same initial conditions of June 2009; thus, the storage plots start with zero to indicate the beginning of the simulation. As discussed earlier, the June 2009 groundwater levels account for the SFPUC Storage Account of 20,000 af in the basin, but do not account for basin hydraulic inefficiencies and potential storage losses. This subject is described in TM 10.4.

As shown in Figures 10.1-10 and 10.1-11, groundwater storage results for Scenario 1 and Scenarios 3a and 3b follow similar trends of general decline, with the decline in Scenarios 3a and 3b greater than that under Scenario 1, due to the increased pumping under the SFGW Project. The aggregate changes in groundwater storage of Scenarios 3a and 3b are similar, as expected, with a slightly greater decline in Scenario 3a. This is in response to the seasonal irrigation pumping in Golden Gate Park under Scenario 3a, compared to Scenario 3b, which assumes regular municipal pumping from the two proposed SFGW Project wells and supplemental recycled water to replace the irrigation pumping in Golden Gate Park. Due to the combined pumping assumed under the Cumulative Scenario (Scenario 4), the change in storage would be greater under the Cumulative Scenario compared to Scenario 1, and compared to Scenario 2 (GSR Project) or Scenarios 3a and 3b (SFGW Project) alone. As expected, the trend in model-simulated groundwater storage decline is similar for Scenarios 2 and 4. The additional storage decline in Scenarios 2 and 4 compared to Scenario 1 is due to the take periods during the 7.5-year Design Drought, but the overall decline is greater under Scenario 4 than Scenario 2 because of the greater combined pumping of the GSR and SFGW Projects in Scenario 4. Similar to the effects seen on groundwater levels, the resulting changes in groundwater storage from the scenarios involving the GSR Project are primarily controlled by the put/take/hold sequence.

Figure 10.1-12 shows the net change in groundwater pumping relative to the Existing Conditions (Scenario 1). As expected for Scenario 2, additional pumping varies as a function of the put/take/hold sequence, where pumping goes below the Existing Conditions rates during put periods, goes above the Existing Conditions rates during take periods, and returns to similar rates as in the Existing Conditions during hold periods. Scenario 4 shows trends similar to Scenario 2, but pumping is greater due to the addition of Scenario 3b pumping for the SFGW Project to Scenario 4; as a result, the hold period pumping under Scenario 4 returns to levels similar to Scenario 3b, as opposed to those of the Existing Conditions.

7.3. Application of Model Scenario Results

In the context of the modeling scenarios and related analyses, the Westside Basin Groundwater Model is considered a useful tool for simulating the relative effect of model scenarios such as those presented in this TM.

It is most useful to evaluate the relative changes of the model results presented here. Scenario 1 represents the Existing Conditions that provides a basis of comparison for evaluating the relative change both with and without the SFPUC Projects in Scenario 2 (GSR Project), Scenarios 3a and 3b (SFGW Project), and Scenario 4 (Cumulative Scenario). Given the same hydrologic sequence and the same initial conditions used in all five model scenarios, the model scenarios can be directly compared to the Existing Conditions. Simulated relative changes in groundwater levels and aquifer storage may not equal the actual changes determined from future observed hydrologic conditions, as also mentioned by HydroFocus (2007).

8. Lake Merced Lake-Level Model

Because of concerns about the ability of MODFLOW (Westside Basin Groundwater Model) to accurately simulate lake levels in Lake Merced, the analysis also utilizes the Lake-Level Model. A more complete discussion of the development of the Lake-Level Model is included in Attachment 10.1-H. Below is a summary of the application of this model to the evaluation of Lake Merced for the analysis of the GSR and SFGW Projects and the Cumulative Scenario.

8.1. Background on the Lake Merced Lake-Level Model

The Lake-Level Model is a spreadsheet-based water balance model. The model sums up the inflows and outflows from Lake Merced on a monthly time scale. The water balance components are each calculated independently. The sum represents the net change in water volume in the lake for that month. Based on this net change in water volume, a new lake level is calculated. A positive net change represents an increase in the lake level, whereas a negative net change represents a decrease in lake level.

The Lake-Level Model was calibrated to historical lake levels over a 70-year period from October 1939 to June 2009. This period includes a variety of hydrological conditions including wet, normal and dry precipitation years, flood events, and periods of high and low lake levels corresponding to a variety of conditions that are considered representative of future conditions. Overall, the Lake-Level Model closely follows both the long-term and short-term trends by demonstrating a very strong correlation of the magnitude of both annual and seasonal fluctuations reasonably well. The comparison of simulated and historical lake levels between October 1939 and June 2009 is discussed in more detail in the technical memorandum documenting the development of the Lake-Level Model, which is included as Attachment 10.1-H.

The Lake-Level Model previously has been used to support the Vista Grande Drainage Basin Alternatives Analysis in 2011 (Brown and Caldwell, 2010, Jacobs Associates, 2011a, 2011b). Some minor modifications have been made to the historical calibration analysis as part of this study, which primarily deal with shifting the basis for precipitation from the Mission Dolores to the Lake Merced Pump Station precipitation gauges. These changes are documented in Attachment 10.1-H.

8.2. Simulation of the GSR and SFGW Projects

For the analysis of the Existing Conditions and the GSR and SFGW Projects (Scenarios 1, 2, 3a and 3b), the Lake-Level Model was based on the historical calibration analysis model but with modifications to the natural hydrology with new provisions to simulate other reasonably foreseeable future projects. The water-balance components that constitute the natural background hydrology, such as precipitation, groundwater inflow/outflow, evaporation, and transpiration, are the foundation for the Lake-Level Model. However, some modifications were necessary for the analysis of the GSR and SFGW Projects to account for potential future conditions rather than historical conditions. These modifications include:

- The same 47.25-year rearranged hydrologic sequence that was used for the MODFLOW scenarios (see Section 6.3). The model inputs for the natural hydrology were based on the same historical data for the appropriate months in the sequence.
- Initial Lake Merced level is set to the measured June 2009 lake level of 14.32 feet (NGVD 29) or 5.7 feet (City Datum).
- The approach used for the groundwater inflow to and outflow from Lake Merced was changed to use the water balance values of groundwater inflow to and outflow from Lake Merced based on the corresponding scenario of the MODFLOW model. Using the MODFLOW water balance results is considered a more reliable approach because the proposed changes incorporate conditions, such as the in-lieu recharge from the GSR Project, that do not have a historical equivalent.

The Lake-Level Model results for Scenarios 1, 2, 3a and 3b are discussed in Attachment 10.1-G, and a composite hydrograph showing the Lake Merced water levels for these scenarios is shown in Figure 10.1-13.

8.3. Simulation of the Vista Grande Drainage Basin Improvements

For this analysis, the Vista Grande Drainage Basin Improvements project is considered a reasonably foreseeable future project as part of the Cumulative Scenario (Scenario 4). In addition to the conditions used in Scenarios 1, 2, 3a and 3b, Scenario 4 required additional modifications to accommodate the Vista Grande Drainage Basin Improvements project.

The primary component of the Vista Grande Drainage Basin Improvements project is the diversion of stormwater flows directly into Lake Merced. As discussed in Section 6.9.4, Scenario 4 incorporates the 75 cfs scenario of the Vista Grande Drainage Basin Improvements project. Below is a summary of how the various aspects of the Vista Grande Drainage Basin Improvements project are addressed in the Lake-Level Model.

Stormwater discharges into Lake Merced would occur when discharge rates in the Vista Grande Canal exceed 75 cfs, and the excess flows would be diverted into Lake Merced. These flows occur periodically in response to large storms, and were calculated as part of the Vista Grande Drainage Basin Alternatives Analysis based on historical precipitation data (Brown and Caldwell, 2010, Jacobs Associates, 2011a, 2011b). Stormwater flows (greater than 75 cfs) were calculated to occur in every year, and range from 19 to 681 afy with an average of 207 afy (Brown and Caldwell, 2010). These stormwater flows were input directly into the Lake-Level Model as an inflow to Lake Merced. The Lake-Level Model was modified to incorporate the flows provided by Brown and Caldwell, and these changes are included here.

The Lake Merced Alternative scenarios of the Vista Grande Drainage Basin Improvements project also include provisions for an engineered wetland and modification of the Lake Merced spillway (Brown and Caldwell, 2010). In the 75 cfs scenario, the average baseflow in the Vista Grande Canal is assumed to be diverted into an engineered wetland for treatment and then discharged to Lake Merced on an ongoing basis. Typical flows in the Vista Grande Canal, or baseflow, would be continuously diverted through an engineered wetland for treatment prior to discharge into Lake Merced. Baseflows have been estimated to range from 18 to 26 af per month (Kennedy/Jenks, 2009). These were also added to the Lake-Level Model.

The Lake-Level Model results for Scenario 4 are presented in Attachment 10.1-G, and a composite hydrograph showing the Lake Merced water levels for these scenarios is shown in Figure 10.1-13.

8.4. Strengths and Limitations of the Lake Merced Lake-Level Model

The primary strength of the Lake-Level Model is that it has a more realistic conceptualization of the lake than does the MODFLOW Lake Package, and has been calibrated to historical data (Attachment 10.1-H). The primary conceptualization strengths include the followings:

- The Lake-Level Model has a significantly stronger correlation to the measured Lake Merced lake levels than the MODFLOW model over the 1958 to 2009 model calibration period. The MODFLOW model has periods where the simulated lake levels differ from the measured data by 3 to 6 feet. The improved performance by the Lake-Level Model is attributed to more site-specific and detailed handling of the hydrologic conditions. The relative strengths of the Lake-Level Model compared to the MODFLOW model for simulating Lake Merced are discussed in more detail in Attachment 10.1-H.
- The Lake-Level Model uses the measured June 2009 lake level of 5.7 feet (City Datum) as the starting condition. The MODFLOW model needs to use the calibrated model lake level of 9.33 feet (City Datum) to maintain equilibrium and not create mass balance issues. Therefore, the Lake-Level Model is more consistent with the Existing Conditions.
- The Lake-Level Model has a mechanism to account for the loss of water over the spillway that is automatically invoked anytime the lake level reaches the spillway level.
- The Lake-Level Model uses measured lake levels whereas the MODFLOW model needs to use simulated lake levels from the Historical Simulation.
- Estimates of stormwater runoff from the surrounding areas are calculated more realistically, allowing for variability of land use and other factors.
- The physical characterization of the lake accounts for changing lake surface area with changing lake levels, which is not available in the MODFLOW Lake Package.
- Evapotranspiration is allowed to vary depending on temperature data, based on whether the month is above, near, or below average.

The primary limitation of the Lake-Level Model is that the groundwater-surface water interactions are based upon an assumption of overall groundwater conditions. This is addressed in the analysis for the GSR and SFGW Projects and for the Cumulative Scenario, by changing this assumption and replacing it with the MODFLOW-generated water balance results for inflows to and outflows from Lake Merced. This change provides a more realistic estimation of groundwater-surface water interactions, especially for the proposed GSR and SFGW Project scenarios that do not necessarily have a historical precedent.

In light of the modeling strengths listed above and the better performance of the Lake-Level Model in simulating lake levels, the Lake-Level Model is considered to be a more appropriate modeling approach and is the primary tool for evaluating the effects of the GSR and SFGW Projects and the Cumulative Scenario on Lake Merced.

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Figure List

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Attachment 10.1-F	Model Scenario Groundwater Elevation Contour Maps for Selected Time Periods
Attachment 10.1-G	Model Scenario Lake Hydrographs from Lake Merced Lake- Level Model
Attachment 10.1-H	Lake Merced Lake-Level Model Development Technical Memorandum

Figures

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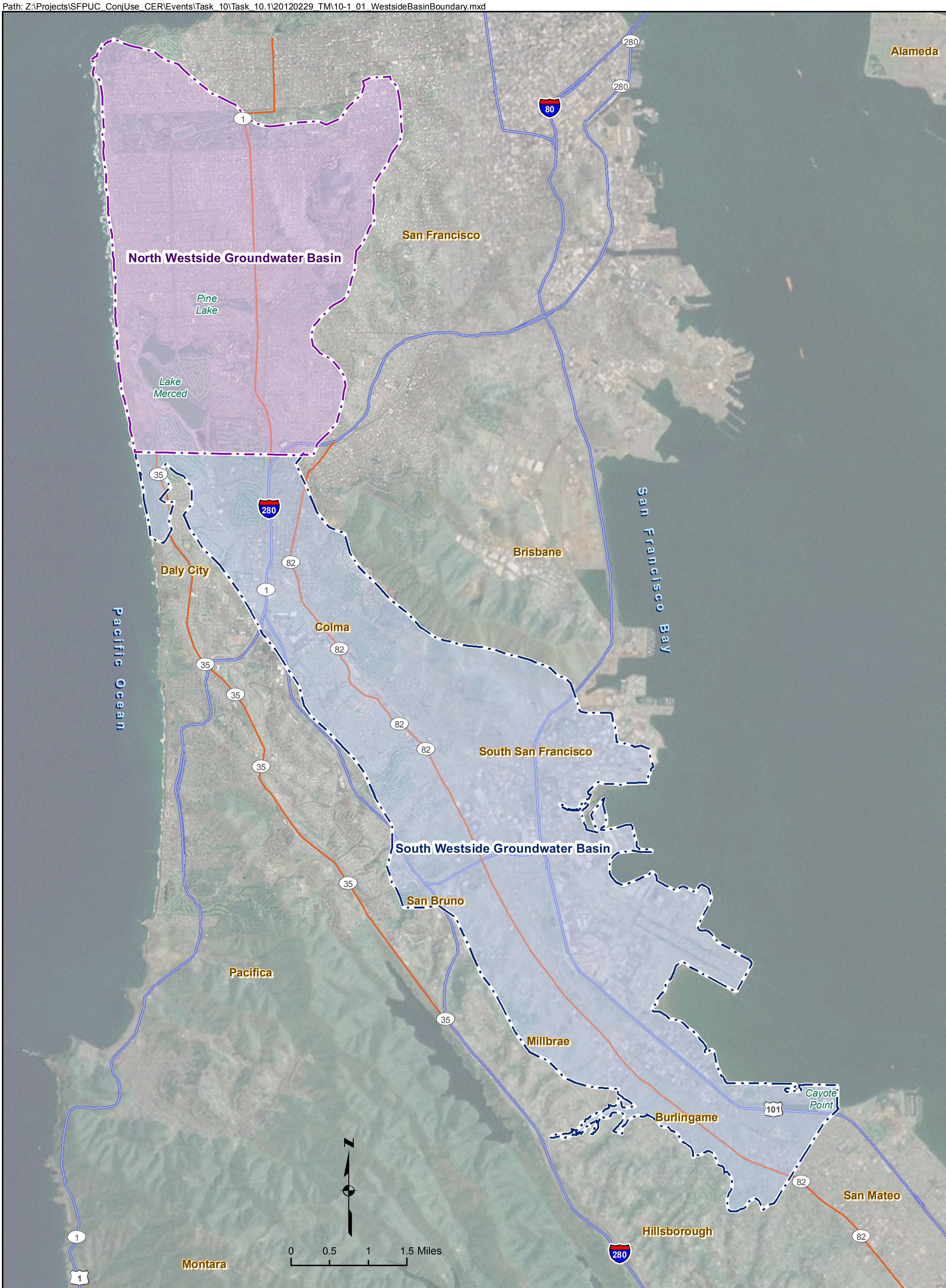

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WESTSIDE GROUNDWATER BASIN BOUNDARY NORTH AND SOUTH WESTSIDE BASINS

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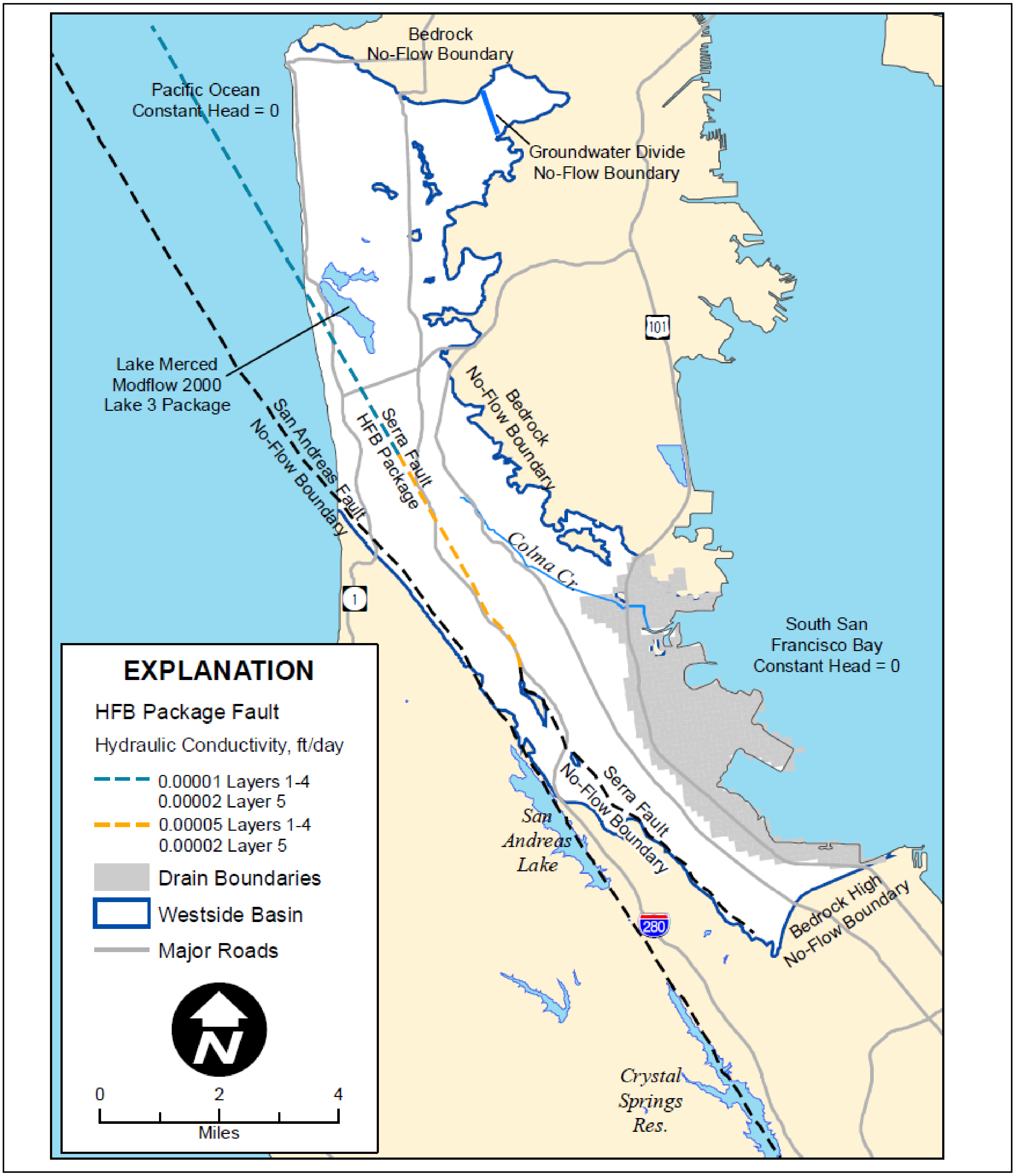
Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Figure **10.1-1**

Date April 2012



Source: Westside Basin Groundwater-Flow Model; Updated Model and 2008 No Project Simulation Results, HydroFocus, May 2011.

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Westside Basin Groundwater-Flow Model Boundary

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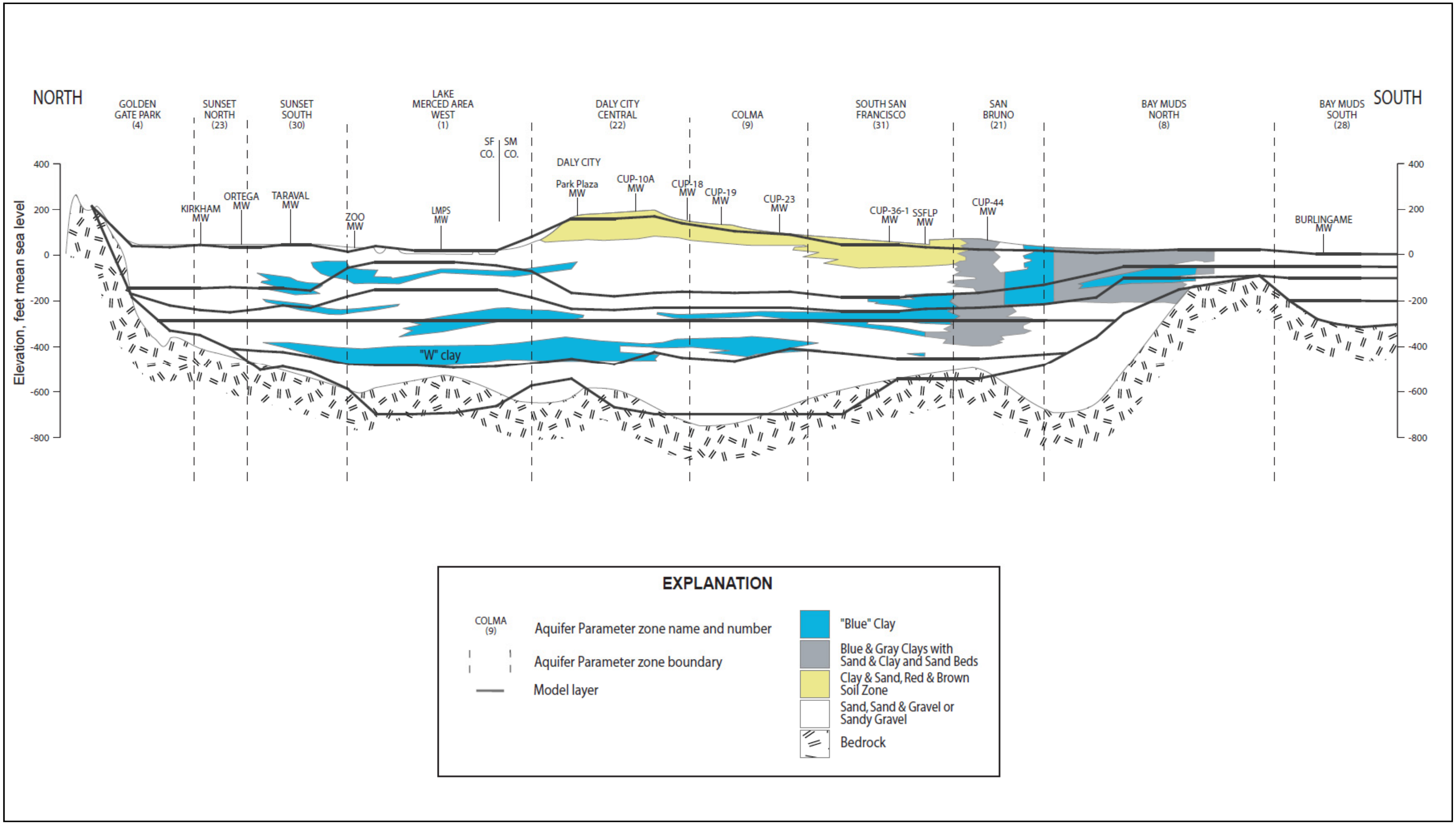
Figure 10.1-2



Source: Westside Basin Groundwater-Flow Model; Updated Model and 2008 No Project Simulation Results, HydroFocus, May 2011.
Note: Modification from North South Geologic Cross Section, Final Task 8B technical Memorandum No.1, Hydrologic Setting of the Westside Basin, LSCE, May 2010.

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Westside Basin Groundwater-Flow Model Layer Structure and Regional Subsurface Hydrogeology

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Figure 10.1-3

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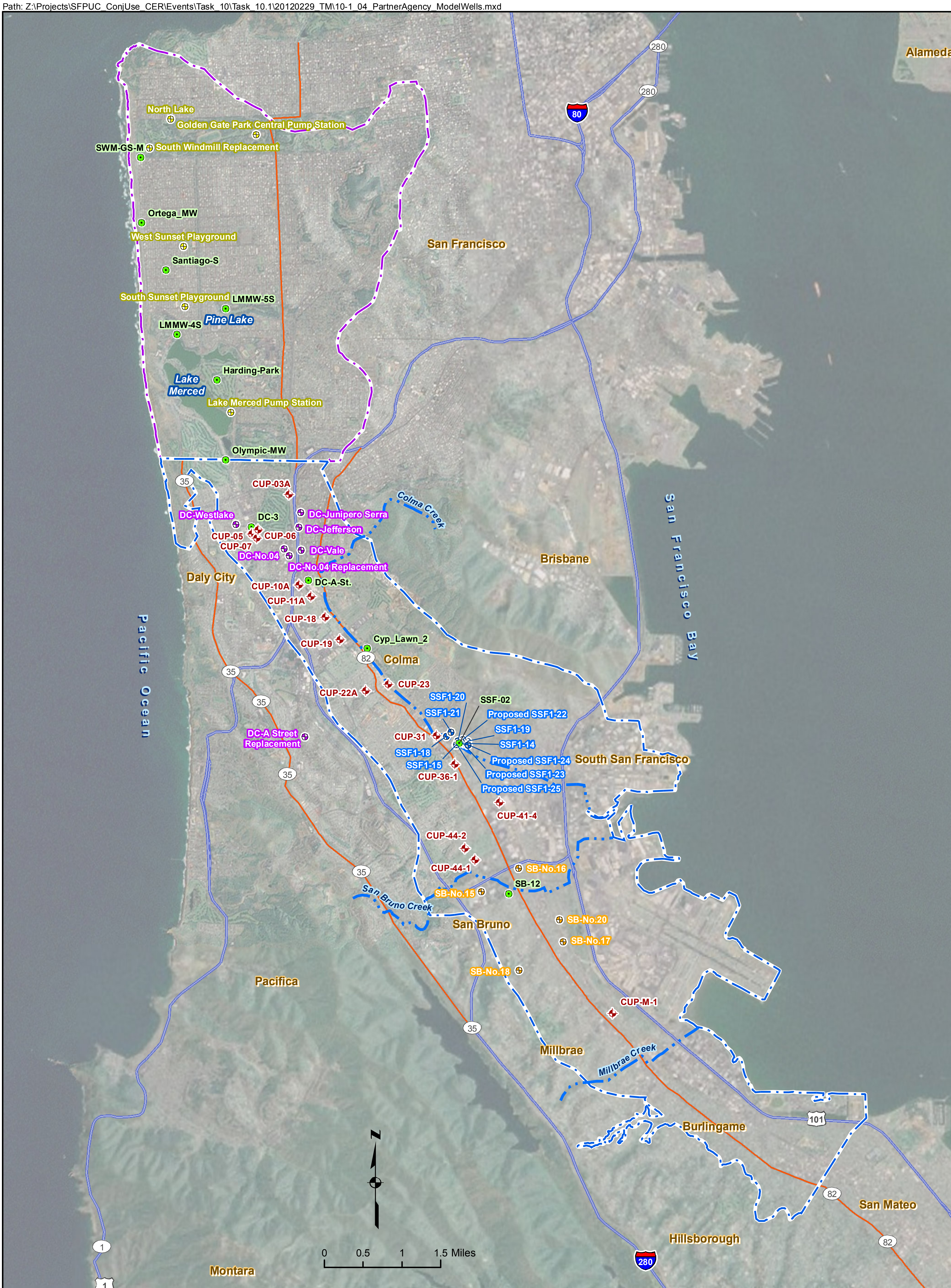

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Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- Selected Representative Monitoring Wells
- Cal Water Municipal Wells
- Daly City Municipal Wells
- San Bruno Municipal Wells
- South Westside Groundwater Basin
- North Westside Groundwater Basin

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LOCATIONS OF PARTNER AGENCY WELLS, PROPOSED GSR AND SFGW PROJECT MUNICIPAL WELLS, AND SELECTED REPRESENTATIVE MONITORING WELLS WITH MODEL RESULTS

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Figure **10.1-4**

Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

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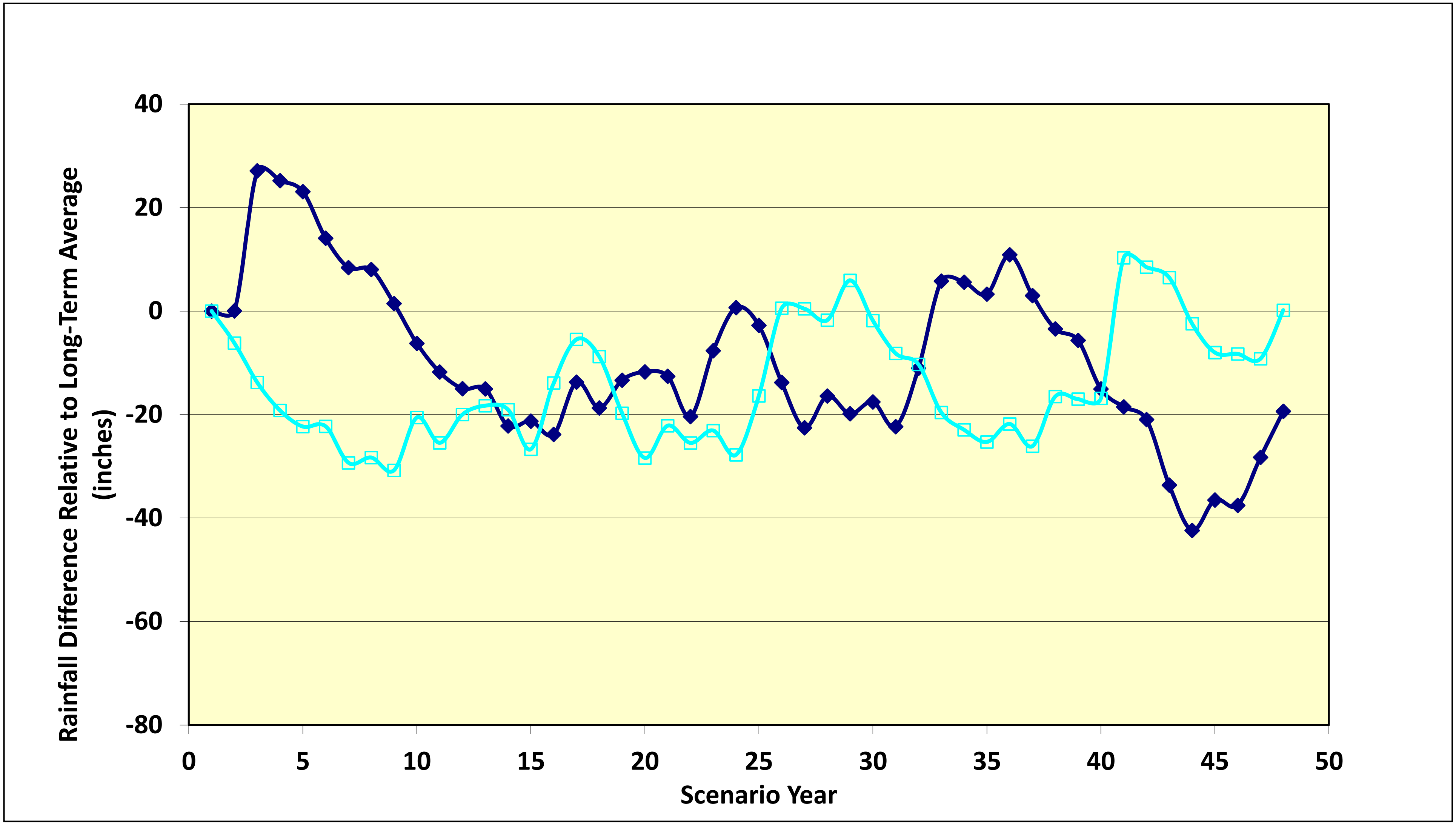

Cumulative Rainfall (inches):

Rearranged Hydrologic Sequence

Historical 1958 to 2005 Precipitation Data

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Cumulative Rainfall Departure Curve Analysis for Historical and Rearranged Hydrological Sequence

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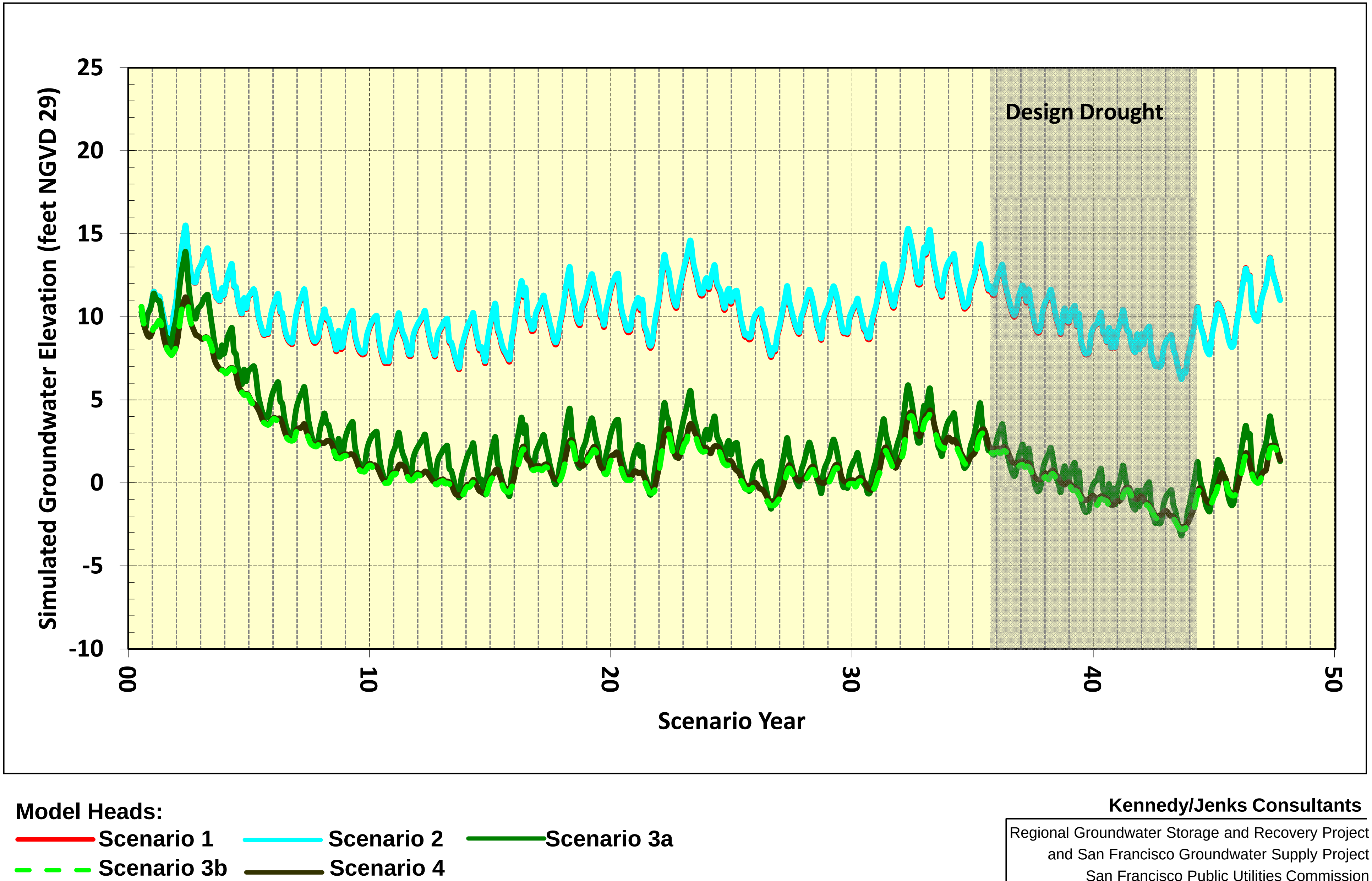
Figure 10.1-5



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Model-Simulated Groundwater Elevations at SWM-GS-M (Model Layer 1)

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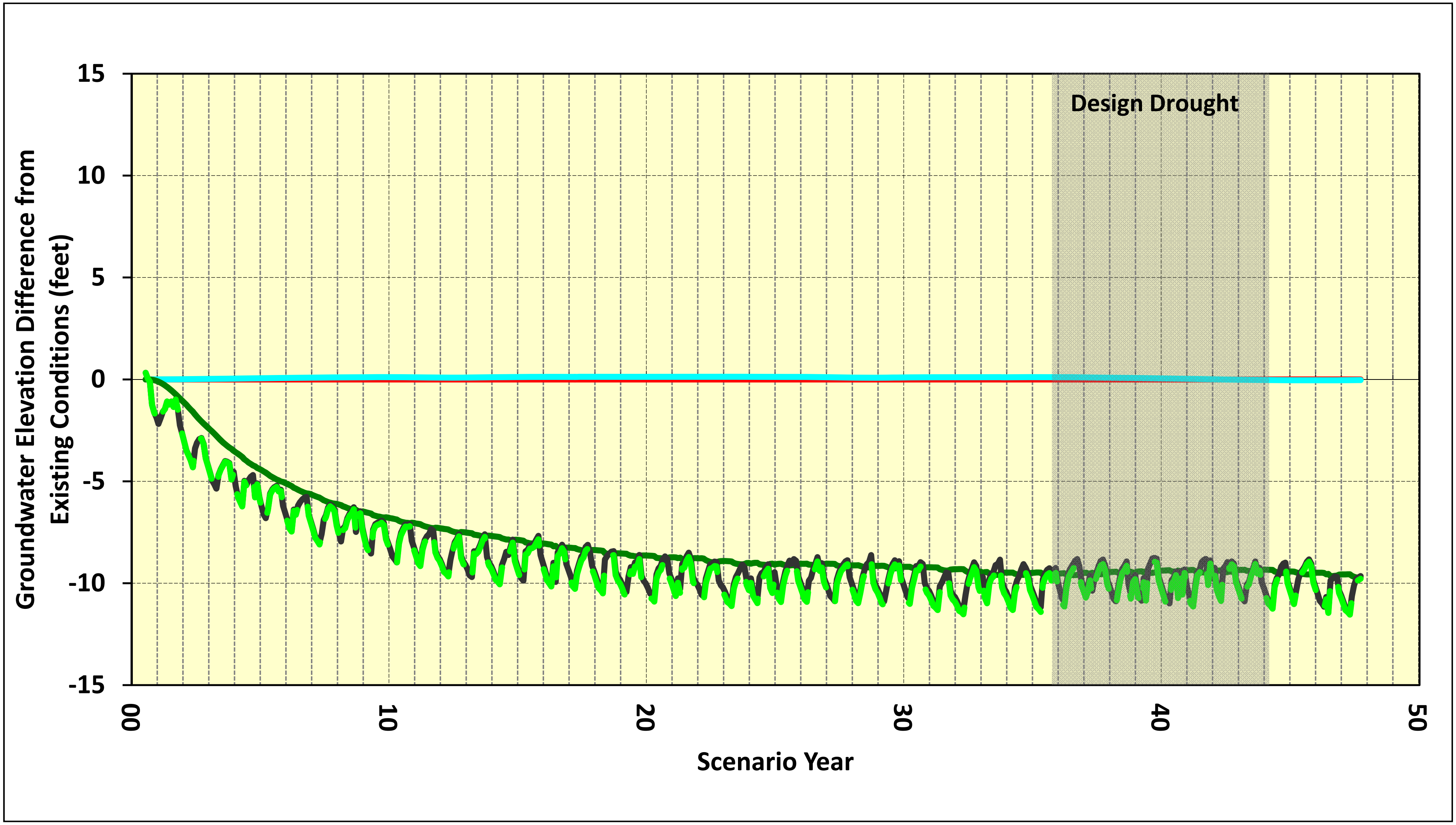
Figure 10.1-6



Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model-Simulated Groundwater Elevations Relative to Existing Conditions at SWM-GS-M (Model Layer 1)

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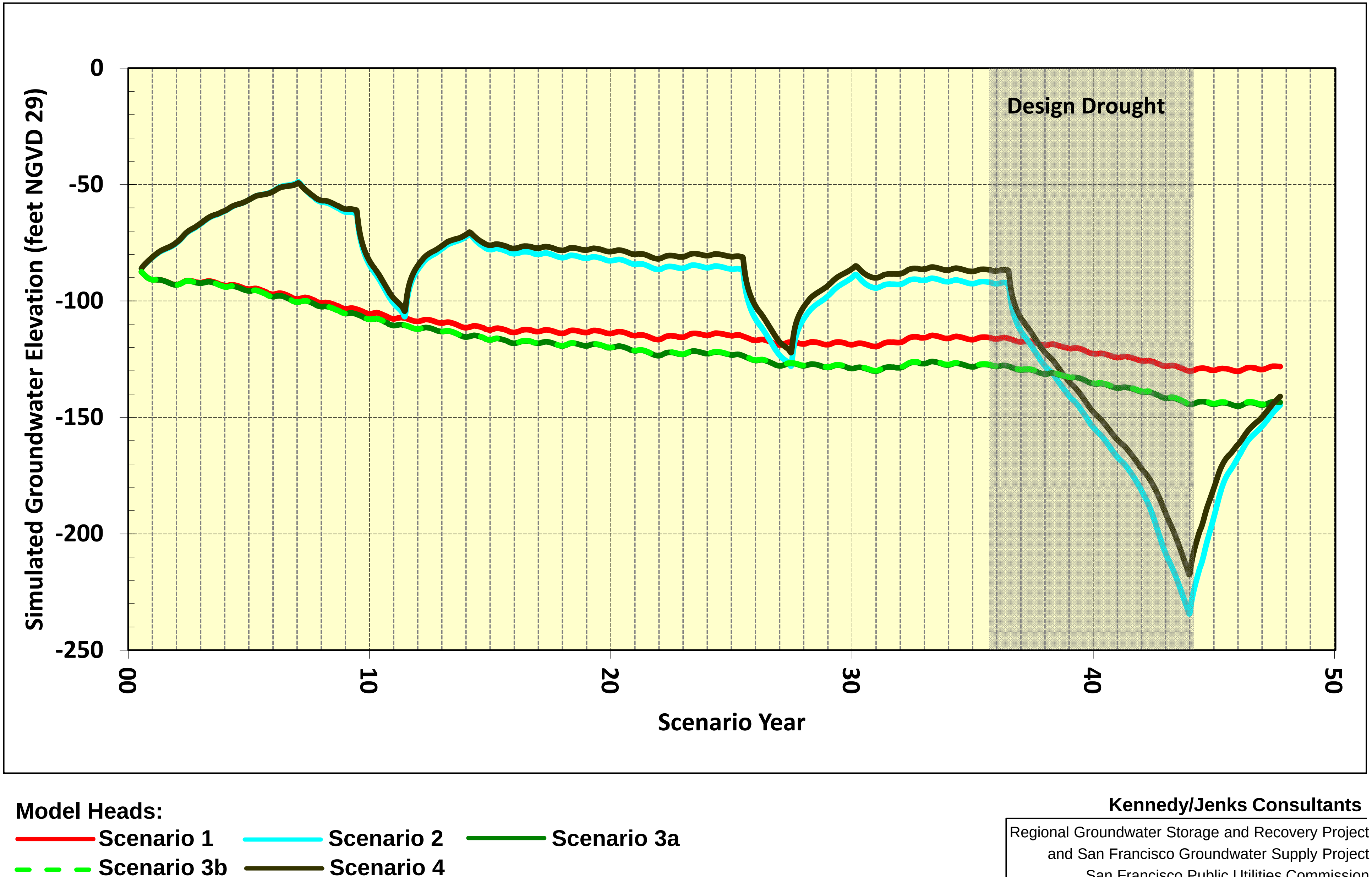
Figure 10.1-7



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Model-Simulated Groundwater Elevations at DC-A St (Model Layer 4)

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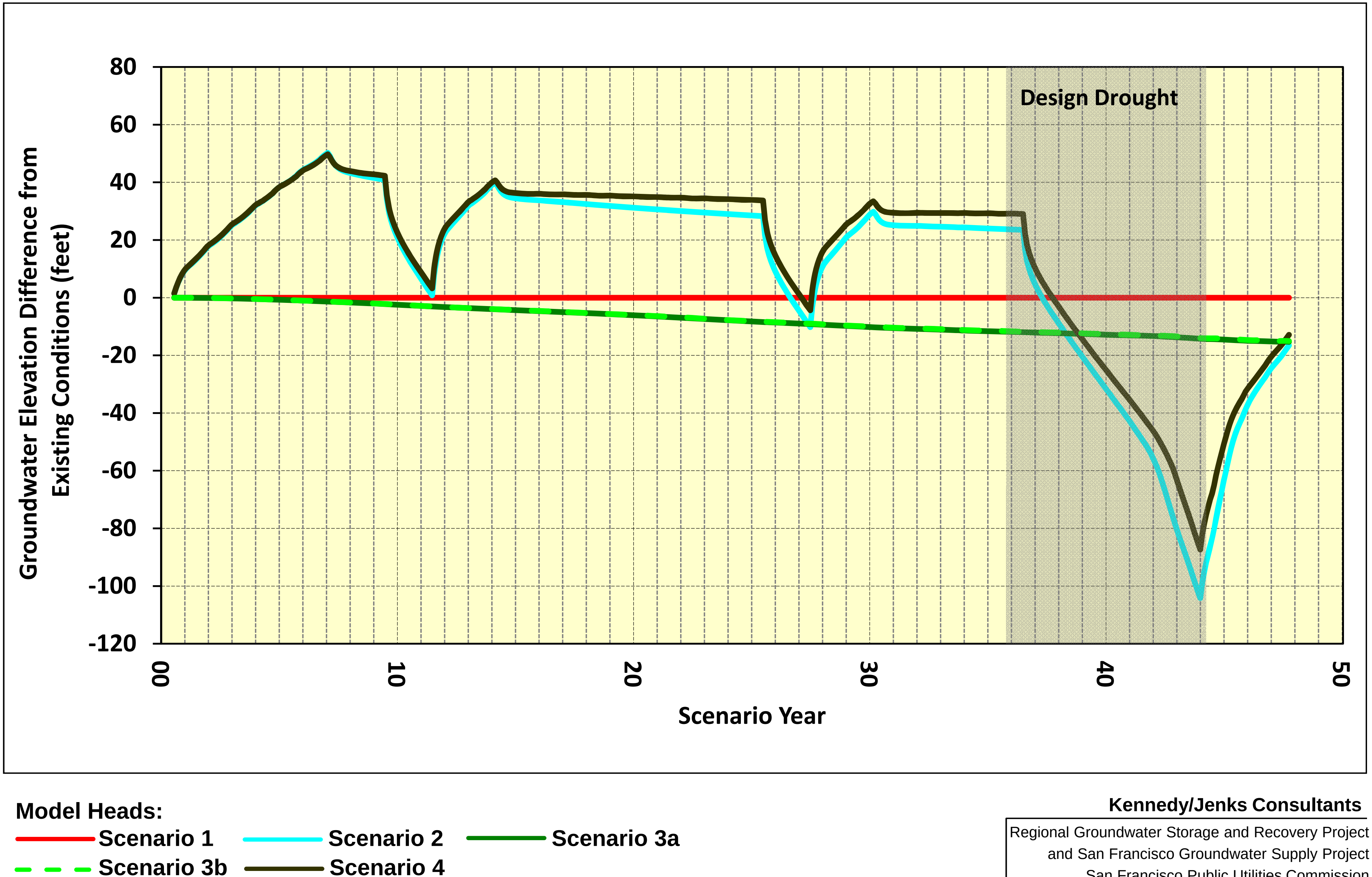
Figure 10.1-8



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Model-Simulated Groundwater Elevations Relative to Existing Conditions at DC-A St (Model Layer 4)

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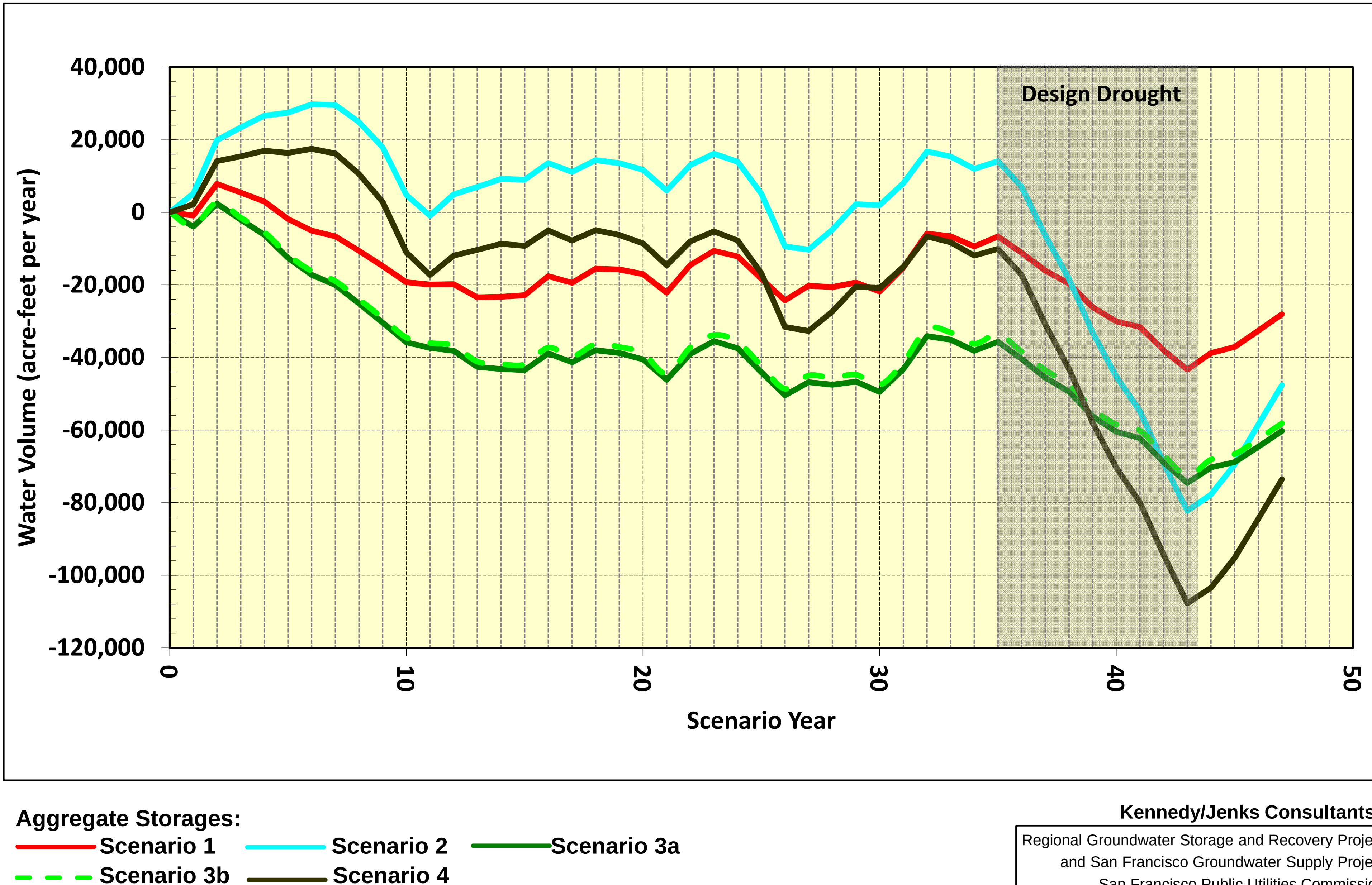
Figure 10.1-9



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Model-Simulated Aggregate Change in Groundwater Storage

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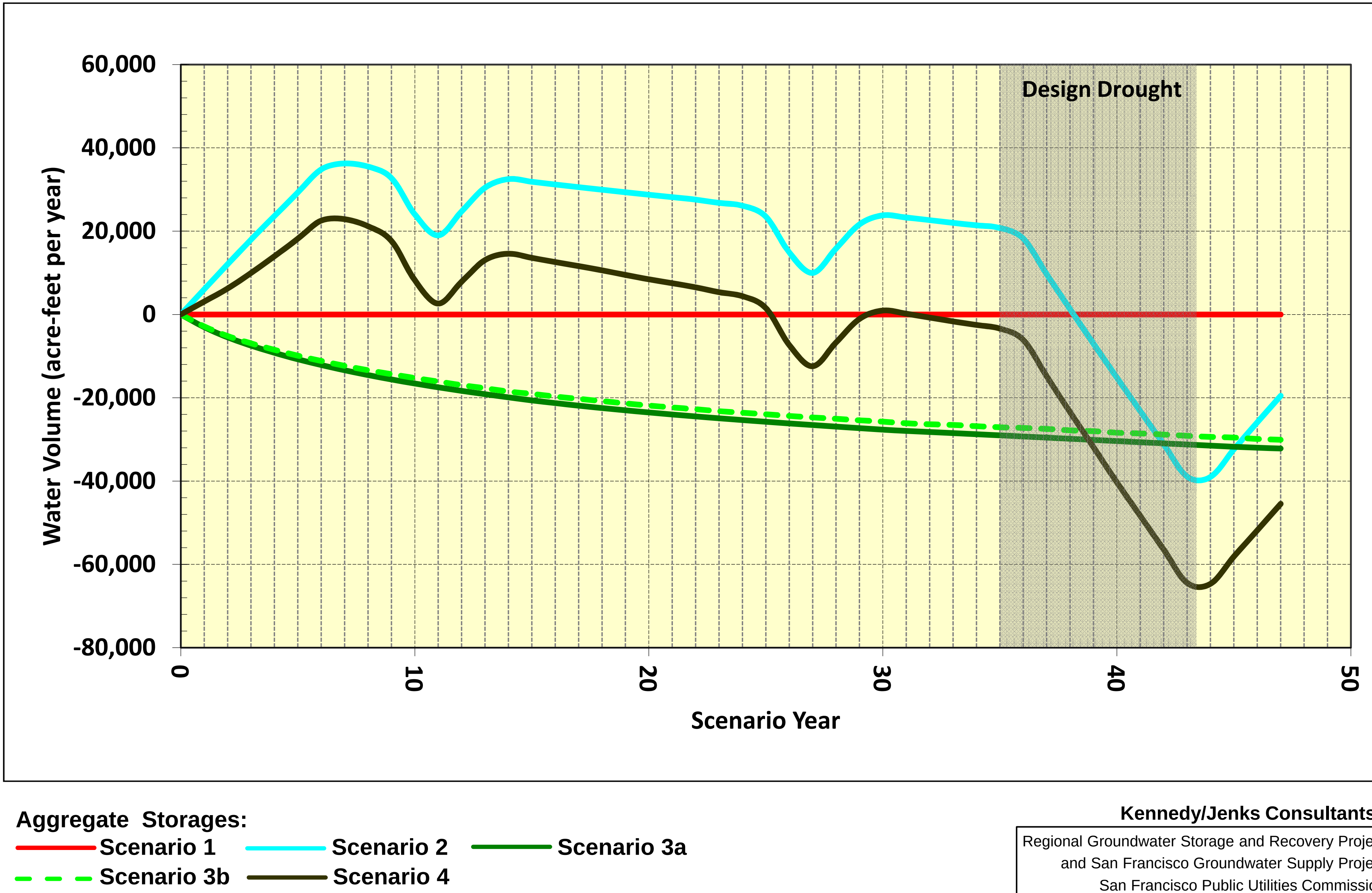
Figure 10.1-10



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Model-Simulated Aggregate Change in Groundwater Storage Relative to Existing Conditions

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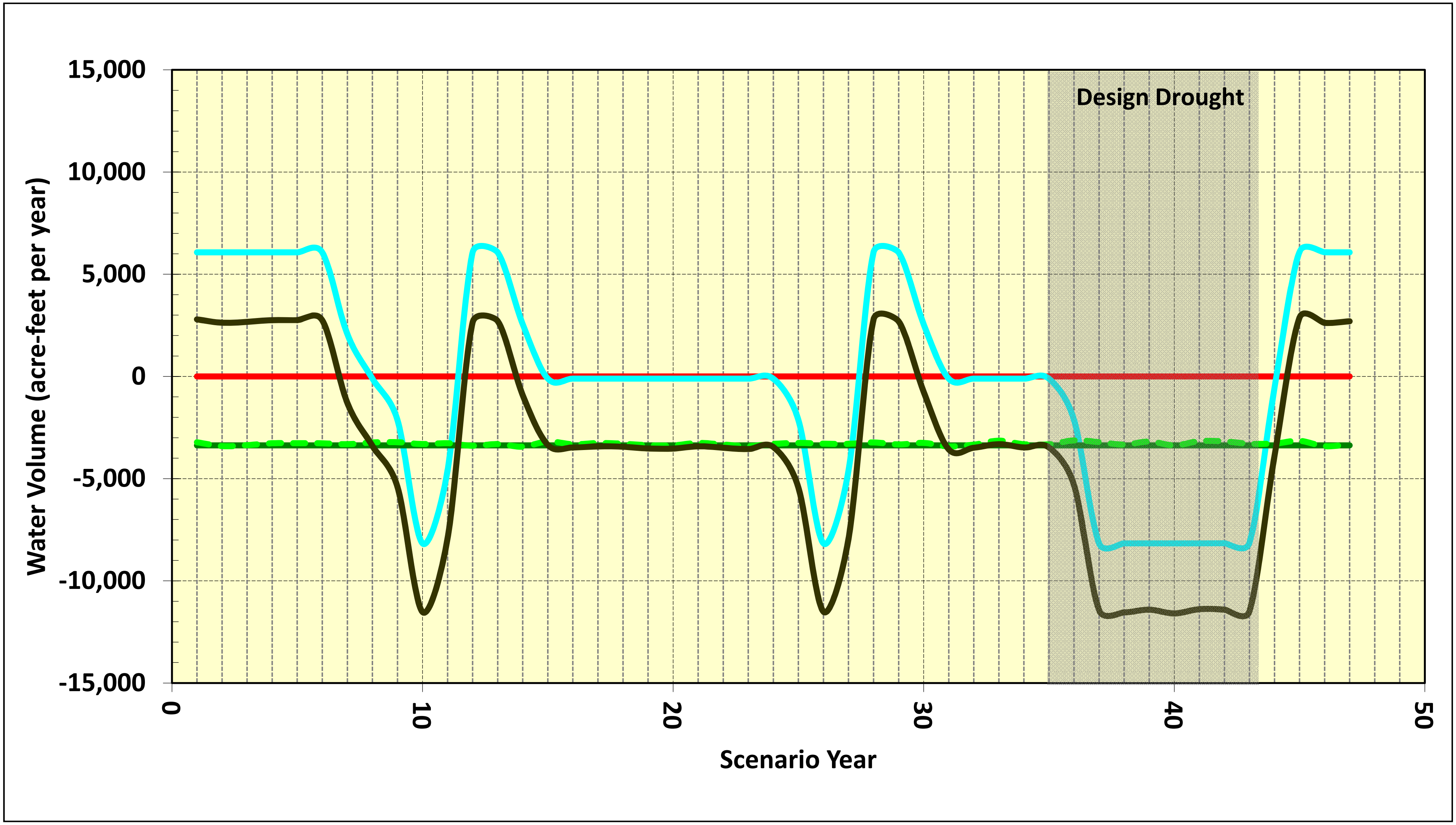
Figure 10.1-11



Pumping Relative to Existing Conditions:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model-Simulated Net Change in Groundwater Pumping Relative to Existing Conditions

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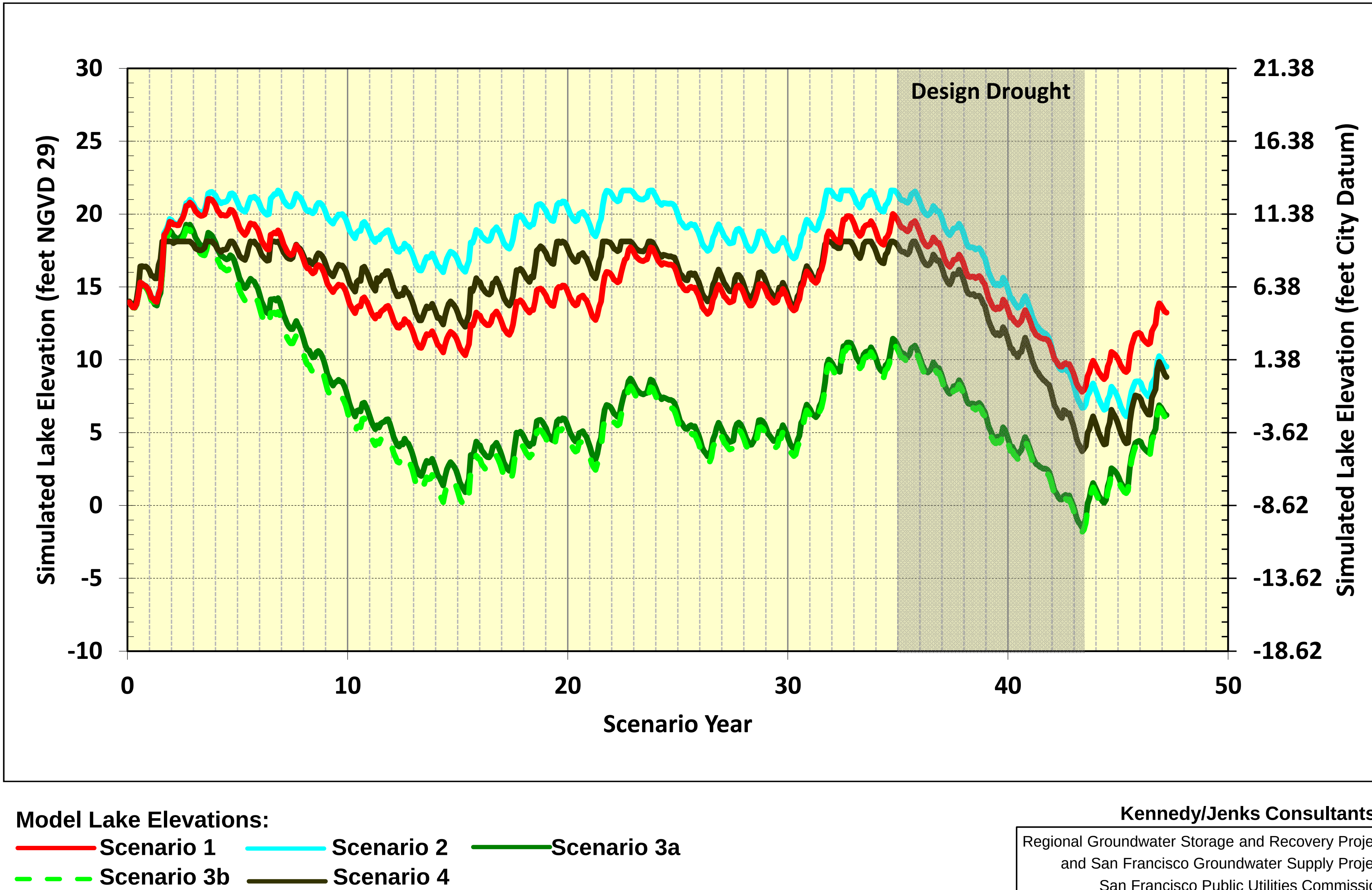
Figure 10.1-12



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Model-Simulated Lake Merced Lake Elevations Based on Lake Merced Lake-Level Model

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April 2012

Figure 10.1-13

Tables

Table 10.1-1: Summary of Model Scenario Descriptions

Ref No.	Assumption	Scenario 1 - Existing Conditions	Scenario 2 - GSR	Scenario 3a/3b - SFGW	Scenario 4 - Cumulative
1	Source Model	2008 No-Project Scenario (HydroFocus, May 2011, ver. 3.1) was used as the basis with changes made for Scenario 1, as listed below.	Same as Scenario 1	Same as Scenario 1	Same as Scenario 1
2	Hydrology	Use the following sequence of historical hydrology provided by SFPUC (personal comm. between David Cameron and Michael Maley, 2011). Total model Scenario duration is 47 years and 3 months, constructed as follows: - Jul 1996 to Sep 2003 - Oct 1958 to Nov 1992 - Dec 1975 to Jun 1978 (to form the last two years of the Design Drought) - Jul 2003 to Sept 2006 (recovery period after the Design Drought)	Same as Scenario 1	Same as Scenario 1	Same as Scenario 1
3	Initial Groundwater Conditions	Model simulated June 2009 groundwater levels from the HydroFocus Historical Model (May 2011, ver. 3.1). This is selected because the available field measured groundwater elevation data for June 2009 were too sparse to construct adequate new groundwater elevation maps of sufficient detail necessary for assigning initial model conditions to all model layers and model cells. Therefore, an approximation method was developed that used the model to generate the initial groundwater elevations.	Same as Scenario 1	Same as Scenario 1	Same as Scenario 1
4	Initial Lake Merced Conditions	Model simulated June 2009 Lake Merced levels (17.95 ft NGVD 1929 or 9.33 ft City Datum at South, North, and Impound Lakes) from the HydroFocus Historical Simulation (May 2011, ver. 3.1). The reason SFPUC is proposing to use the simulated rather than measured (observed) Lake Merced water level is because this change will improve the model performance. Specifically, the use of simulated starting conditions will ensure that the model is in equilibrium. It is appropriate to use simulated starting conditions because the intent of the Model is to evaluate relative change and trends (rather than absolute changes and trends).	Same as Scenario 1	Same as Scenario 1	Same as Scenario 1
5	Lake Merced Lake Package	Lake package was revised consistent with the revised hydrological sequence; No stormwater inputs.	Same as Scenario 1	Same as Scenario 1	Lake package was revised consistent with the new hydrological sequence. The groundwater models use the Daly City proposed scenario "75 cfs Scenario with Completed Wetlands" (which includes wetlands and a spillway at 9.5 feet City Datum).
6	Recharge Package	Soil Moisture Budget (SMB) and recharge package were revised consistent with the revised hydrological sequence.	Same as Scenario 1	Same as Scenario 1	Same as Scenario 1
7	Partner Agency Total Pumping	6.84 mgd total pumping, based on the median of each agency pumping from 1959-2009. Pumping distributed among individual wells based on HydroFocus 2008 No-Project Scenario. - Daly City: 3.78 mgd - San Bruno: 1.88 mgd - Cal Water: 1.18 mgd	6.9 mgd total pumping - the amount of pumping determined to result in no appreciable storage change in the South Westside Basin (HydroFocus, 2011). - Daly City: 3.43 mgd - San Bruno: 2.10 mgd - Cal Water: 1.37 mgd	Same as Scenario 1 - 6.84 mgd total pumping	Same as Scenario 2 - 6.9 mgd total pumping
8	Daly City Municipal Wells	Daly City Jefferson Daly City Vale Daly City Westlake Daly City Junipero Serra Daly City No.4	Daly City Jefferson Daly City Vale Daly City Westlake Daly City Junipero Serra Daly City No.4	Daly City Jefferson Daly City Vale Daly City Westlake Daly City Junipero Serra Daly City No.4	Daly City Jefferson Daly City Vale Daly City Westlake Daly City Junipero Serra Daly City No.4 Replacement Daly City A Street Replacement
9	Cal Water Municipal Wells	SSF1-14 SSF1-15 SSF 1-17 (inactive) SSF1-18 SSF1-19 SSF1-20 SSF1-21 SSF1-22 SSF1-23	SSF1-15 SSF1-19 SSF1-20 SSF1-21 SSF1-22 SSF1-23	SSF1-14 SSF1-15 SSF 1-17 (inactive) SSF1-18 SSF1-19 SSF1-20 SSF1-21 SSF1-22 SSF1-23	SSF1-20 SSF1-21 SSF1-22 SSF1-23 SSF1-24 SSF1-25
10	San Bruno Municipal Wells	San Bruno No.15 San Bruno No.16 San Bruno No.17 San Bruno No.18 San Bruno No.20	San Bruno No.15 San Bruno No.16 San Bruno No.17 San Bruno No.18 San Bruno No.20	San Bruno No.15 San Bruno No.16 San Bruno No.17 San Bruno No.18 San Bruno No.20	San Bruno No.15 San Bruno No.16 San Bruno No.17 San Bruno No.18 San Bruno No.20
11	Irrigation pumping except changes noted below from Ref No. 12 through 17.	SMB was revised and irrigation pumping rates updated as necessary based on the results of the SMB, except for specific values noted in Ref No. 12 through 17 below.	Same as Scenario 1	Same as Scenario 1, except changes noted below (see the GGP irrigation [Ref. No. 12] and Stern Grove well pumping [Ref. No. 16]).	Same as Scenario 1, except changes noted below (see the GGP irrigation [Ref. No. 12] and Holy Cross irrigation [Ref. No. 17]).
12	Golden Gate Park (GGP) irrigation wells - Elk Glen, South Windmill, and North Lake	Modified irrigation pumping, based on 2008 metered data, provided by SFPUC (personal comm. between Jeff Gilman and Sevim Onsoy, 2011). Total pumping of 1.14 mgd (or 1,279 afy). - Elk Glen: 0.081 mgd (91 afy) - South Windmill: 0.498 mgd (558 afy) - North Lake: 0.563 mgd (631 afy)	Same as Scenario 1	Scenario 3a assumes same pumping assumptions as Scenario 1; Scenario 3b assumes no irrigation pumping from the three GGP wells.	Assumes no irrigation pumping from the three GGP wells.
13	California Golf No. 02	Revised irrigation pumping from 198 afy to 215 afy (from 0.18 mgd to 0.19 mgd), based on pumping rates provided verbally by the California Golf Club (personal comm. between Rick Kavakoff and Pete Leffler,2009).	Same as Scenario 1	Same as Scenario 1	Same as Scenario 1
14	Edgewood Development Center	Revised irrigation pumping from 8 afy to 10 afy (from 0.007 mgd to 0.009 mgd), based on pumping rates provided by SFPUC (personal comm. between Jeff Gilman and Sevim Onsoy, 2009).	Same as Scenario 1	Same as Scenario 1	Same as Scenario 1
15	Zoo. No.5	Revised from 447 to 360 afy (from 0.399 mgd to 0.321 mgd), based on average of 2005 - 2009, based on inputs provided by SFPUC (personal comm. between Jeff Gilman and Sevim Onsoy, 2011).	Same as Scenario 1	Same as Scenario 1	Same as Scenario 1
16	Stern Grove Well	Reduced pumping from 47 afy to 4.8 afy (from 0.042 mgd to 0.0043 mgd) for this well to account for the new information available about the use of this well as a supplemental water source for Pine Lake, based on inputs provided by SFPUC (personal comm. between Jeff Gilman and Sevim Onsoy, 2010).	Same as Scenario 1	Pumping reduced from 47 afy to 13.6 afy (from 0.042 mgd to 0.012 mgd) for Scenario 3a, which is 8.8 acre-feet more than under Scenario 1. Similarly, pumping reduced from 47 afy to 14.8 afy (from 0.042 mgd to 0.013 mgd) for Scenario 3b, which is 10 acre-feet more than under Scenario 1. These pumping values are based on the supplemental water needed to maintain the water level in Pine Lake at 31.5 feet (City Datum), as discussed in the CDM report (January, 2011).	Same as Scenario 3b
17	Holy Cross	Irrigation pumping rates are based on the results of the revised SMB. The resulting annual average pumping is 0.19 mgd (212 afy).	Same as Scenario 1	Same as Scenario 1	Additional pumping of 45 afy (0.04 mgd) estimated based on the future projected buildout (personal comm. between Roger Appleby and Pete Leffler, 2010).

Key:
afy - acre-feet per year
SMB - Soil Moisture Budget
GGP - Golden Gate Park
GSR - Regional Groundwater Storage and Recovery
mgd - million gallons per day
SFGW - San Francisco Groundwater Supply

Table 10.1-2: Summary of Model Scenario Pumping Assumptions

Model Scenarios		Scenario 1 Existing Conditions	Scenario 2 GSR	Scenario 3a SFGW	Scenario 3b SFGW	Scenario 4 Cumulative
Establish Initial Conditions		Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence
	June 2009 Condition	√	√	√	√	√
Model Scenario Simulation Period						
	47.25 years (including Design Drought) Hydrologic Sequence: July 1996 to September 2003 -> October 1958 to November 1992 -> December 1975 to June 1978 -> July 2003 - September 2006		√	√	√	√
Pumping Assumptions for Municipal Use						
PA Municipal Wells (mgd)						
	"Take" Periods	6.84	6.90	6.84	6.84	6.90
	"Put" Periods	6.84	1.38	6.84	6.84	1.38
	"Hold" Periods	6.84	6.90	6.84	6.84	6.90
GSR Project Proposed Municipal Wells (mgd)						
	"Take" Periods	0.0	7.23	0.0	0.0	7.23
	"Put" Periods	0.0	0.04	0.0	0.0	0.04
	"Hold" Periods	0.0	0.04	0.0	0.0	0.04
SFGW Project Proposed Municipal Wells (mgd)						
	Year-Round Pumping	0.0	0.0	3.0	4.0	4.0
Total Municipal Pumping (PA + GSR + SFGW)						
	"Take" Periods	***6.84***	***14.13***	***9.84***	***10.84***	***18.13***
	"Put" Periods	***6.84***	***1.42***	***9.84***	***10.84***	***5.42***
	"Hold" Periods	***6.84***	***6.94***	***9.84***	***10.84***	***10.94***
Irrigation and Other Non-Potable Pumping Assumptions (mgd)[1]						
Golden Gate Park	Elk Glen (GGP)	0.081	0.081	0.081	0.000	0.000
	South Windmill (GGP)	0.498	0.498	0.498	0.000	0.000
	North Lake (GGP)	0.563	0.563	0.563	0.000	0.000
	Sub-Total	***1.142***	***1.142***	***1.142***	***0.000***	***0.000***
Golf Courses	Burlingame Golf Club	0.150	0.150	0.150	0.150	0.150
	California Golf No. 02	0.192	0.192	0.192	0.192	0.192
	Green Hills No. 05	0.099	0.099	0.099	0.099	0.099
	Lake Merced Golf No. 01	0.004	0.004	0.004	0.004	0.004
	Lake Merced Golf No. 02	0.004	0.004	0.004	0.004	0.004
	Lake Merced Golf No. 03	0.010	0.010	0.010	0.010	0.010
	Olympic Club No. 09[2]	0.002	0.002	0.002	0.002	0.002
	SF Golf West	0.035	0.035	0.035	0.035	0.035
	Sub-Total	***0.495***	***0.495***	***0.495***	***0.495***	***0.495***
Cemeteries	Cypress Lawn No. 02	0.020	0.020	0.020	0.020	0.020
	Cypress Lawn No. 03	0.144	0.144	0.144	0.144	0.144
	Eternal Home	0.013	0.013	0.013	0.013	0.013
	Hills of Eternity No. 02	0.020	0.020	0.020	0.020	0.020
	Holy Cross No. 03[3]	0.190	0.190	0.190	0.190	0.230
	Home of Peace No. 02	0.039	0.039	0.039	0.039	0.039
	Italian Cemetery	0.033	0.033	0.033	0.033	0.033
	Olivet	0.098	0.098	0.098	0.098	0.098
	Woodlawn No. 02	0.085	0.085	0.085	0.085	0.085
	Sub-Total	***0.641***	***0.641***	***0.641***	***0.641***	***0.681***
Other	Hillsborough Residents No. 1-12	0.291	0.291	0.291	0.291	0.291
	Edgewood Development Ctr.	0.009	0.009	0.009	0.009	0.009
	Zoo No.05	0.321	0.321	0.321	0.321	0.321
	Stern Grove	0.004	0.004	0.012	0.013	0.013
	Sub-Total	***0.626***	***0.626***	***0.634***	***0.635***	***0.635***
Total Irrigation and Other Non-Potable Pumping		***2.90***	***2.90***	***2.91***	***1.77***	***1.81***

Key:
afy - acre-feet per year
mgd - million gallons per day
PA - Partner Agencies
GGP - Golden Gate Park
GSR - Regional Groundwater Storage and Recovery
SFGW - San Francisco Groundwater Supply
SFPUC - San Francisco Public Utilities Commission

Notes:
(1) Pumping wells that are listed identify the wells in the model scenarios whose pumping assumptions were modified compared to the 2008 No-Project Scenario by HydroFocus (May, 2011, ver. 3.1), as a result of revised Soil Moisture Budget (SMB). Pumping rates for the three wells in the GGP, California Golf No. 02, Edgewood Development Center, Zoo No. 05, and Stern Grove wells were further modified compared to the results of revised SMB.
(2) Olympic Club No. 09 values include pumping for both Olympic Golf Club wells.
(3) Holy Cross No. 3 well irrigation pumping for Scenarios 1, 2, 3a, and 3b is based on the results of revised SMB. Based on the projected future build-out at the Holy Cross cemetery, an additional pumping of 0.04 mgd (45 afy) was estimated to occur under Scenario 4 (Cumulative).

Table 10.1-3: Regional Groundwater Storage and Recovery Project Proposed Municipal Wells

Well No.	Well Site	NOP Well Site[1]	Location	Estimated Pumping Capacity (gpm)[2]
1	CUP-3A	1	Daly City	400
2	CUP-5	3	Daly City	300
3	CUP-6	2	Daly City	300
4	CUP-7	4	Daly City	300
5	CUP-10A	5	Daly City	400
6	CUP-11A	6	Daly City	400
7	CUP-18	7	Colma	400
8	CUP-19	8	Colma	400
9	CUP-22A	10	South San Francisco	330
10	CUP-23	9	South San Francisco	330
11	CUP-31	11	South San Francisco	220
12	CUP-36-1	12	South San Francisco	220
13	CUP-41-4	13	South San Francisco	220
14	CUP-44-1	15	San Bruno	330
15	CUP-44-2	14	San Bruno	330
16	CUP-M-1	16	Millbrae	160

Key:
gpm - gallons per minute
NOP - Notice of Preparation

Notes:
(1) NOP of the EIR for the Regional Groundwater Storage and Recovery Project dated June 24, 2009.
(2) Estimated pumping capacities based on the Final Conceptual Engineering Report prepared for the Regional Groundwater Storage and Recovery Project (MWH, 2008).

Table 10.1-4: Partner Agency Municipal Pumping Wells

Location	Well Name	Note
Daly City Municipal Wells		
Daly City	Daly City Jefferson	Existing
Daly City	Daly City Vale	Existing
Daly City	Daly City Westlake	Existing
Daly City	Daly City Junipero Serra	Existing
Daly City	Daly City No. 4	Existing
Daly City	Daly City No. 4 Replacement	Proposed Replacement
Daly City	Daly City A Street Replacement	Proposed Replacement
Cal Water Municipal Wells		
South San Francisco	SSF1-14	Existing
South San Francisco	SSF1-15	Existing
South San Francisco	SSF1-17 (inactive)	Existing
South San Francisco	SSF1-18	Existing
South San Francisco	SSF1-19	Existing
South San Francisco	SSF1-20	Existing
South San Francisco	SSF1-21	Existing
South San Francisco	SSF1-22	Proposed
South San Francisco	SSF1-23	Proposed
South San Francisco	SSF1-24 (redundant)	Proposed
South San Francisco	SSF1-25 (redundant)	Proposed
San Bruno Municipal Wells		
San Bruno	San Bruno No. 15	Existing
San Bruno	San Bruno No. 16	Existing
San Bruno	San Bruno No. 17	Existing
San Bruno	San Bruno No. 18	Existing
San Bruno	San Bruno No. 20	Existing

Table 10.1-5: SFPUC Supplemental Surface Water Deliveries

Date	Cal Water (af)	Daly City (afy)	San Bruno (af)
October-2002	0.0	189.2	0.0
November-2002	0.0	241.5	0.0
December-2002	0.0	250.2	0.0
January-2003	0.0	258.5	72.1
February-2003	77.9	225.7	183.6
March-2003	86.3	248.7	203.3
April-2003	83.5	240.9	196.7
May-2003	86.3	248.3	203.3
June-2003	83.5	240.7	196.7
July-2003	86.3	248.2	203.3
August-2003	86.3	248.9	198.1
September-2003	83.5	239.7	196.7
October-2003	86.3	250.9	190.2
November-2003	41.7	0.0	24.2
December-2003	0.0	0.0	0.0
January-2004	0.0	0.0	0.0
February-2004	0.0	0.0	0.0
March-2004	0.0	0.0	0.0
April-2004	86.3	250.9	150.8
May-2004	83.5	259.2	203.3
June-2004	86.3	280.2	144.3
July-2004	83.5	289.8	203.3
August-2004	86.3	291.4	203.3
September-2004	86.3	282.6	196.7
October-2004	83.5	324.6	203.3
November-2004	86.3	267.0	196.7
December-2004	83.5	286.8	203.3
January-2005	86.3	0.0	203.3
February-2005	86.3	251.6	137.7
March-2005	77.9	285.7	0.0
April-2005	86.3	252.4	0.0
May-2005	83.5	285.8	0.0
June-2005	86.3	276.3	0.0
July-2005	83.5	286.6	0.0
August-2005	86.3	287.4	0.0
September-2005	86.3	278.8	0.0
October-2005	83.5	288.0	0.0
November-2005	86.3	280.1	0.0
December-2005	83.5	297.7	0.0
January-2006	86.3	286.7	0.0
February-2006	86.3	261.4	0.0
March-2006	77.9	289.2	0.0
April-2006	86.3	277.9	0.0
May-2006	83.5	0.0	0.0
June-2006	86.3	0.0	0.0
July-2006	83.5	318.4	0.0
August-2006	86.3	264.9	0.0
September-2006	86.3	259.2	0.0
October-2006	83.5	264.9	0.0
November-2006	86.3	275.4	0.0
December-2006	83.5	286.0	0.0
January-2007	86.3	284.9	0.0
February-2007	0.0	250.7	0.0
March-2007	0.0	251.8	0.0
April-2007	0.0	235.1	0.0
May-2007 to Dec-2009	No supplemental water deliveries		
Total	***3,685***	***12,541***	***3,914***

Source: Data provided by SFPUC.

Key: af - acre-feet

Note: This table contains SFPUC's monthly supplemental water deliveries to Daly City, Cal Water, and San Bruno from October 2002 to December 31, 2009. The supplemental water deliveries account for the SFPUC Storage Account of 20,000 acre-feet of water stored in the basin through the In-Lieu Demonstration Study.

Table 10.1-6: San Francisco Groundwater Supply Project Proposed Municipal Wells

Well No.	Well Name	Normal Design Pumping Capacity		Average Pumping Rate Based on 4.0 mgd Total[1]	
		gpm	mgd	gpm	mgd
1	Lake Merced Pump Station	600 (17 hour/day)	0.61	299	0.43
2	South Sunset Playground	500	0.72	317	0.46
3	West Sunset Playground	650	0.94	412	0.59
4	GGP Central Pump Station	1,500	2.16	951	1.37
5	South Windmill Replacement	1,000	1.44	451	0.65
6	North Lake	500	0.72	347	0.50
	Total	**-**	***6.59***	**-**	***4.00***

Key:
gpm - gallons per minute
mgd - million gallons per day
GGP - Golden Gate Park

Notes:
(1) Six SFGW Project wells included in the table would be pumping for project target pumping rate at 4.0 mgd.

Table 10.1-7: Proposed Pumping Rate Assumptions for Regional Groundwater Storage and Recovery Project Proposed Municipal Wells and Partner Agency Municipal Wells

		Scenario 1 Scenario 3a/3b - SFGW	Scenario 2 GSR				Scenario 4 Cumulative			
Location	Well Site/ Well Name	Pumping Year Round (mgd)	Pumping During "Take" Periods (mgd)	Pumping During "Put" Periods (mgd)	Pumping During "Hold" Periods (mgd)	In-Lieu Recharge During "Put" Periods (mgd)	Pumping During "Take" Periods (mgd)	Pumping During "Put" Periods (mgd)	Pumping During "Hold" Periods (mgd)	In-Lieu Recharge During "Put" Periods (mgd)
Regional Groundwater Storage and Recovery Project Proposed Municipal Wells										
Daly City	CUP-3A	-	0.57	0.003	0.003	-	0.57	0.003	0.003	-
Daly City	CUP-5	-	0.43	0.002	0.002	-	0.43	0.002	0.002	-
Daly City	CUP-6	-	0.43	0.002	0.002	-	0.43	0.002	0.002	-
Daly City	CUP-7	-	0.43	0.002	0.002	-	0.43	0.002	0.002	-
Daly City	CUP-10A	-	0.57	0.003	0.003	-	0.57	0.003	0.003	-
Daly City	CUP-11A	-	0.57	0.003	0.003	-	0.57	0.003	0.003	-
Colma	CUP-18	-	0.57	0.003	0.003	-	0.57	0.003	0.003	-
Colma	CUP-19	-	0.57	0.003	0.003	-	0.57	0.003	0.003	-
South San Francisco	CUP-22A	-	0.47	0.003	0.003	-	0.47	0.003	0.003	-
South San Francisco	CUP-23	-	0.47	0.003	0.003	-	0.47	0.003	0.003	-
South San Francisco	CUP-31	-	0.32	0.002	0.002	-	0.32	0.002	0.002	-
South San Francisco	CUP-36-1	-	0.32	0.002	0.002	-	0.32	0.002	0.002	-
South San Francisco	CUP-41-4	-	0.32	0.002	0.002	-	0.32	0.002	0.002	-
San Bruno	CUP-44-1	-	0.47	0.003	0.003	-	0.47	0.003	0.003	-
San Bruno	CUP-44-2	-	0.47	0.003	0.003	-	0.47	0.003	0.003	-
Millbrae	CUP-M-1	-	0.23	0.001	0.001	-	0.23	0.001	0.001	-
	Sub-Total		***7.23***	***0.04***	***0.04***	***-***	***7.23***	***0.04***	***0.04***	***-***
Partner Agency Municipal Wells										
Daly City Municipal Wells										
Daly City	Daly City Jefferson	0.72	0.65	0.13	0.65	0.52	0.57	0.11	0.57	0.46
Daly City	Daly City Vale	0.98	0.89	0.18	0.89	0.71	0.57	0.11	0.57	0.46
Daly City	Daly City Westlake	0.76	0.69	0.14	0.69	0.55	0.57	0.11	0.57	0.46
Daly City	Daly City Junipero Serra	0.95	0.86	0.17	0.86	0.69	0.57	0.11	0.57	0.46
Daly City	Daly City No. 4	0.38	0.34	0.07	0.34	0.27	-	-	-	-
Daly City	Daly City No.4 Replacement	-	-	-	-	-	0.57	0.11	0.57	0.46
Daly City	Daly City A Street Replacement	-	-	-	-	-	0.57	0.1	0.6	0.5
	Sub-Total	***3.78***	***3.43***	***0.69***	***3.43***	***2.74***	***3.43***	***0.69***	***3.43***	***2.74***
Cal Water Municipal Wells										
South San Francisco	SSF1-14	0.13	-	-	-	-	-	-	-	-
South San Francisco	SSF1-15	0.09	0.0	0.0	0.0	0.0	-	-	-	-
South San Francisco	SSF1-17 (inactive)	0.00	-	-	-	-	-	-	-	-
South San Francisco	SSF1-18	0.23	-	-	-	-	-	-	-	-
South San Francisco	SSF1-19	0.23	0.17	0.03	0.17	0.14	-	-	-	-
South San Francisco	SSF1-20	0.22	0.16	0.03	0.16	0.13	0.26	0.05	0.26	0.21
South San Francisco	SSF1-21	0.28	0.22	0.04	0.22	0.18	0.29	0.06	0.29	0.23
South San Francisco	SSF1-22	0.00	0.48	0.10	0.48	0.38	0.48	0.10	0.48	0.38
South San Francisco	SSF1- 23	0.00	0.34	0.07	0.34	0.27	0.34	0.07	0.34	0.27
South San Francisco	SSF1-24 (redundant)	-	-	-	-	-	Per Cal Water letter to SFPUC dated Jan 19, 2011, this well is shown redundant			
South San Francisco	SSF1-25 (redundant)	-	-	-	-	-	Per Cal Water letter to SFPUC dated Jan 19, 2011, this well is shown redundant			
	Sub-Total	***1.18***	***1.37***	***0.27***	***1.37***	***1.10***	***1.37***	***0.27***	***1.37***	***1.10***
San Bruno Municipal Wells										
San Bruno	San Bruno No. 15	0.23	0.25	0.05	0.25	0.20	0.25	0.05	0.25	0.20
San Bruno	San Bruno No. 16	0.49	0.55	0.11	0.55	0.44	0.55	0.11	0.55	0.44
San Bruno	San Bruno No. 17	0.24	0.27	0.05	0.27	0.22	0.27	0.05	0.27	0.22
San Bruno	San Bruno No. 18	0.26	0.29	0.06	0.29	0.24	0.29	0.06	0.29	0.24
San Bruno	San Bruno No. 20	0.66	0.73	0.15	0.73	0.59	0.73	0.15	0.73	0.59
	Sub-Total	***1.88***	***2.10***	***0.42***	***2.10***	***1.68***	***2.10***	***0.42***	***2.10***	***1.68***
	Total Partner Agency Pumping	***6.84***	***6.90***	***1.38***	***6.90***	***5.52***	***6.90***	***1.38***	***6.90***	***5.52***

Key:
GSR - Regional Groundwater Storage and Recovery
mgd - million gallons per day
Shaded cells identify municipal pumping wells that are not applicable and not considered for a given model scenario.

Table 10.1-8: Depth Distribution of Pumping by Model Layers

Location	Well Site/Well Name	Depth Distribution of Pumping (Fraction in Model Layer 1 - 5) Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Total
Regional Groundwater Storage and Recovery Project Proposed Municipal Wells							
Daly City	CUP-3A	0.00	0.00	1.00	0.00	0.00	1.00
Daly City	CUP-5	0.00	0.00	0.10	0.60	0.30	1.00
Daly City	CUP-6	0.00	0.00	0.10	0.70	0.20	1.00
Daly City	CUP-7	0.00	0.00	0.15	0.55	0.30	1.00
Daly City	CUP-10A	0.00	0.00	0.50	0.50	0.00	1.00
Daly City	CUP-11A	0.00	0.00	0.40	0.50	0.10	1.00
Colma	CUP-18	0.00	0.00	0.35	0.55	0.10	1.00
Colma	CUP-19	0.00	0.00	0.20	0.60	0.20	1.00
South San Francisco	CUP-22A	0.00	0.00	0.20	0.80	0.00	1.00
South San Francisco	CUP-23	0.00	0.00	0.20	0.80	0.00	1.00
South San Francisco	CUP-31	0.00	0.00	0.00	0.70	0.30	1.00
South San Francisco	CUP-36-1	0.00	0.00	0.00	0.75	0.25	1.00
South San Francisco	CUP-41-4	0.00	0.00	0.00	0.80	0.20	1.00
San Bruno	CUP-44-1	0.00	0.00	0.00	0.80	0.20	1.00
San Bruno	CUP-44-2	0.00	0.00	0.05	0.75	0.20	1.00
Millbrae	CUP-M-1	0.00	0.00	0.50	0.50	0.00	1.00
Daly City Municipal Wells							
Daly City	Daly City Jefferson	0.00	0.00	0.12	0.73	0.15	1.00
Daly City	Daly City Vale	0.00	0.00	0.15	0.70	0.15	1.00
Daly City	Daly City Westlake	0.00	0.00	0.15	0.56	0.29	1.00
Daly City	Daly City Junipero Serra	0.00	0.43	0.57	0.00	0.00	1.00
Daly City	Daly City No. 4	0.00	0.50	0.32	0.18	0.00	1.00
Daly City	Daly City No. 4 Replacement	0.00	0.50	0.32	0.18	0.00	1.00
Daly City	Daly City A Street Replacement	0.00	0.06	0.29	0.65	0.00	1.00
Cal Water Municipal Wells							
South San Francisco	SSF1-19	0.00	0.19	0.12	0.50	0.19	1.00
South San Francisco	SSF1-20	0.00	0.00	0.00	0.48	0.52	1.00
South San Francisco	SSF1-21	0.00	0.00	0.00	0.50	0.50	1.00
South San Francisco	SSF1-22	0.00	0.00	0.00	0.50	0.50	1.00
South San Francisco	SSF1-23	0.00	0.00	0.00	0.50	0.50	1.00
South San Francisco	SSF1-24	0.00	0.00	0.00	0.50	0.50	1.00
South San Francisco	SSF1-25	0.00	0.00	0.00	0.50	0.50	1.00
San Bruno Municipal Wells							
San Bruno	San Bruno No. 15	0.00	0.16	0.16	0.54	0.14	1.00
San Bruno	San Bruno No. 16	0.00	0.00	0.00	0.80	0.20	1.00
San Bruno	San Bruno No. 17	0.00	0.00	0.00	0.72	0.28	1.00
San Bruno	San Bruno No. 18	0.00	0.11	0.44	0.34	0.11	1.00
San Bruno	San Bruno No. 20	0.00	0.00	0.00	0.55	0.45	1.00
San Francisco Groundwater Supply Project Proposed Municipal Wells							
San Francisco	Lake Merced Pump Station	0.00	0.00	0.00	1.00	0.00	1.00
San Francisco	South Sunset Playground	0.21	0.38	0.16	0.26	0.00	1.00
San Francisco	West Sunset Playground	0.60	0.34	0.06	0.00	0.00	1.00
San Francisco	GGP Central Pump Station(1)	1.00	0.00	0.00	0.00	0.00	1.00
San Francisco	South Windmill Replacement	0.45	0.54	0.01	0.00	0.00	1.00
San Francisco	North Lake	0.44	0.17	0.39	0.00	0.00	1.00

Key:
GGP - Golden Gate Park

Note:
(1) All pumping assigned to Layer 1 because the HydroFocus Model (May 2011, ver. 3.1) assumes only one model layer in this vicinity.

Table 10.1-9: Put/Take/Hold Sequence for Model Scenarios

Scenario Year	No. of Months	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0	3										put	put	put
1	15	put	put	put	put	put	put	put	put	put	put	put	put
2	27	put	put	put	put	put	put	put	put	put	put	put	put
3	39	put	put	put	put	put	put	put	put	put	put	put	put
4	51	put	put	put	put	put	put	put	put	put	put	put	put
5	63	put	put	put	put	put	put	put	put	put	put	put	put
6	75	put	put	put	put	put	put	put	put	put	put	put	put
7	87	put	put	put	put	hold	hold	hold	hold	hold	hold	hold	hold
8	99	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
9	111	hold	hold	hold	hold	hold	hold	hold	hold	hold	take	take	take
10	123	take	take	take	take	take	take	take	take	take	take	take	take
11	135	take	take	take	take	take	take	take	take	take	put	put	put
12	147	put	put	put	put	put	put	put	put	put	put	put	put
13	159	put	put	put	put	put	put	put	put	put	put	put	put
14	171	put	put	put	put	put	hold	hold	hold	hold	hold	hold	hold
15	183	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
16	195	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
17	207	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
18	219	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
19	231	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
20	243	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
21	255	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
22	267	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
23	279	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
24	291	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
25	303	hold	hold	hold	hold	hold	hold	hold	hold	hold	take	take	take
26	315	take	take	take	take	take	take	take	take	take	take	take	take
27	327	take	take	take	take	take	take	take	take	take	put	put	put
28	339	put	put	put	put	put	put	put	put	put	put	put	put
29	351	put	put	put	put	put	put	put	put	put	put	put	put
30	363	put	put	put	put	put	hold	hold	hold	hold	hold	hold	hold
31	375	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
32	387	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
33	399	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
34	411	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
35	423	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold	hold
36	435	hold	hold	hold	hold	hold	hold	hold	hold	hold	take	take	take
37	447	take	take	take	take	take	take	take	take	take	take	take	take
38	459	take	take	take	take	take	take	take	take	take	take	take	take
39	471	take	take	take	take	take	take	take	take	take	take	take	take
40	483	take	take	take	take	take	take	take	take	take	take	take	take
41	495	take	take	take	take	take	take	take	take	take	take	take	take
42	507	take	take	take	take	take	take	take	take	take	take	take	take
43	519	take	take	take	take	take	take	take	take	take	take	take	take
44	531	take	take	take	hold	hold	hold	hold	hold	hold	put	put	put
45	543	put	put	put	put	put	put	put	put	put	put	put	put
46	555	put	put	put	put	put	put	put	put	put	put	put	put
47	567	put	put	put	put	put	put	put	put	put	put	put	put

Table 10.1-10: Pumping Rate Assumptions for San Francisco Groundwater Supply Project Proposed Municipal Wells

Well No.	Well Name	Pumping Rates mgd	Pumping Rates afy	Pumping Proportion Relative to Total
Scenario 3a[1], [2]				
1	Lake Merced Pump Station	0.43	482	0.14
2	South Sunset Playground	0.48	544	0.16
3	West Sunset Playground	0.63	707	0.21
4	GGP Central Pump Station	1.45	1,631	0.48
5	South Windmill Replacement [3]	-	-	-
6	North Lake [3]	-	-	-
	Total	***3.00***	***3,363***	***1.00***
Scenario 3b [1]				
1	Lake Merced Pump Station	0.43	482	0.11
2	South Sunset Playground	0.46	512	0.11
3	West Sunset Playground	0.59	665	0.15
4	GGP Central Pump Station	1.37	1,536	0.34
5	South Windmill Replacement	0.65	729	0.16
6	North Lake	0.50	561	0.13
	Total	***4.00***	***4,484***	***1.00***

Key:
afy - acre-feet per year
mgd - million gallons per day
GGP - Golden Gate Park

Notes:
(1) For Scenarios 3a and 3b, the pumping rate for each of the SFGW Project wells is provided by SFPUC.
(2) Four of the SFGW Project wells would be pumping for municipal purposes for the SFGW Project under Scenario 3a.
(3) For Scenario 3a, South Windmill Replacement and North Lake wells would remain as irrigation wells and not be used for municipal pumping as part of the SFGW Project. Irrigation pumping rates by South Windmill Replacement and North Lake wells would be the same as in Scenario 1, and they are accounted for in the irrigation pumping assumptions presented in Table 10.1-2.

Table 10.1-11: Monthly Pumping Rate Assumptions for San Francisco Groundwater Supply Project Proposed Municipal Wells

Scenario 3a

Month	Lake Merced Pump Station (af)	South Sunset Playground (af)	West Sunset Playground (af)	GGP Central Pump Station (af)	South Windmill Replacement (af)	North Lake (af)	Total Pumping (af)
January	457	515	670	1,545	0	0	3,186
February	485	547	711	1,642	0	0	3,386
March	451	509	662	1,527	0	0	3,150
April	464	523	680	1,570	0	0	3,237
May	500	564	733	1,691	0	0	3,486
June	523	590	767	1,770	0	0	3,651
July	541	610	793	1,830	0	0	3,774
August	524	590	768	1,771	0	0	3,653
September	500	564	734	1,693	0	0	3,491
October	482	543	707	1,630	0	0	3,362
November	433	488	635	1,464	0	0	3,020
December	424	478	622	1,435	0	0	2,959
Annual Average (af)	***482***	***544***	***707***	***1,631***	***0***	***0***	***3,363***
Annual Average (mgd)	***0.43***	***0.48***	***0.63***	***1.45***	***0.00***	***0.00***	***3.0***

Scenario 3b

	Lake Merced Pump Station (af)	South Sunset Playground (af)	West Sunset Playground (af)	GGP Central Pump Station (af)	South Windmill Replacement (af)	North Lake (af)	Total Pumping (af)
January	457	485	630	1,455	690	531	4,249
February	485	515	670	1,546	734	564	4,515
March	451	479	623	1,438	682	525	4,200
April	464	493	641	1,478	701	540	4,316
May	500	531	690	1,592	755	581	4,648
June	523	556	722	1,667	791	608	4,868
July	541	574	747	1,723	818	629	5,032
August	524	556	723	1,668	792	609	4,871
September	500	531	691	1,594	756	582	4,655
October	482	512	665	1,535	728	560	4,483
November	433	460	597	1,379	654	503	4,026
December	424	450	586	1,351	641	493	3,946
Annual Average (af)	***482***	***512***	***665***	***1,536***	***729***	***561***	***4,484***
Annual Average (mgd)	***0.4***	***0.5***	***0.6***	***1.4***	***0.7***	***0.5***	***4.0***

Key:
af - acre-feet
GGP - Golden Gate Park
mgd - million gallons per day

Table 10.1-12: Summary of Westside Basin Annual Water Balance

Scenarios		Inflow from Bay & Ocean (afy)(1)	Seepage from GGP Lakes (afy)(1)	Rain + Irrigation (afy)(1)	Seepage from Lake Merced (afy)(1)	Outflow to Bay & Ocean (afy)(2)	Wells - Pumping (afy)(2)	Seepage to Lake Merced (afy)(2)	Drains (afy)(2)	Change in Groundwater Storage (afy)(3)
Scenario 1	**Average**	12	551	14,034	846	-4,172	-10,814	-960	-94	-597
	Maximum	31	558	24,922	1,171	-3,057	-10,230	-634	-68	9,340
	Minimum	5	545	7,618	456	-5,439	-11,398	-1,383	-129	-6,468
Scenario 2	**Average**	11	551	14,034	640	-4,418	-10,926	-784	-122	-1,013
	Maximum	65	558	24,922	1,498	-2,948	-4,227	-522	-71	14,744
	Minimum	4	545	7,618	351	-5,526	-19,363	-1,453	-176	-14,738
Scenario 3a	**Average**	403	551	14,034	940	-1,982	-14,189	-946	-93	-1,282
	Maximum	1,123	558	24,922	1,105	-1,115	-13,604	-534	-68	9,072
	Minimum	5	545	7,618	485	-4,731	-14,773	-1,246	-128	-6,755
Scenario 3b	**Average**	312	626	14,034	950	-2,012	-14,106	-949	-93	-1,237
	Maximum	937	628	24,922	1,116	-1,114	-13,655	-531	-68	9,102
	Minimum	5	618	7,618	485	-4,703	-14,544	-1,257	-128	-6,666
Scenario 4	**Average**	186	626	14,034	760	-2,181	-14,264	-603	-122	-1,565
	Maximum	681	628	24,922	1,390	-866	-7,671	-325	-71	11,867
	Minimum	5	618	7,618	336	-4,735	-22,607	-1,156	-177	-14,852

Key:
afy - acre-feet per year

Notes:
(1) Positive values define inflows to groundwater basin.
(2) Negative values define outflows from groundwater basin.
(3) Positive change in storage values define increase in groundwater storage; negative change in storage values define decline in groundwater storage.

Attachment 10.1-A

Key Proposed Elements of GSR Project Operating Agreement for EIR Analysis

SUMMARY OF DRAFT GSR PROJECT OPERATING AGREEMENT
February 29, 2012

Under a proposed agreement between the SFPUC and the Partner Agencies for operation of groundwater pumping by these entities from the South Westside Groundwater Basin, the SFPUC would "store" water in the South Westside Groundwater Basin through the mechanism of in-lieu recharge by providing surface water as a substitute for groundwater pumping by the Partner Agencies. As part of its annual April 15 estimate of water supply available to the Regional Water System, the SFPUC would determine and give notice to the Partner Agencies of the availability, anticipated quantities and timing of the in-lieu water deliveries, thereby requiring the Partner Agencies to accept delivery of surface water in lieu of groundwater pumped using their existing wells (generally during wet and normal water years). This determination would take into consideration the amount of groundwater that the Partner Agencies must continue to pump due to water quality blending, distribution system constraints, well maintenance, and other requirements.

During these times when water would be stored in the groundwater basin (Put Periods[1]), the SFPUC could require the Partner Agencies to take delivery of up to 5.52 mgd of in-lieu water using their existing turnouts on SFPUC transmission pipelines in lieu of pumping a like amount of groundwater from their existing facilities. As a result of the in-lieu deliveries, up to 60,500 acre feet of groundwater storage or "put" credits could accrue to the SFPUC Storage Account described below. During shortages of SFPUC system water due to drought, emergencies or scheduled maintenance, the Partner Agencies would return to pumping from their existing wells. In addition, the SFPUC and the Partner Agencies would extract groundwater from the SFPUC Storage Account using the new wells installed by the SFPUC as part of the Project, at a maximum annual volume of 8,100 acre feet withdrawn at an average rate of 7.2 mgd. The SFPUC will not direct pumping during these periods (Take Periods[2]) unless a positive balance exists in the SFPUC Storage Account as described below.

An accounting of the additional storage volumes (the SFPUC Storage Account) accrued during Put Periods would be maintained by the SFPUC as a book account tracking the amount of water that has been stored during normal and wet years and the amount of water pumped from the SFPUC Storage Account during Take Periods. Accruals in the SFPUC Storage Account would be recorded based on metered, in-lieu surface water deliveries and corresponding metered decreases in groundwater pumping below "designated quantities" agreed to by the Partner Agencies. An operating committee would be formed to monitor and track the SFPUC Storage Account, including any losses from the system, and establish annual pumping schedules for Project wells.

As discussed in Section 3.3, the Partner Agencies would continue to maintain and operate their existing wells and associated infrastructure, and could install new or replacement wells in the future if necessary. The Partner Agencies would agree to limit pumping from their existing wells and any new wells to the designated quantities totaling 6.9 mgd over a 5 year averaging period, the estimated modeled volume of municipal pumping that the South Westside Basin can sustain without causing a decline in groundwater levels on an annual average basis and the amounts identified in the respective Partner Agencies Urban Water Management Plans, allocated in the initial year as follows:

---

[1] Put Periods may also be referred to as Storage Periods in the operating agreement and other documentation concerning the Project.
[2] Take Periods may also be referred to as Recovery Periods in the operating agreement and other documentation concerning the Project.

- Daly City: 3.43 mgd/ 3,840 acre feet per year
- Cal Water: 1.37 mgd/ 1,534 acre feet per year
- San Bruno: 2.1 mgd/ 2,350 acre feet per year

Pumping from the Partner Agency existing facilities during years when the SFPUC has not directed take of water from the SFPUC Storage Account and years where the SFPUC has neither directed take nor put of in lieu groundwater (Hold Periods) could not exceed 7.6 mgd in any year of the 5 year averaging period. This 10% increase over 6.9 mgd could occur as a result of transfer of designated quantities between Partner Agencies, which would be permitted under the operating agreement provided such adjustment received unanimous approval of the operating committee based on actual operating experience that demonstrates that such an increase is consistent with sustainable groundwater basin management.   If a Partner Agency engages in over production, then that agency would be required to (1) take steps to pump less during future years to bring pumping back within the 6.9 mgd aggregate designated quantity; (2) provide a source of water that has the effect of replacing water lost from the Basin due to the over production; or (3) take other actions that may be recommended by the operating committee.

During normal and wet years, Project wells would be operated by the SFPUC or the Partner Agencies only periodically to exercise the wells for maintenance purposes at a rate of approximately 0.04 mgd and the Partner Agencies' would pump their existing wells at a rate of approximately 1.38 mgd to 1.9 mgd. In circumstances where the SFPUC determines that delivery of in-lieu water cannot be made due to a dry year, emergencies, system rehabilitation, scheduled maintenance or malfunctioning of the water system, or upon recommendation of the operating committee established by the operating agreement for purposes of Basin management, the SFPUC may direct the Partner Agencies to extract groundwater from the SFPUC Storage Account using Project wells, in addition to continued pumping from the Partner Agencies' existing wells to meet the remainder of their water supply needs. Pumping from the SFPUC Storage Account by the Partner Agencies and the SFPUC would only occur if a positive balance exists in the SFPUC Storage Account as a result of previous in lieu recharge.

During droughts, Project wells would be operated beginning in the second consecutive year of a multi-year drought, following implementation of the Shortage Allocation Plan. Partner Agency pumping from the SFPUC Storage Account using Project wells during droughts, combined with the remaining reduced surface water deliveries from the Regional Water System to the Partner Agencies, would be limited to the total quantity of water allocated to each Partner Agency under Tier 2 of the Shortage Allocation Plan[3]. Partner Agency pumping during droughts using their existing wells would be limited to their respective Designated Quantities, which in total equal an aggregate volume of 7,724 acre feet per year, extracted at an annual cumulative rate of 6.9 mgd and computed on a 5 year rolling average basis. The specific volumes to be pumped during a drought shown in Figure 3-2 (see Section 3.3.1 above) are based on the Project Operations, but actual volumes in any given year could vary depending on factors including: (1) the final location and capacity of the Project well facilities, (2) the volume of water in the SFPUC Storage Account, and (3) direction from the operating committee regarding which wells should be used, based on the need to avoid well interference and other basin management considerations.

[3] In the July 2009 WSA, the SFPUC and its wholesale customers adopted a Water Shortage Allocation Plan to allocate water between retail and wholesale customers during system wide shortages of 20% or less (the Tier 1 plan). The specific amount of rationing required by each wholesale customer, including the Participating Pumpers, is determined either by agreement of the wholesale customers themselves (the Tier 2 Plan) or, in the absence of such agreement, by the SFPUC after discussion with the wholesale customers.

The SFPUC would own the Project well facilities, and there would be no change to the Partner Agencies' ownership and operation of their existing and any new well facilities, except to the extent of their agreement regarding cessation and resumption of groundwater pumping as agreed to under a proposed operating agreement. The SFPUC and the Partner Agencies would operate and maintain Project wells connected to their respective water systems. The Partner Agencies may be allowed to use Project facilities for non-Project purposes but only under certain specified conditions where necessary, with approval of the operating committee and only for periods not to exceed 30 days duration. In the event of a sudden, non-drought event such as an earthquake or other catastrophic event, the operating committee may allow Partner Agency use of Project facilities for the duration of the emergency.

Project Operation

As described above, the Project would use vacated storage space in the South Westside Groundwater Basin filled through in lieu recharge during normal and wet years. Neither Project wells nor Partner Agency wells would be pumped in these Put Periods, apart from volumes needed to periodically exercise the wells. Water would accrue in the SFPUC Storage Account based on the metered reduction in each Partner Agency's designated quantity described in section 3.8.1.

When the SFPUC Storage Account is full, defined as 60,500 acre feet, but there is no shortage requiring the SFPUC to pump groundwater from Project wells (Hold Periods), the Project wells installed by the SFPUC would remain inactive apart from well exercising. Existing Partner Agency wells would be pumped at rates not to exceed an annual amount of 6.9 mgd (or up to 7.6 mgd in the event of a 10% increase) in any year of the 5 year periods as described in Section 3.8.1. The Partner Agencies would continue to be able to take delivery of their entitlements to surface water from the SFPUC (their "Individual Supply Guarantees") during these Hold Periods, as the SFPUC Storage Account would remain full.

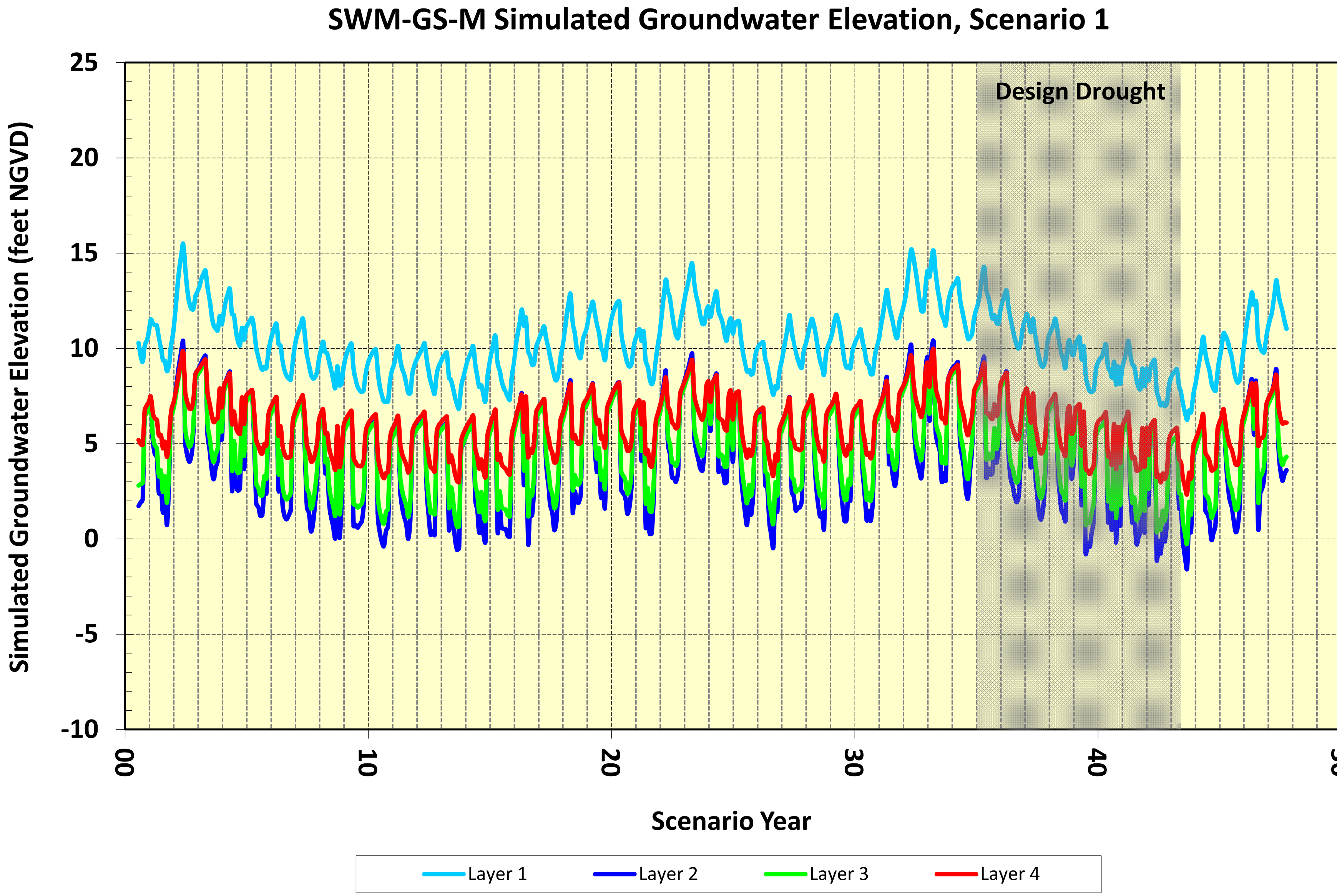
New Project wells installed by the SFPUC would be operated under the following circumstances:

- Beginning in the second dry year of a multiple year drought
- During emergencies
- During system rehabilitation, scheduled maintenance or malfunctioning of the water system
- Upon recommendation of the operating committee established by the operating agreement for purposes of Basin management

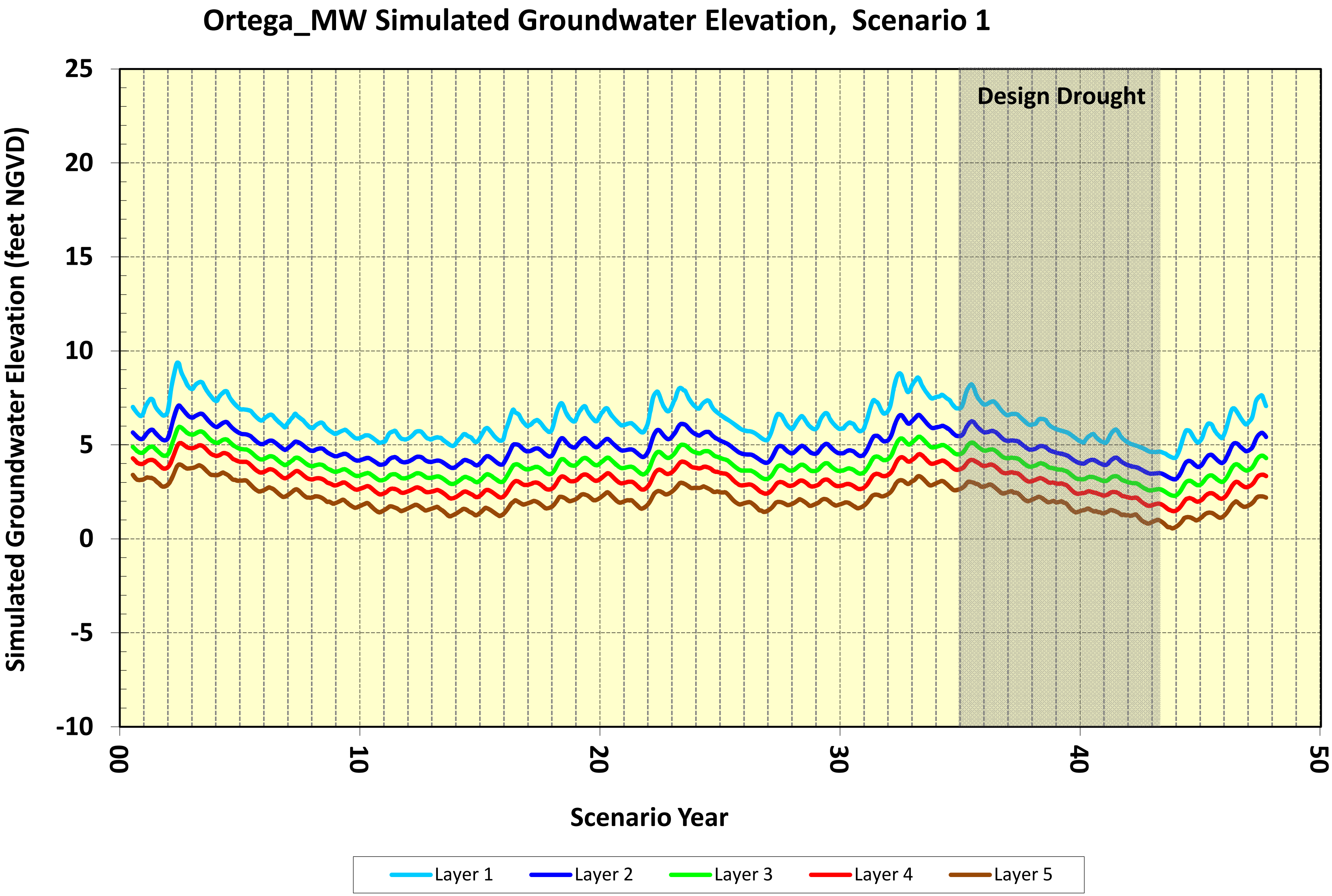
In these circumstances, new Project wells could be operated continuously or for shorter intervals, depending on the need for water. The primary purpose of the Project is to provide a dry year water supply during a multiple year drought. During these Take Periods, when groundwater is pumped to provide a dry year supply, pumping would reduce the balance of water in the SFPUC Storage Account. Project wells would be operated by the Partner Agencies and the SFPUC, depending on whether the water is sent to the Partner Agencies' retail water distribution systems or the SFPUC regional water transmission system. Project wells would only be pumped in Take Periods if there is a positive balance in the SFPUC Storage Account, and that pumping may not exceed 8,100 acre-feet per "supply year," defined as the period from July 1 to June 30 of the following year. Existing Partner Agency wells would be pumped at up to the rates indicated above during Hold Periods and the combined (reduced) deliveries of SFPUC surface water to the Partner Agencies and water pumped by the Partner Agencies from the SFPUC Storage Account using new Project wells would not exceed the Partner Agencies' individual Tier 2 allocations under the Shortage Allocation Plan.

Attachment 10.1-B

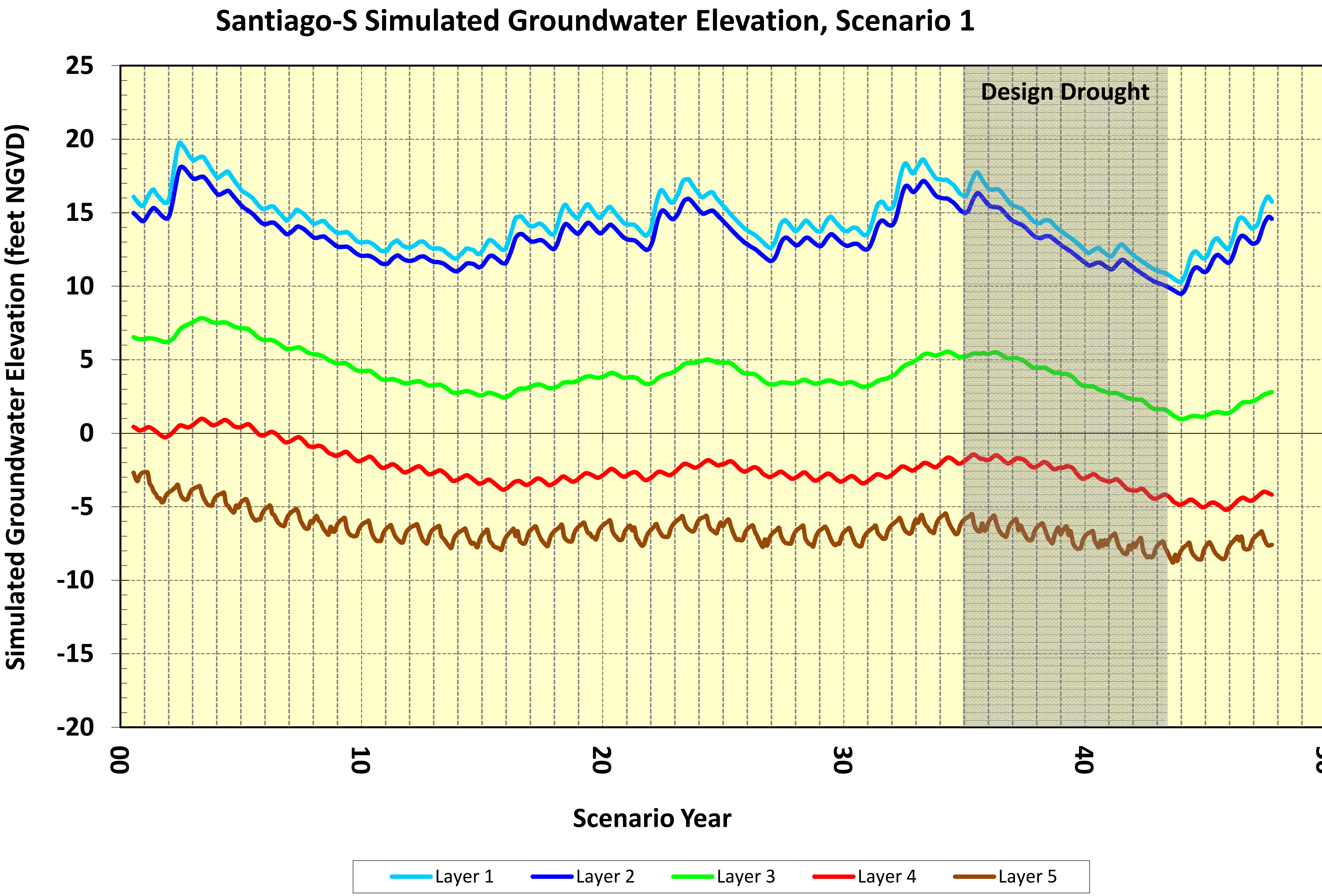
Model Scenario Hydrographs for Selected Locations

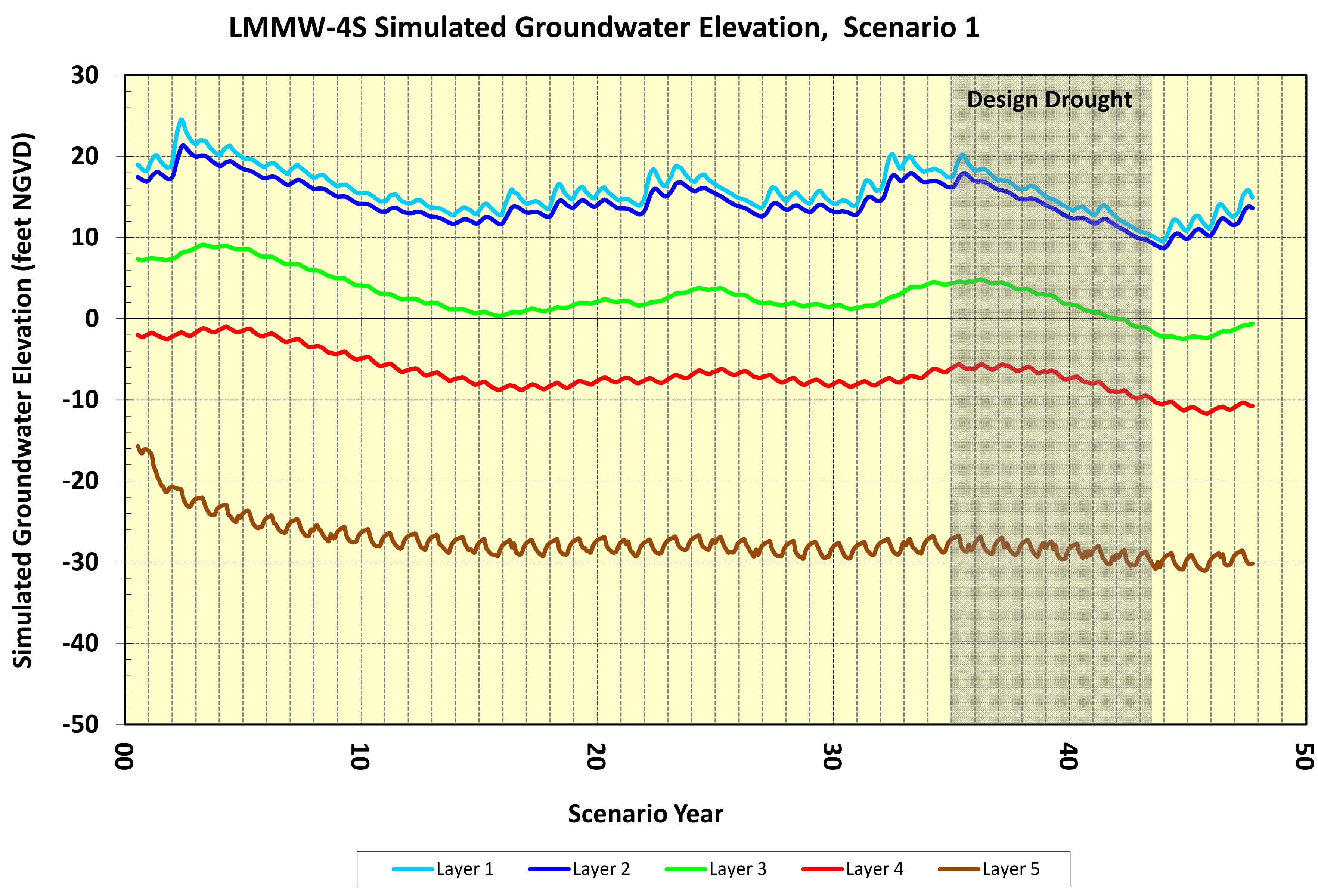


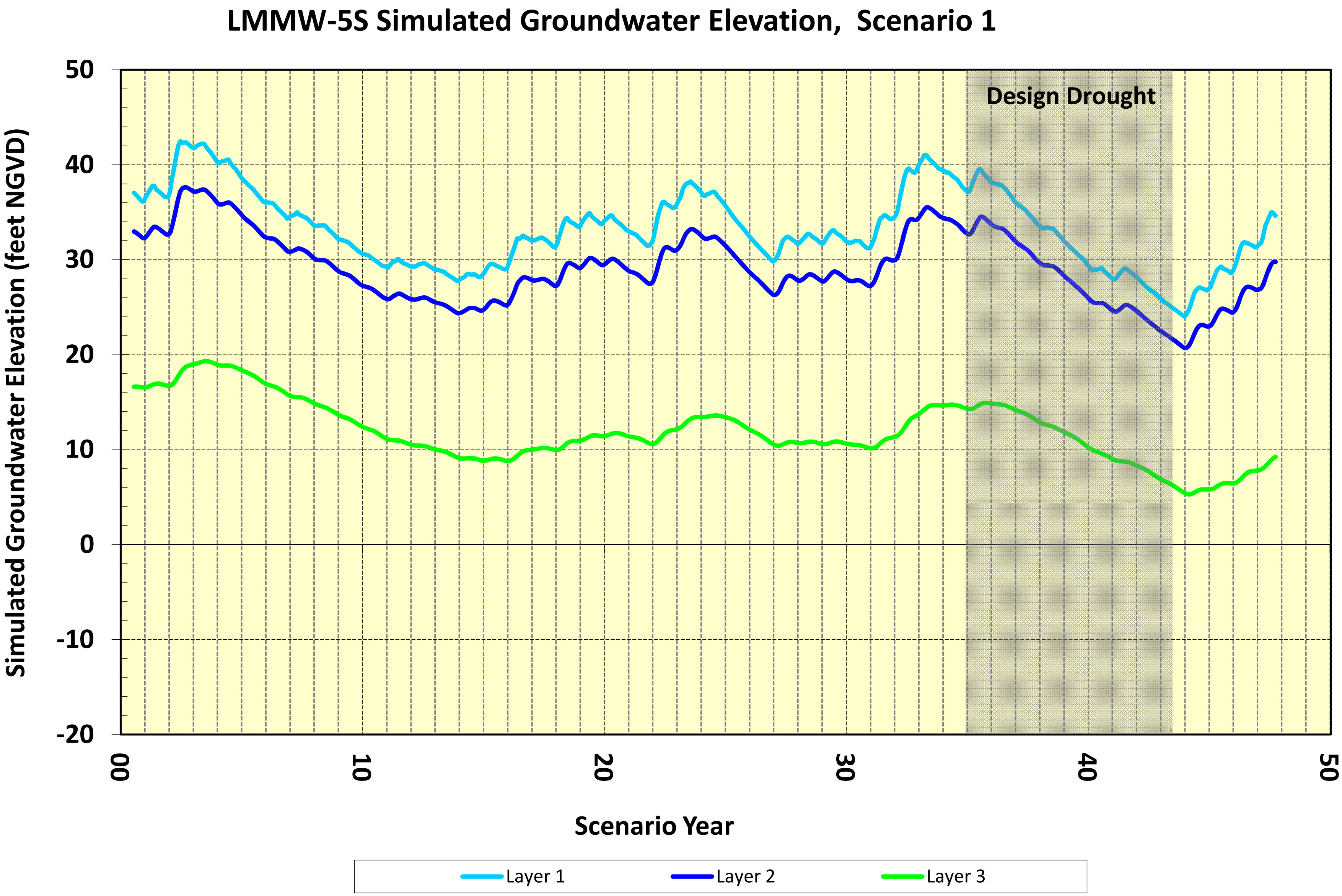
Note: At the location of SWM-GS-M, the model does not contain Model Layer 5.



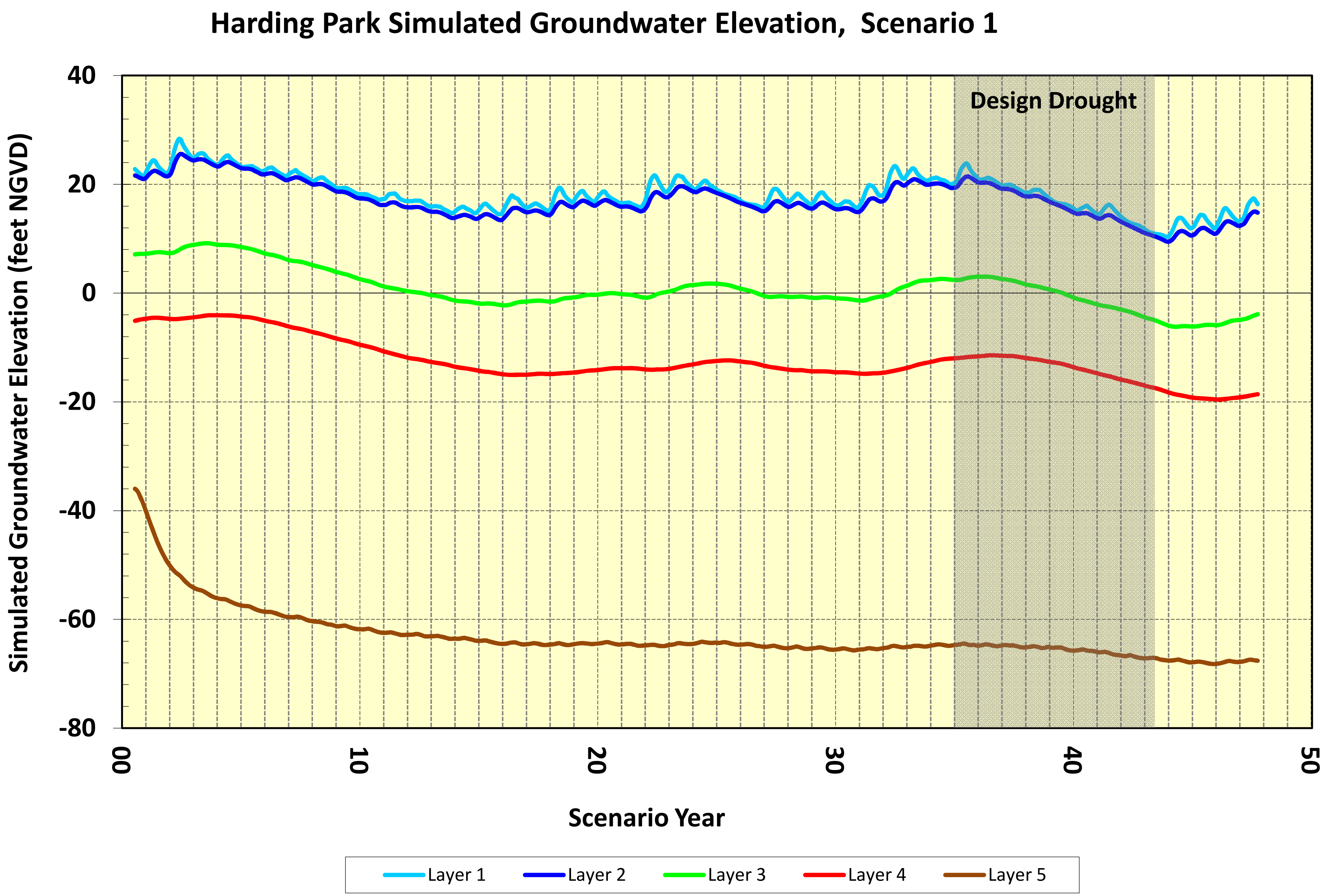
Ortega_MW Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

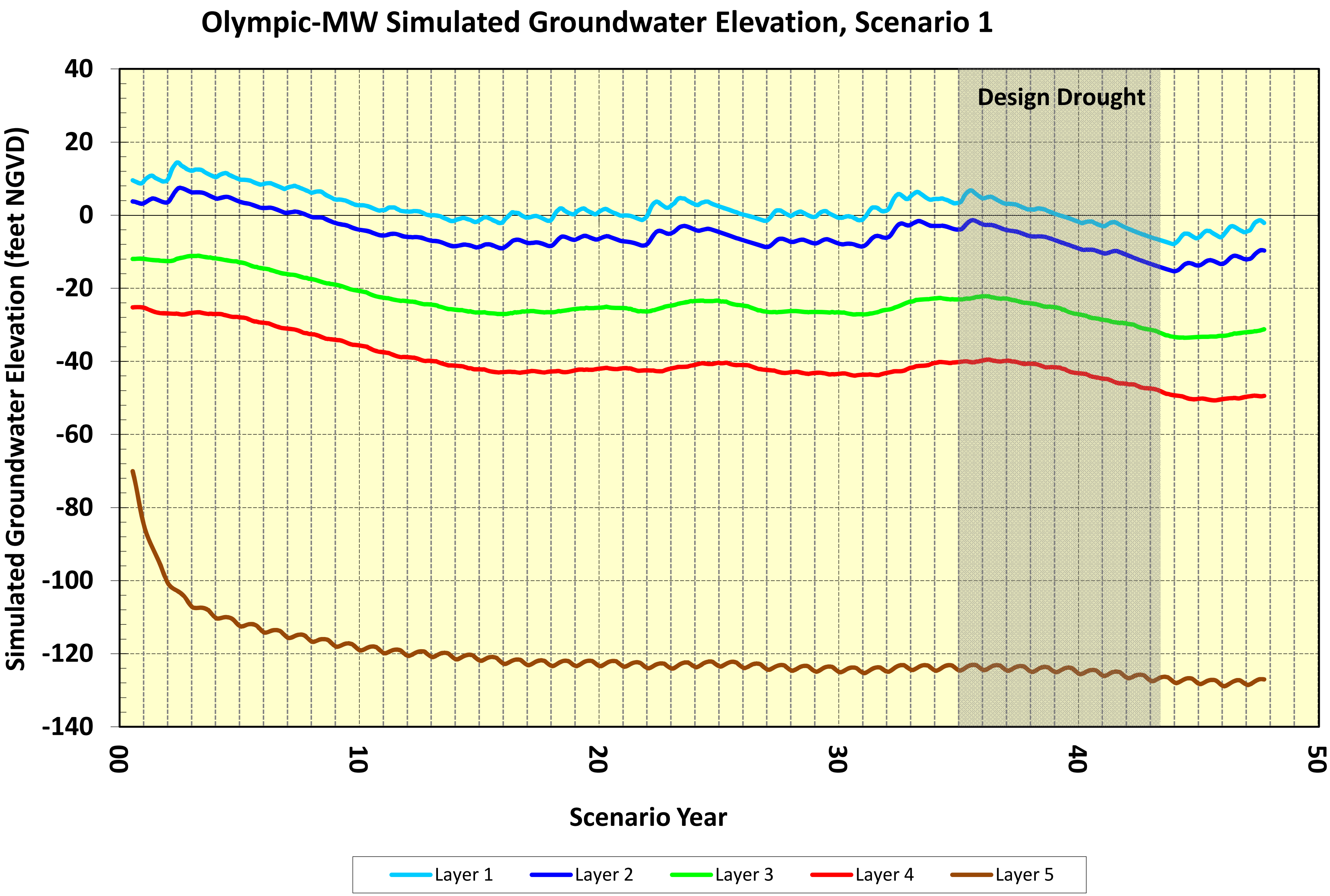

Santiago-S Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
-15
-20
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

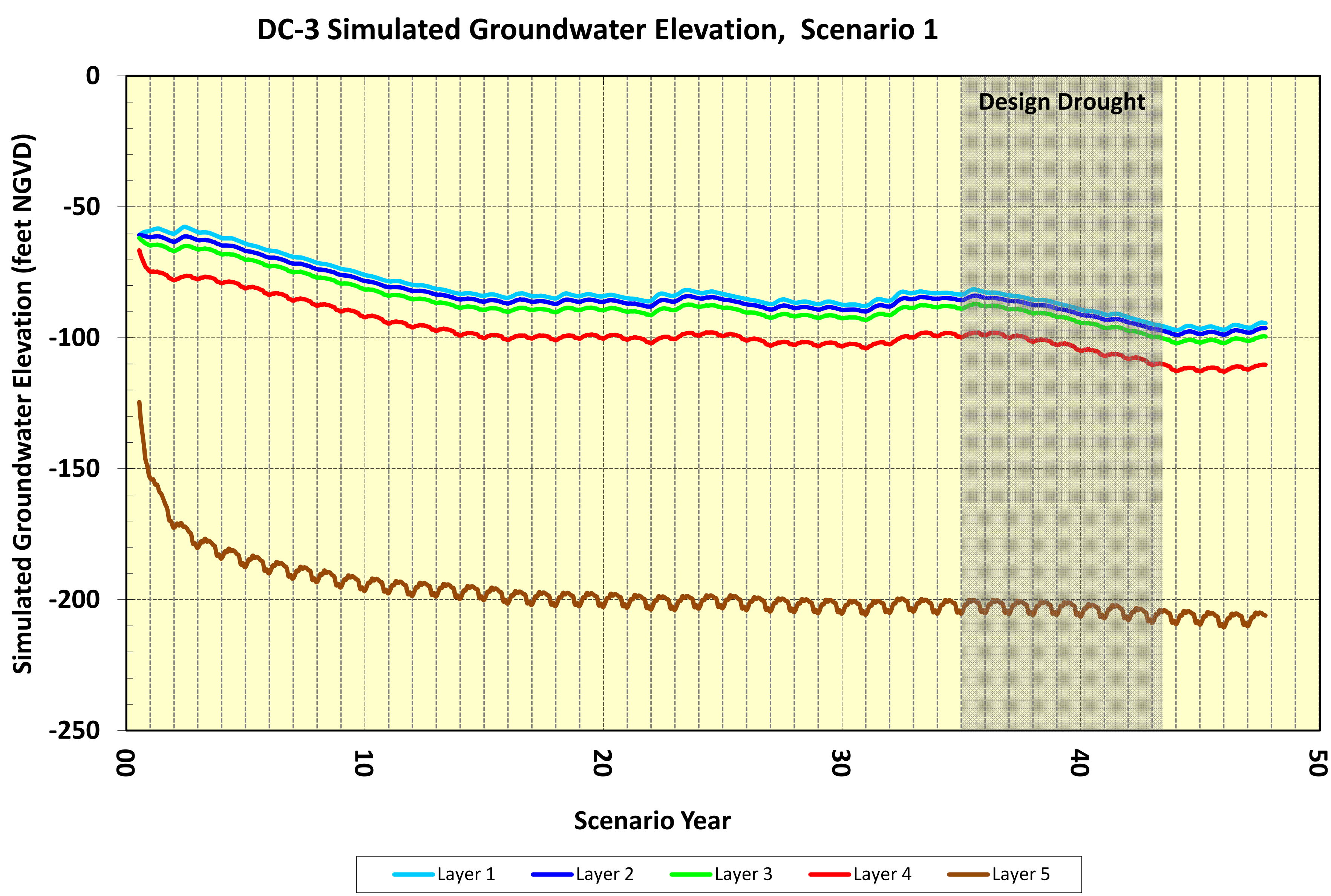

LMMW-4S Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
30
20
10
0
-10
-20
-30
-40
-50
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

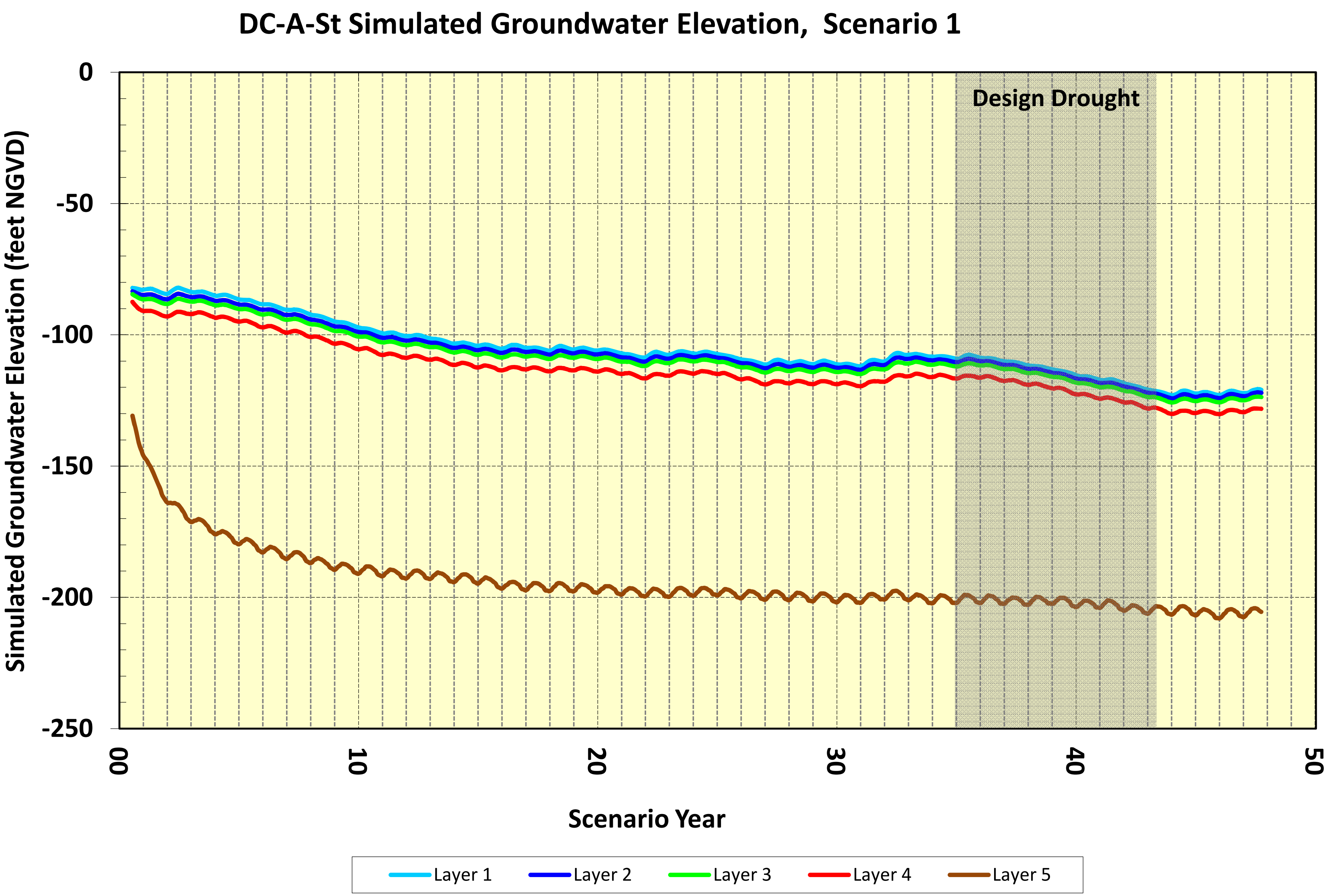


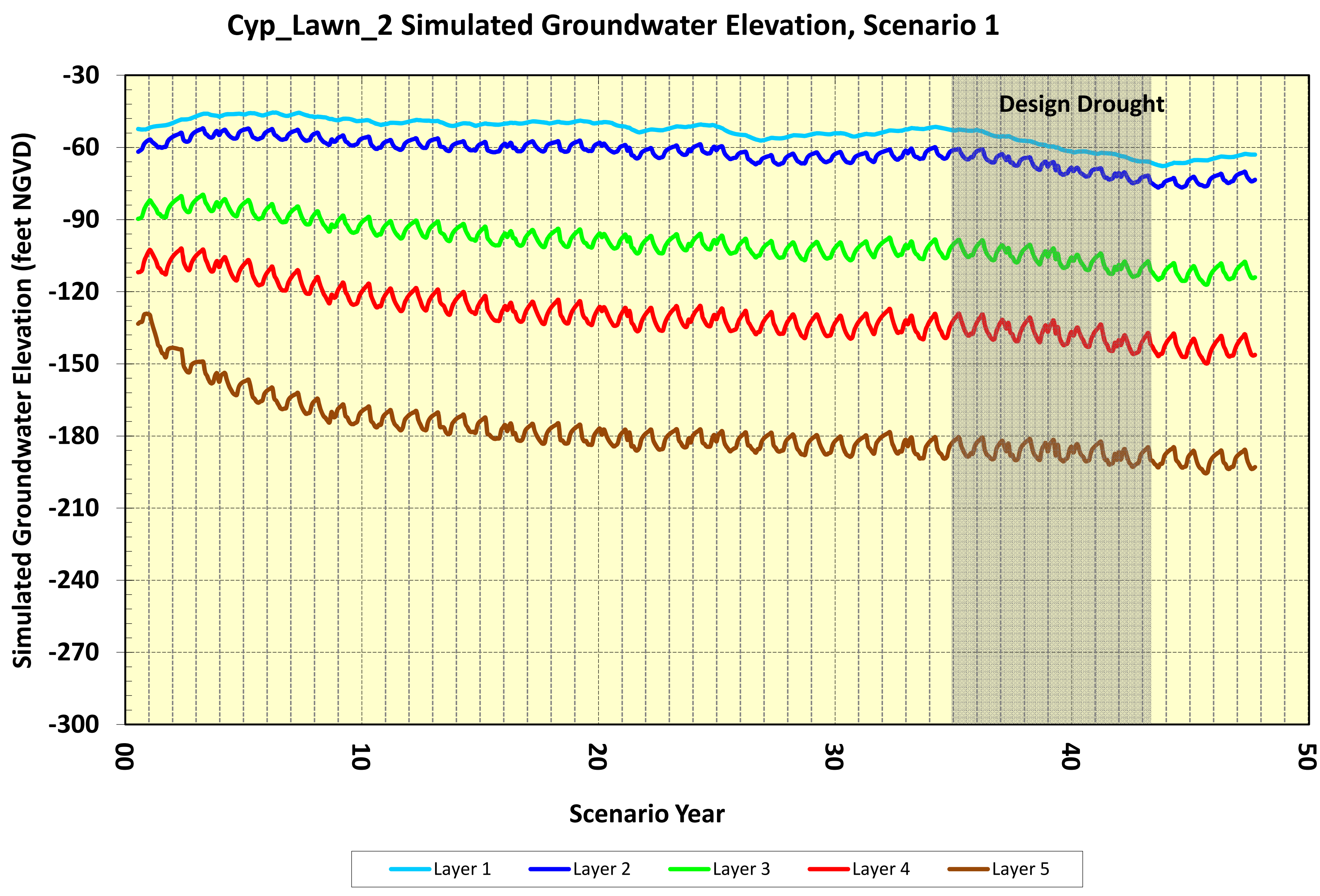
Note: At the location of LMMW-5S, the model does not contain Model Layers 4 and 5.


Harding Park Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


Olympic-MW Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
-100
-120
-140
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

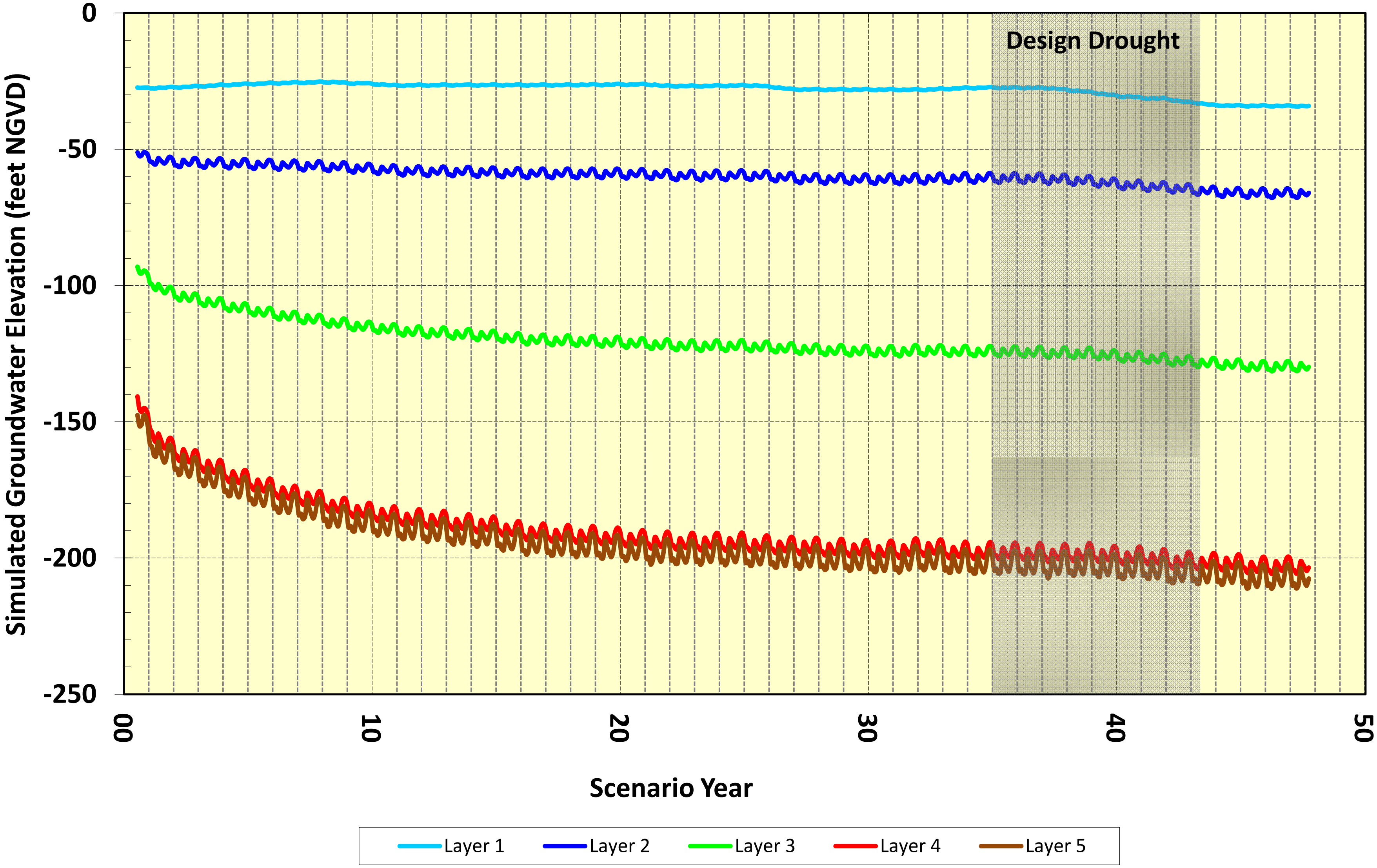

DC-3 Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

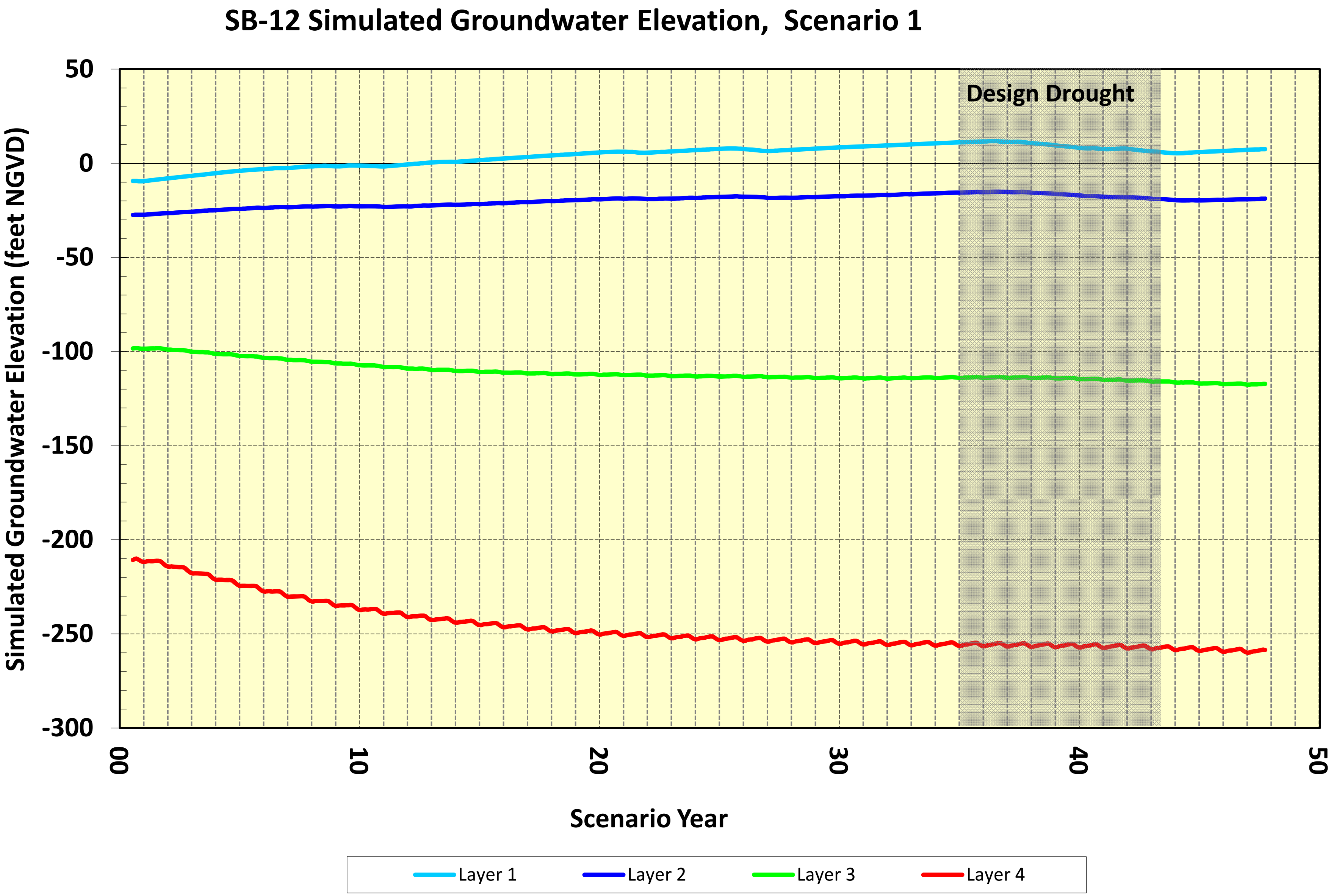

DC-A-St Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



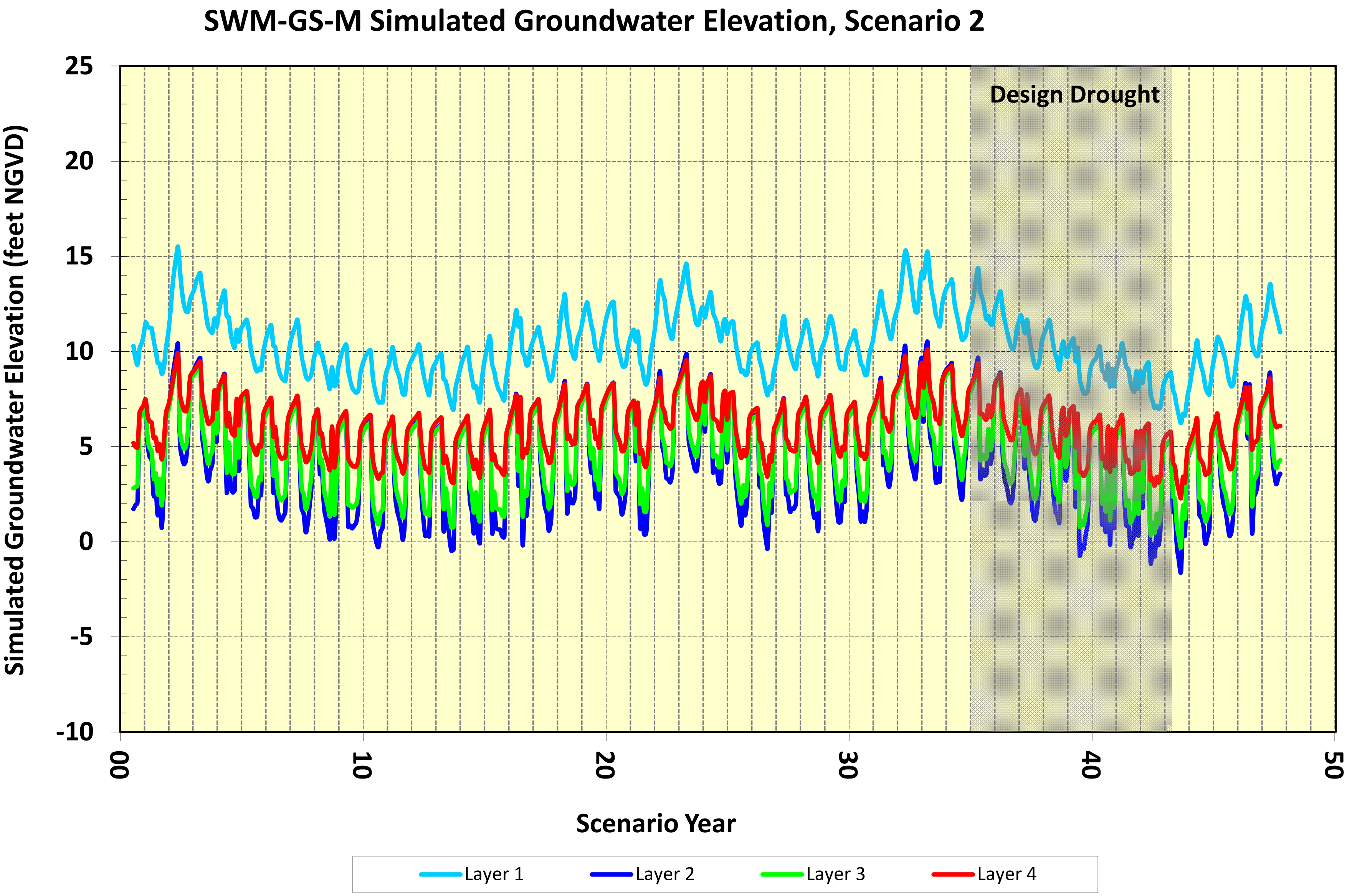
Cyp_Lawn_2 Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
-30
-60
-90
-120
-150
-180
-210
-240
-270
-300
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

SSF-02 Simulated Groundwater Elevation, Scenario 1

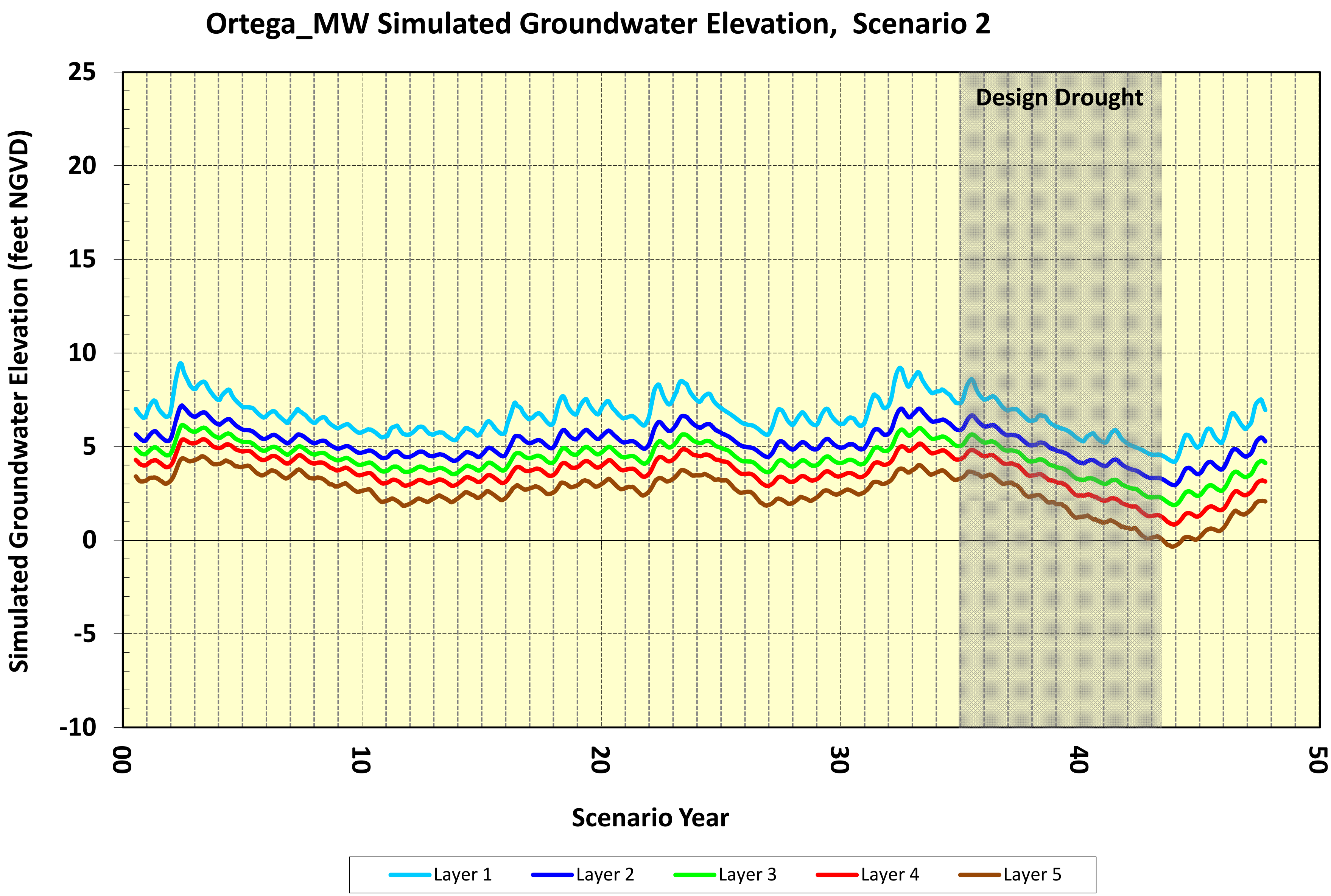


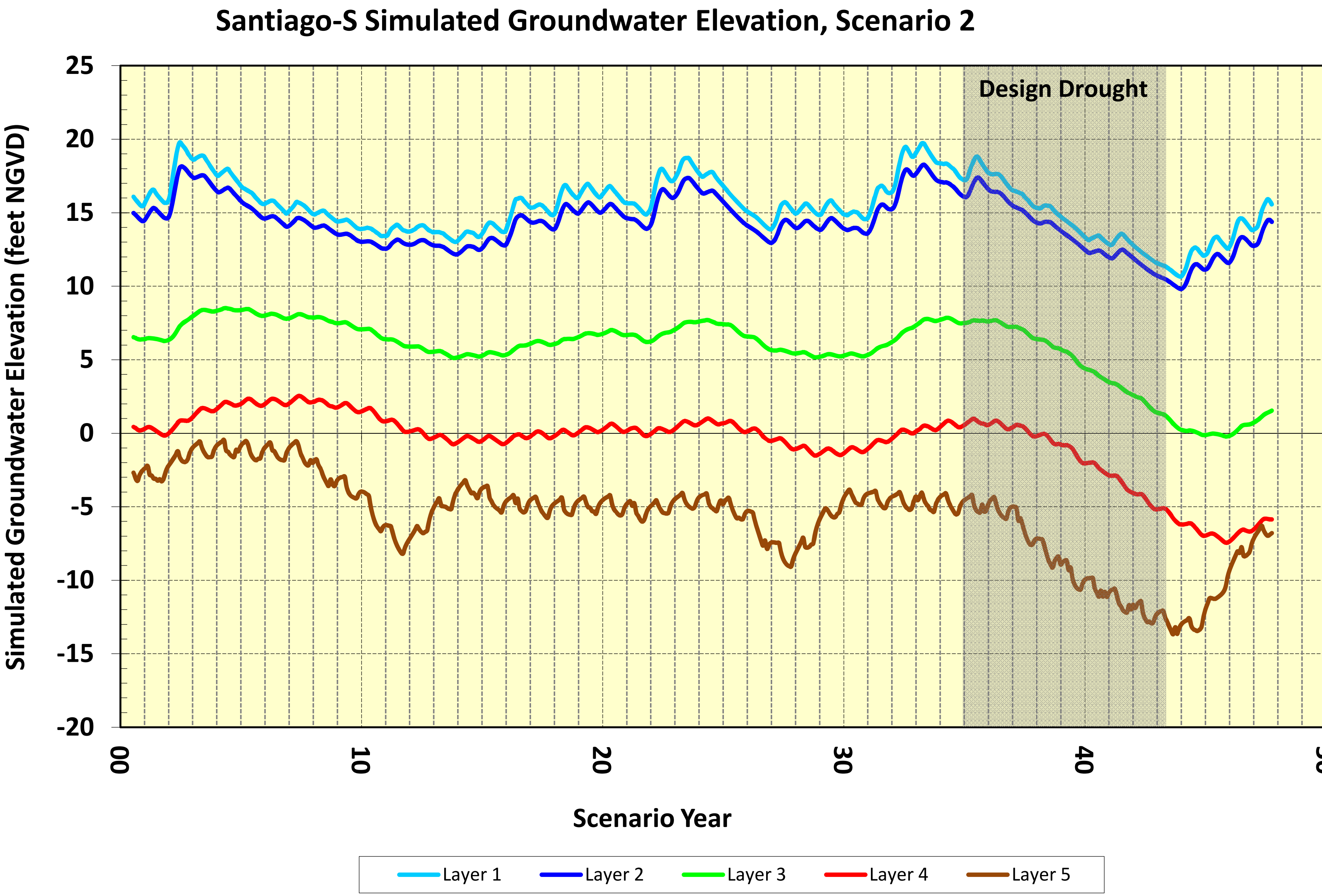


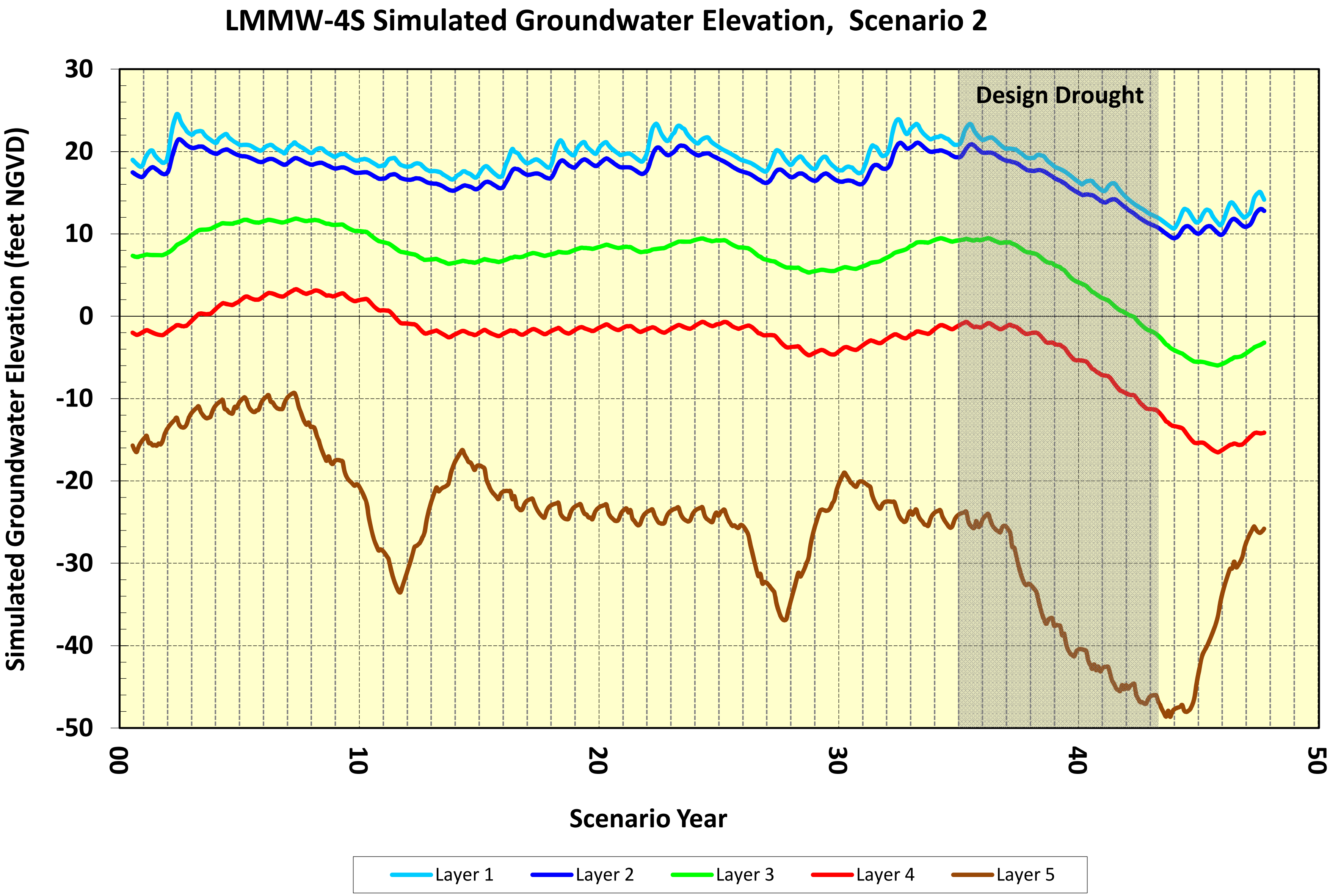
Note: At the location of SB-12, the model does not contain Model Layer 5.



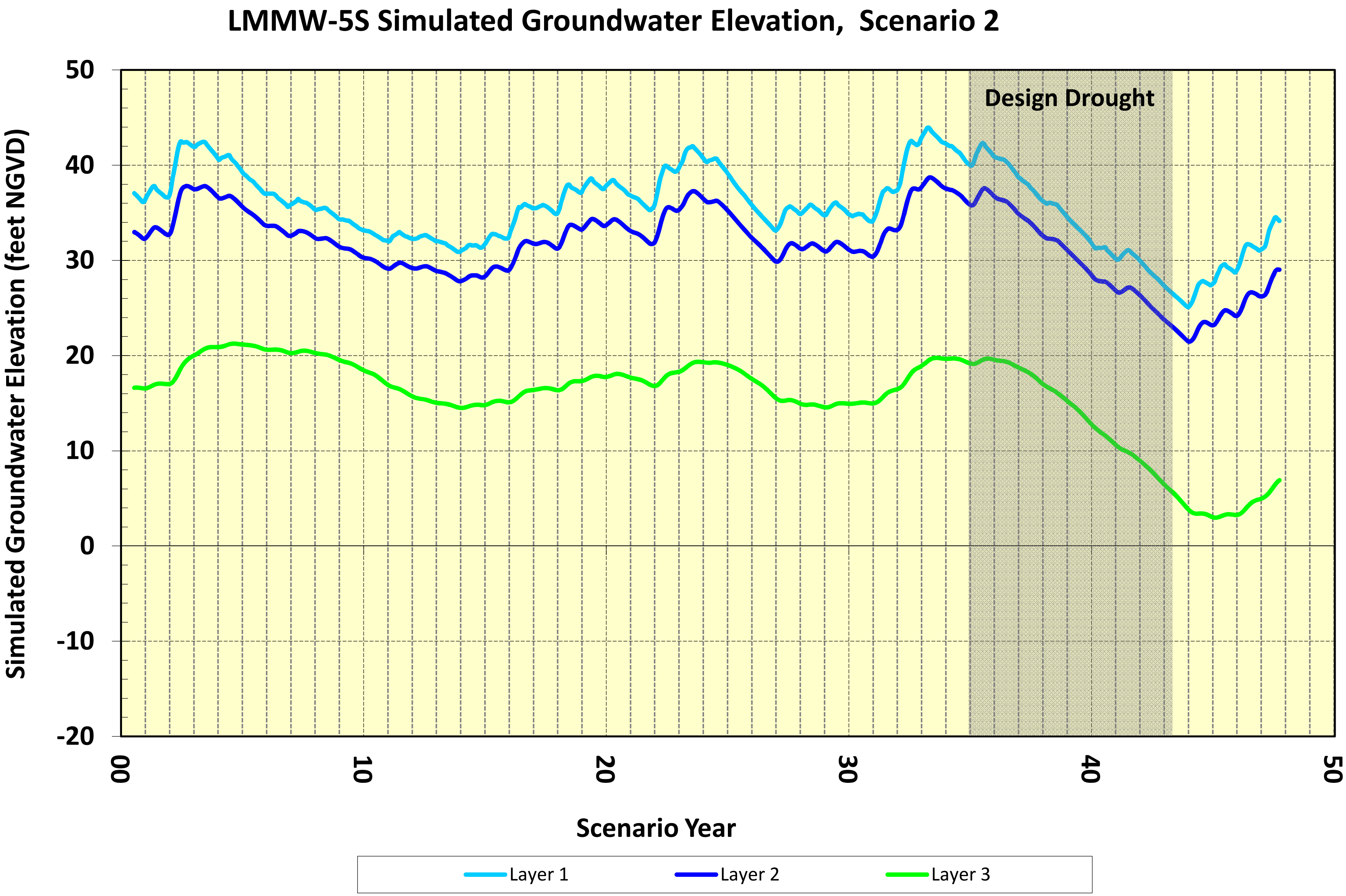
Note: At the location of SWM-GS-M, the model does not contain Model Layer 5.


Ortega_MW Simulated Groundwater Elevation, Scenario 2
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

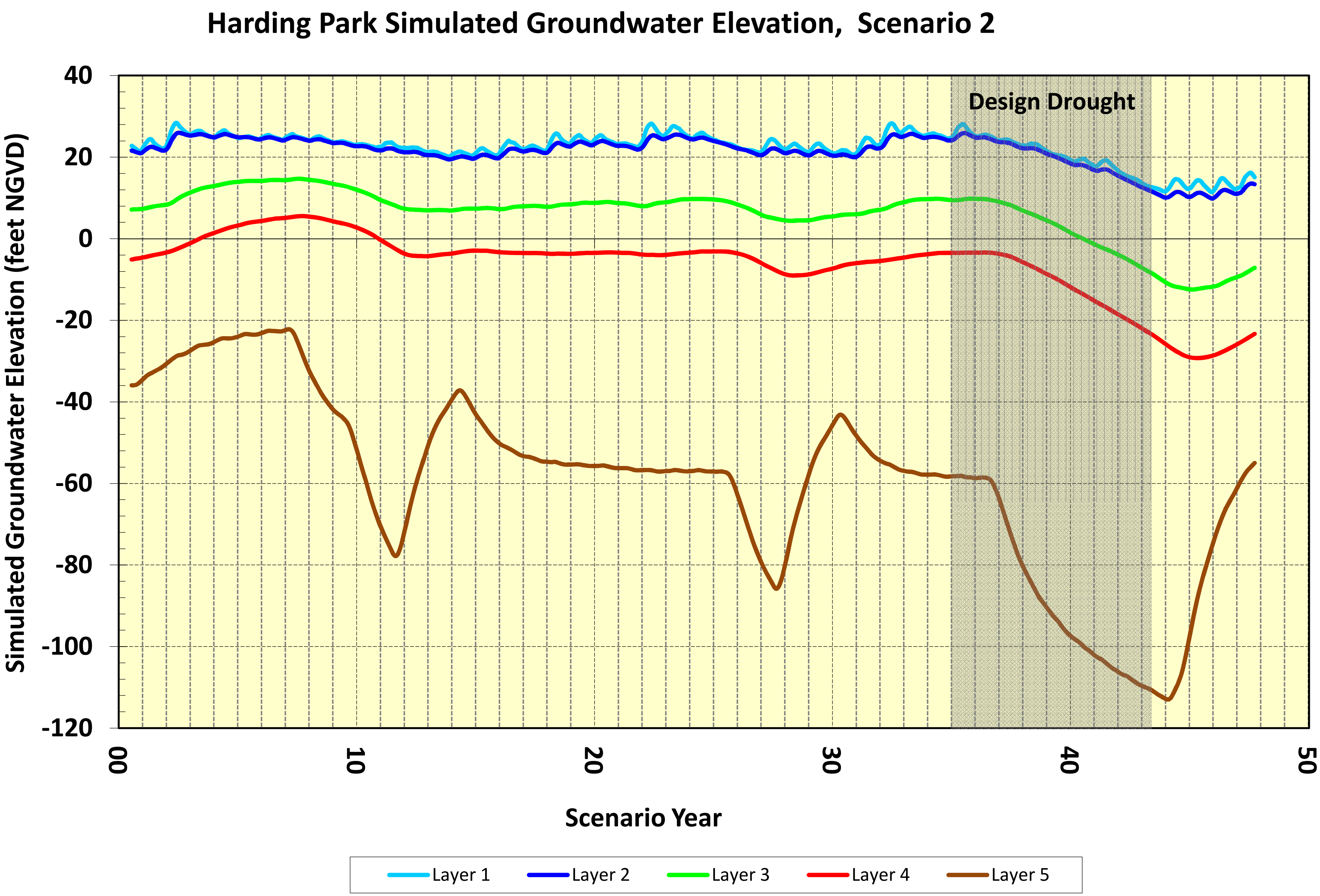

Santiago-S Simulated Groundwater Elevation, Scenario 2
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
-15
-20
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

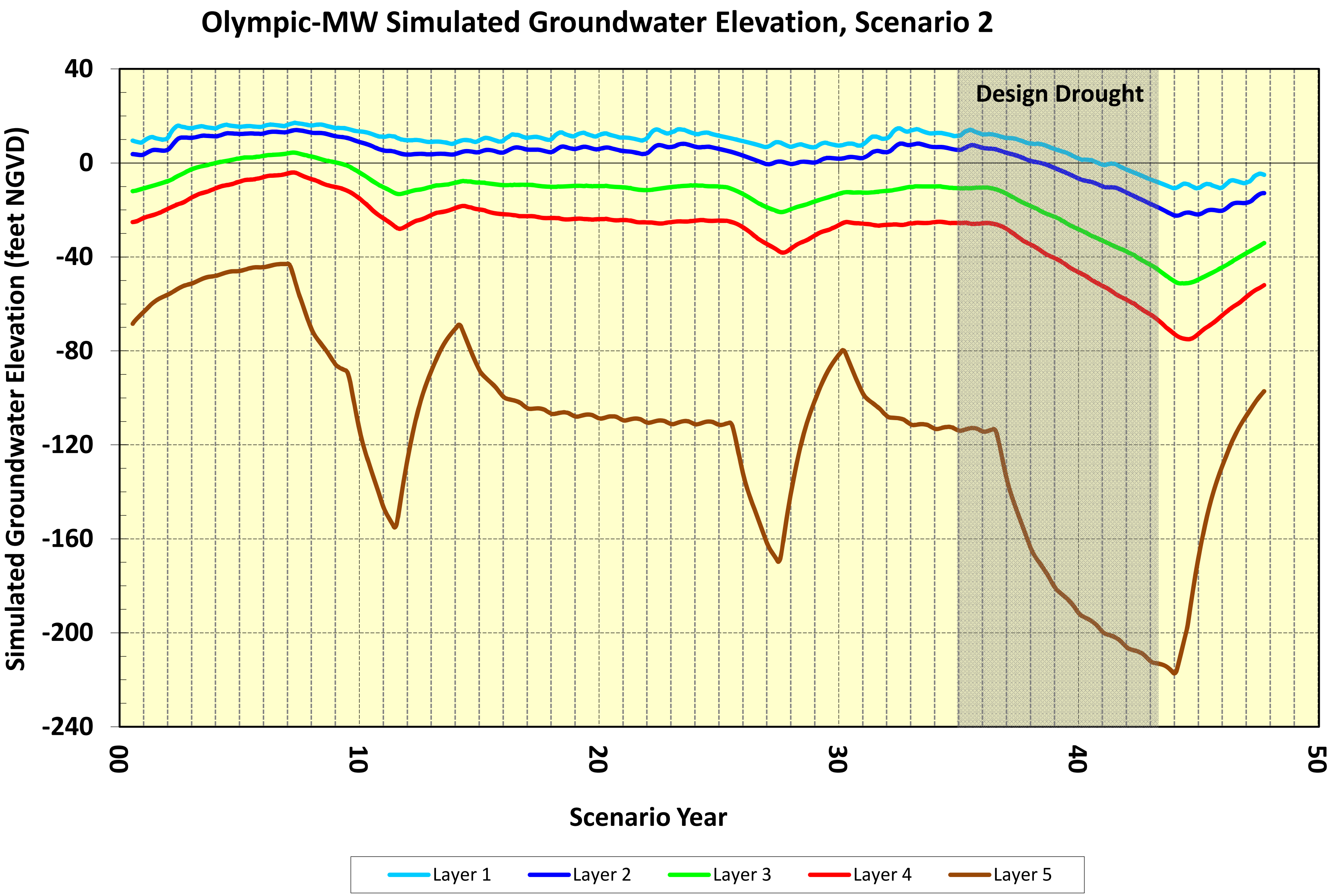


LMMW-4S Simulated Groundwater Elevation, Scenario 2
Design Drought
Simulated Groundwater Elevation (feet NGVD)
30
20
10
0
-10
-20
-30
-40
-50
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

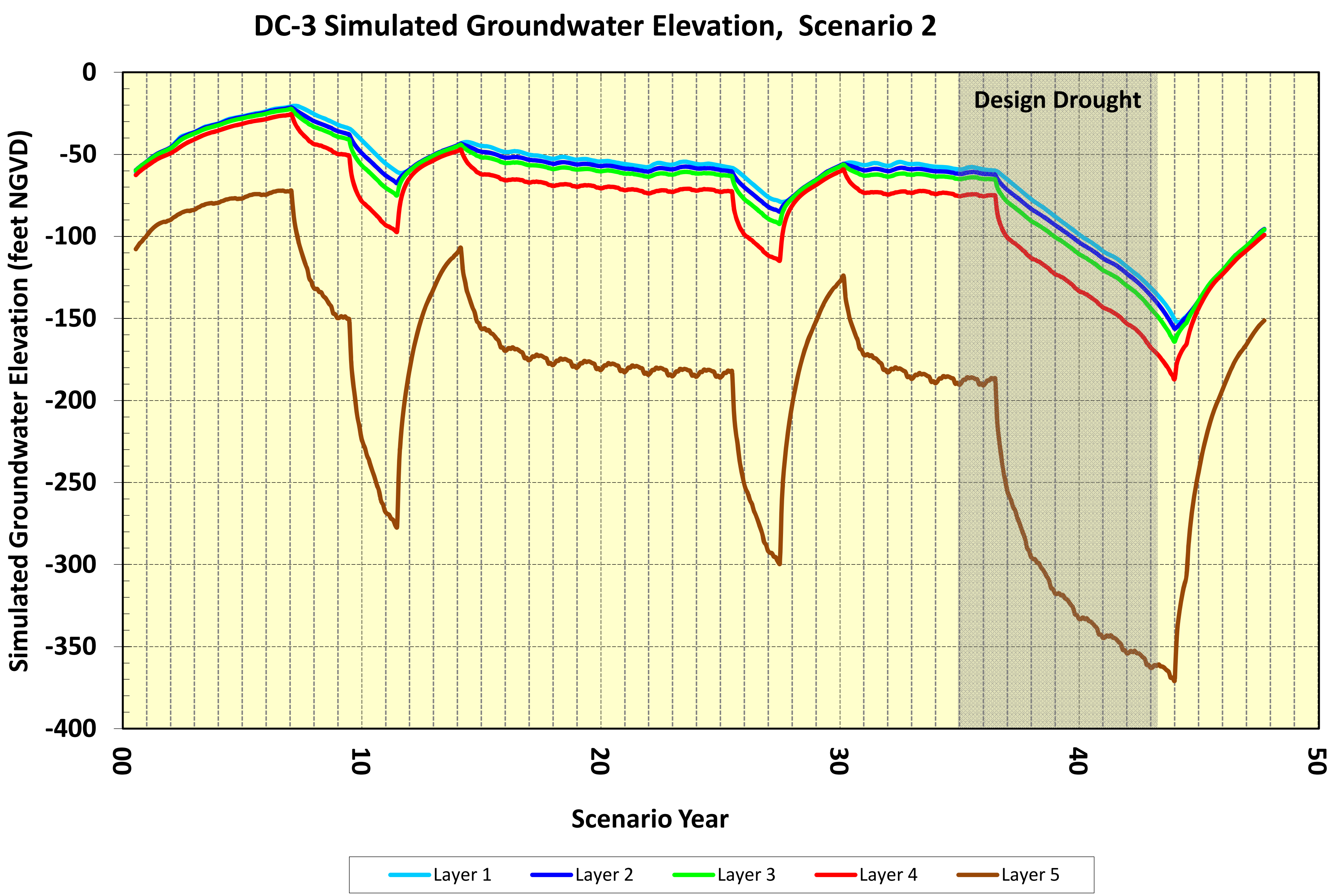


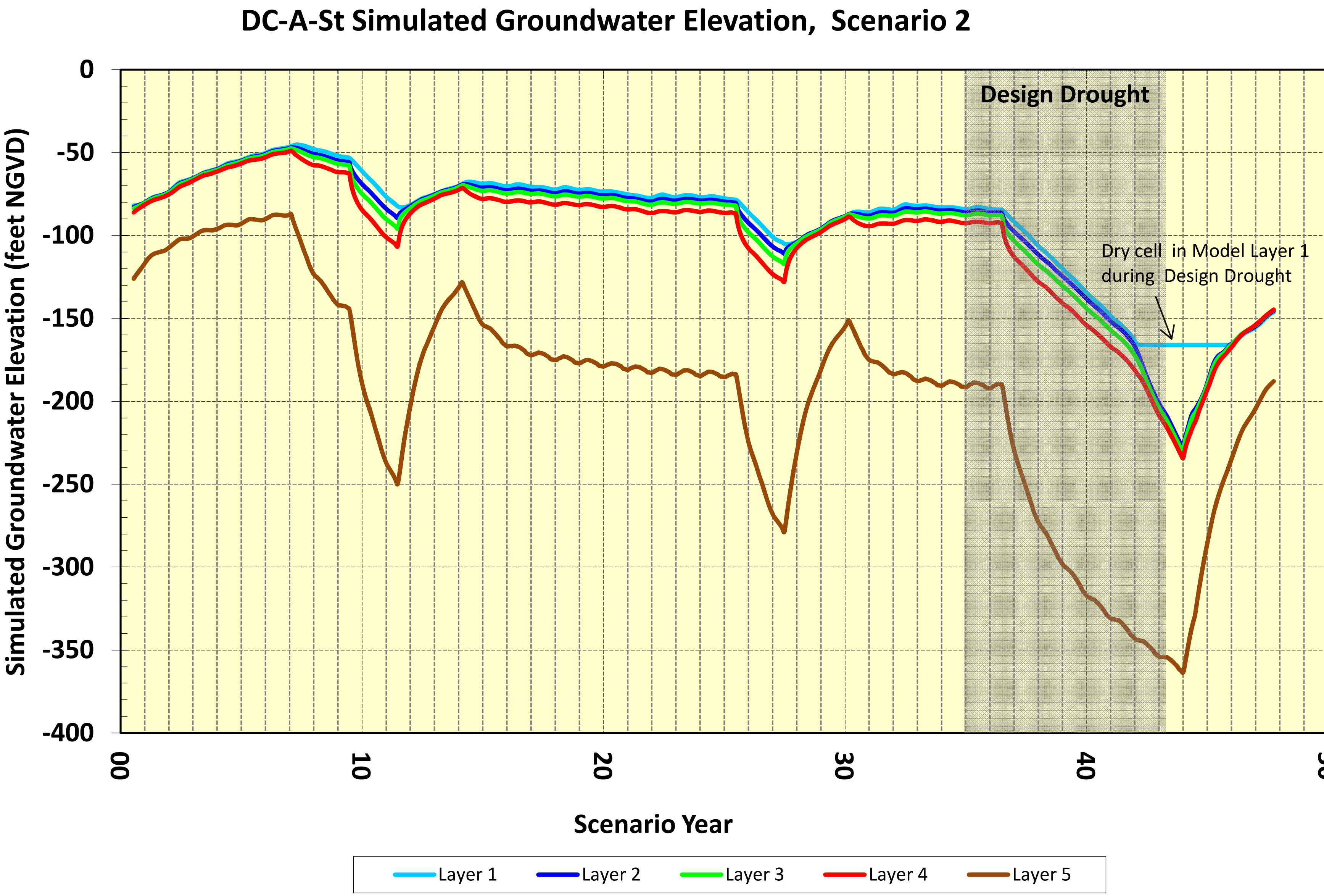
Note: At the location of LMMW-5S, the model does not contain Model Layers 4 and 5.

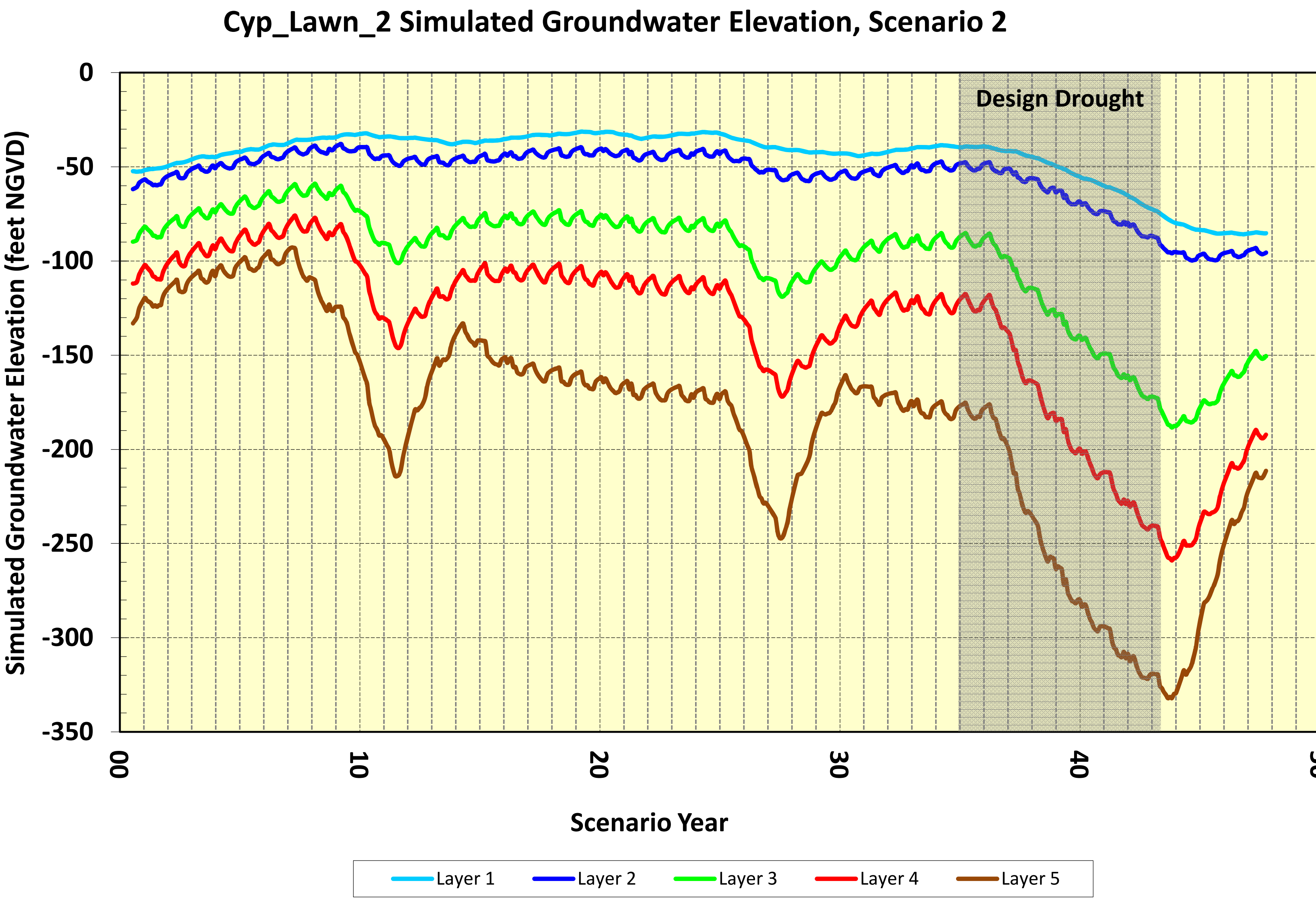

Harding Park Simulated Groundwater Elevation, Scenario 2
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
-100
-120
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

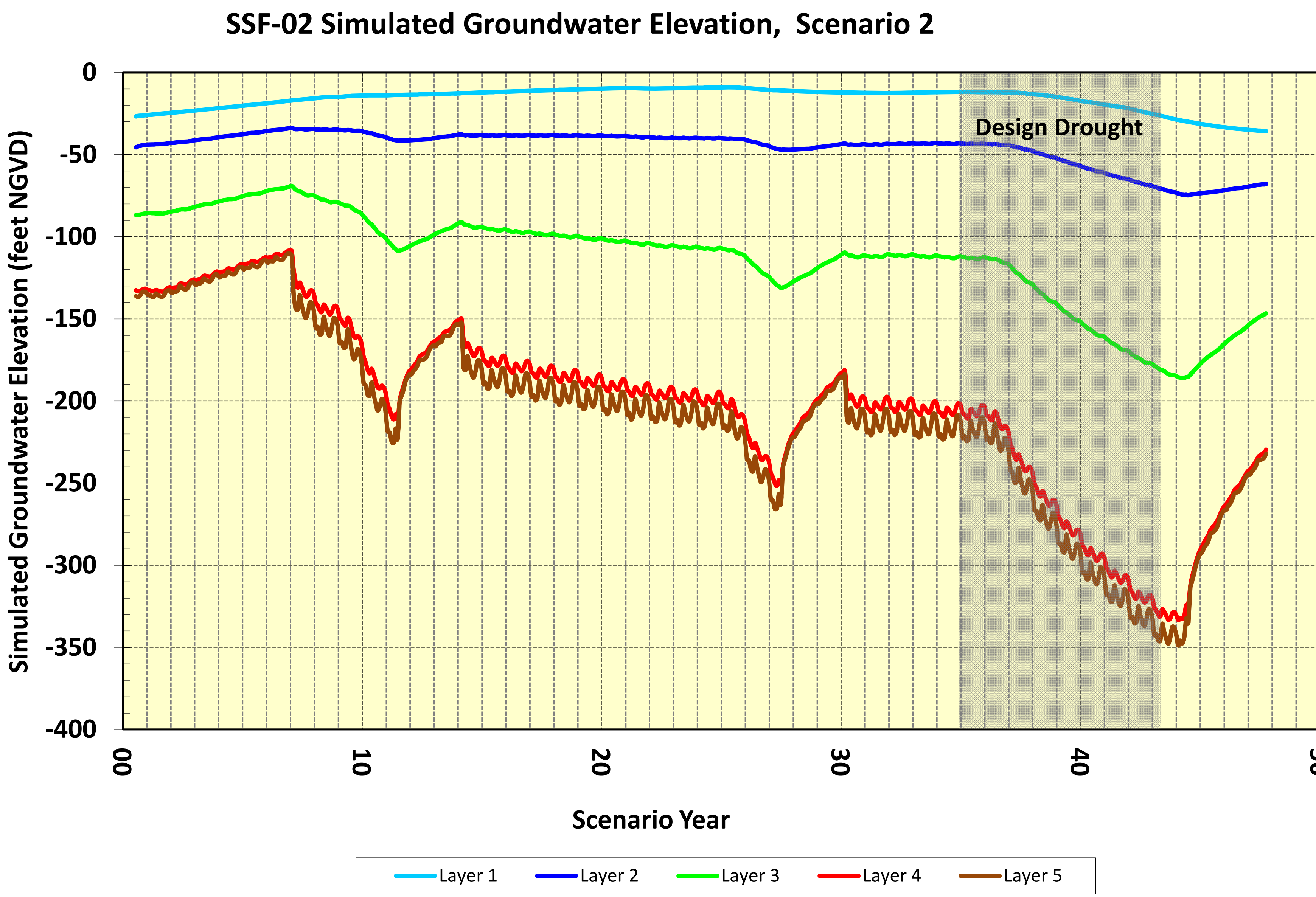


Olympic-MW Simulated Groundwater Elevation, Scenario 2
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
0
-40
-80
-120
-160
-200
-240
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

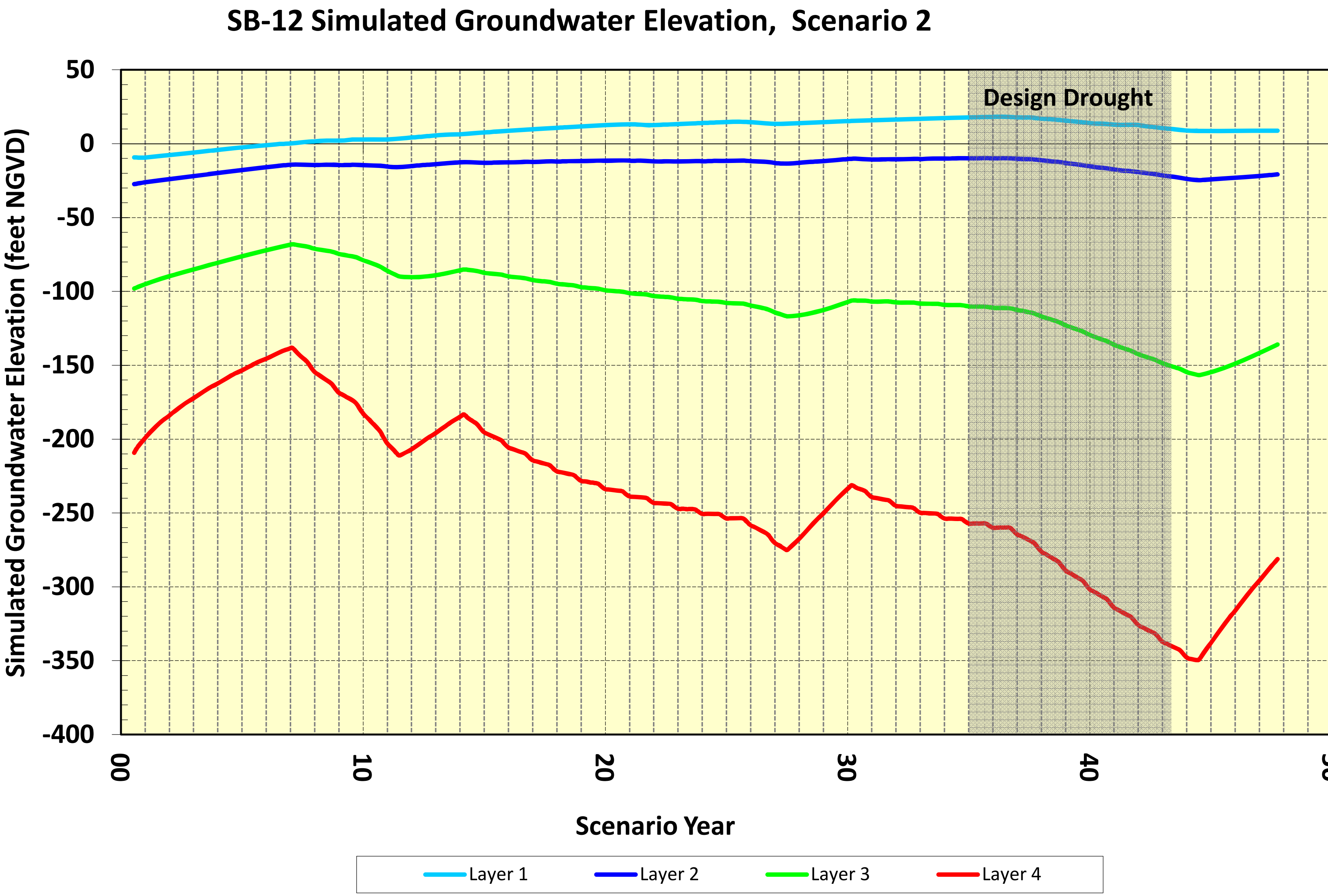

DC-3 Simulated Groundwater Elevation, Scenario 2
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


DC-A-St Simulated Groundwater Elevation, Scenario 2
Design Drought
Dry cell in Model Layer 1
during Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

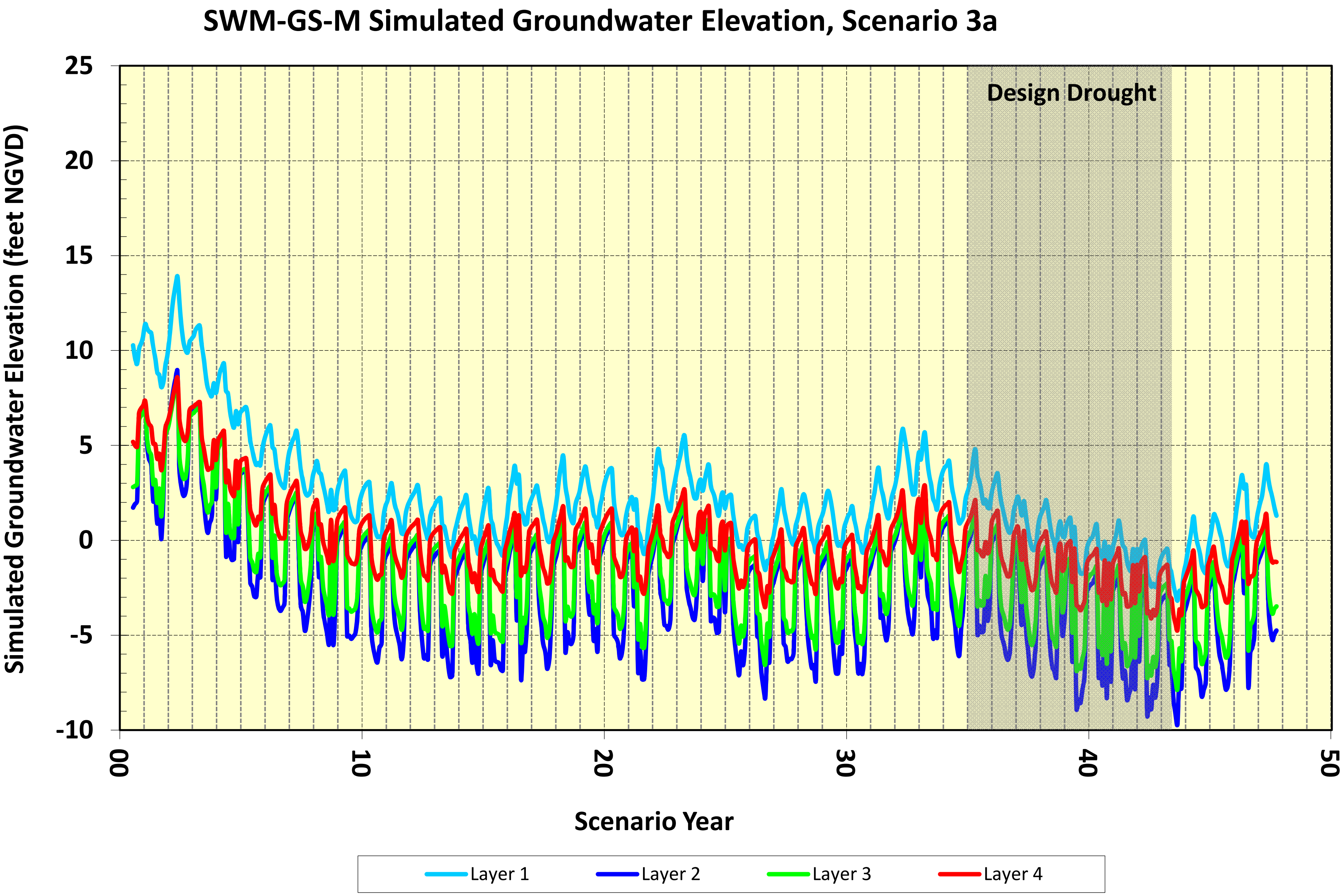

Cyp_Lawn_2 Simulated Groundwater Elevation, Scenario 2
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
Design Drought
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



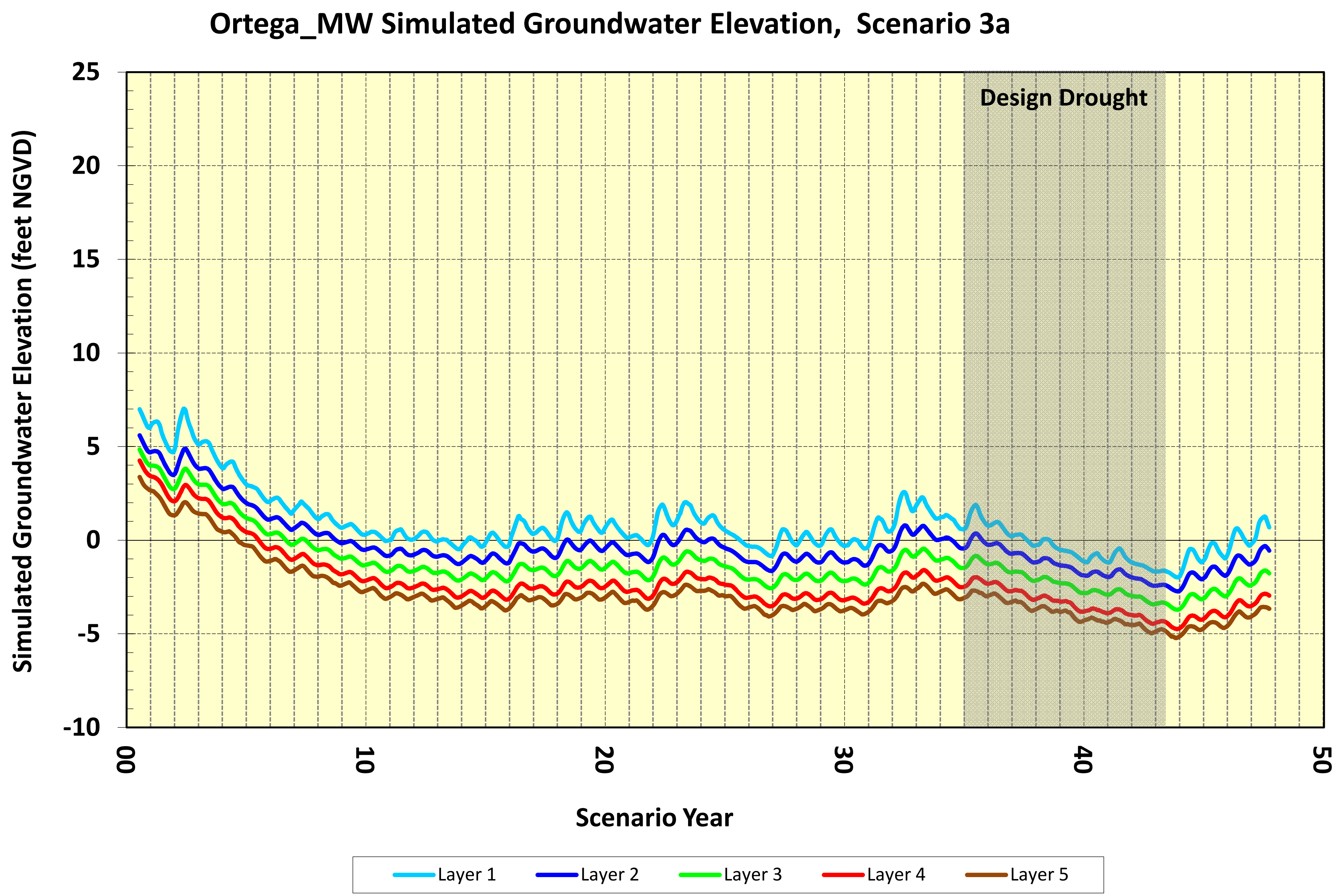
SSF-02 Simulated Groundwater Elevation, Scenario 2
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

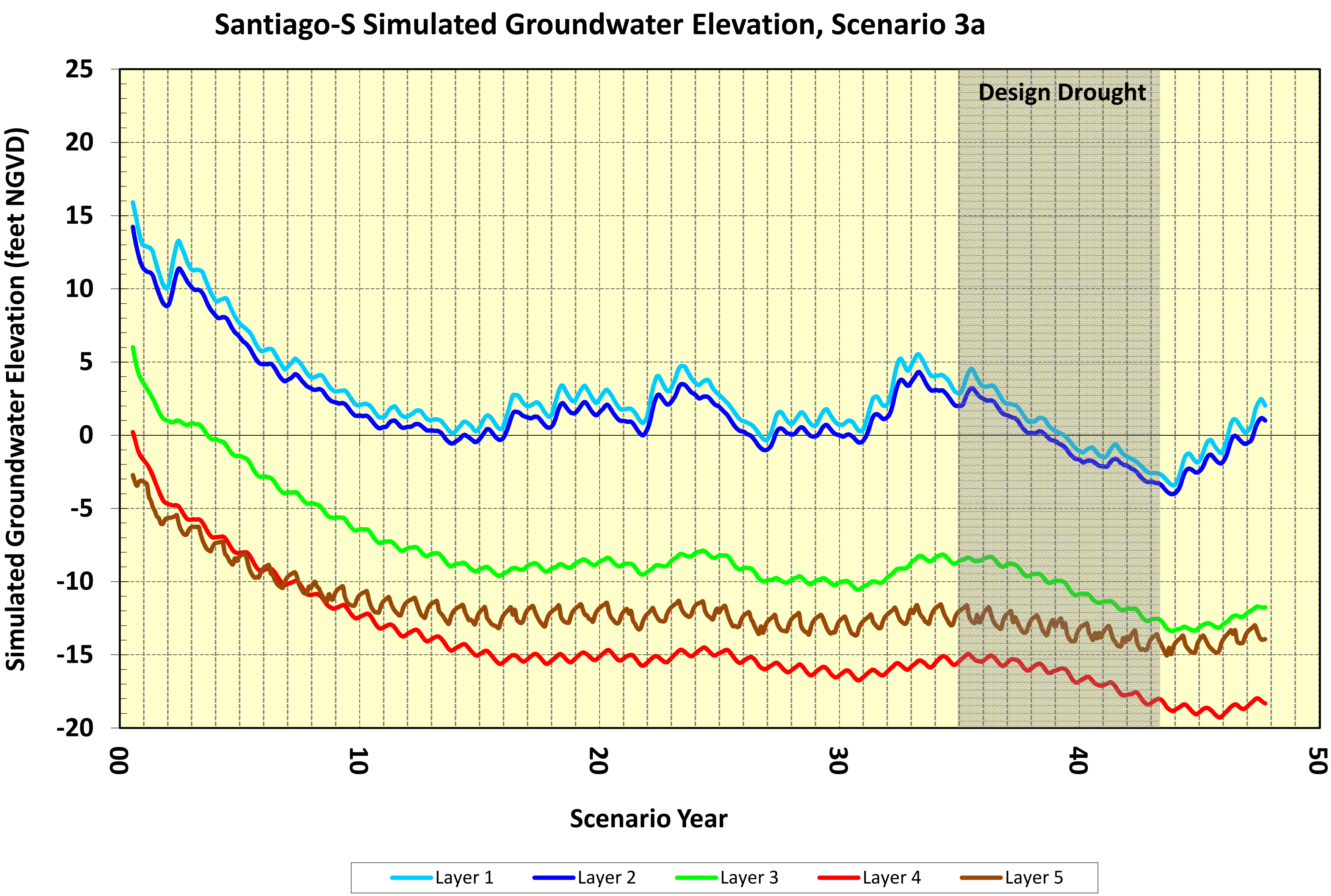


Note: At the location of SB-12, the model does not contain Model Layer 5.

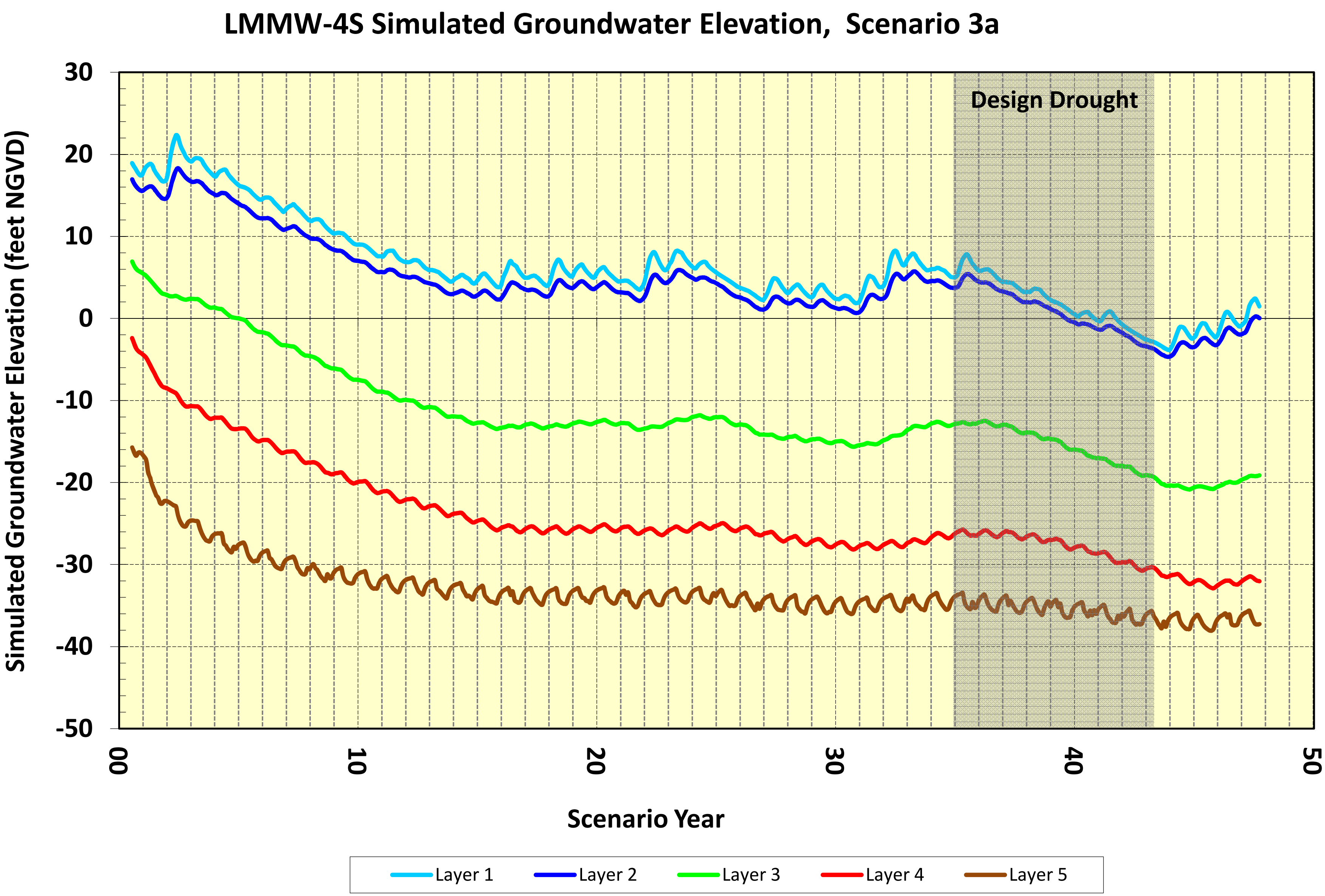


Note: At the location of SWM-GS-M, the model does not contain Model Layer 5.

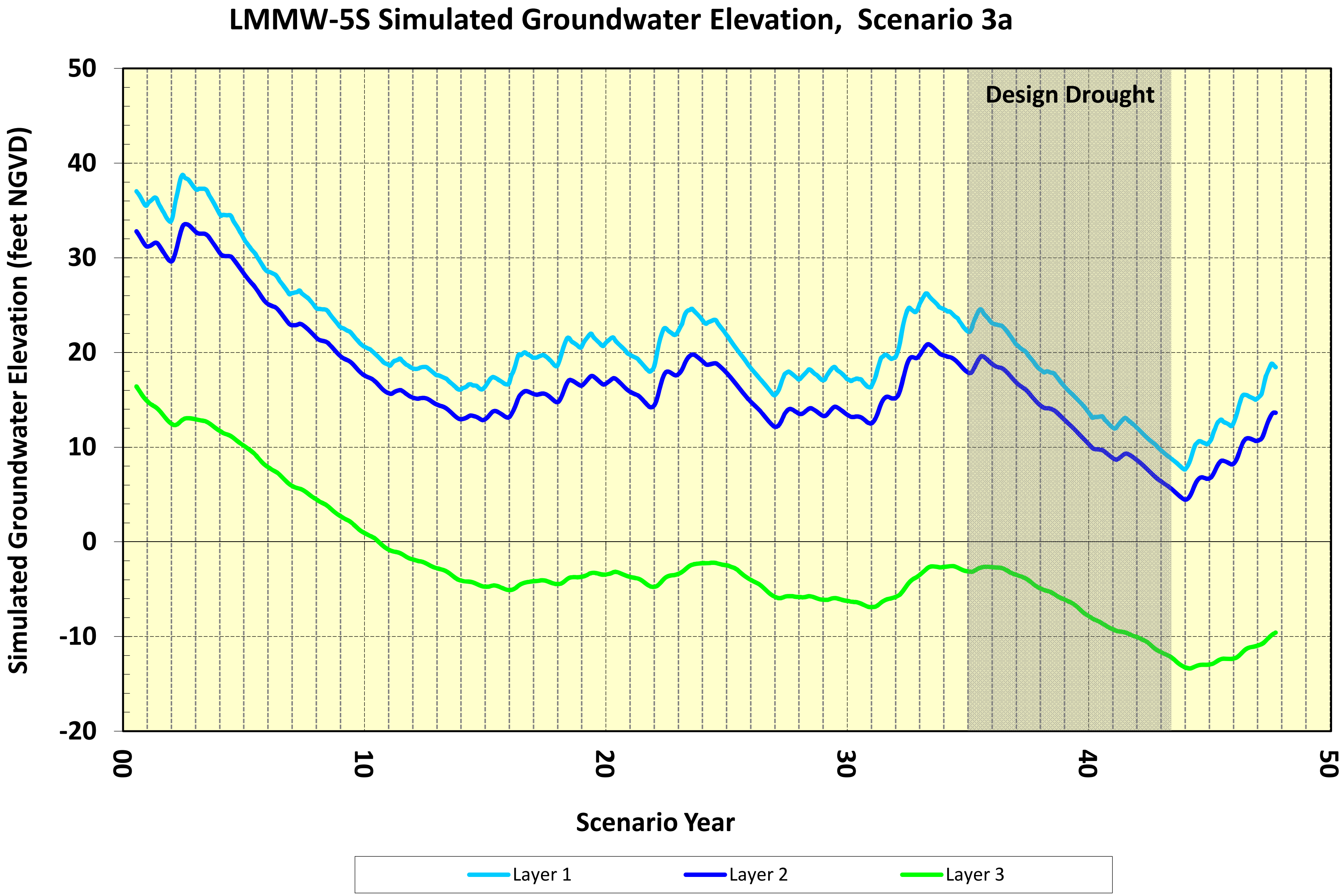

Ortega_MW Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



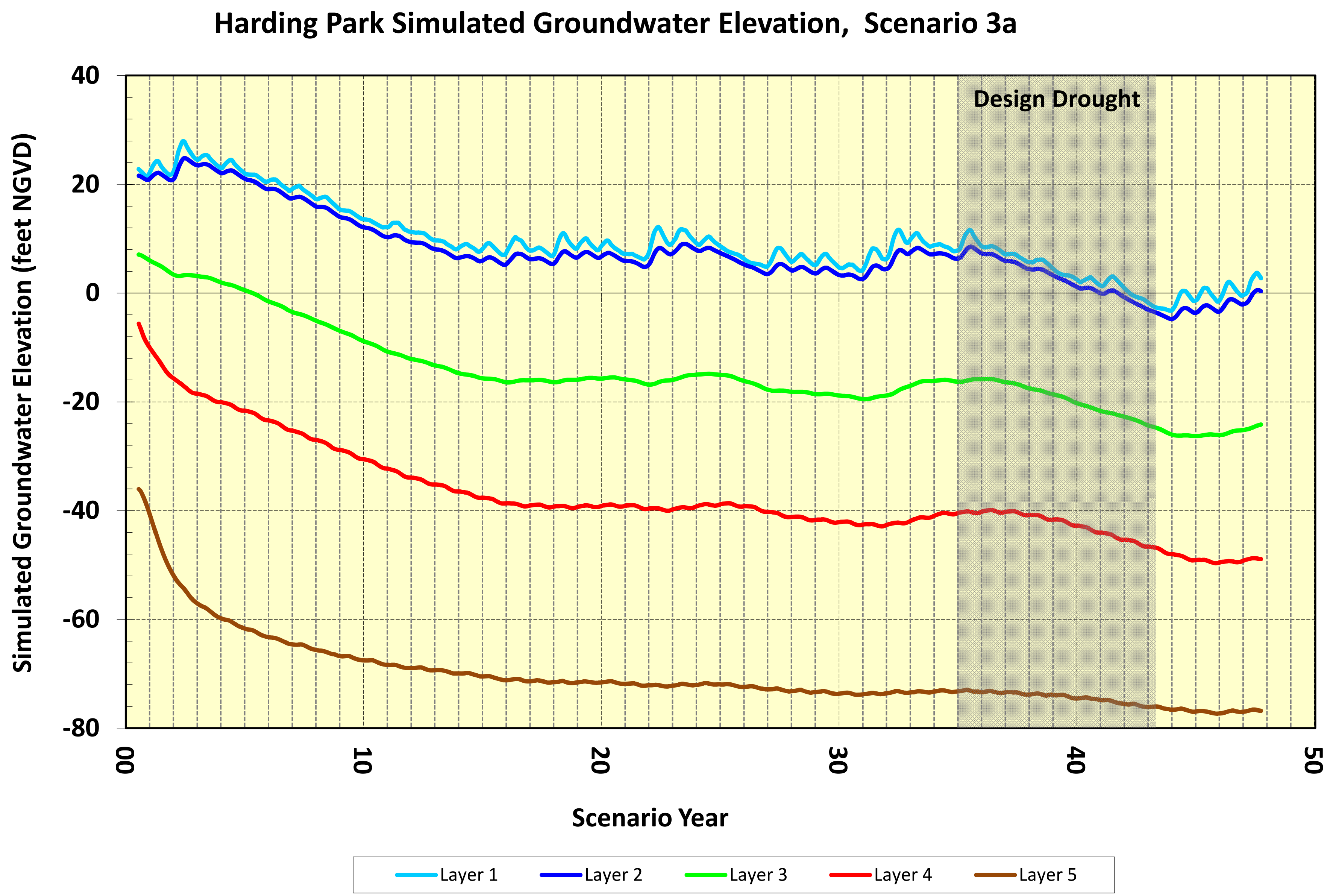
Santiago-S Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
-15
-20
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

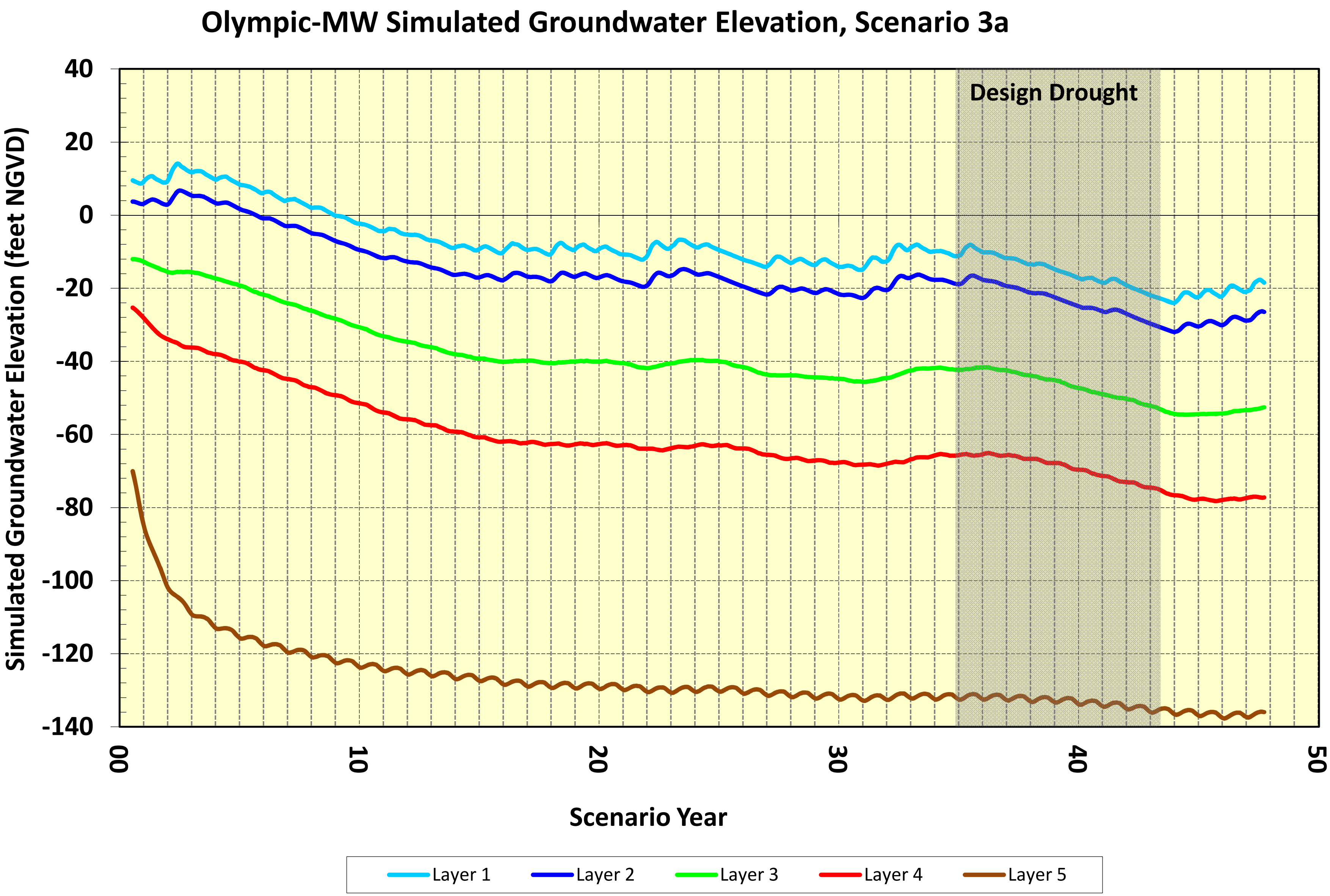


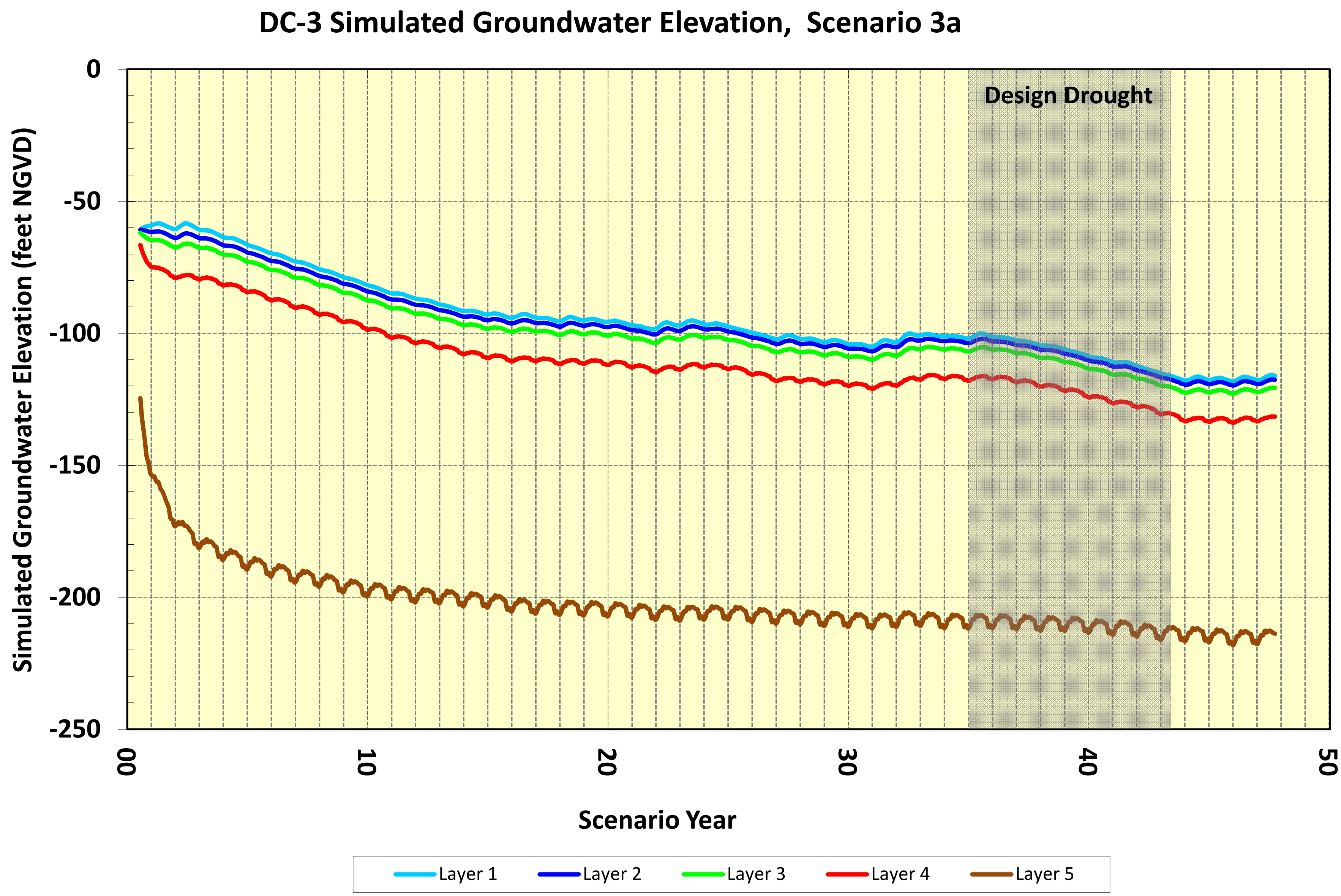
LMMW-4S Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
30
20
10
0
-10
-20
-30
-40
-50
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



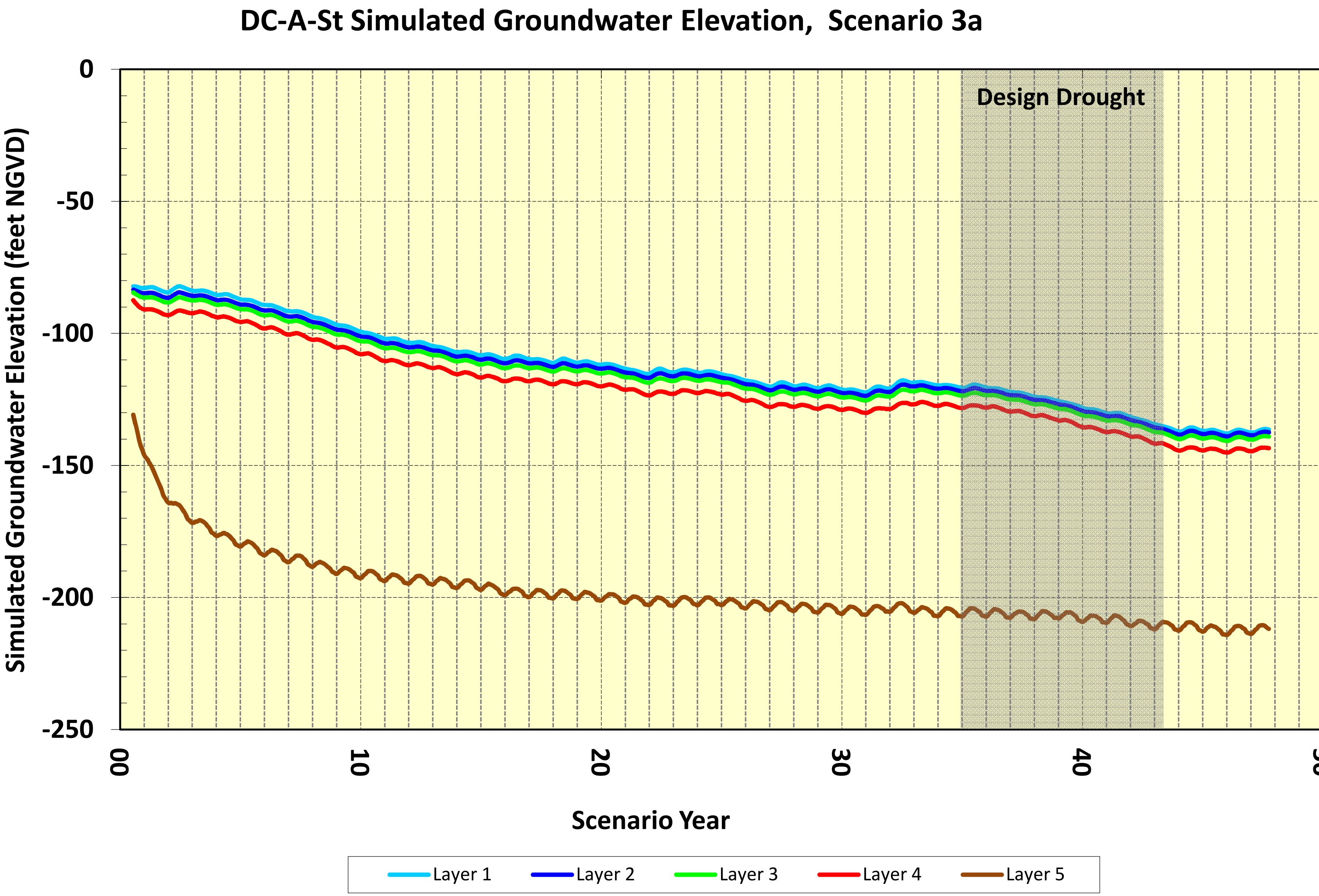
Note: At the location of LMMW-5S, the model does not contain Model Layers 4 and 5.


Harding Park Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

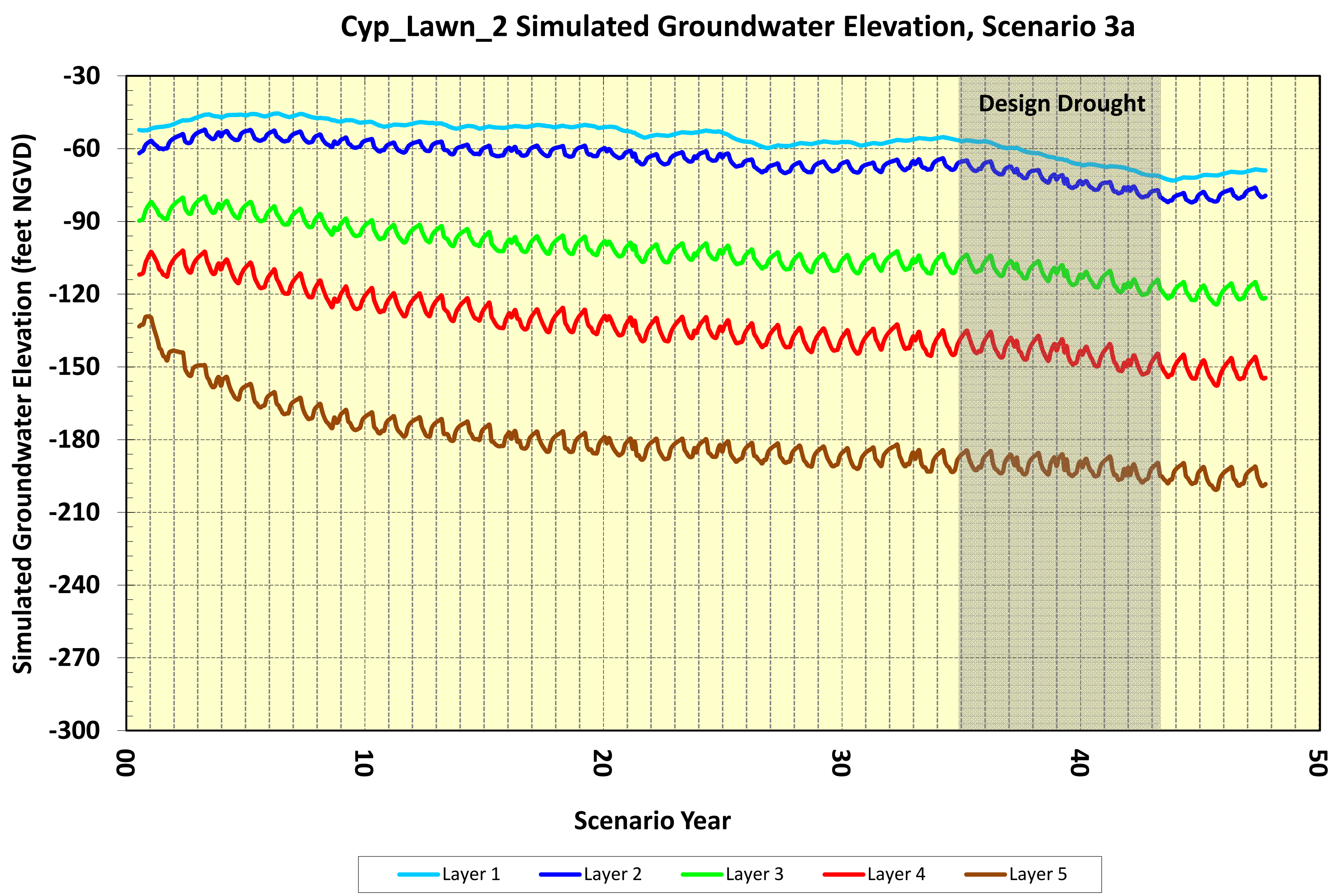

Olympic-MW Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
-100
-120
-140
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



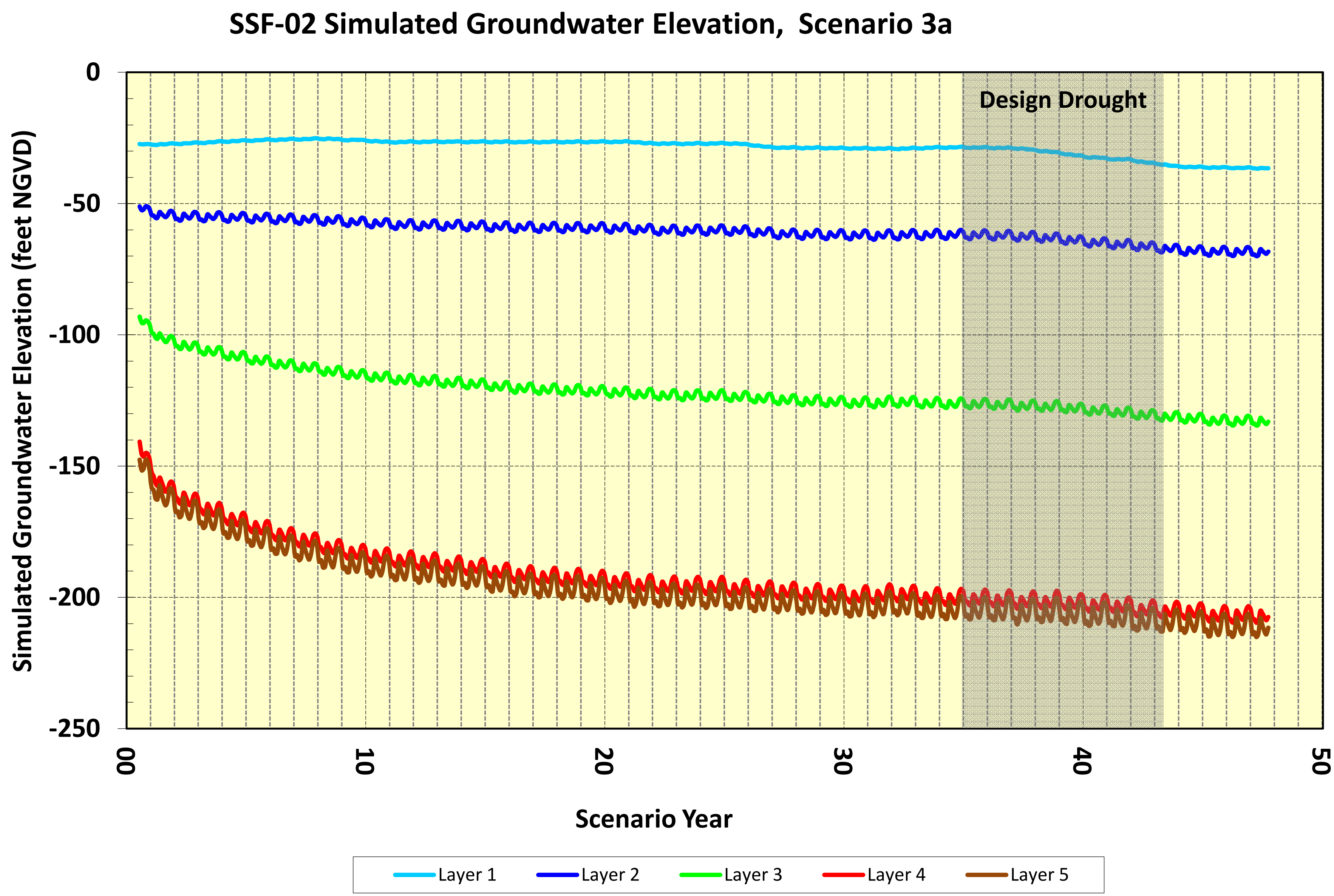
DC-3 Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



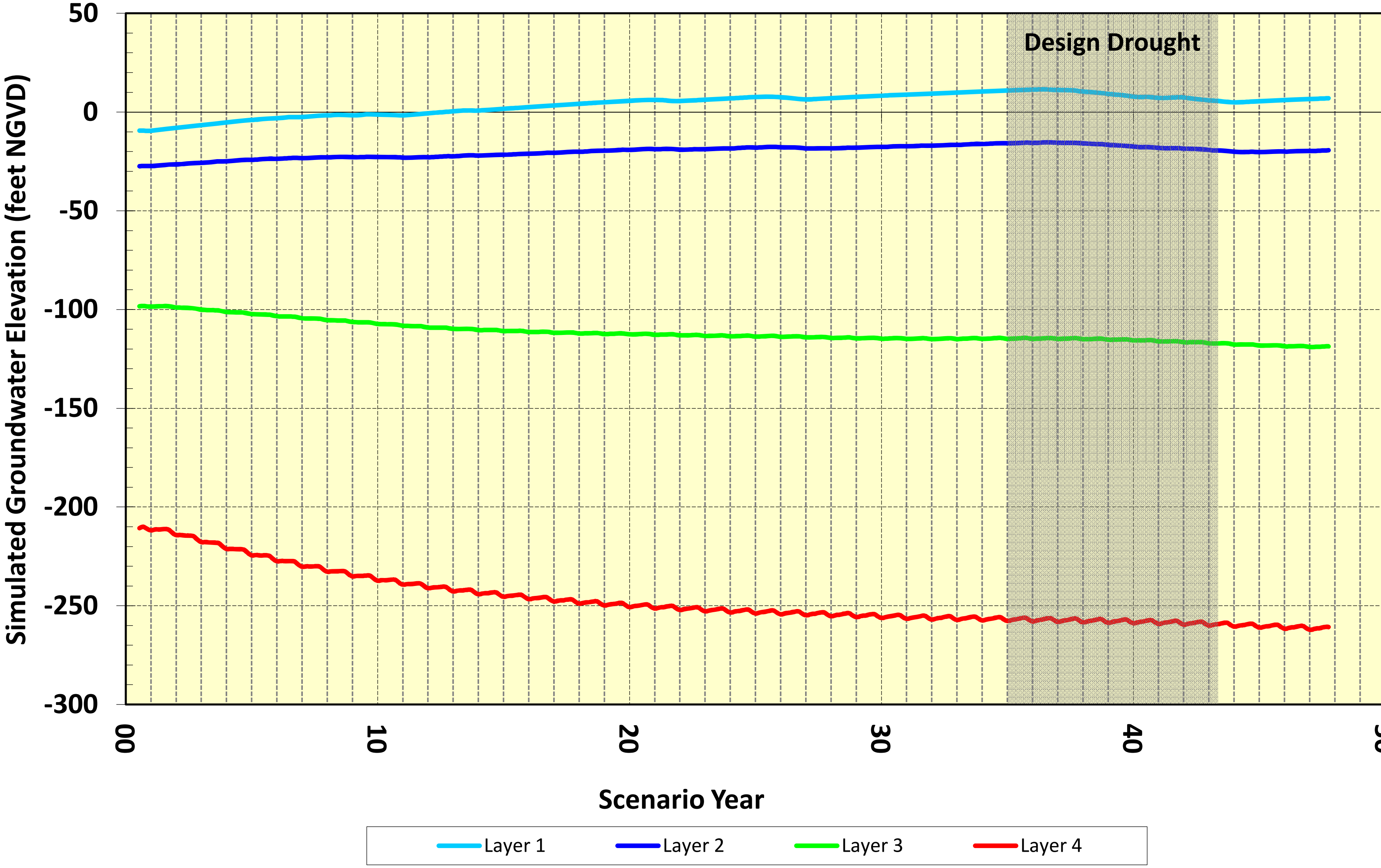
DC-A-St Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



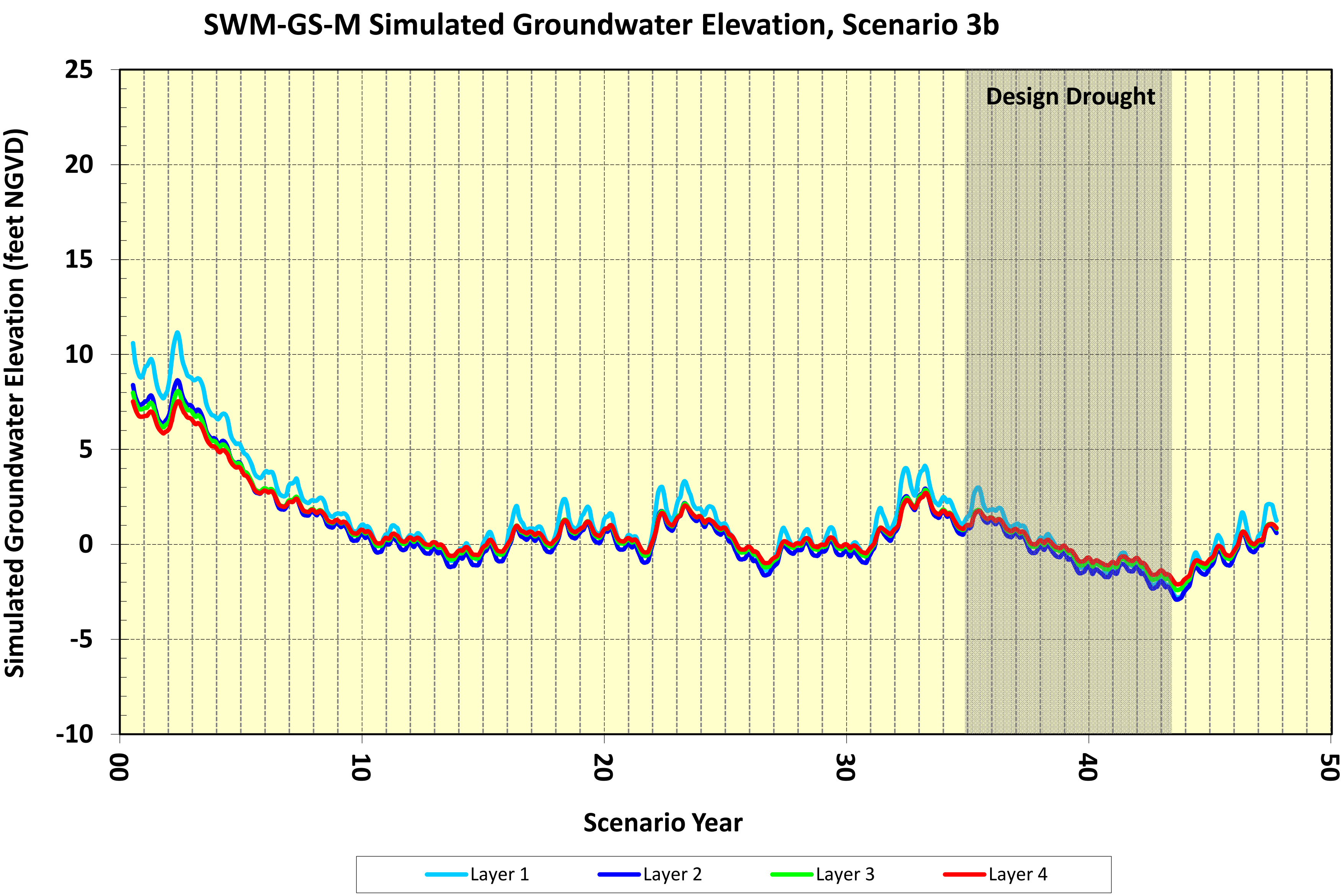
Cyp_Lawn_2 Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
-30
-60
-90
-120
-150
-180
-210
-240
-270
-300
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


SSF-02 Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

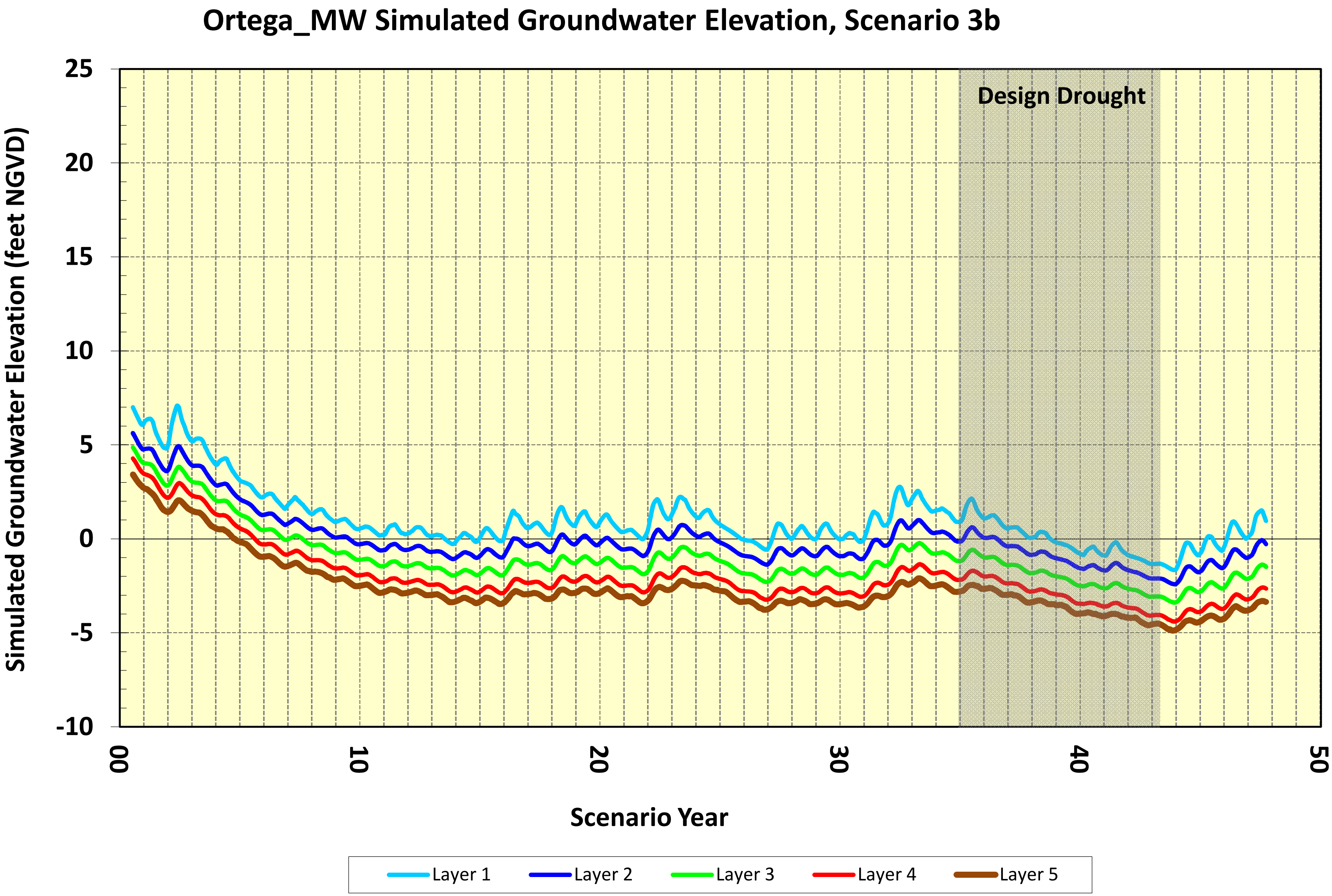
SB-12 Simulated Groundwater Elevation, Scenario 3a



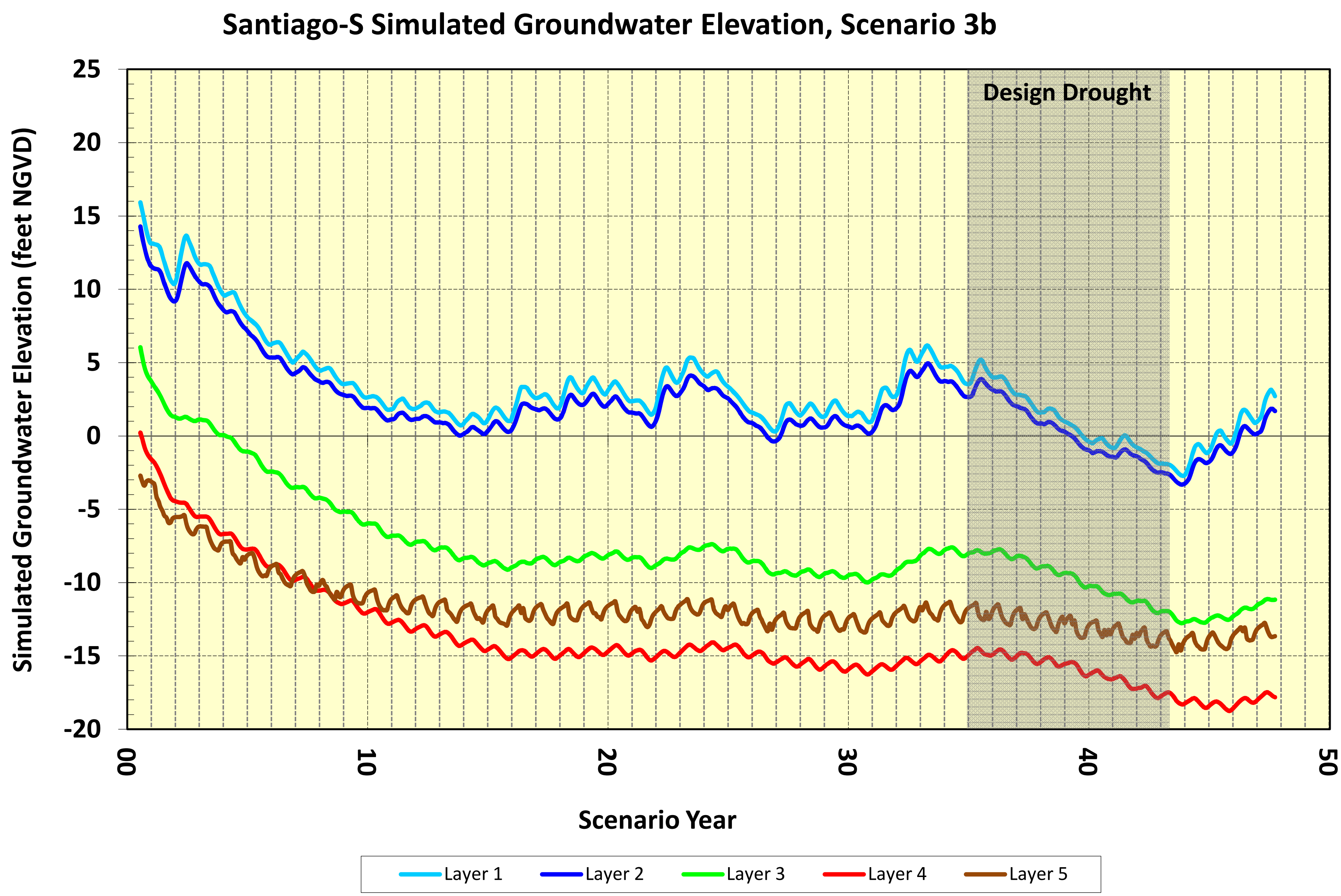
Note: At the location of SB-12, the model does not contain Model Layer 5.



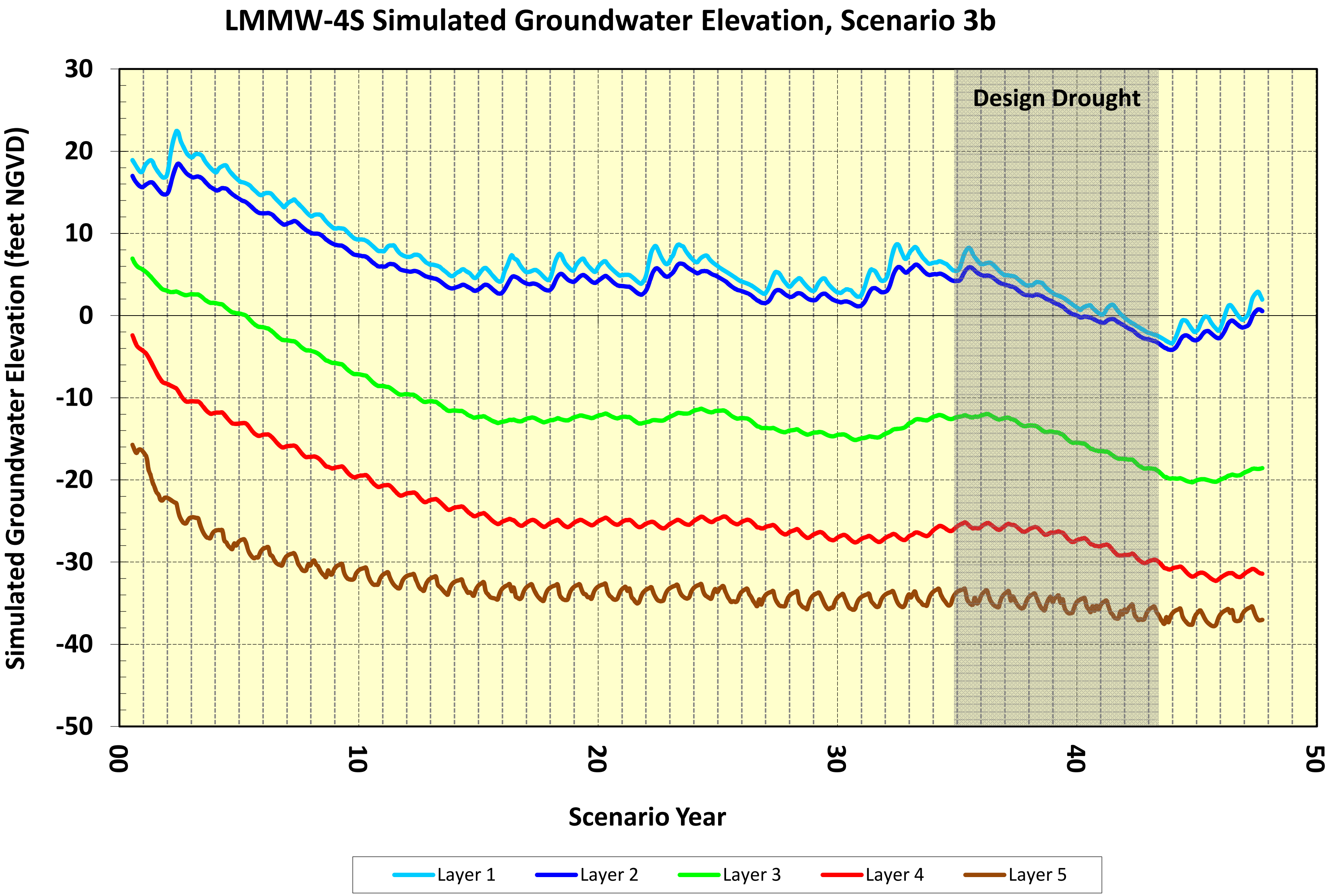
Note: At the location of SWM-GS-M, the model does not contain Model Layer 5.



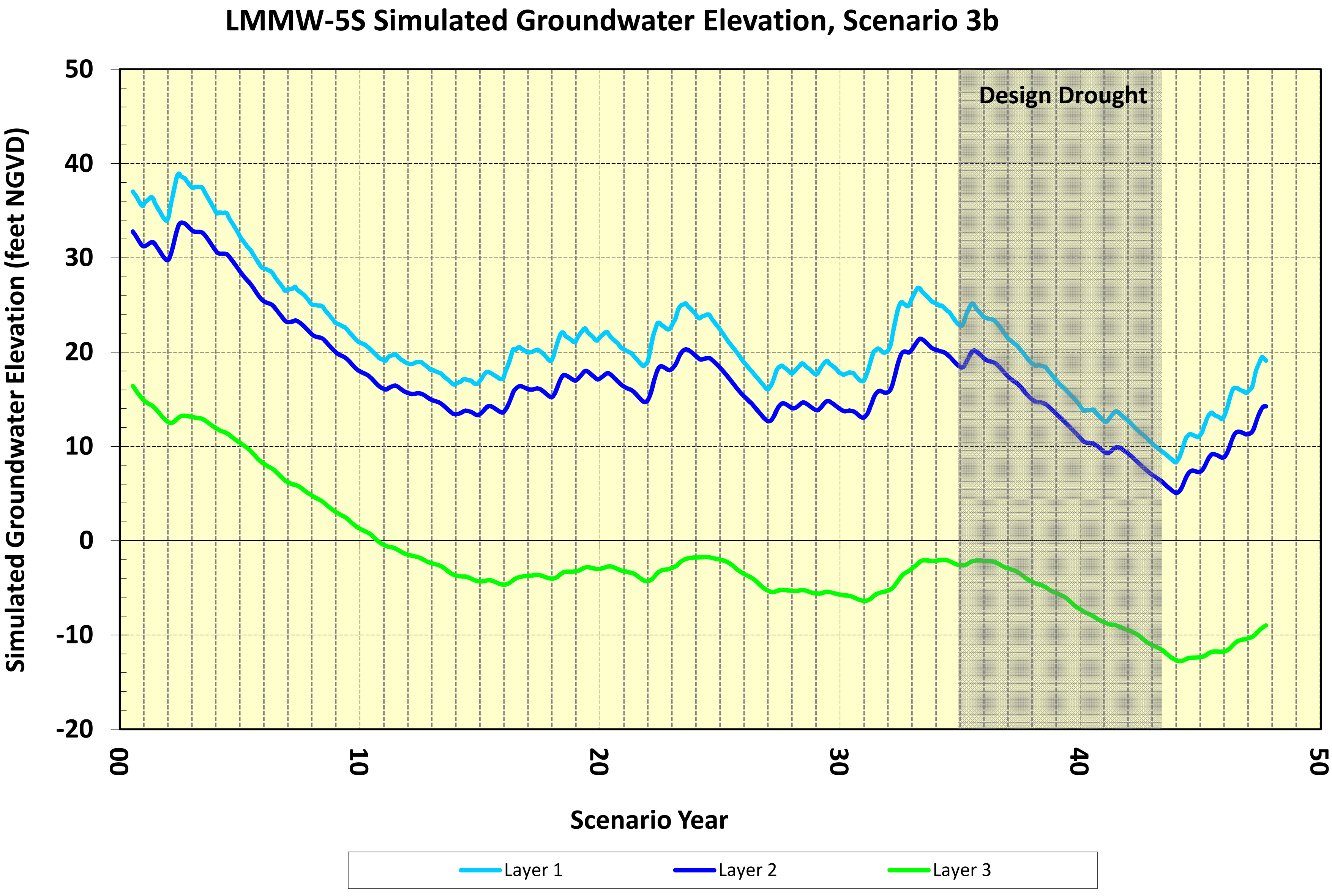
Ortega_MW Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



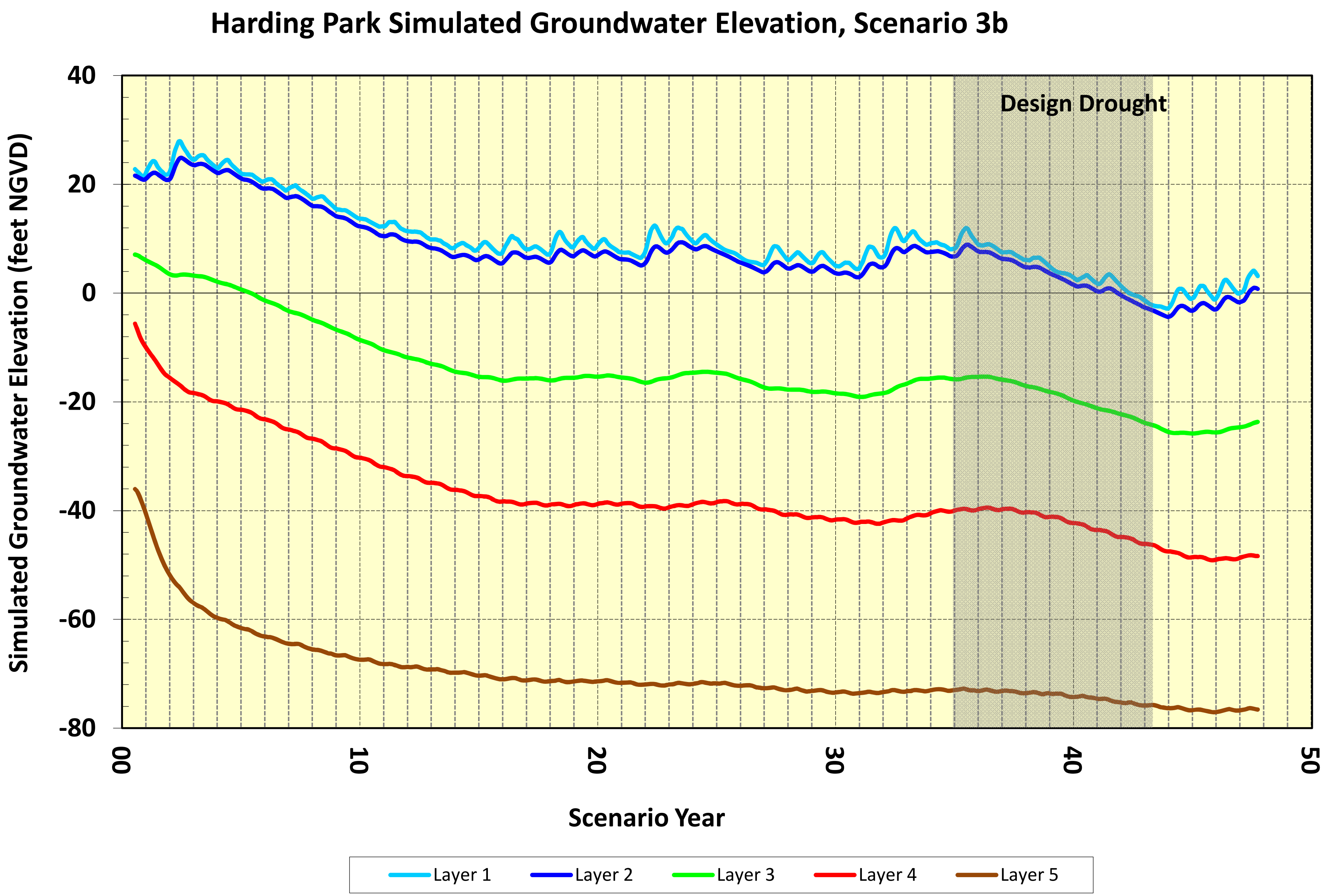
Santiago-S Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
-15
-20
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



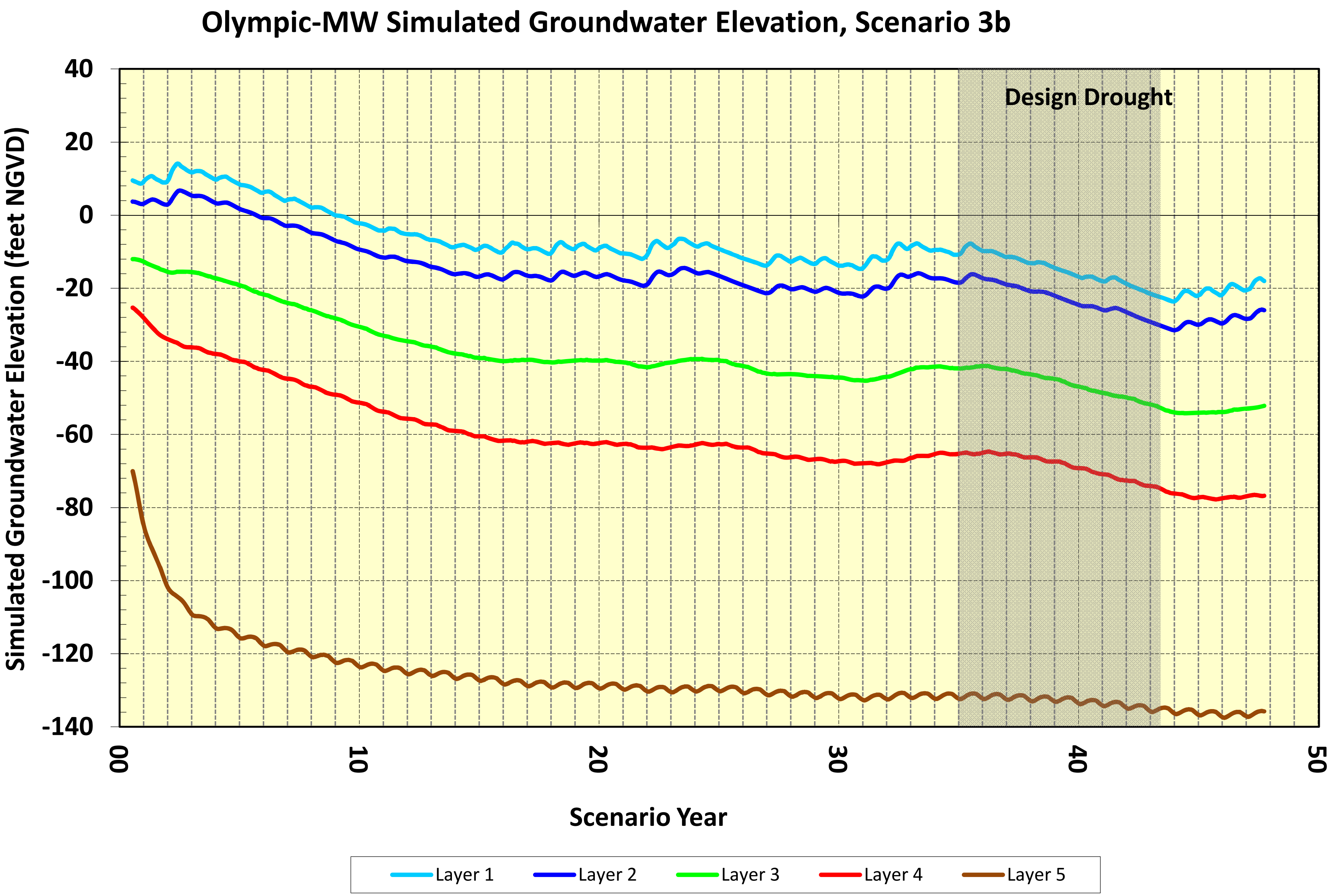
LMMW-4S Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
30
20
10
0
-10
-20
-30
-40
-50
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



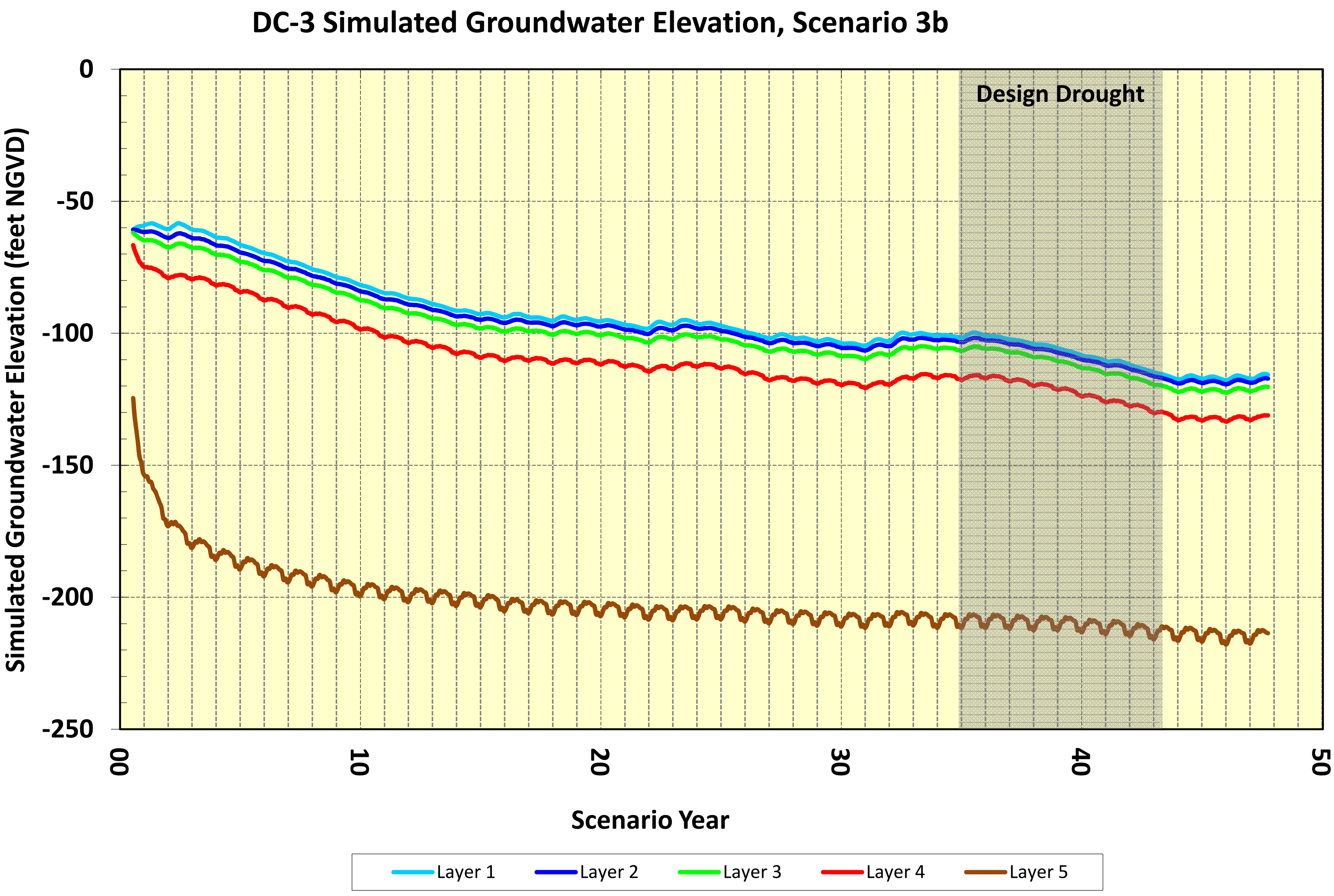
Note: At the location of LMMW-5S, the model does not contain Model Layers 4 and 5.

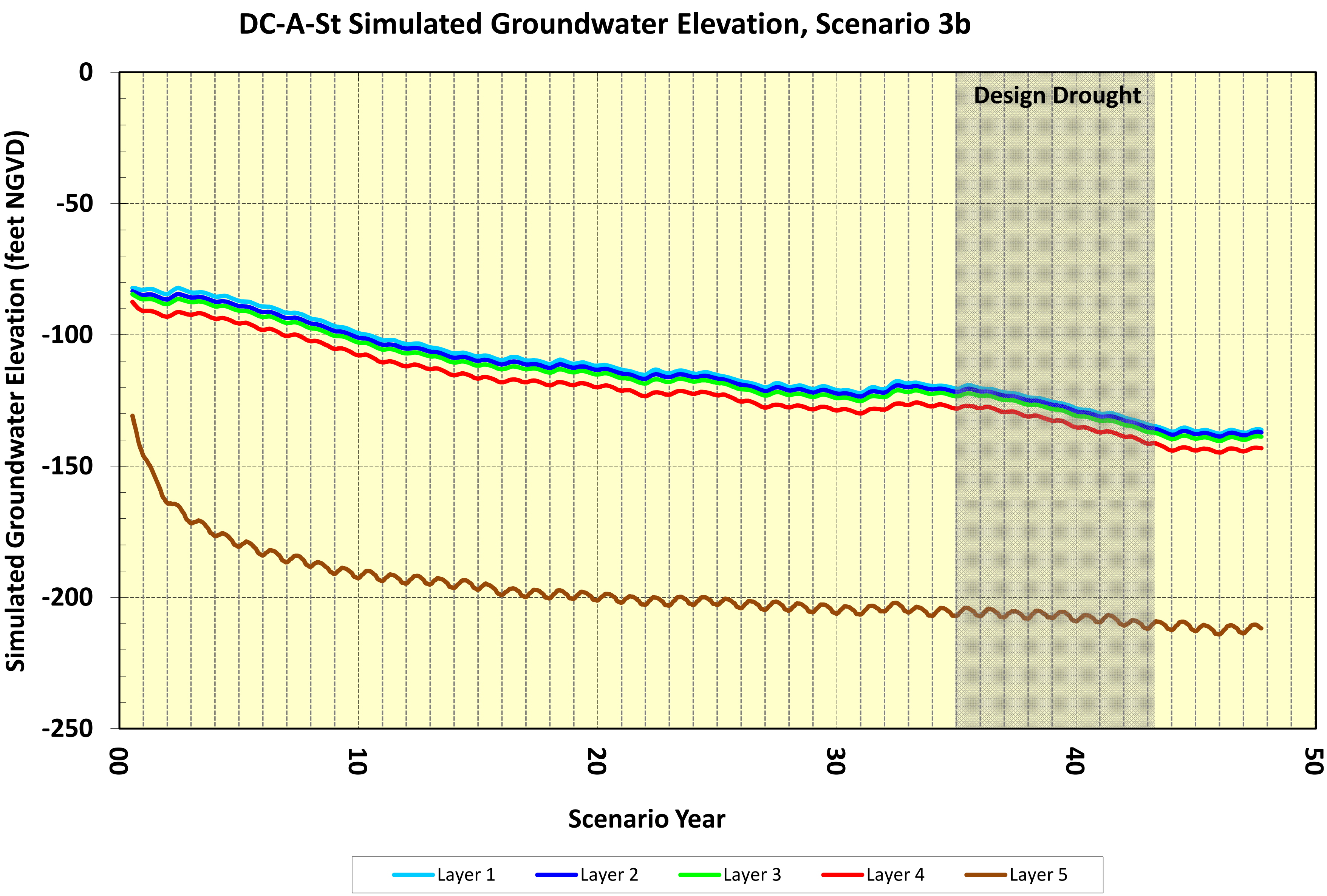


Harding Park Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

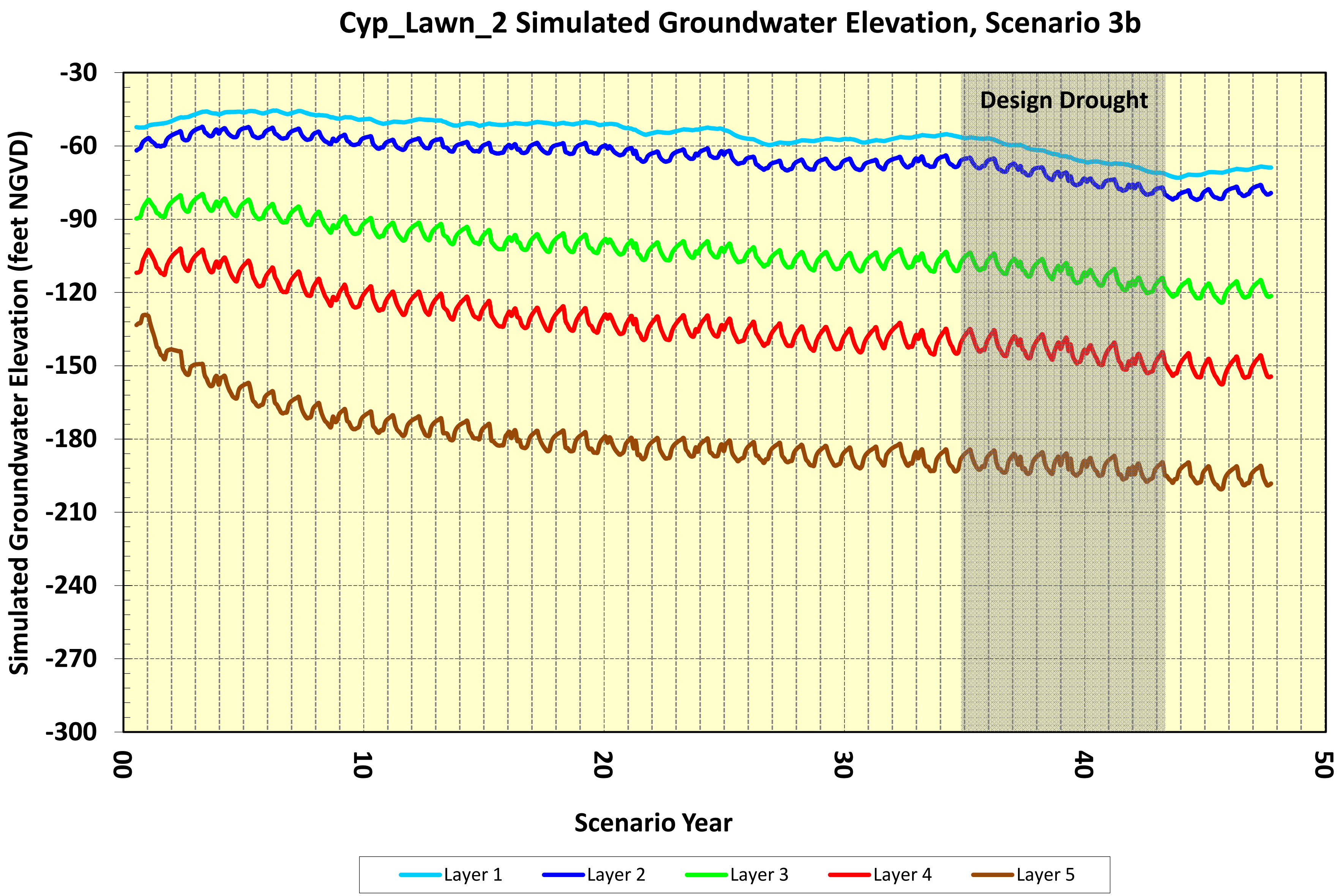


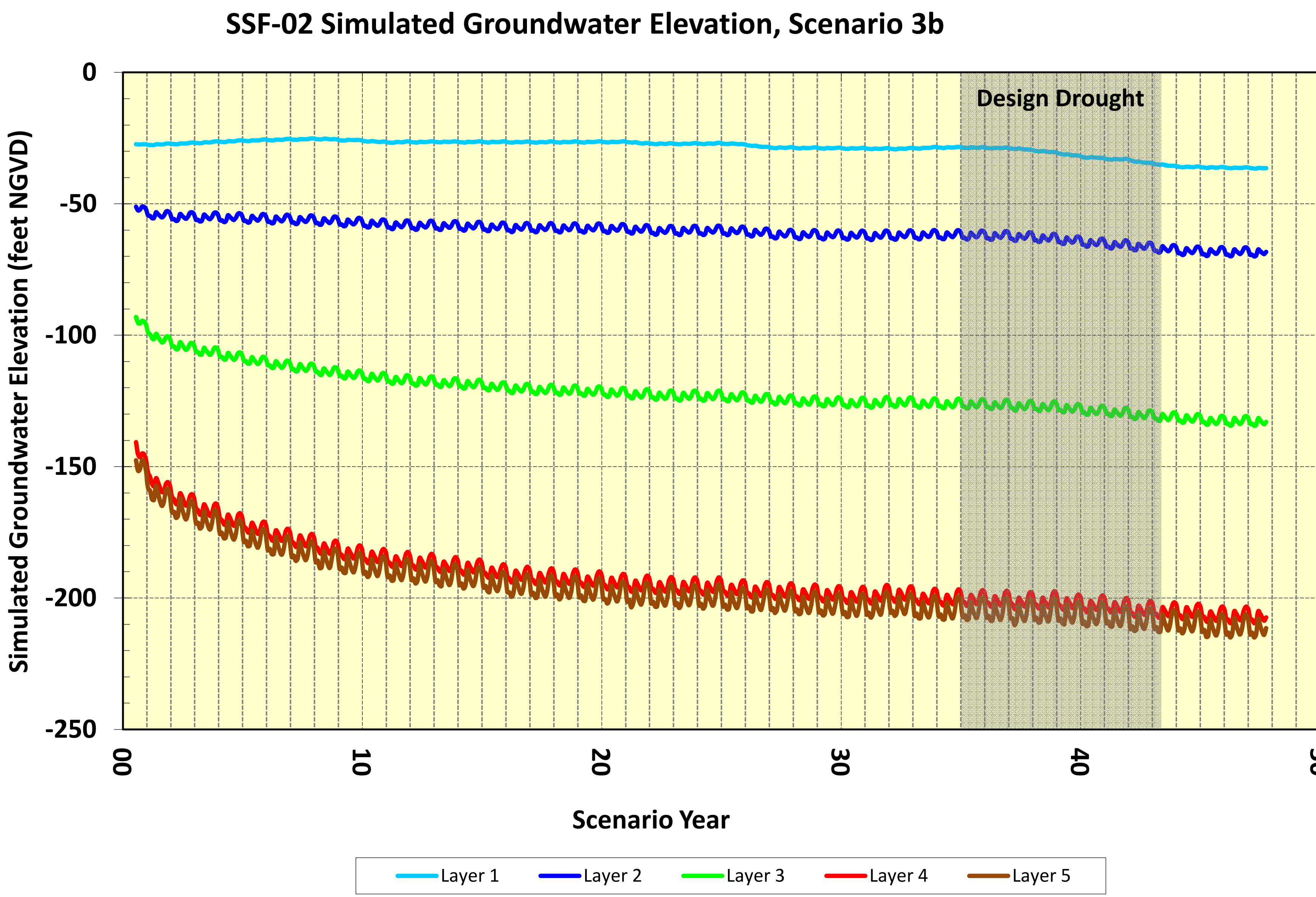
Olympic-MW Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
-100
-120
-140
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

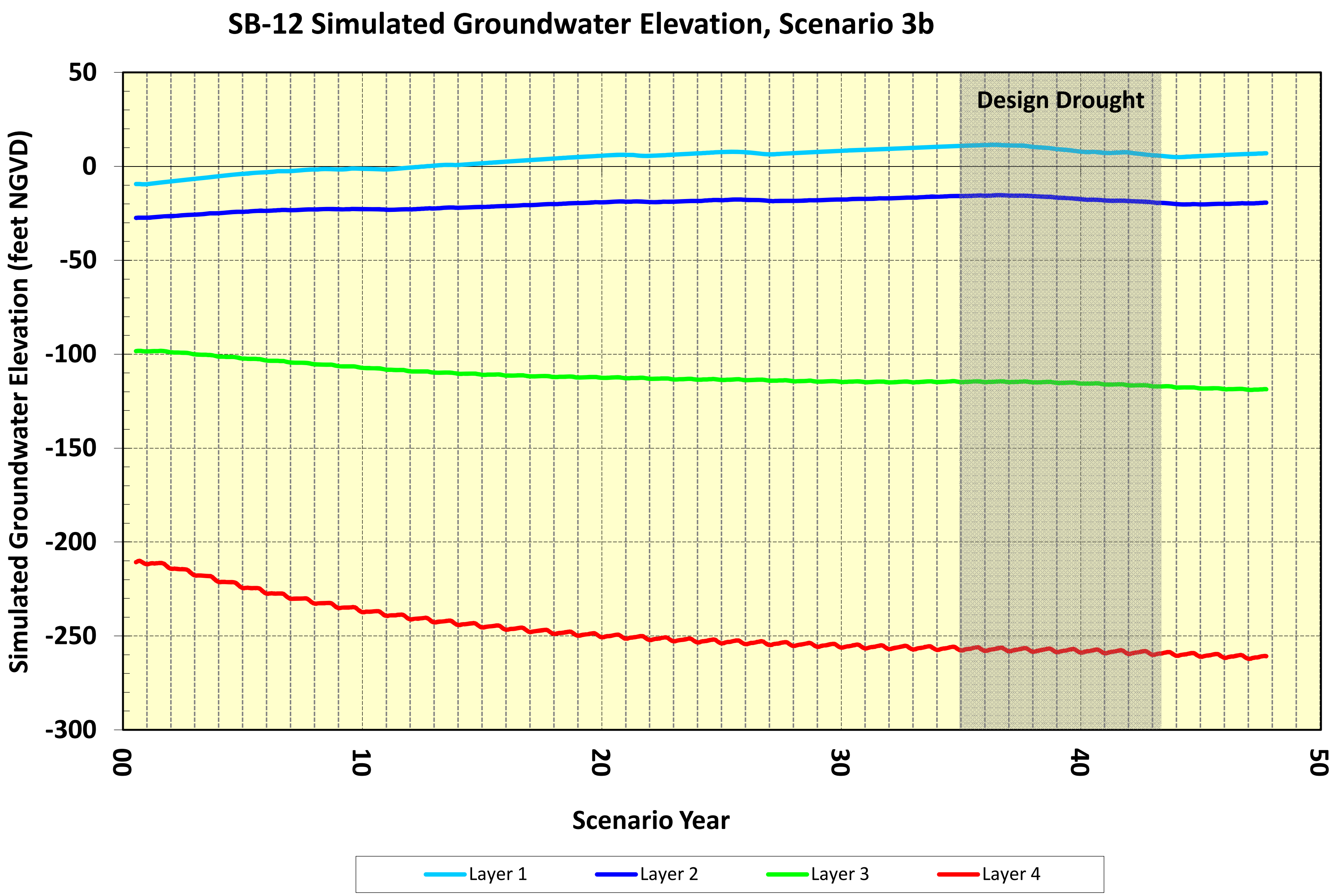

DC-3 Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



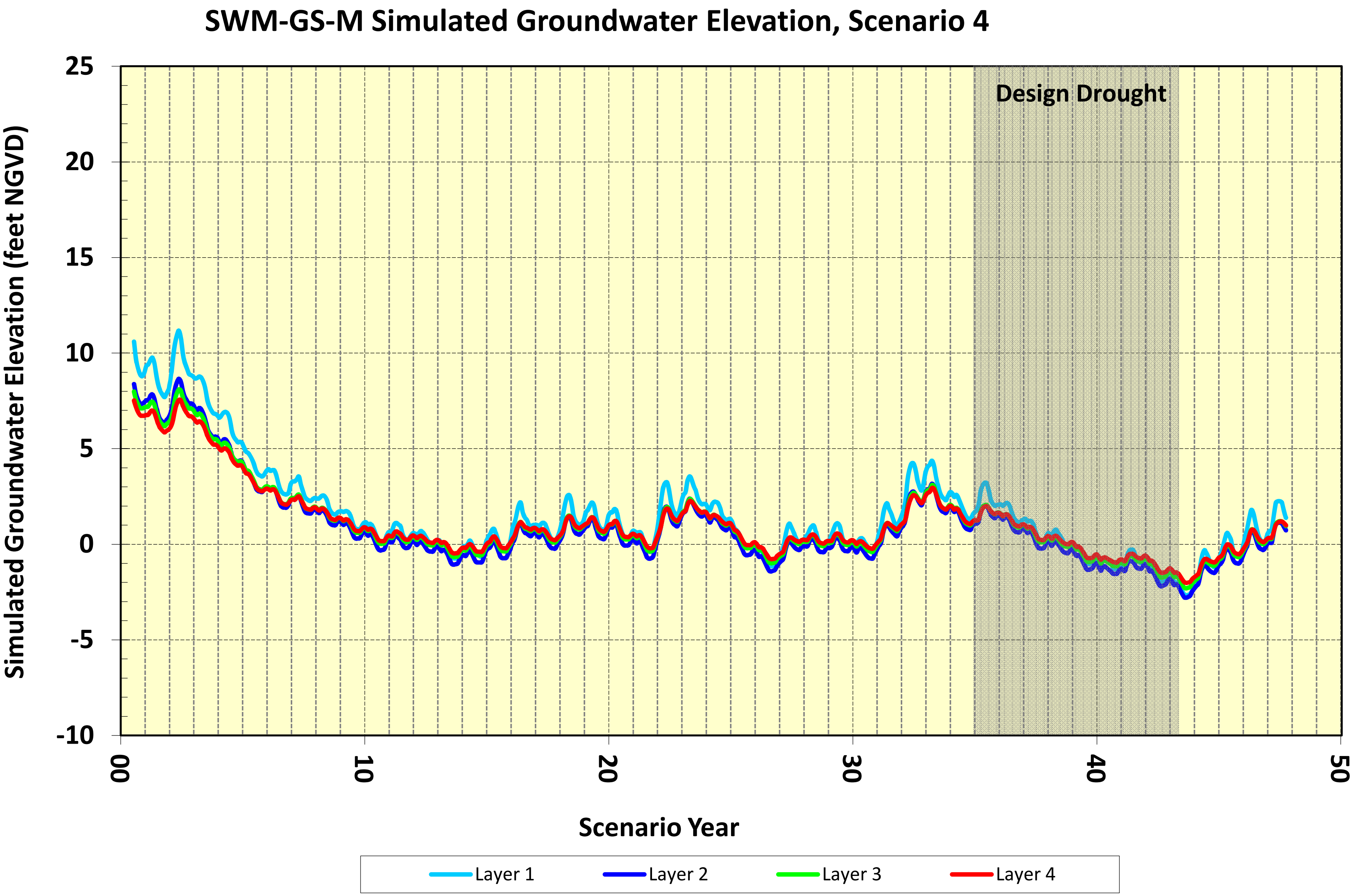
DC-A-St Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


Cyp_Lawn_2 Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
-30
-60
-90
-120
-150
-180
-210
-240
-270
-300
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

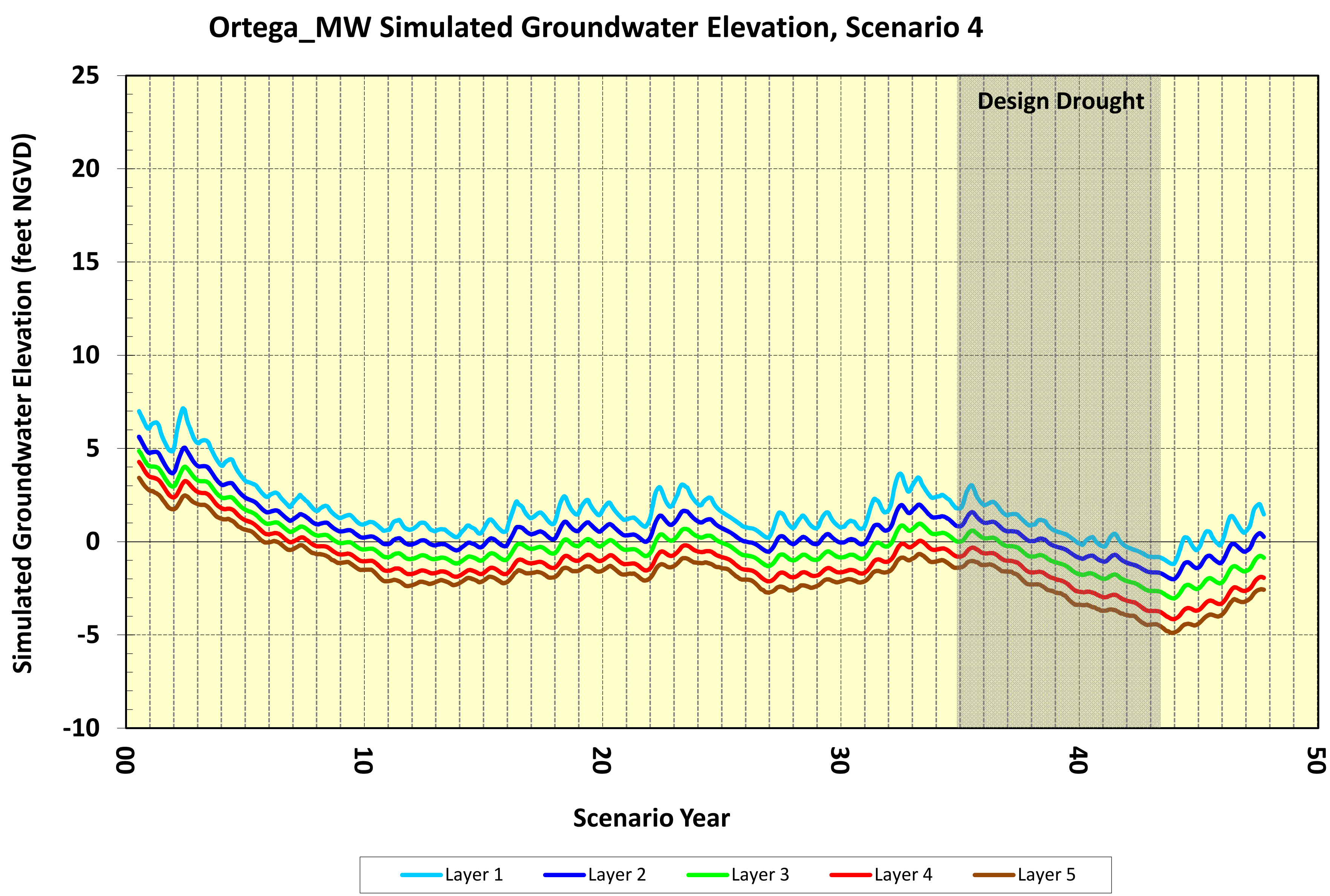

SSF-02 Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



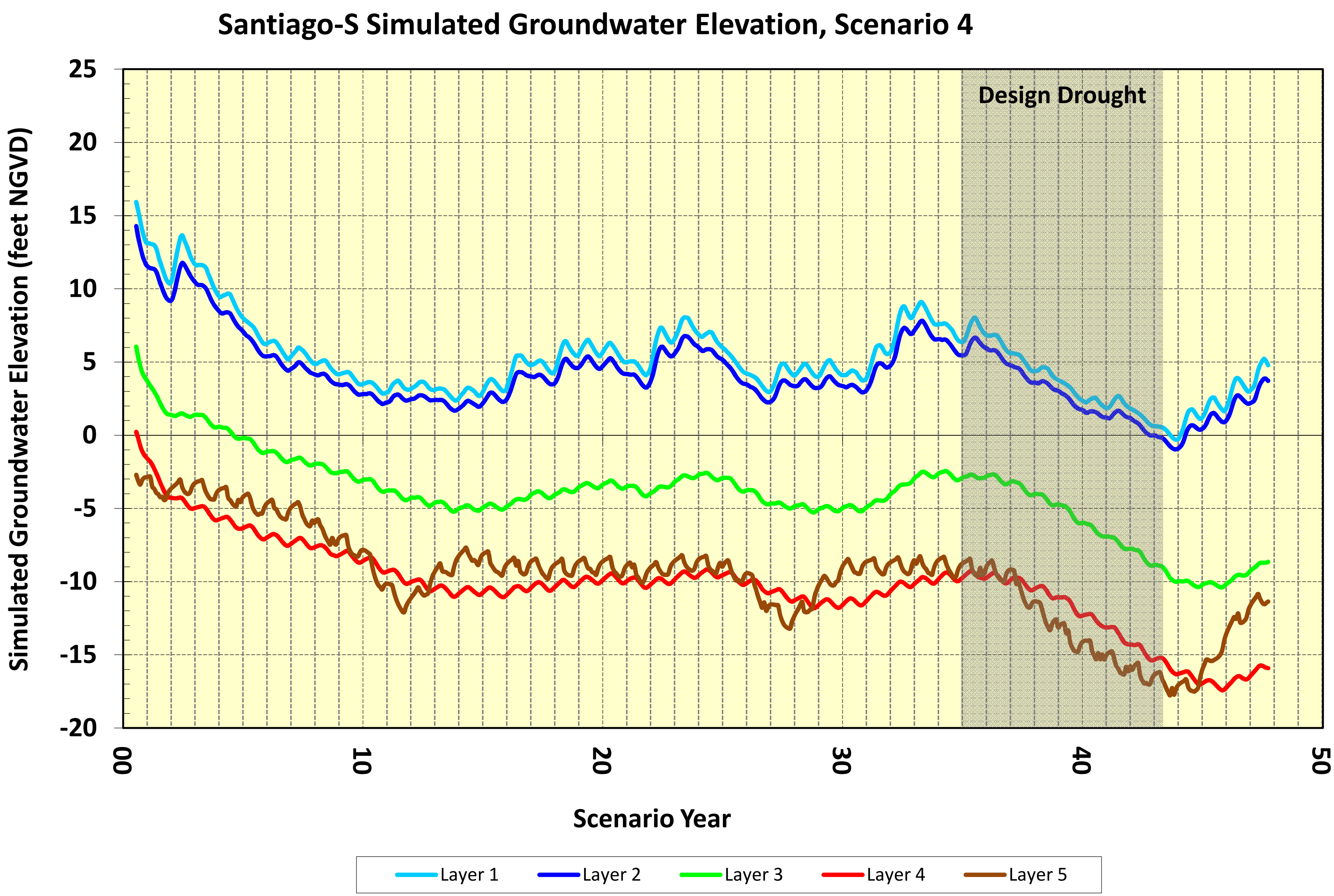
Note: At the location of SB-12, the model does not contain Model Layer 5.



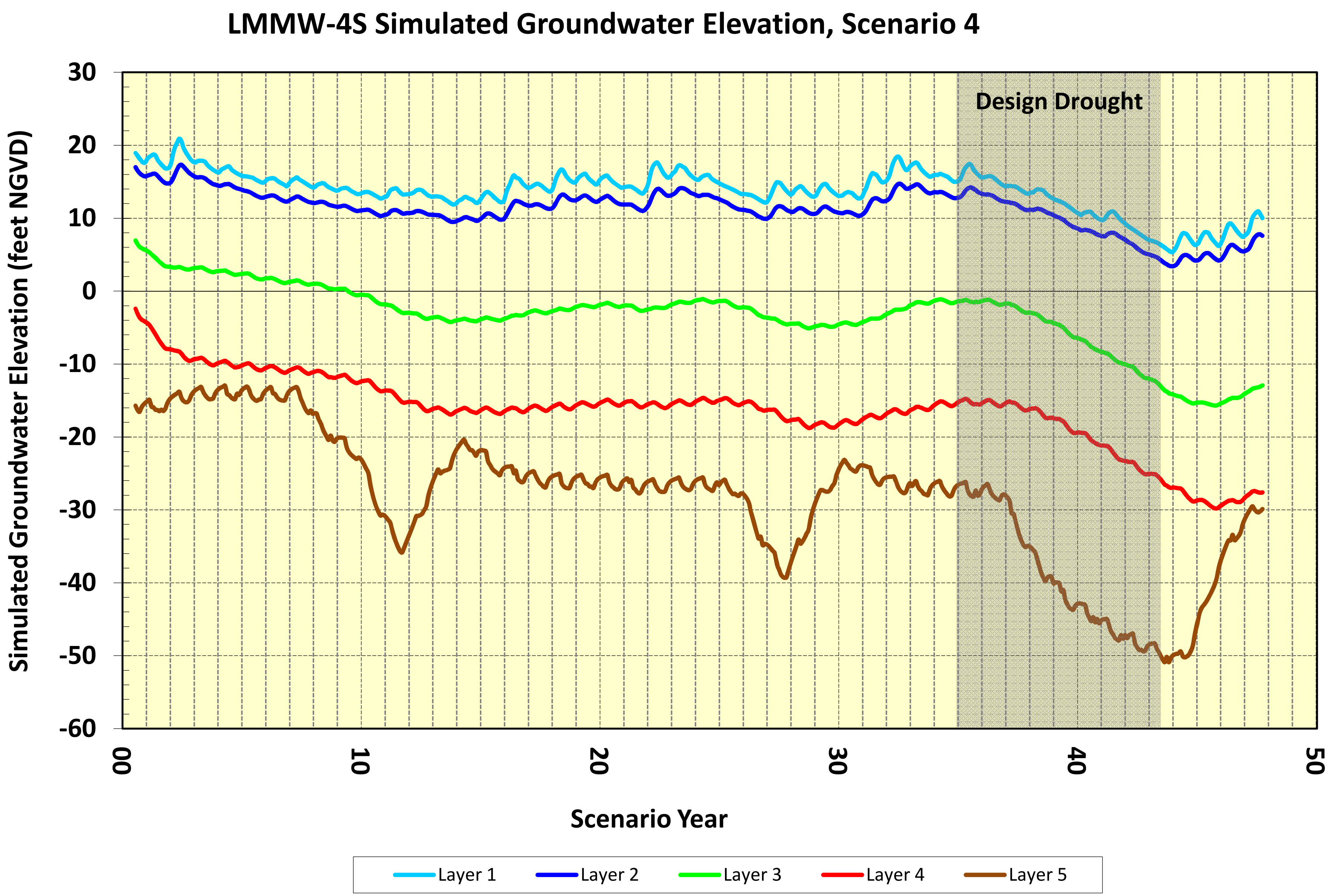
Note: At the location of SWM-GS-M, the model does not contain Model Layer 5.

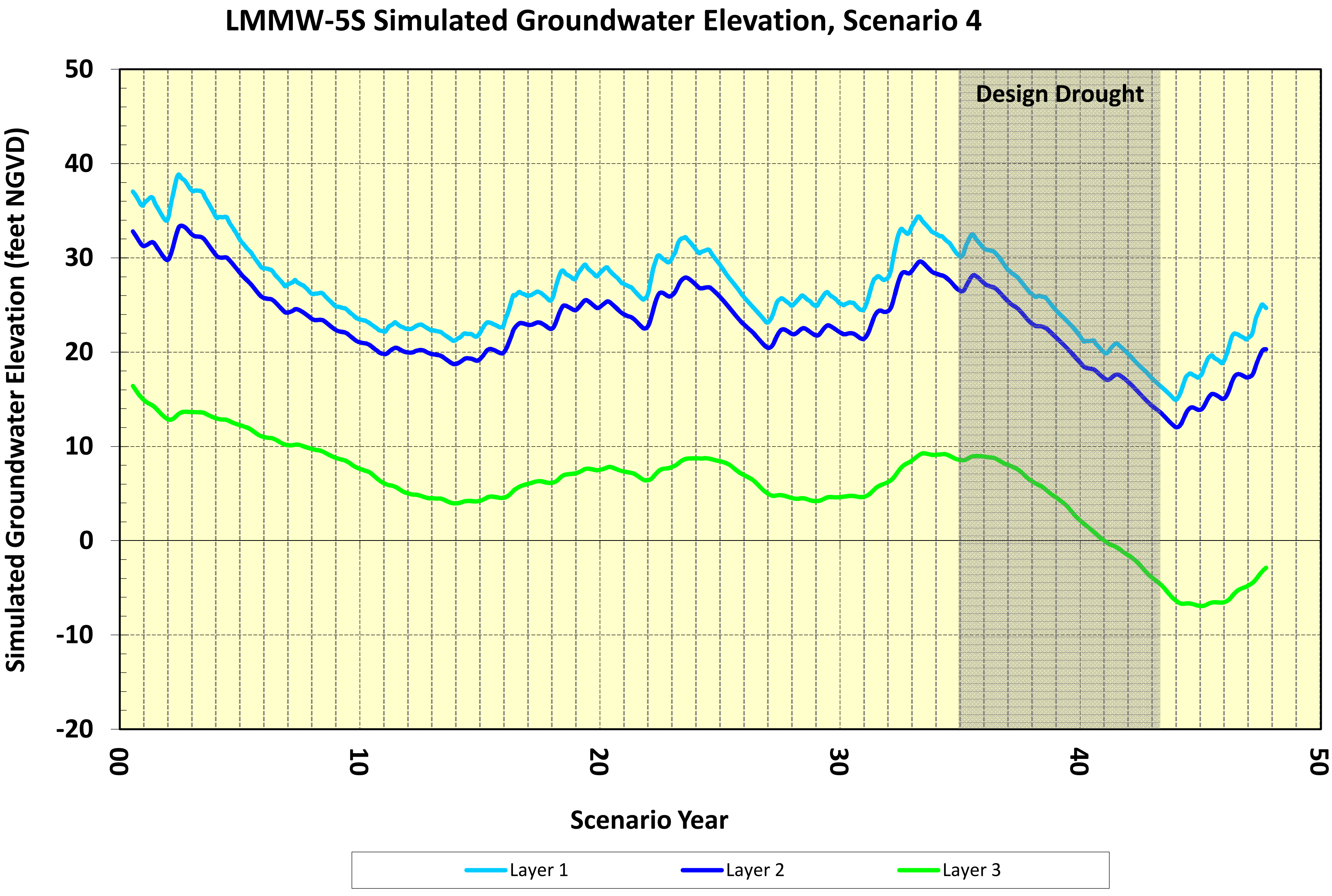


Ortega_MW Simulated Groundwater Elevation, Scenario 4
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
Design Drought
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

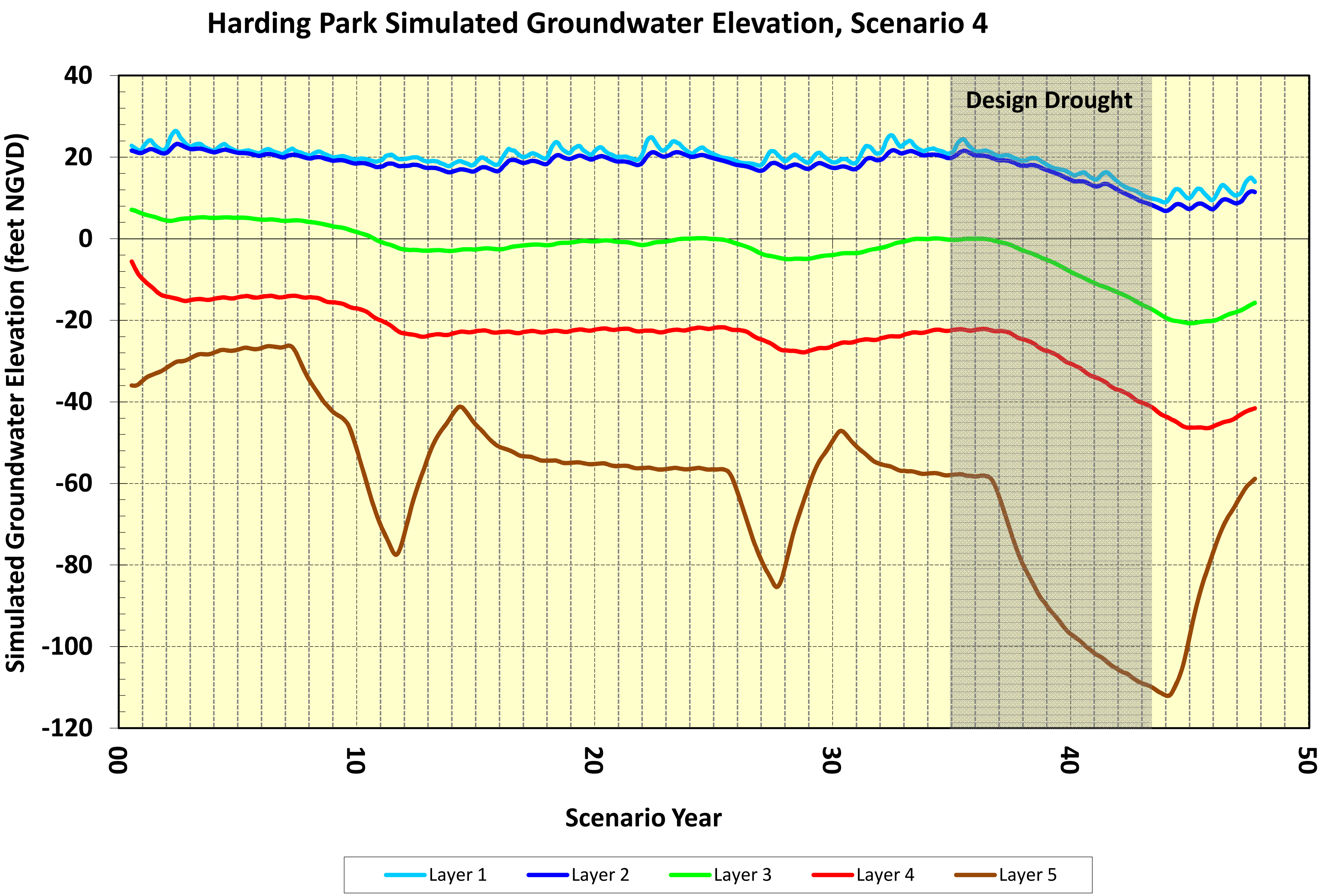


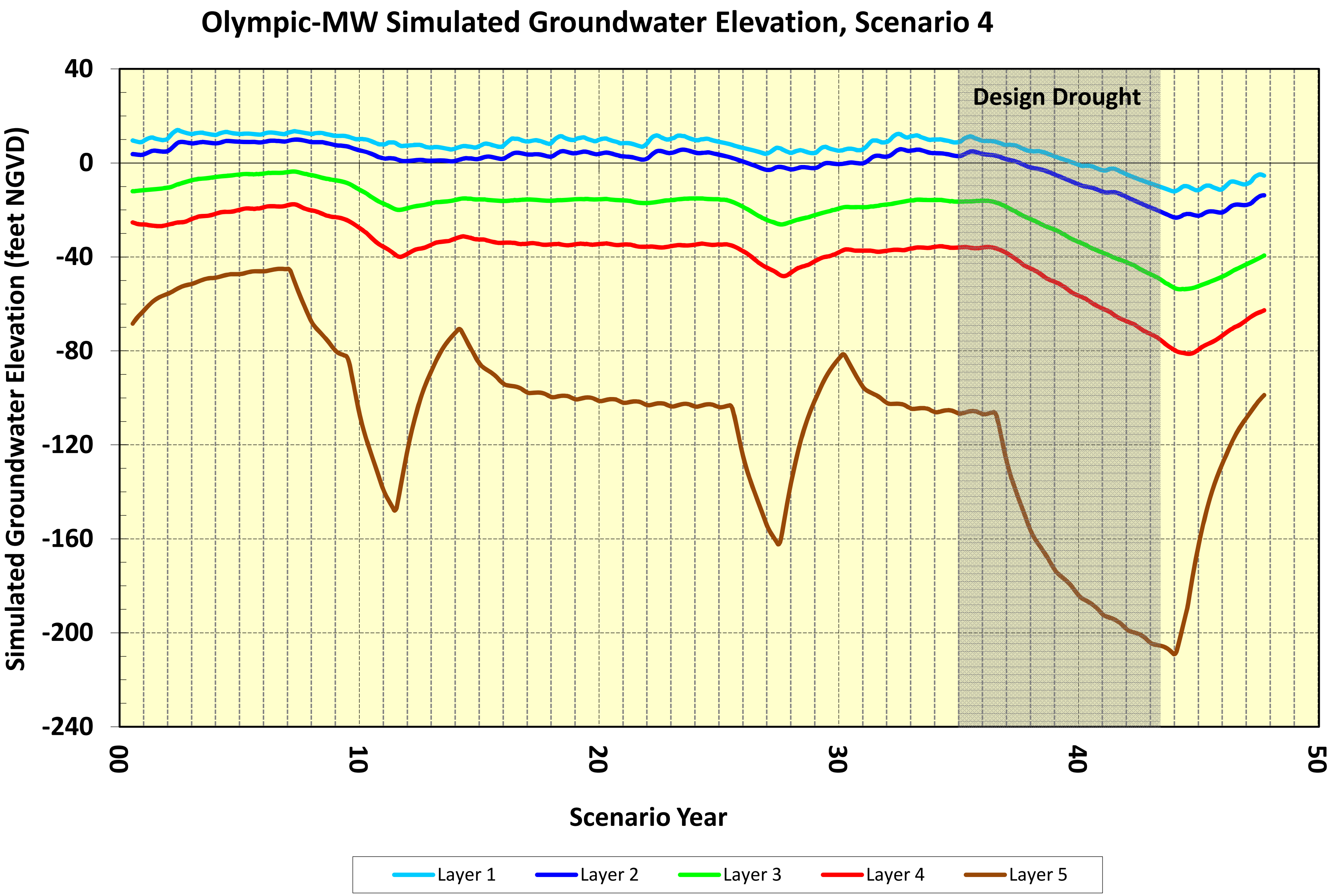
Santiago-S Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
-15
-20
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


LMMW-4S Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
30
20
10
0
-10
-20
-30
-40
-50
-60
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

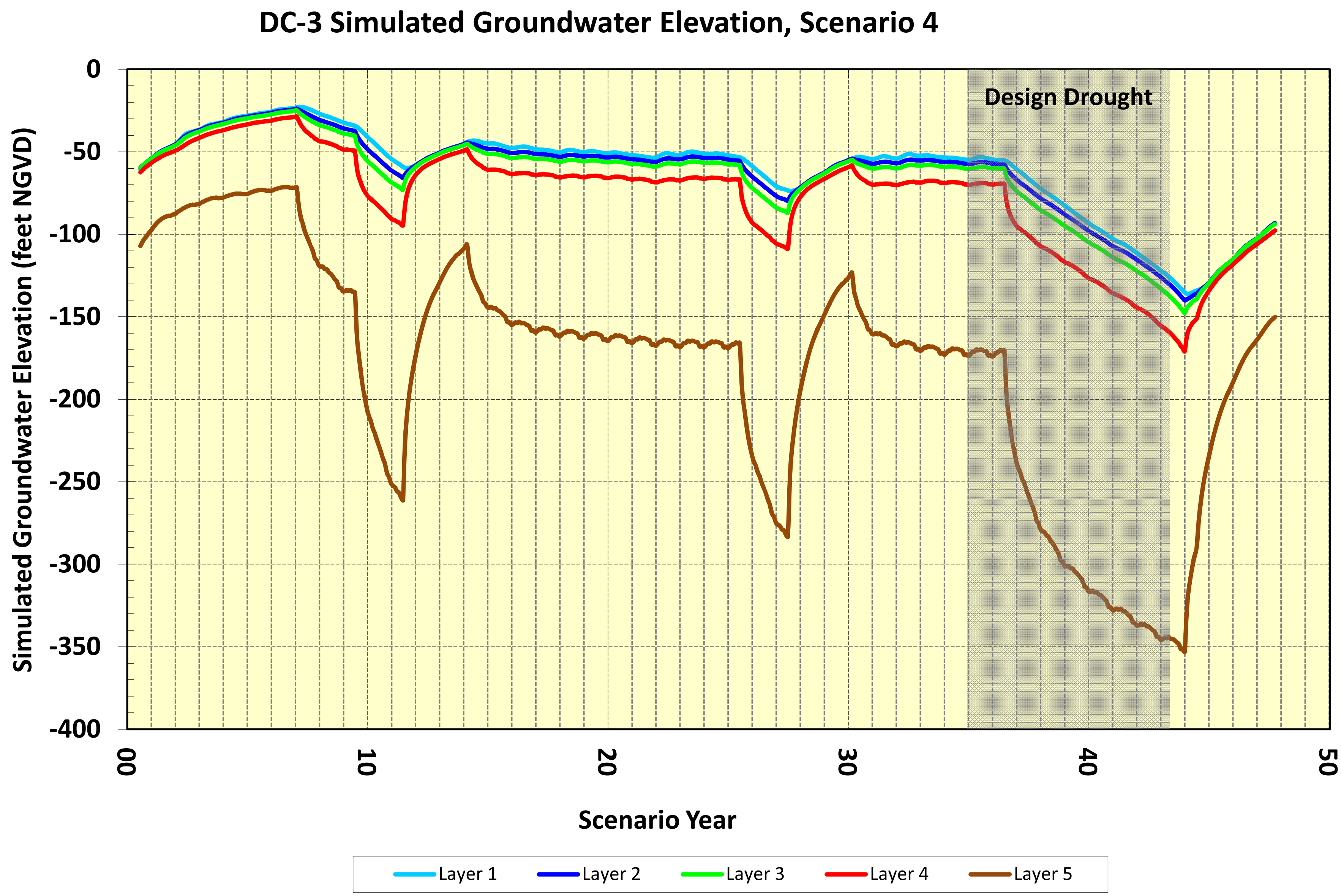


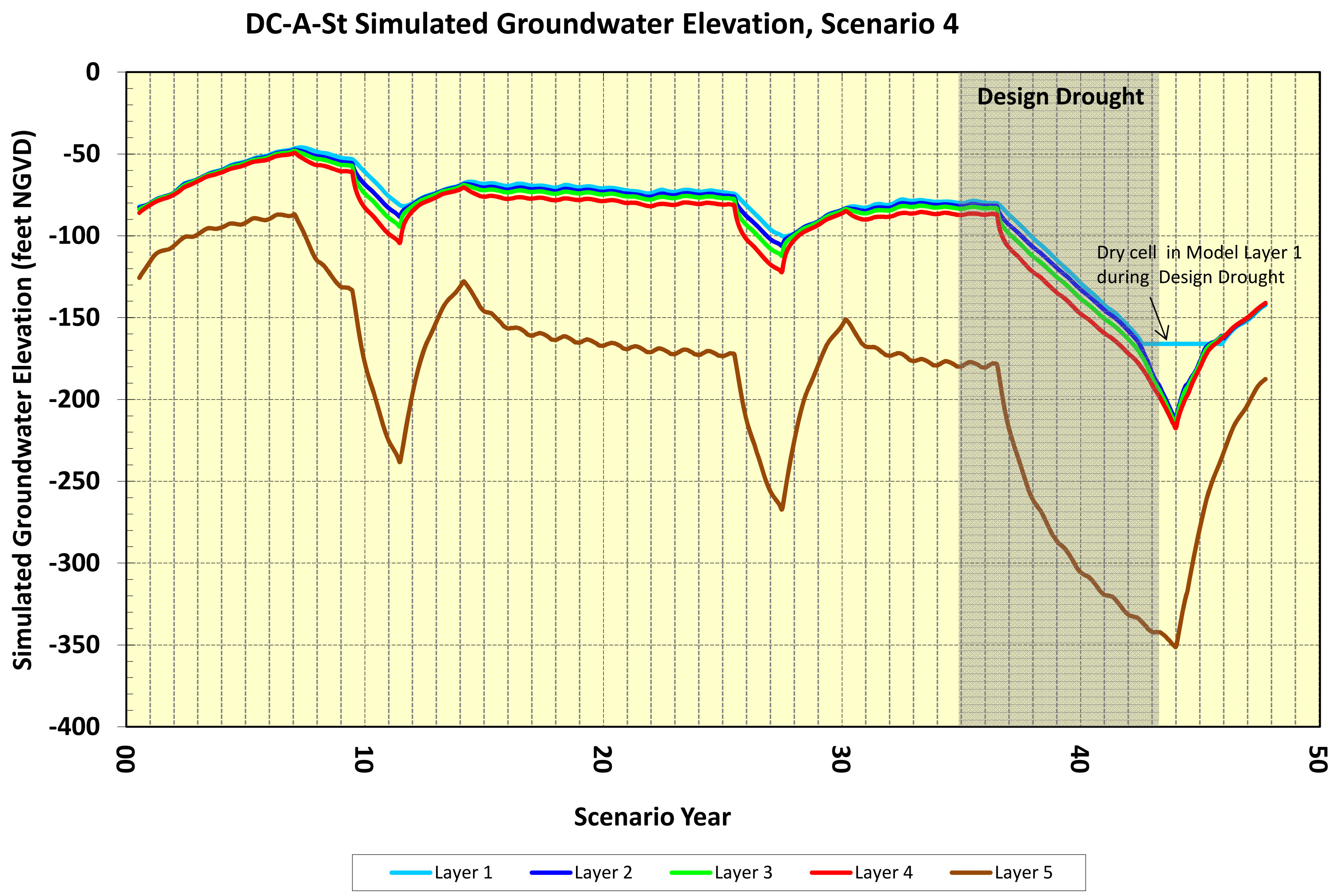
Note: At the location of LMMW-5S, the model does not contain Model Layers 4 and 5.


Harding Park Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
-100
-120
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

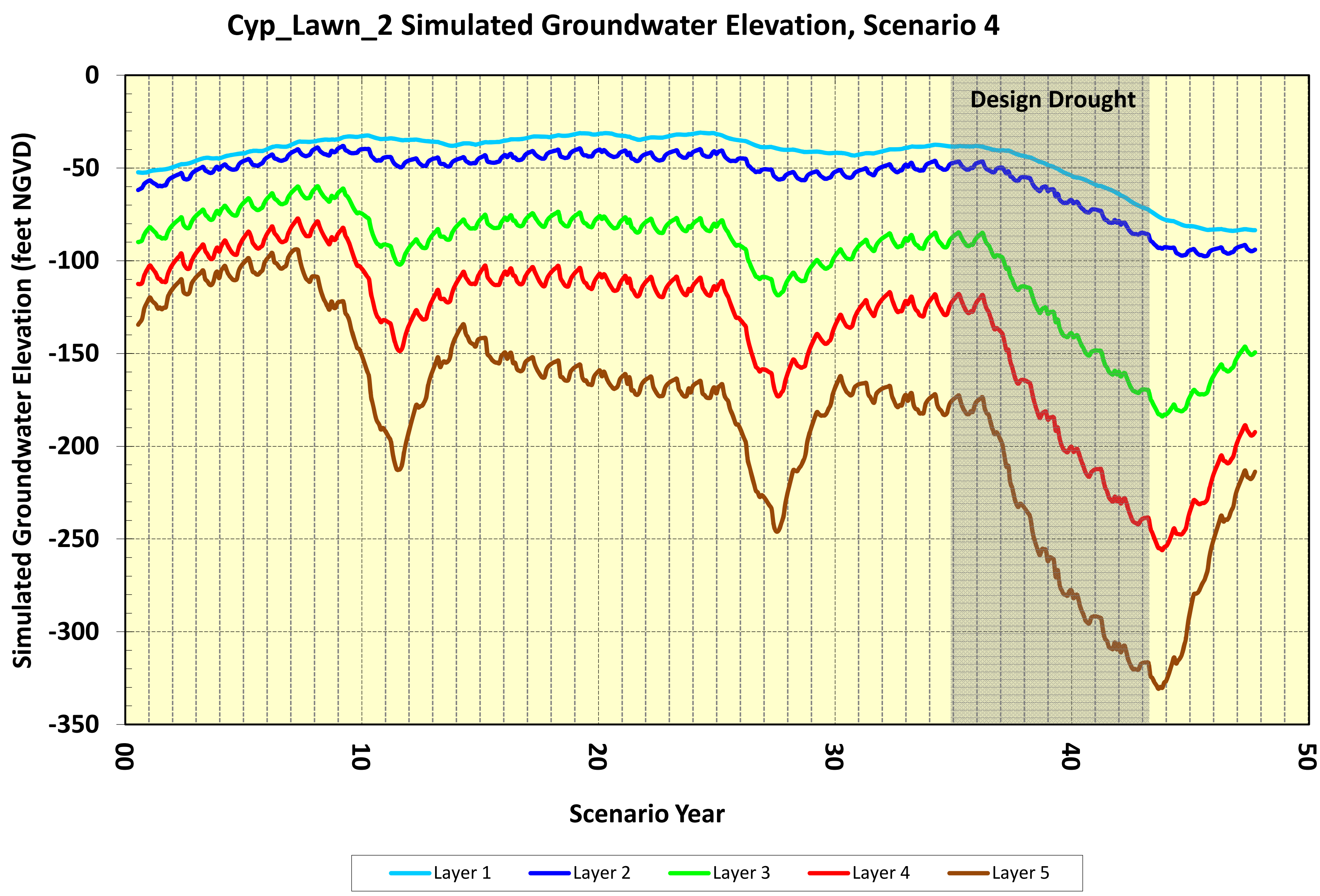


Olympic-MW Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
0
-40
-80
-120
-160
-200
-240
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

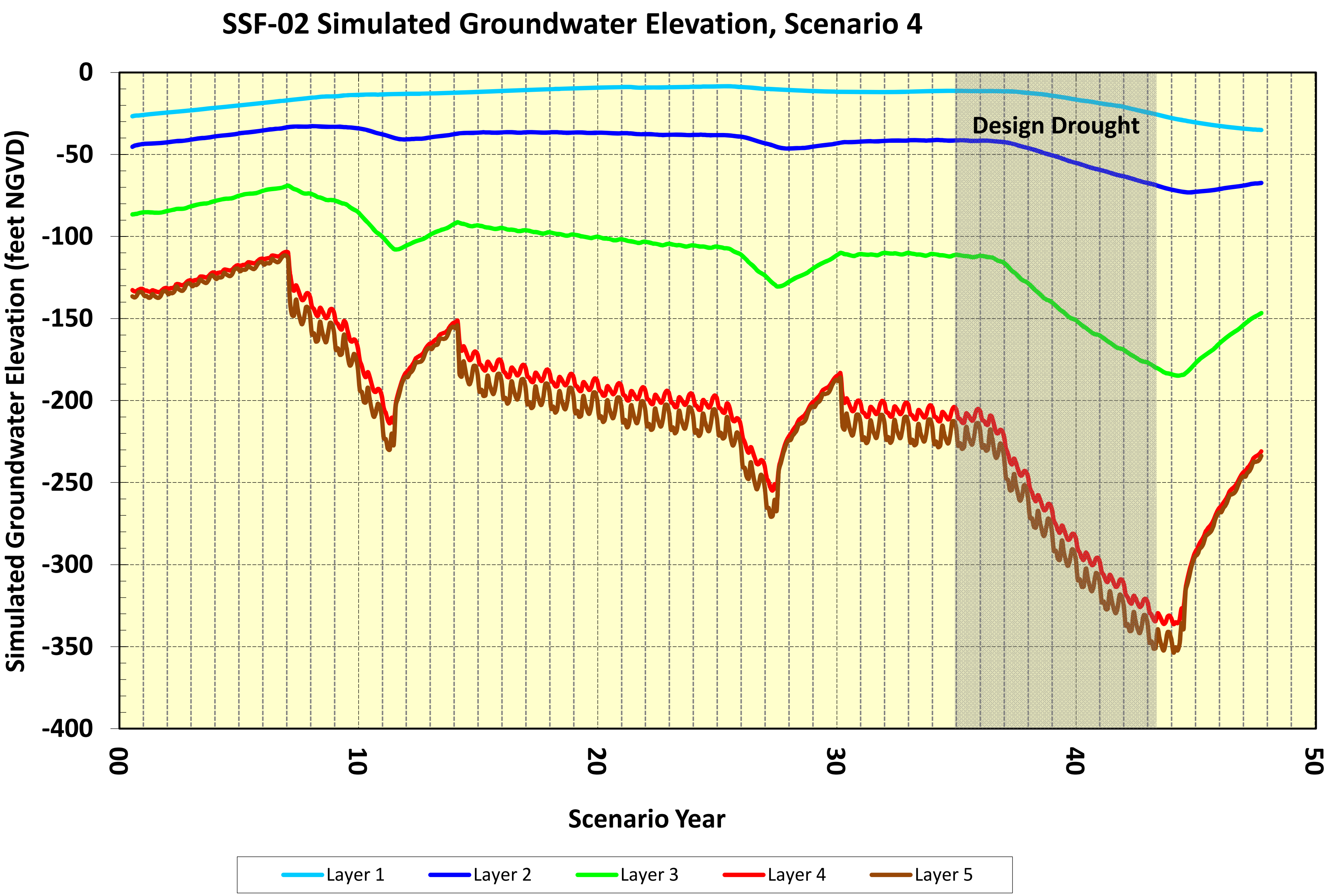

DC-3 Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

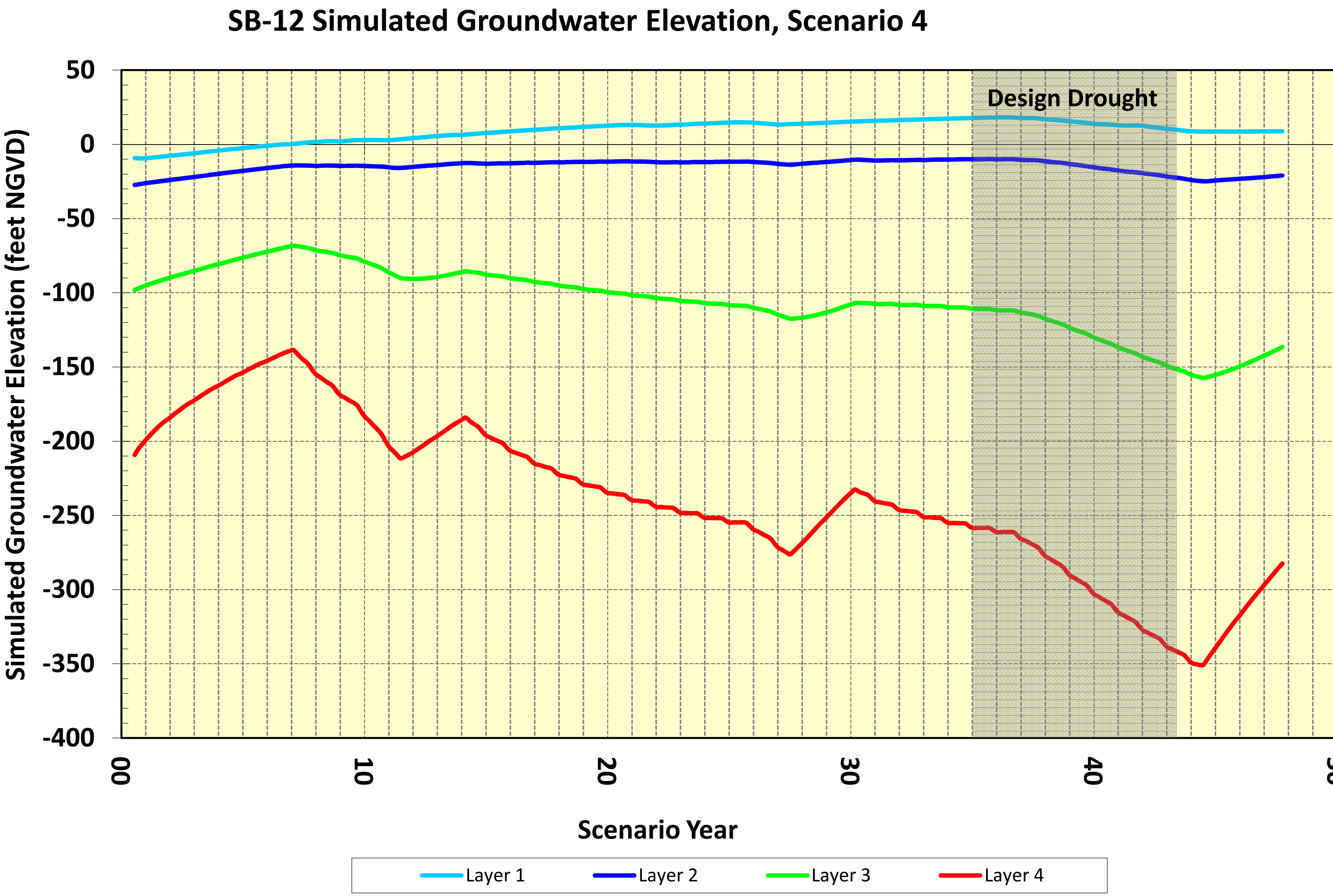


DC-A-St Simulated Groundwater Elevation, Scenario 4
Design Drought
Dry cell in Model Layer 1
during Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

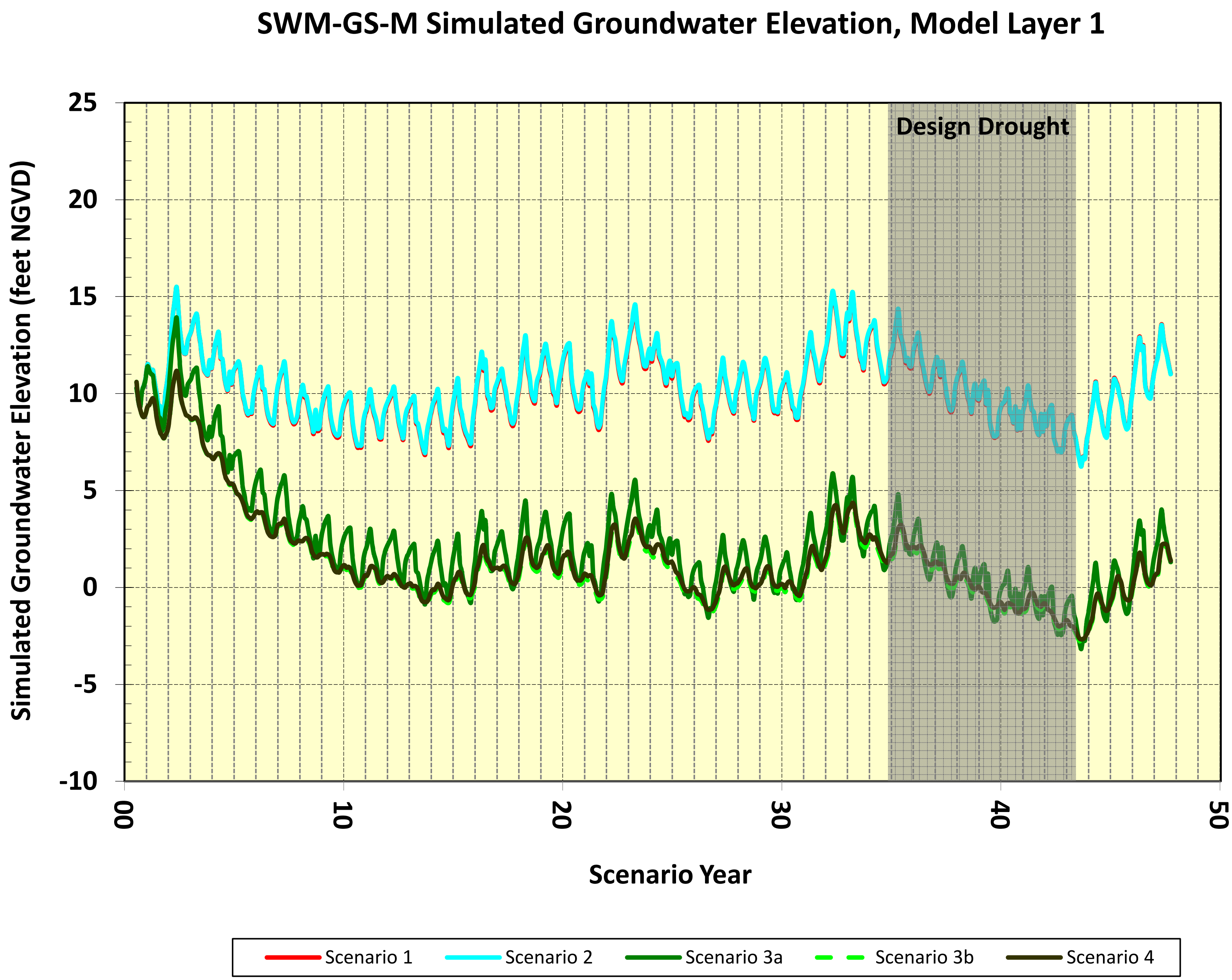


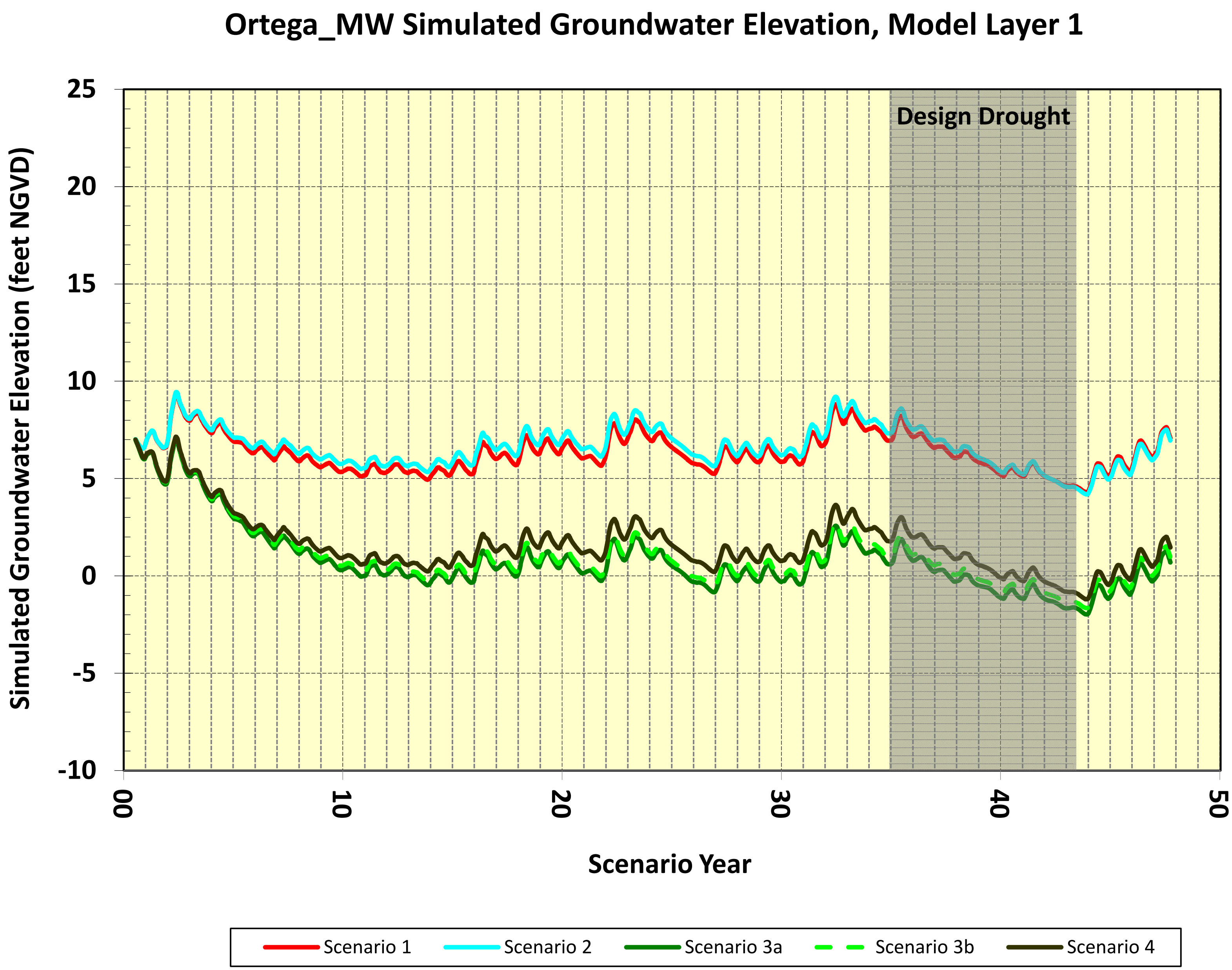
Cyp_Lawn_2 Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

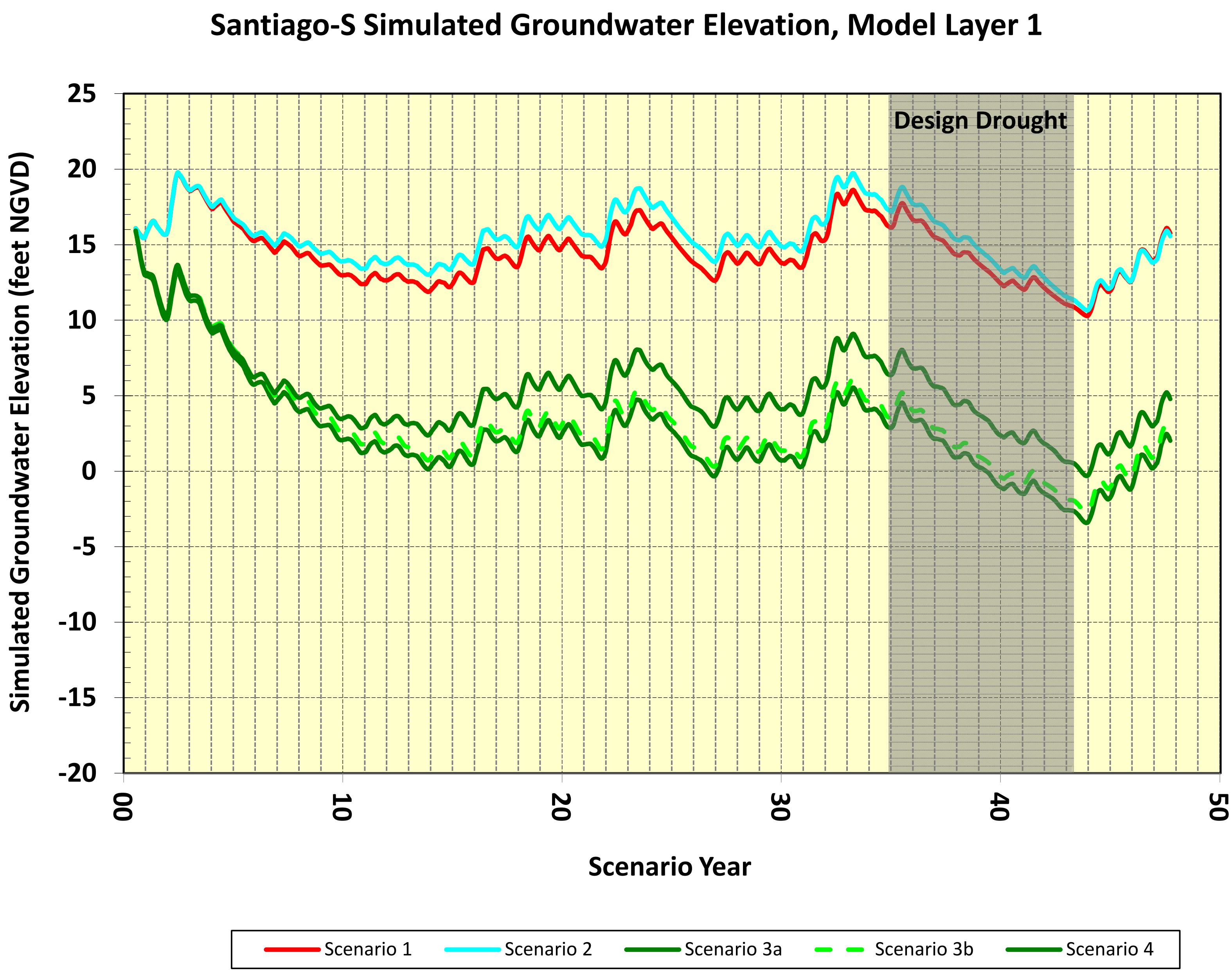

SSF-02 Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



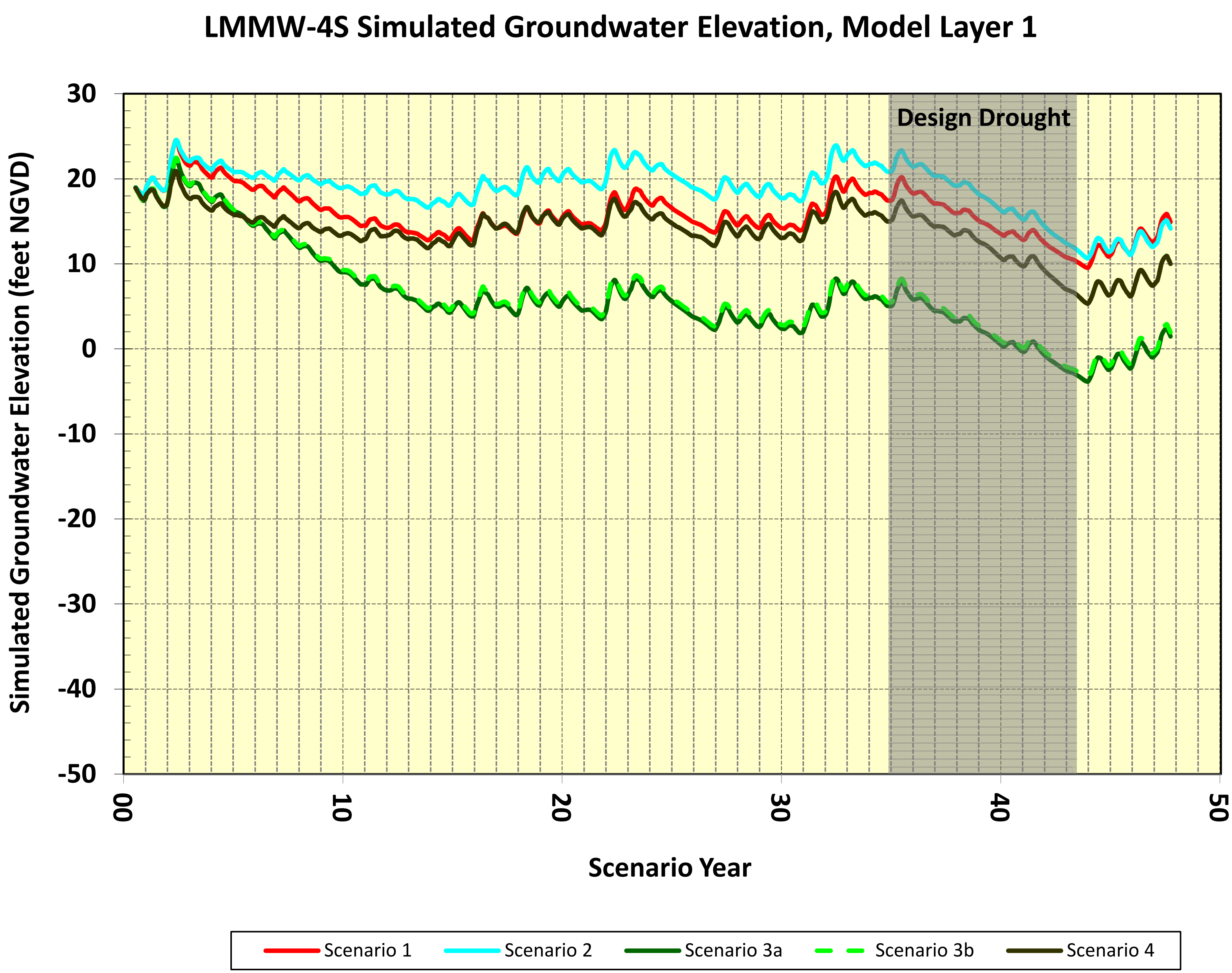
Note: At the location of LMMW-5S, the model does not contain Model Layers 4 and 5.


SWM-GS-M Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

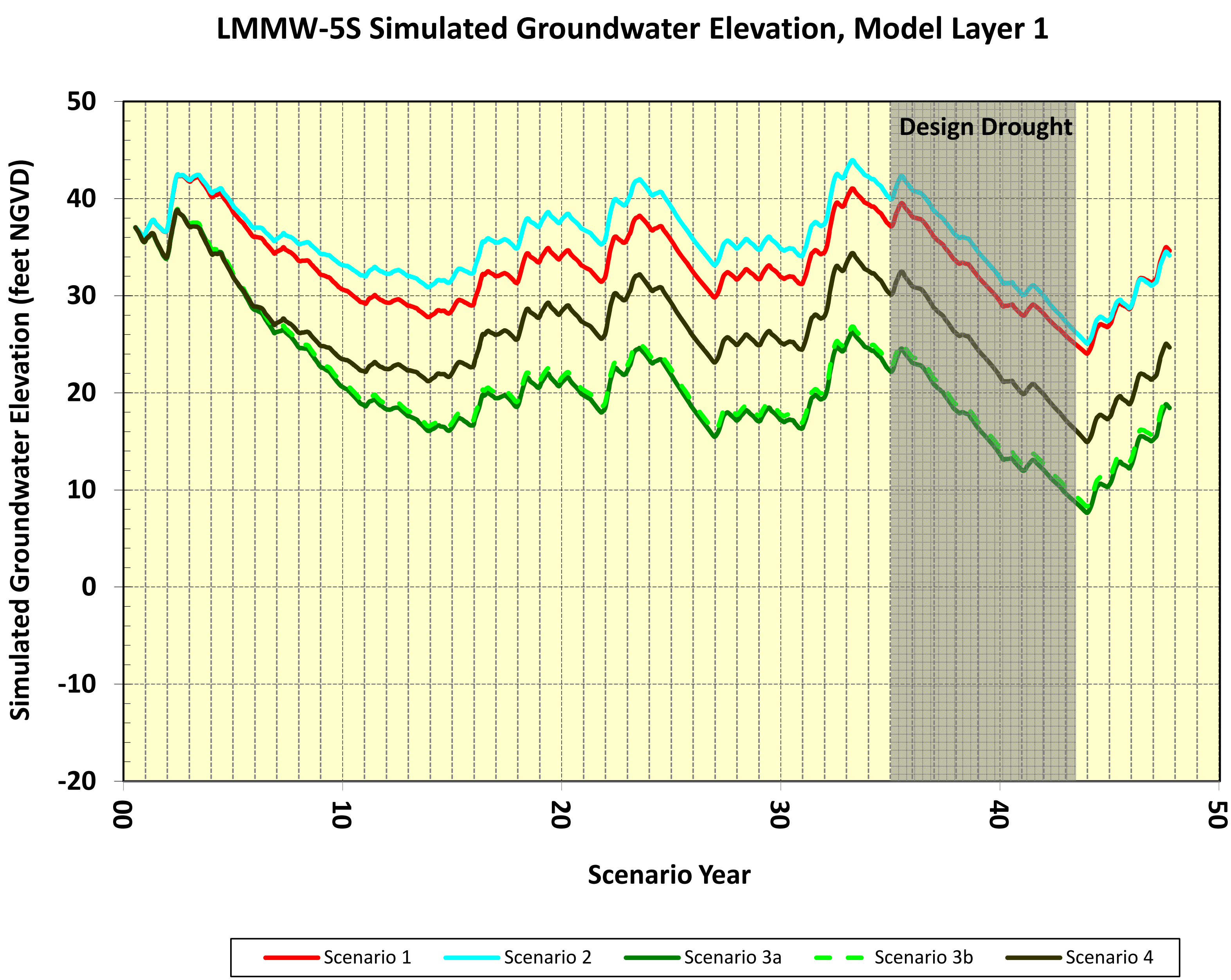

Ortega_MW Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

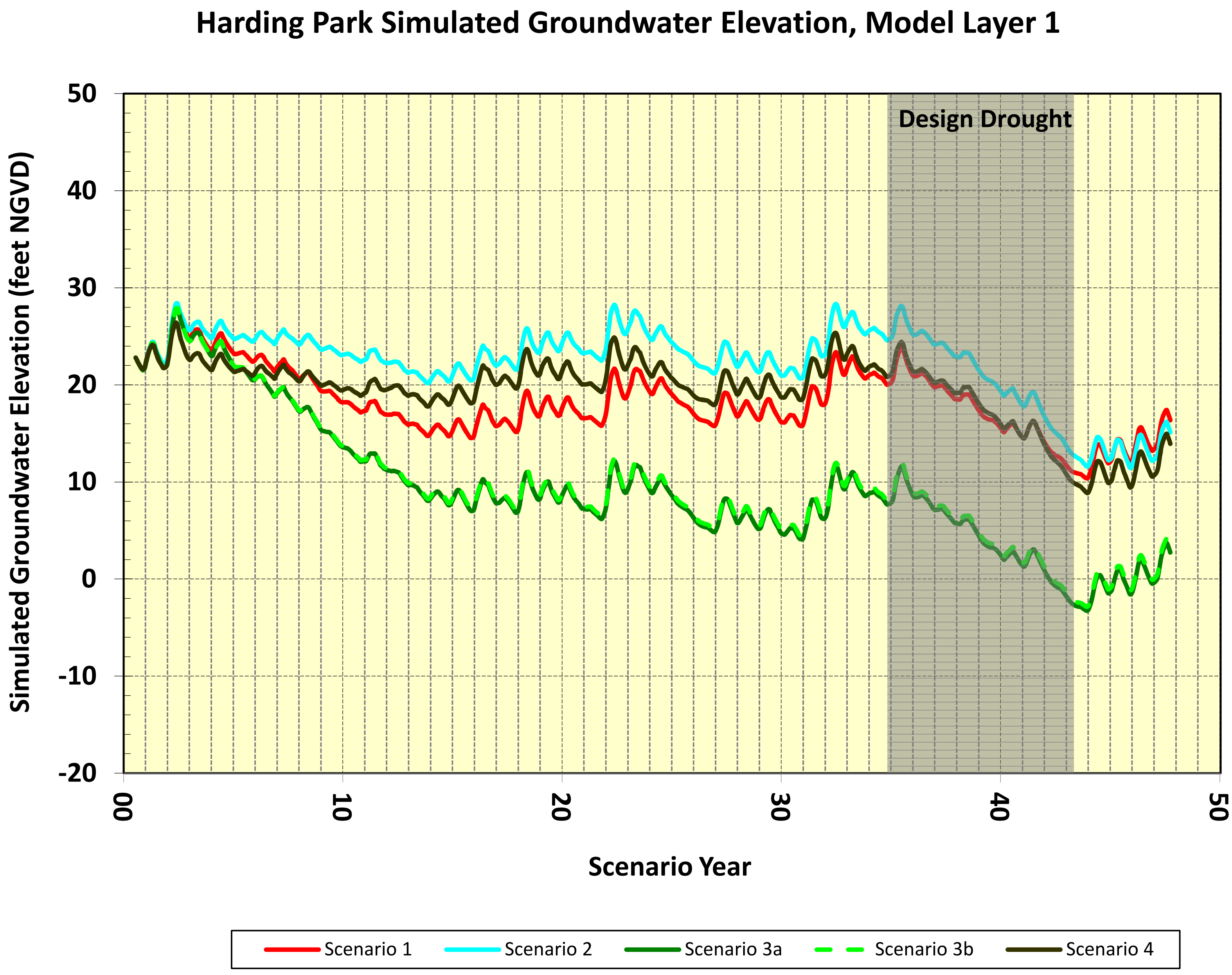


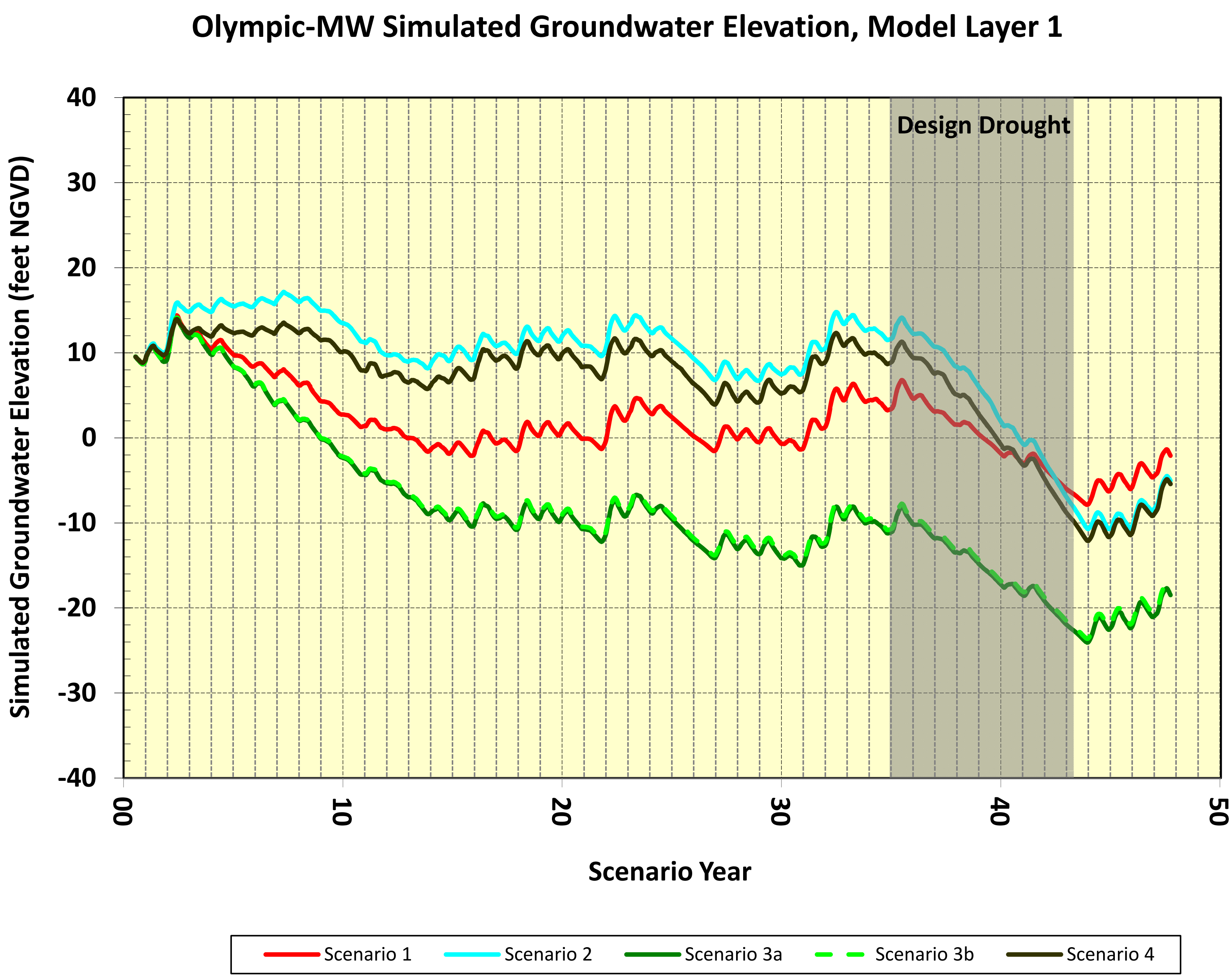
Santiago-S Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
-15
-20
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



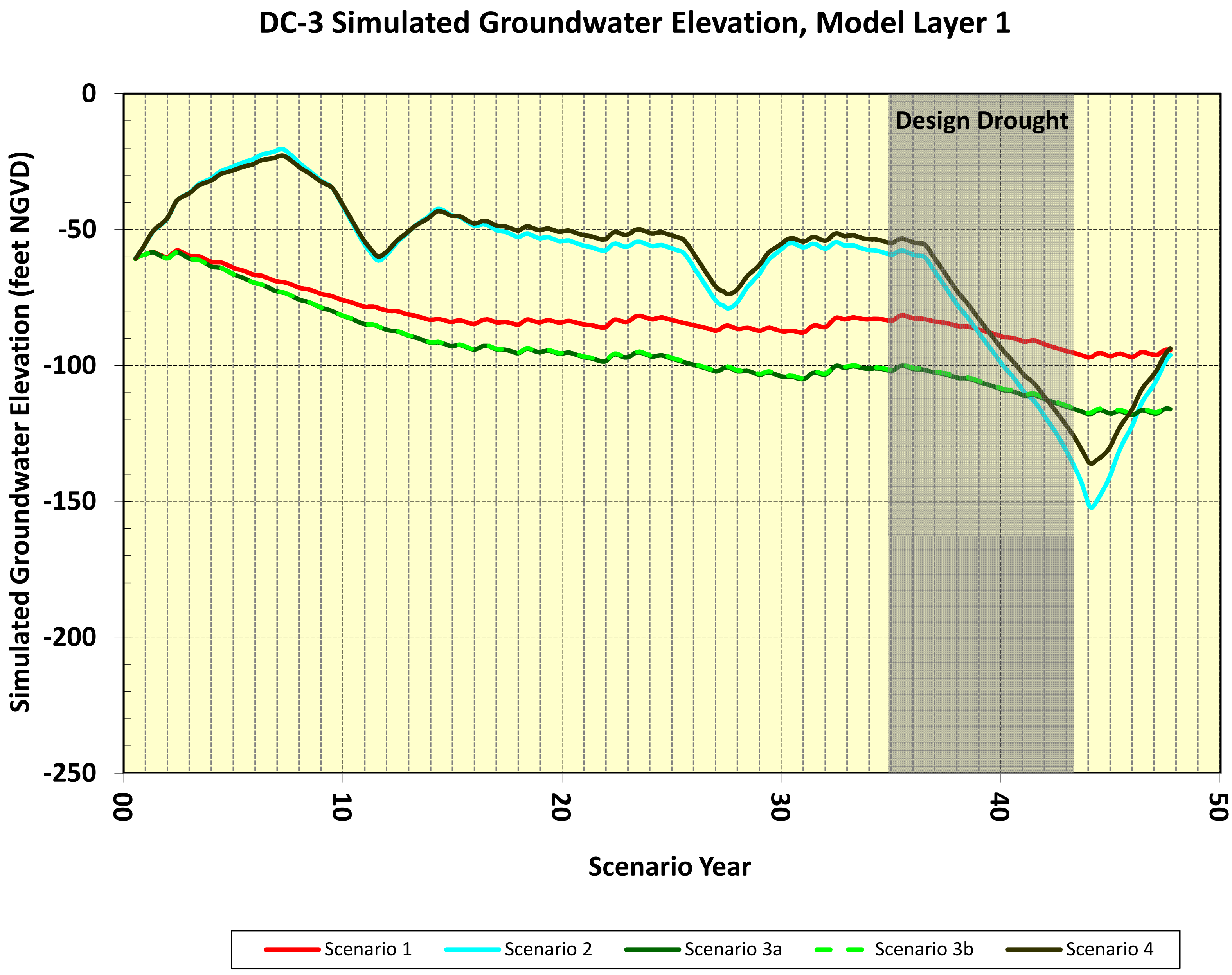
LMMW-4S Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
30
20
10
0
-10
-20
-30
-40
-50
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

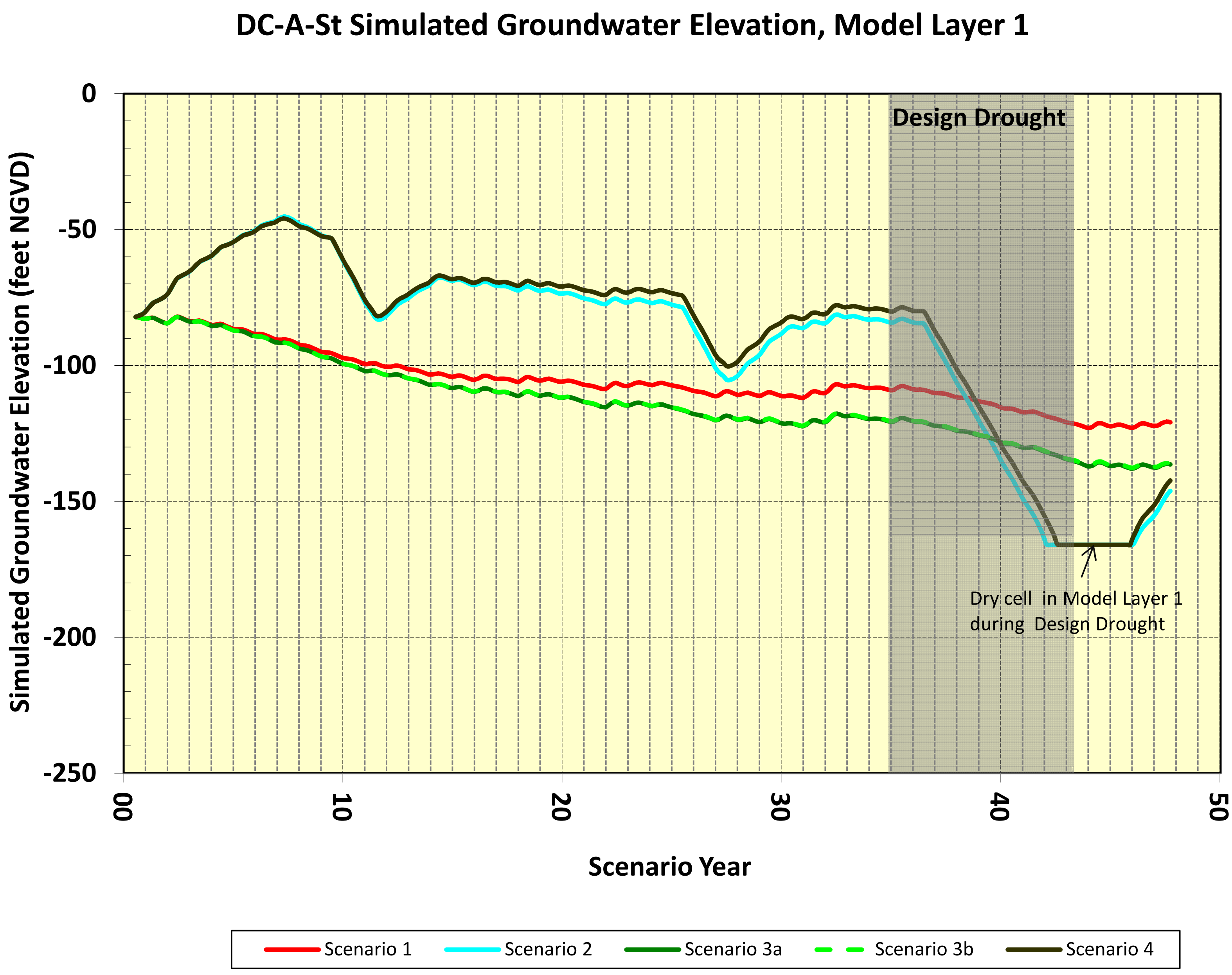

LMMW-5S Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
50
40
30
20
10
0
-10
-20
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

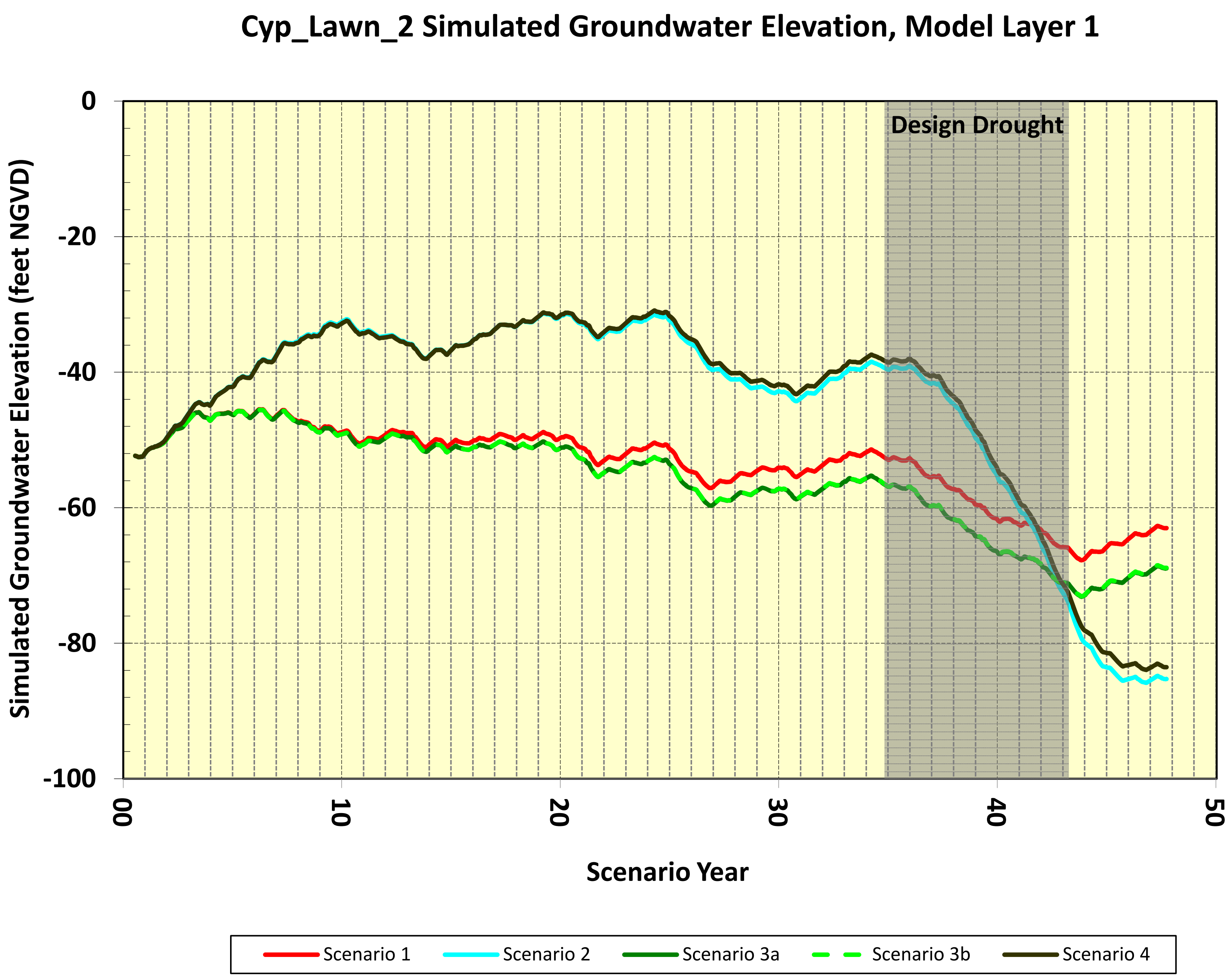

Harding Park Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
50
40
30
20
10
0
-10
-20
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



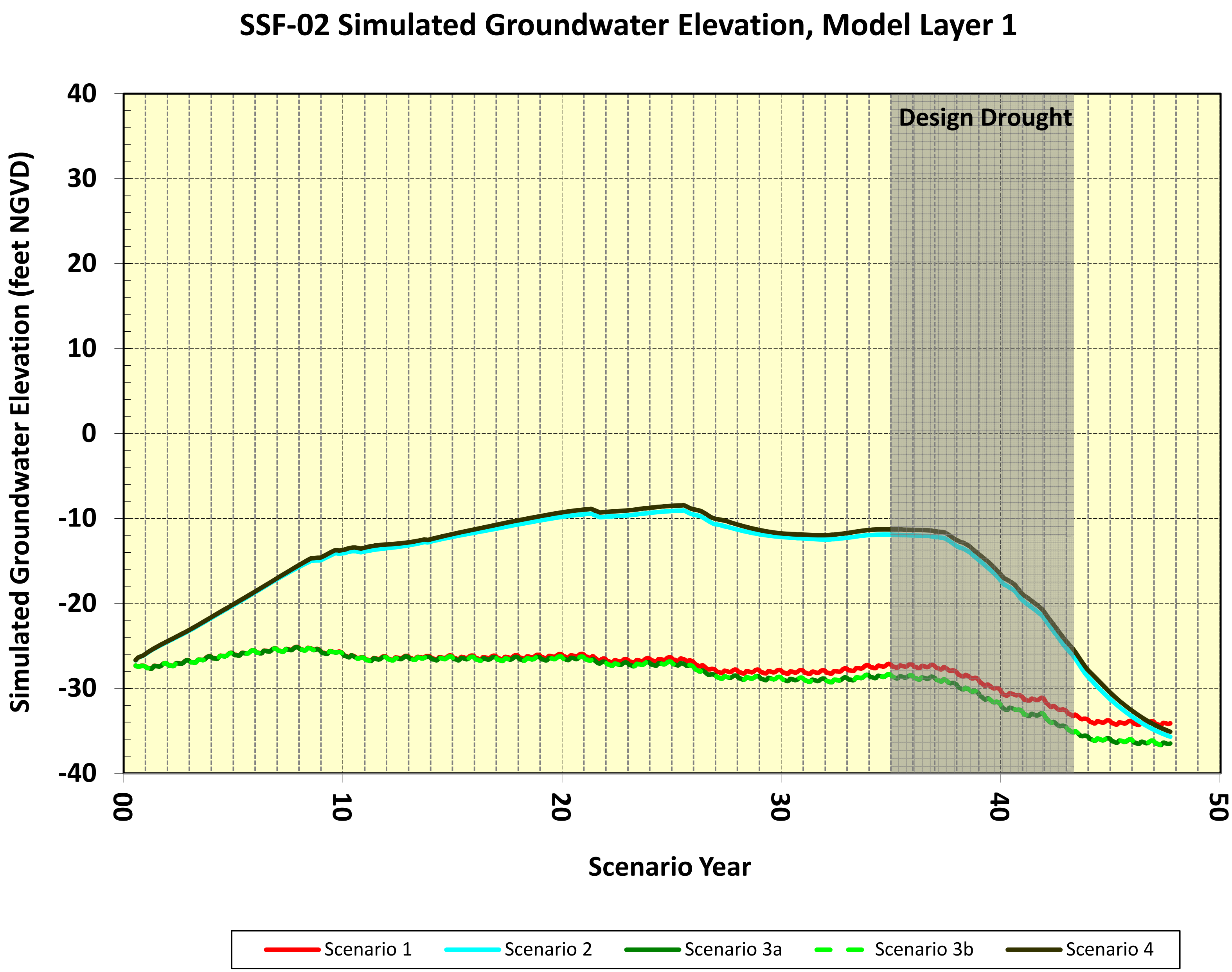
Olympic-MW Simulated Groundwater Elevation, Model Layer 1
Design Drought
40
30
20
10
0
-10
-20
-30
-40
Simulated Groundwater Elevation (feet NGVD)
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

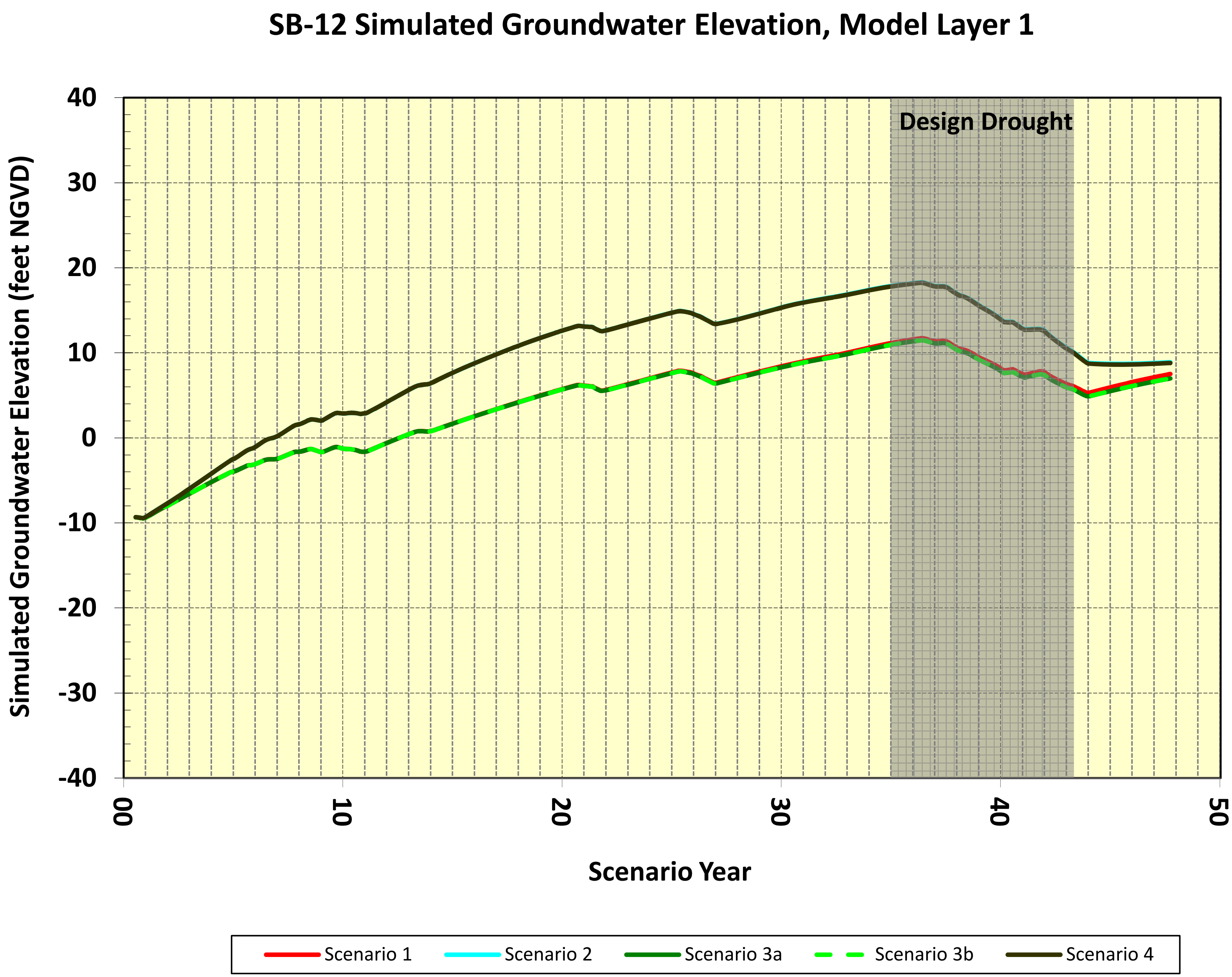

DC-3 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

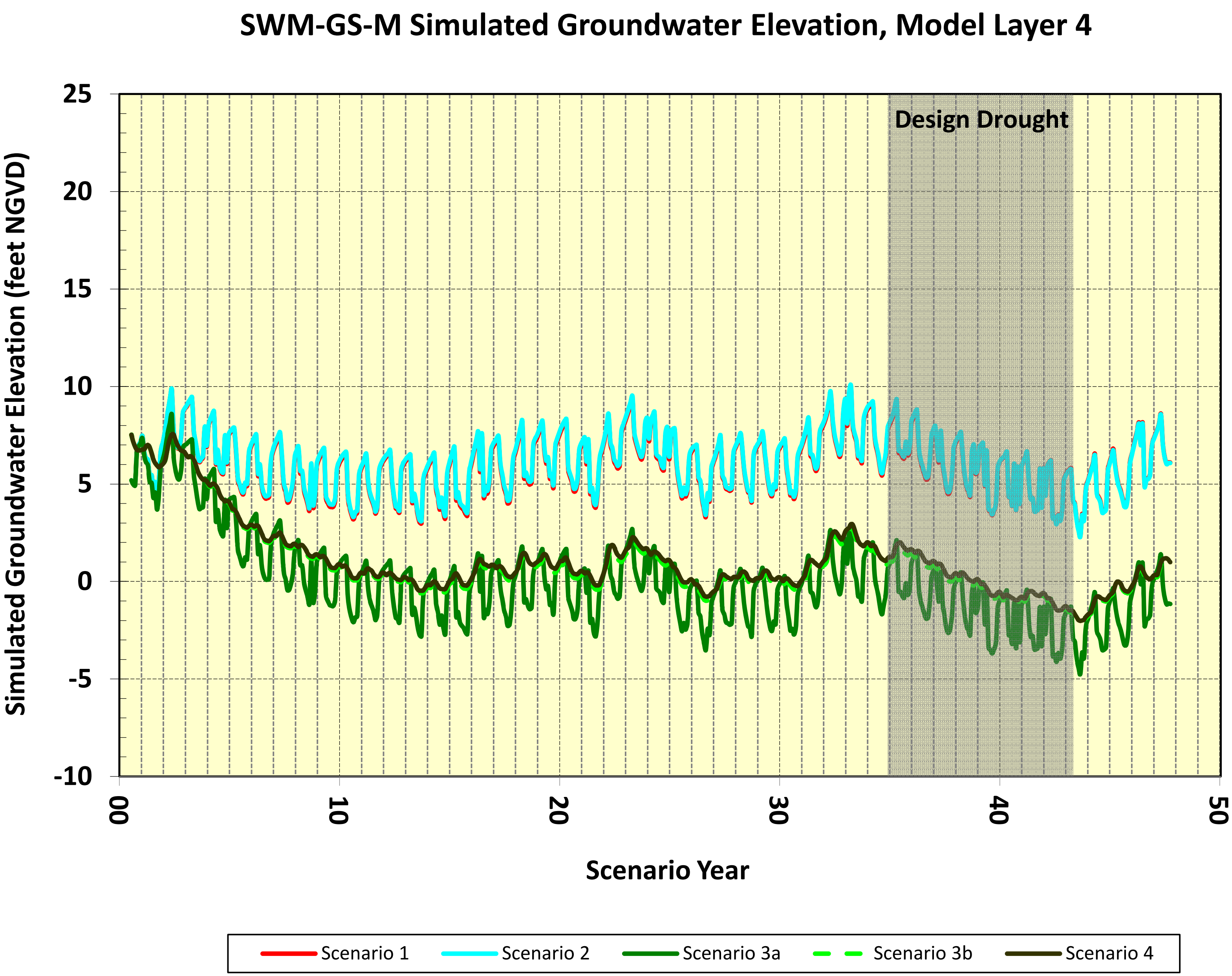

DC-A-St Simulated Groundwater Elevation, Model Layer 1
Design Drought
Dry cell in Model Layer 1
during Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

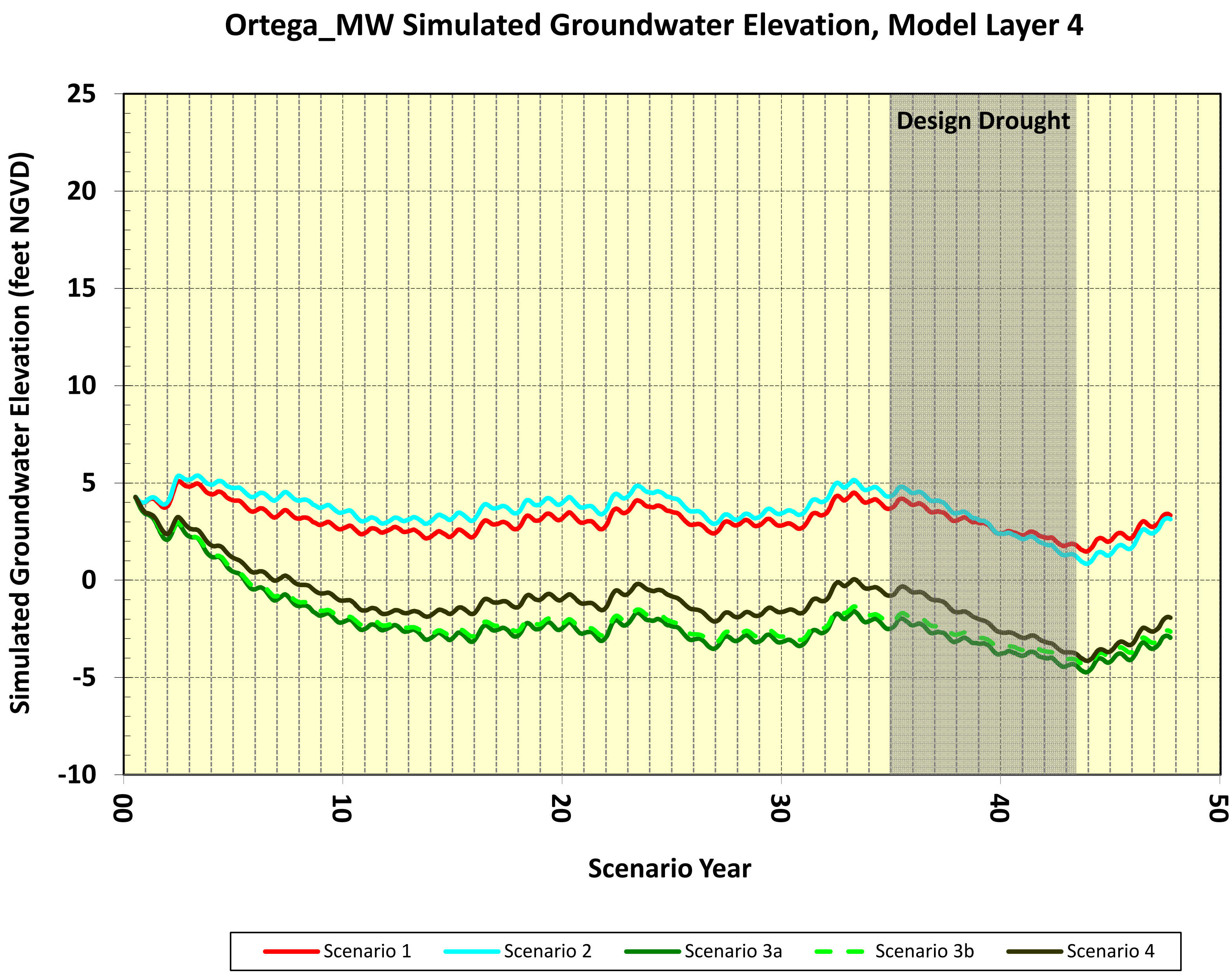


Cyp_Lawn_2 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-20
-40
-60
-80
-100
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

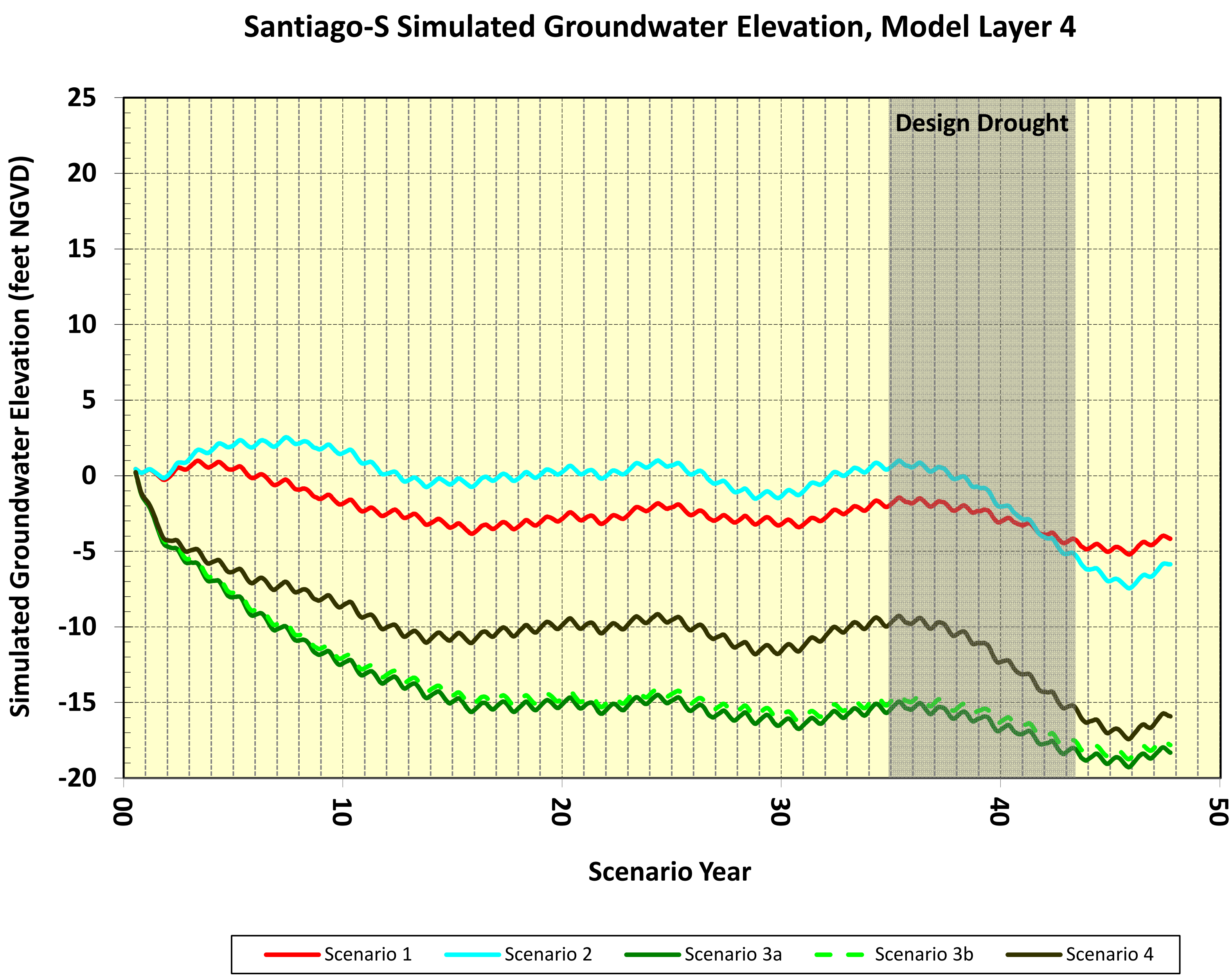

SSF-02 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
30
20
10
0
-10
-20
-30
-40
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

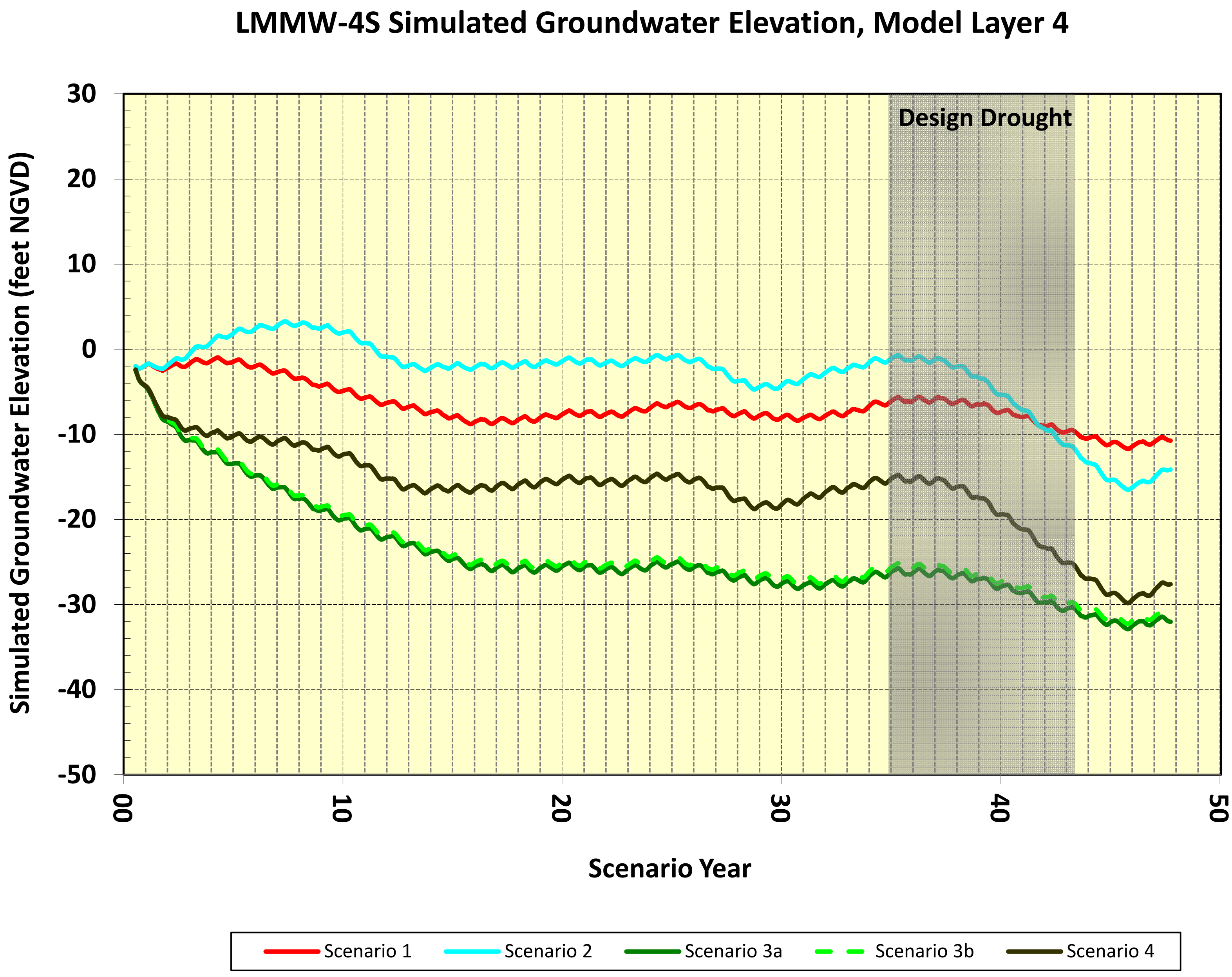

SB-12 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
30
20
10
0
-10
-20
-30
-40
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


SWM-GS-M Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

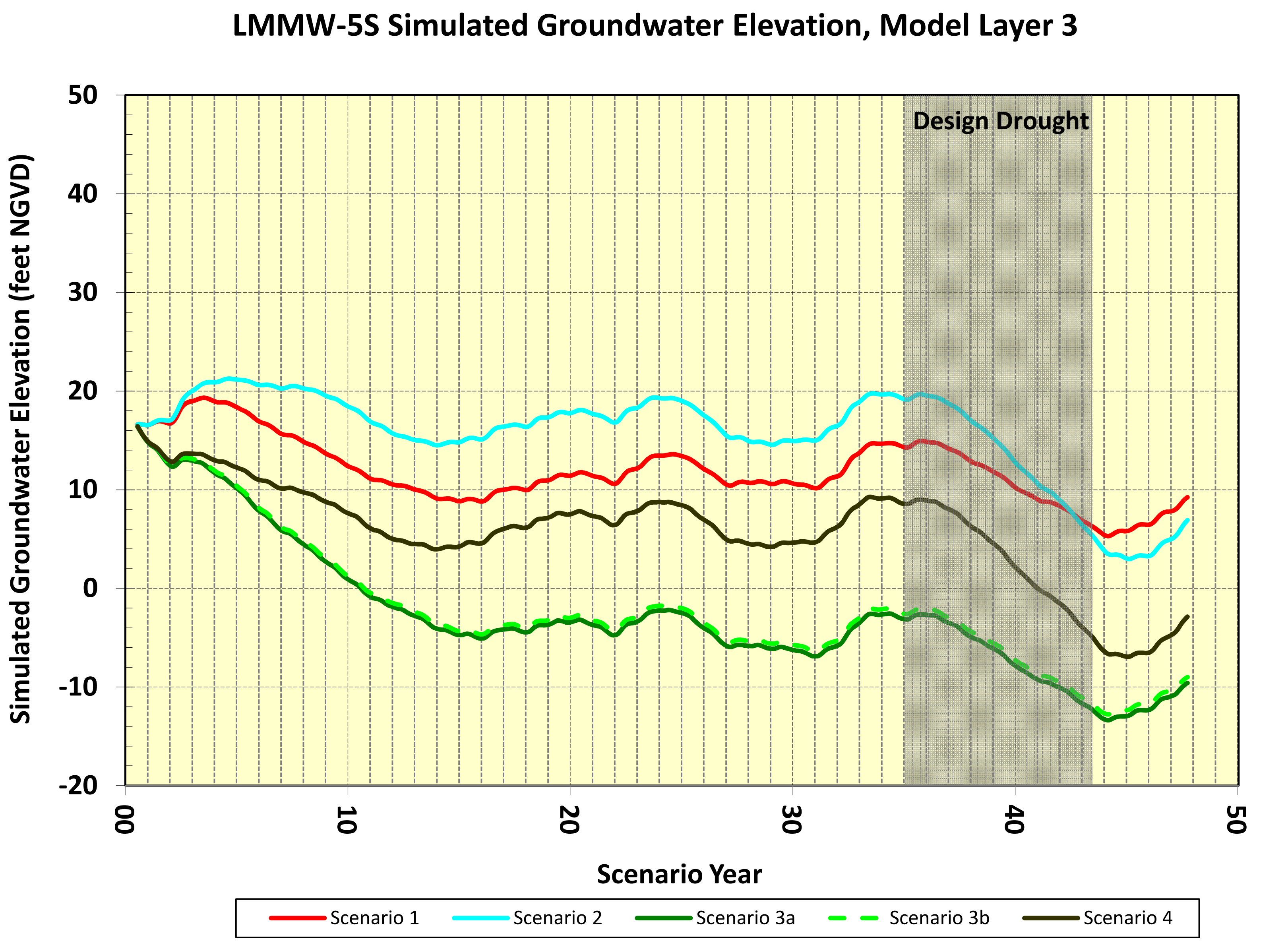


Ortega_MW Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

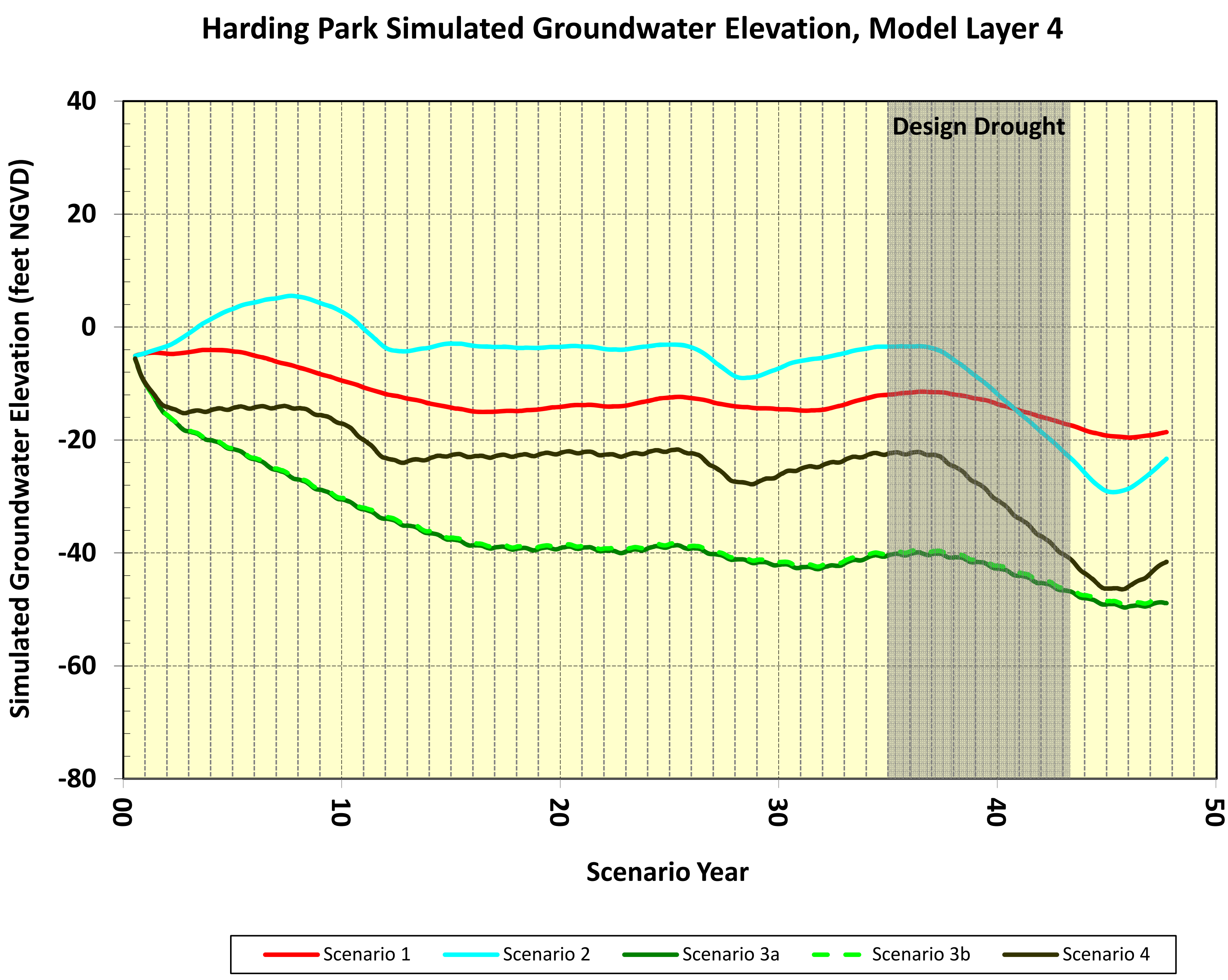

Santiago-S Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
-15
-20
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



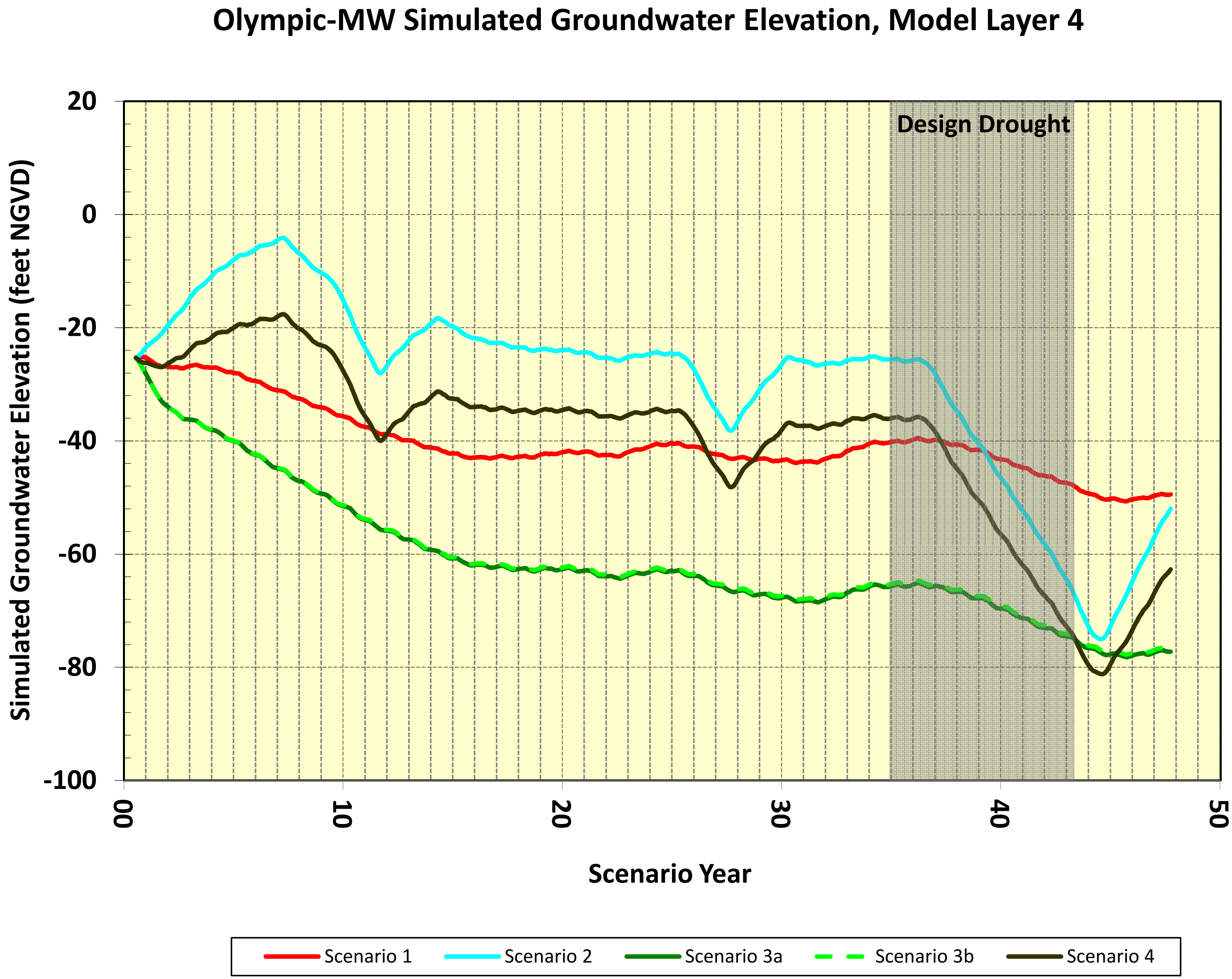
LMMW-4S Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
30
20
10
0
-10
-20
-30
-40
-50
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

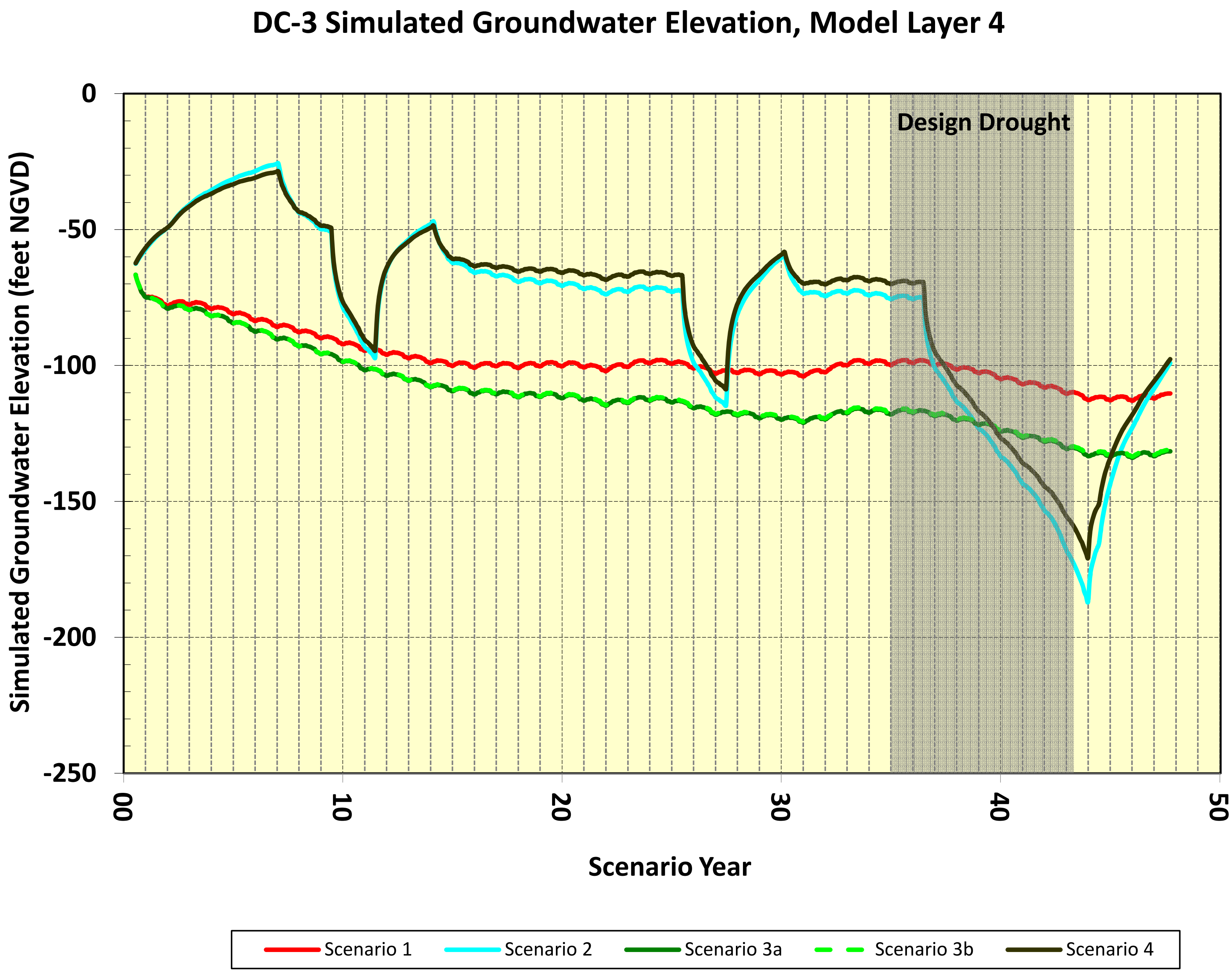


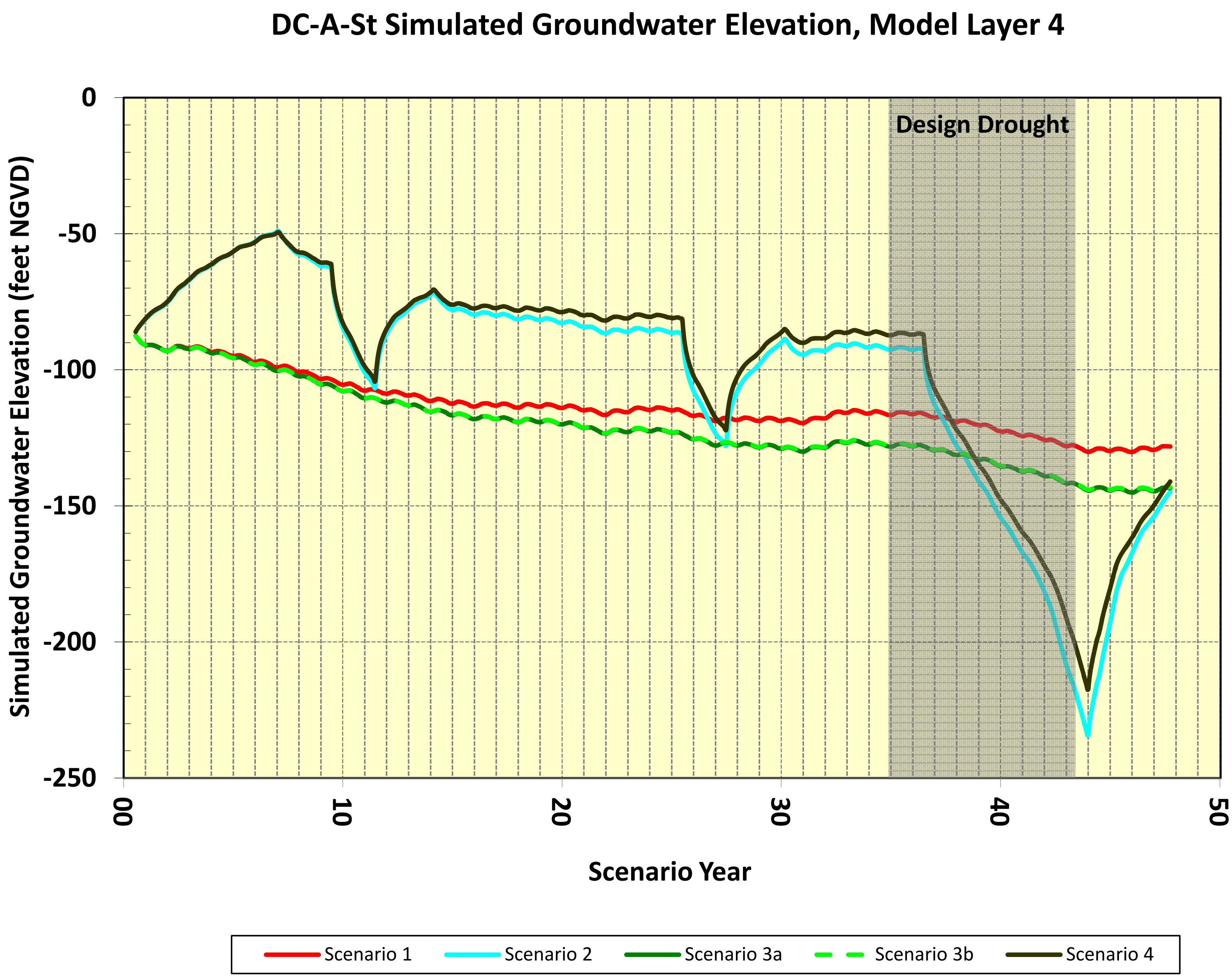
Note: At the location of LMMW-5S, the model does not contain layer 4. Layer 3 is presented in order to show the deepest layer response.

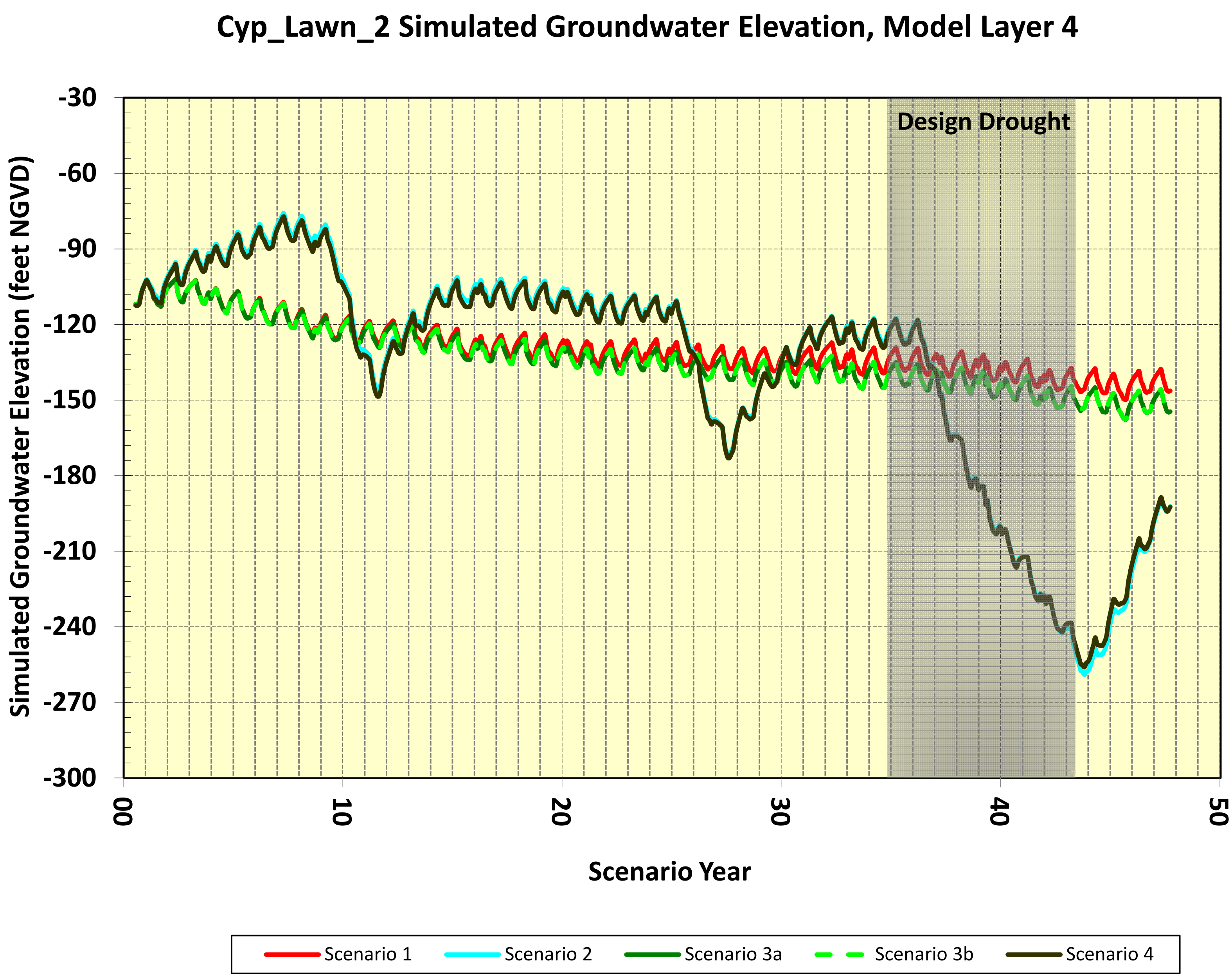


Harding Park Simulated Groundwater Elevation, Model Layer 4
Design Drought
40
20
0
-20
-40
-60
-80
Simulated Groundwater Elevation (feet NGVD)
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

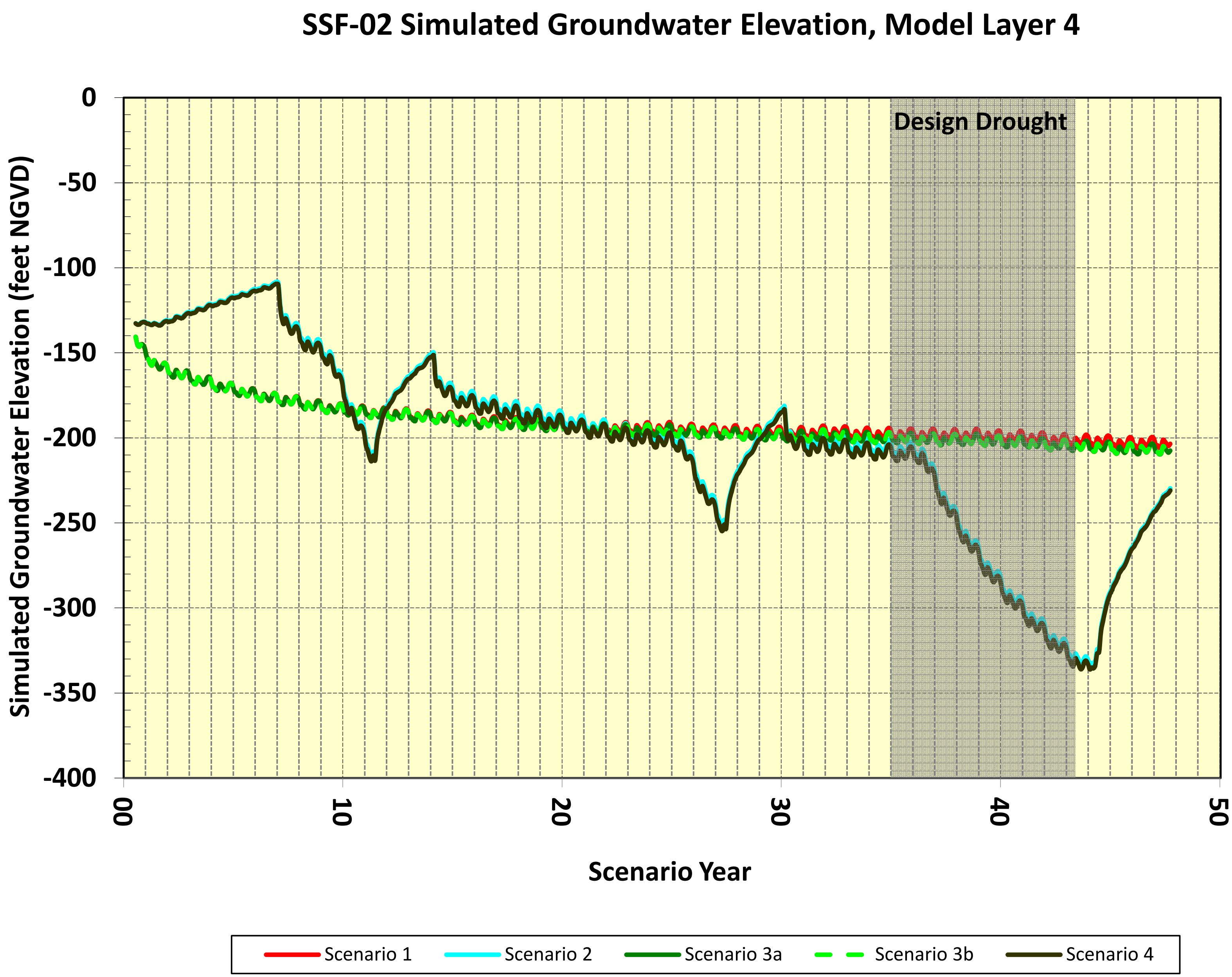

Olympic-MW Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
20
0
-20
-40
-60
-80
-100
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

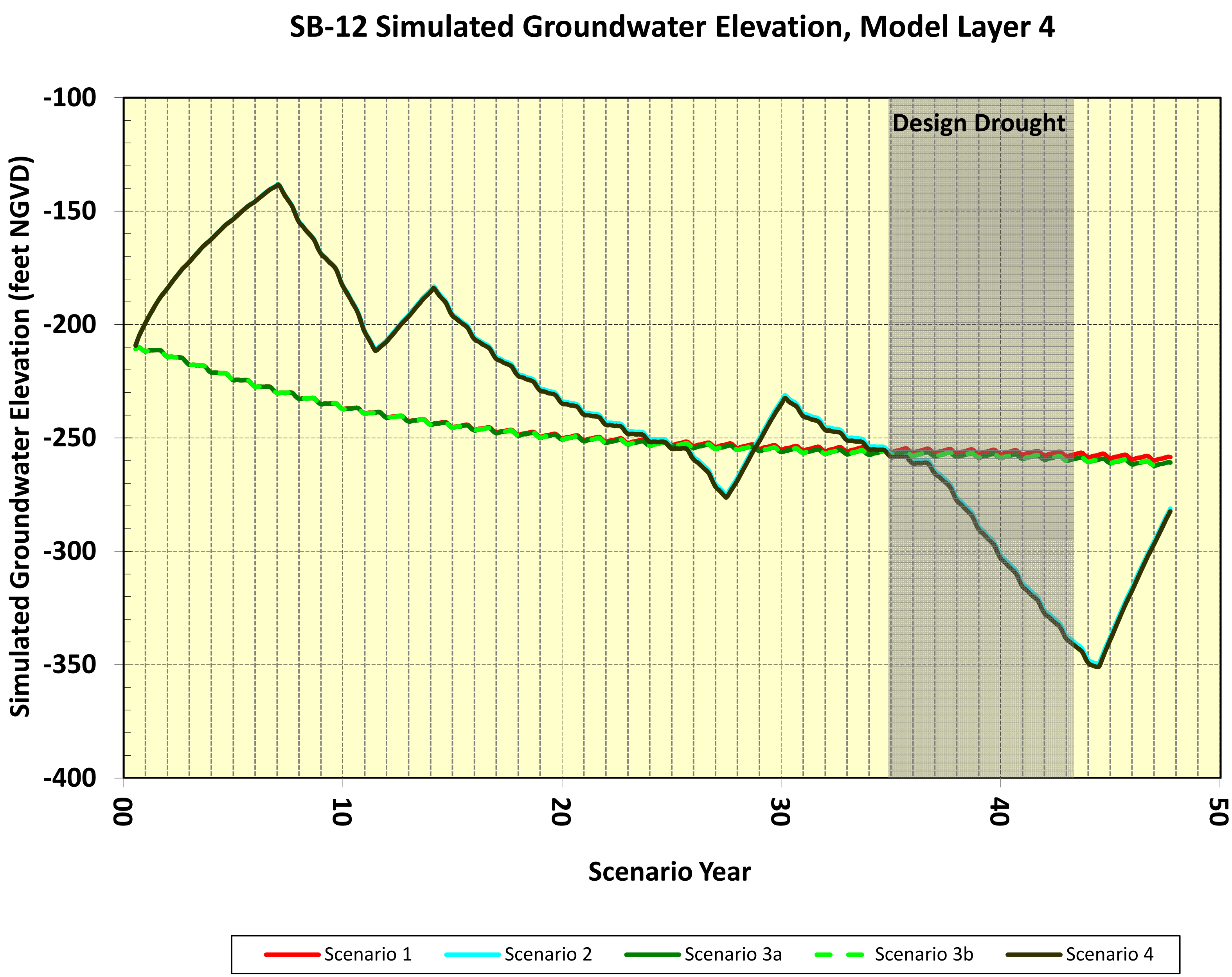

DC-3 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


DC-A-St Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



Cyp_Lawn_2 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
-30
-60
-90
-120
-150
-180
-210
-240
-270
-300
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


SSF-02 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


SB-12 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

Attachment 10.1-C

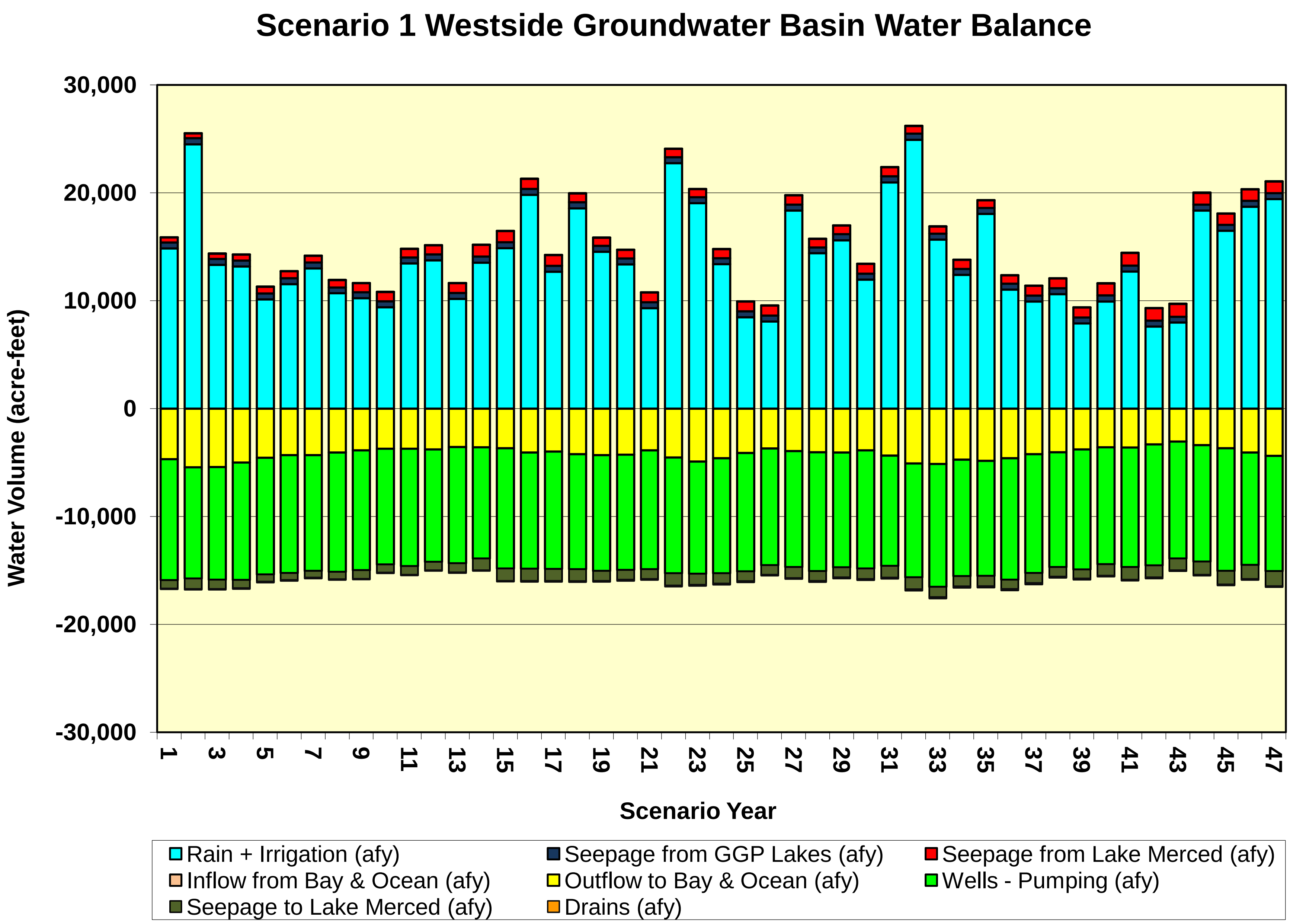
Model Scenario Water Balance Results – Westside Basin

Scenario 1 Westside Groundwater Basin Water Balance Summary

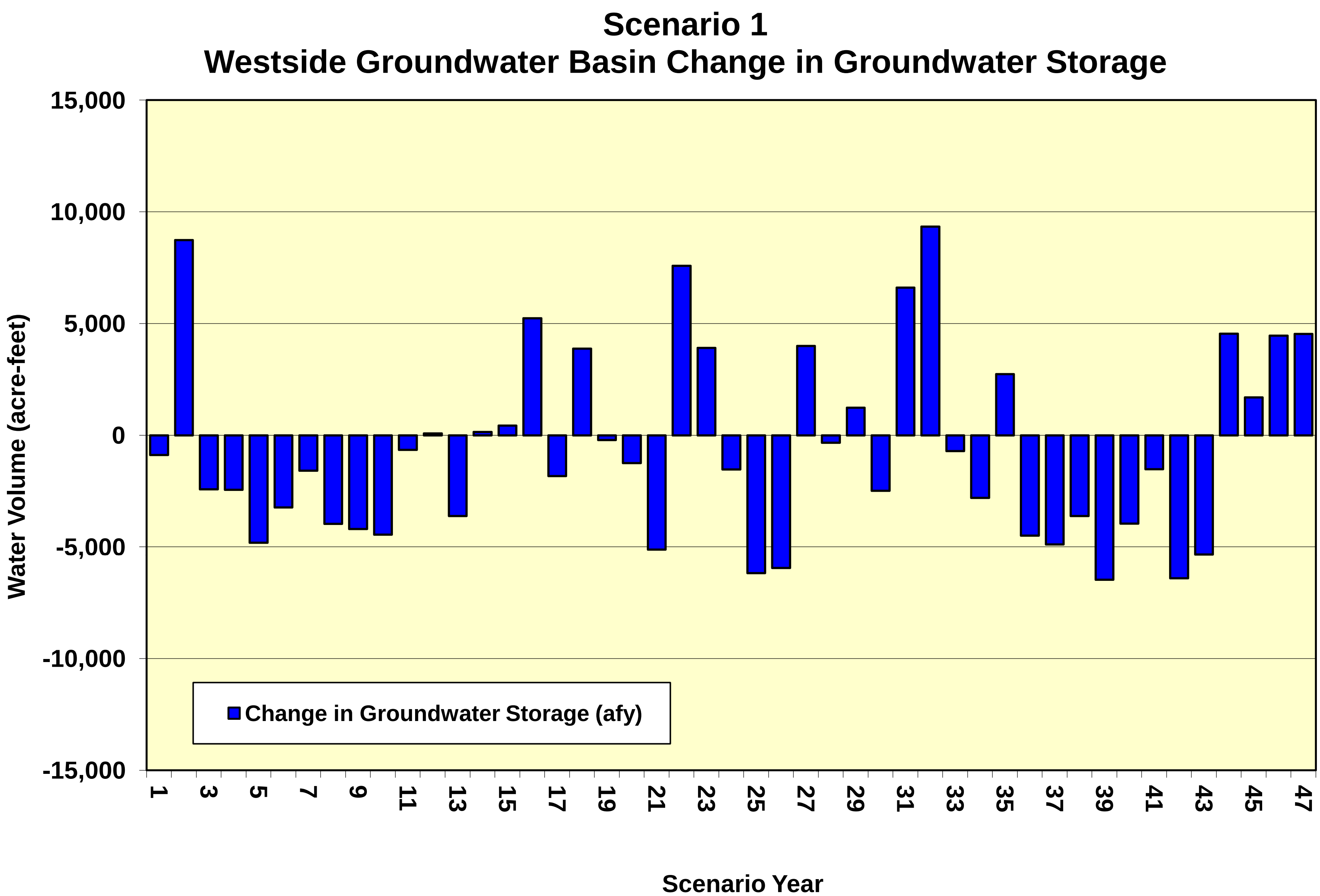
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	5	546	14,845	464	-4,684	-11,229	-753	-71	-877
2	5	558	24,505	456	-5,439	-10,299	-974	-72	8,739
3	5	552	13,329	475	-5,406	-10,445	-858	-73	-2,420
4	5	549	13,169	547	-4,988	-10,889	-758	-74	-2,440
5	5	549	10,129	623	-4,561	-10,804	-679	-74	-4,814
6	5	551	11,546	624	-4,317	-10,917	-653	-73	-3,234
7	5	552	12,988	614	-4,317	-10,717	-634	-72	-1,580
8	5	545	10,691	671	-4,064	-11,064	-680	-72	-3,968
9	6	549	10,235	853	-3,868	-11,113	-788	-70	-4,198
10	6	554	9,386	875	-3,717	-10,720	-767	-68	-4,451
11	7	549	13,455	807	-3,710	-10,879	-807	-68	-647
12	8	556	13,751	820	-3,780	-10,420	-772	-74	89
13	9	553	10,162	915	-3,568	-10,761	-841	-76	-3,609
14	10	558	13,533	1,086	-3,585	-10,315	-1,067	-75	145
15	11	549	14,876	1,040	-3,666	-11,154	-1,139	-81	437
16	12	556	19,804	925	-4,070	-10,766	-1,142	-84	5,234
17	10	549	12,678	995	-3,989	-10,883	-1,095	-88	-1,823
18	10	554	18,568	828	-4,225	-10,663	-1,102	-92	3,879
19	9	553	14,531	755	-4,322	-10,710	-932	-96	-212
20	9	556	13,363	791	-4,272	-10,673	-920	-100	-1,245
21	9	548	9,310	896	-3,869	-11,010	-912	-93	-5,120
22	10	554	22,751	765	-4,542	-10,729	-1,125	-94	7,591
23	9	556	19,036	745	-4,914	-10,402	-1,014	-101	3,915
24	9	549	13,397	837	-4,599	-10,670	-949	-105	-1,530
25	9	549	8,479	893	-4,123	-10,963	-904	-107	-6,167
26	11	550	8,071	921	-3,694	-10,827	-871	-96	-5,935
27	12	552	18,354	870	-3,946	-10,732	-1,017	-96	3,997
28	12	549	14,398	788	-4,057	-11,007	-911	-104	-331
29	12	553	15,609	801	-4,065	-10,650	-921	-109	1,231
30	13	550	11,960	905	-3,871	-10,961	-964	-112	-2,479
31	13	556	20,974	840	-4,352	-10,230	-1,076	-115	6,611
32	12	556	24,922	717	-5,079	-10,564	-1,106	-118	9,340
33	12	545	15,668	661	-5,124	-11,398	-951	-121	-709
34	11	554	12,389	855	-4,732	-10,800	-955	-124	-2,802
35	11	553	18,045	708	-4,839	-10,663	-951	-128	2,737
36	11	545	11,034	780	-4,601	-11,255	-871	-129	-4,486
37	11	545	9,932	915	-4,215	-11,035	-919	-121	-4,886
38	11	554	10,605	904	-4,058	-10,620	-900	-114	-3,618
39	12	549	7,905	926	-3,789	-11,119	-846	-106	-6,468
40	15	556	9,935	1,119	-3,588	-10,839	-1,052	-100	-3,953
41	17	549	12,714	1,156	-3,608	-11,081	-1,163	-100	-1,516
42	22	550	7,618	1,146	-3,322	-11,202	-1,120	-96	-6,403
43	28	549	7,975	1,171	-3,057	-10,827	-1,087	-87	-5,335
44	31	552	18,357	1,090	-3,379	-10,805	-1,216	-87	4,544
45	29	545	16,490	1,030	-3,669	-11,371	-1,263	-95	1,697
46	27	556	18,714	1,050	-4,069	-10,412	-1,305	-98	4,464
47	23	545	19,422	1,095	-4,385	-10,681	-1,383	-101	4,535
Average (afy)	**12**	**551**	**14,034**	**846**	**-4,172**	**-10,814**	**-960**	**-94**	**-597**
Maximum (afy)	**31**	**558**	**24,922**	**1,171**	**-3,057**	**-10,230**	**-634**	**-68**	**9,340**
Minimum (afy)	**5**	**545**	**7,618**	**456**	**-5,439**	**-11,398**	**-1,383**	**-129**	**-6,468**

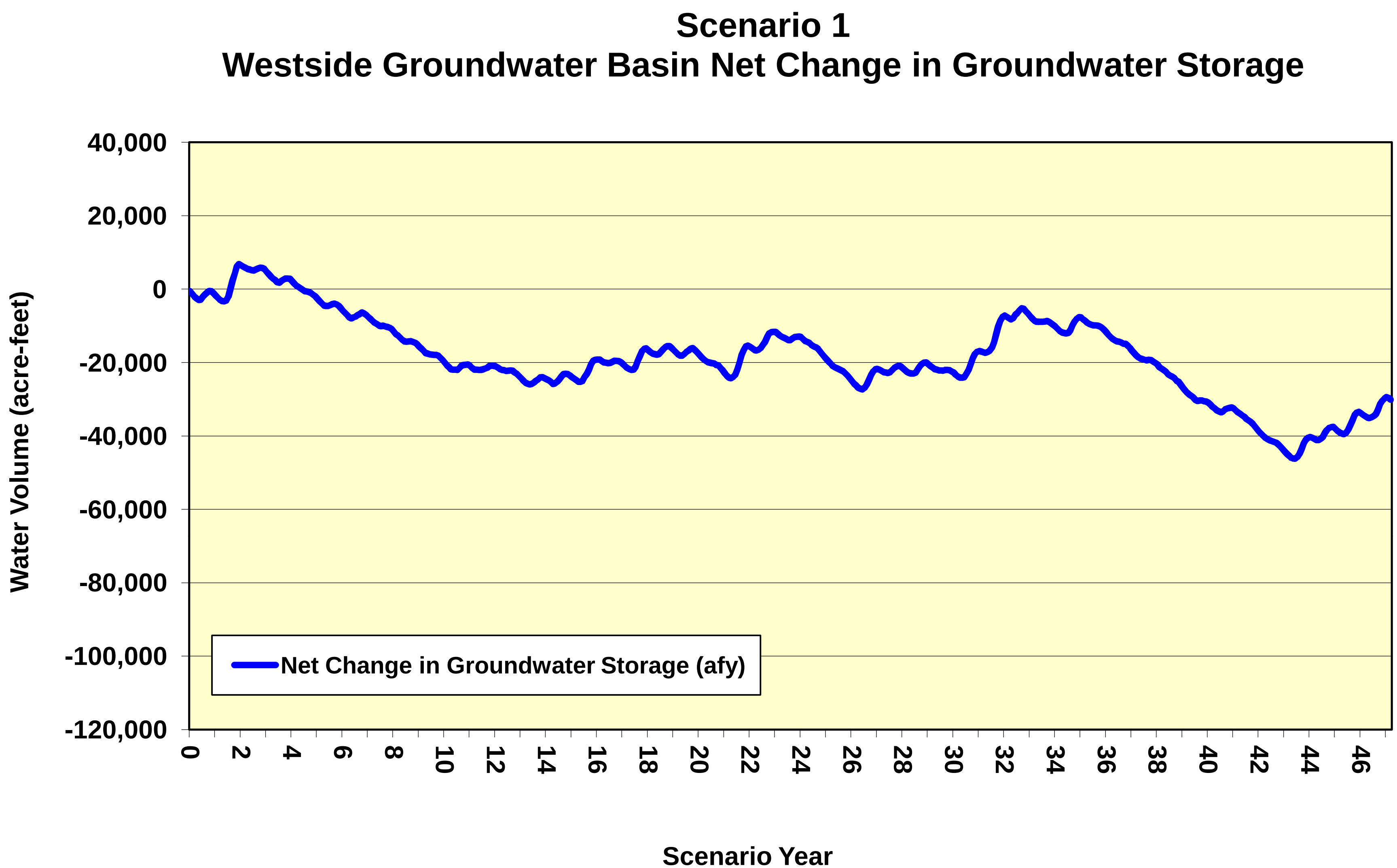
Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.



Note: Volume of some water balance components may be too small to be visible.


Scenario 1
Westside Groundwater Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
Change in Groundwater Storage (afy)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year

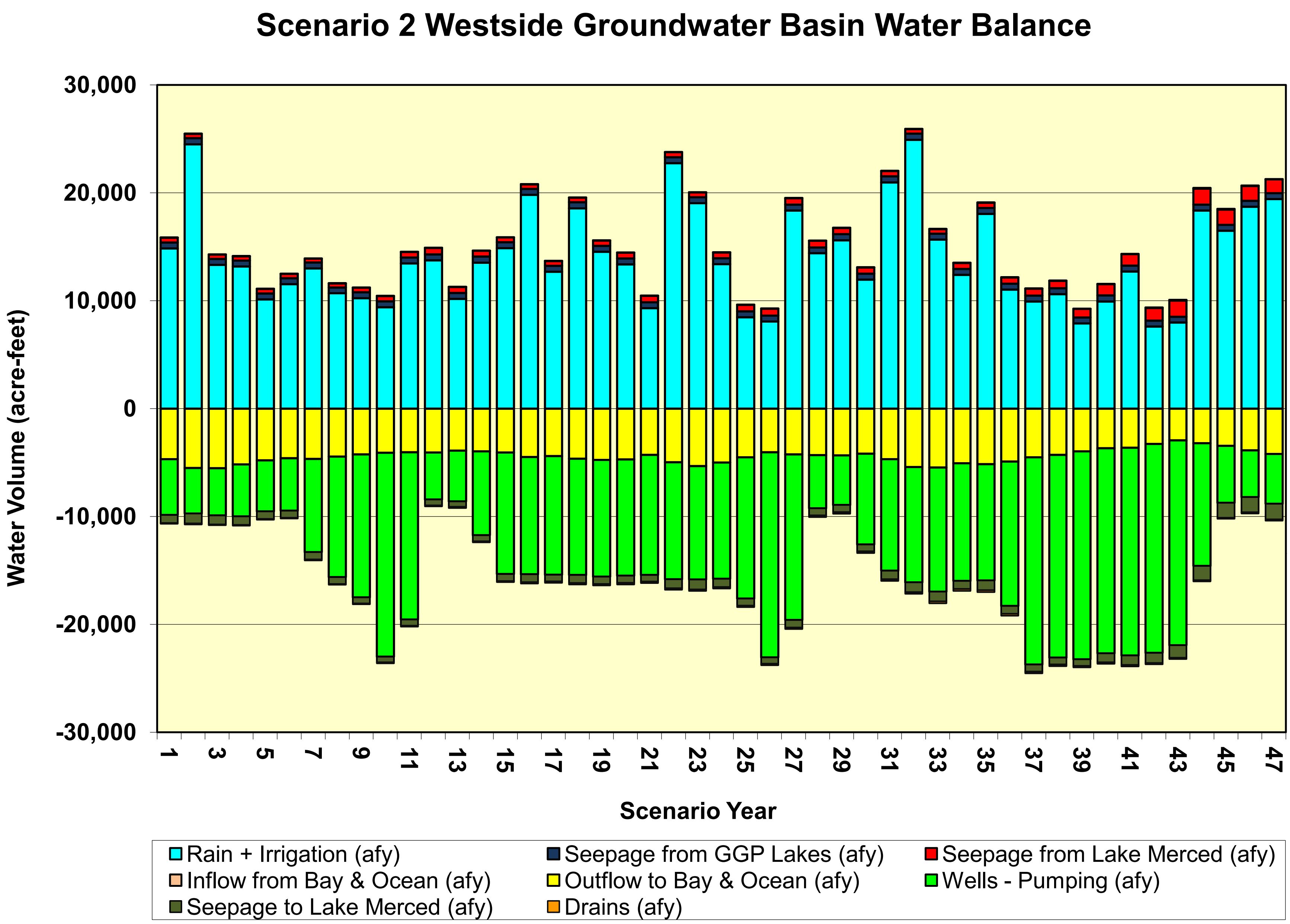

Scenario 1
Westside Groundwater Basin Net Change in Groundwater Storage
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
-100,000
-120,000
Water Volume (acre-feet)
Net Change in Groundwater Storage (afy)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
Scenario Year

Scenario 2 Westside Groundwater Basin Water Balance Summary

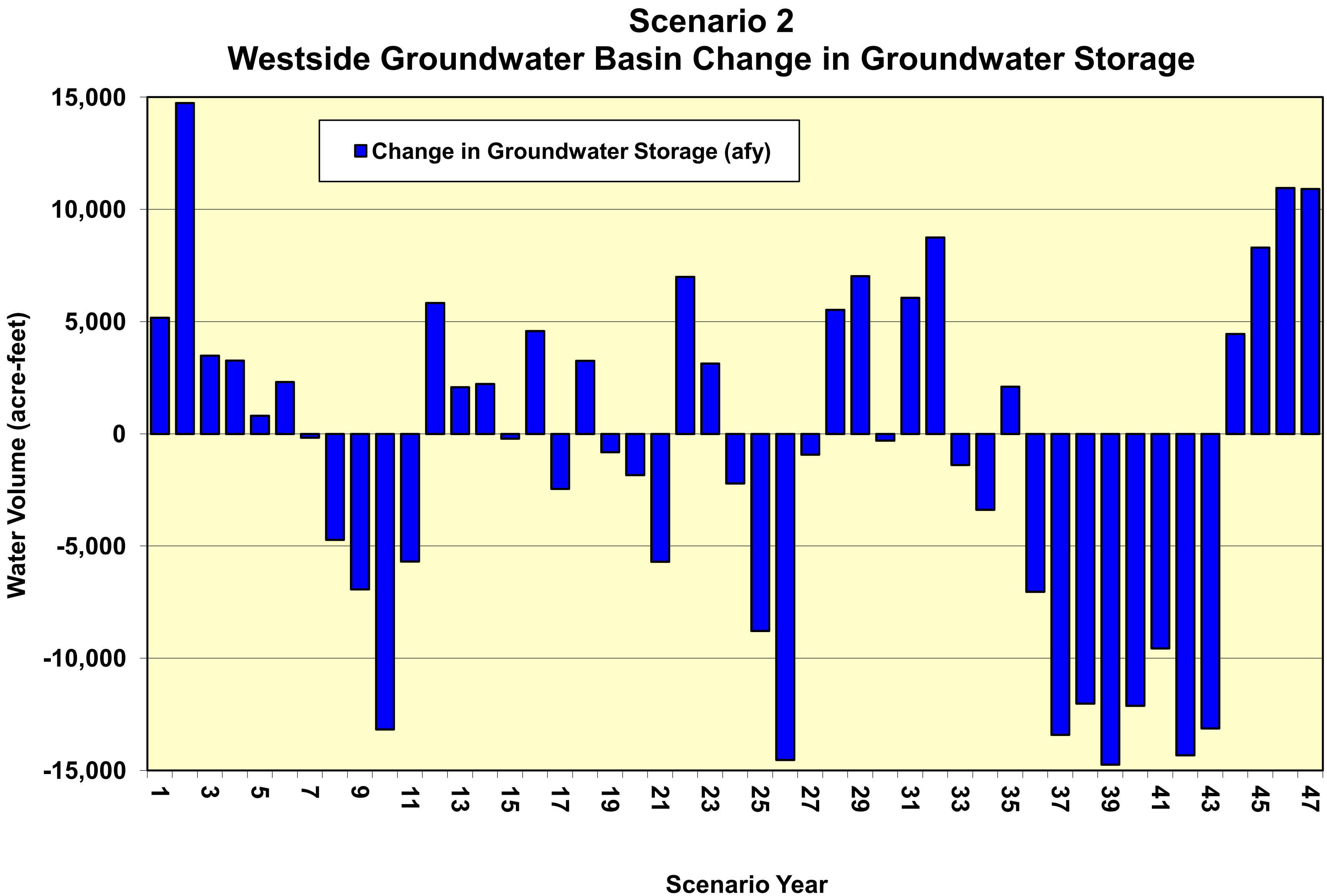
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	5	546	14,845	452	-4,698	-5,157	-754	-71	5,168
2	5	558	24,505	405	-5,499	-4,227	-931	-72	14,744
3	5	552	13,329	402	-5,526	-4,373	-835	-74	3,480
4	5	549	13,169	395	-5,165	-4,817	-798	-75	3,262
5	5	549	10,129	418	-4,789	-4,732	-698	-77	805
6	4	551	11,546	394	-4,601	-4,845	-667	-77	2,305
7	4	552	12,988	351	-4,657	-8,647	-680	-78	-166
8	4	545	10,691	365	-4,435	-11,173	-640	-81	-4,723
9	4	549	10,235	425	-4,252	-13,237	-569	-84	-6,929
10	4	554	9,386	492	-4,097	-18,889	-529	-85	-13,164
11	4	549	13,455	512	-4,044	-15,498	-574	-87	-5,683
12	5	556	13,751	575	-4,081	-4,348	-533	-94	5,832
13	4	553	10,162	567	-3,900	-4,689	-522	-98	2,077
14	4	558	13,533	526	-3,963	-7,759	-583	-99	2,218
15	4	549	14,876	448	-4,070	-11,262	-647	-109	-213
16	4	556	19,804	419	-4,482	-10,874	-728	-117	4,582
17	4	549	12,678	461	-4,406	-10,991	-624	-124	-2,453
18	4	554	18,568	427	-4,647	-10,771	-752	-130	3,253
19	4	553	14,531	486	-4,749	-10,818	-690	-136	-819
20	4	556	13,363	530	-4,702	-10,781	-671	-141	-1,841
21	4	548	9,310	595	-4,296	-11,119	-611	-134	-5,702
22	4	554	22,751	471	-4,969	-10,837	-840	-135	6,999
23	4	556	19,036	442	-5,333	-10,510	-920	-144	3,132
24	4	549	13,397	517	-4,993	-10,778	-762	-149	-2,214
25	4	549	8,479	595	-4,504	-13,087	-662	-151	-8,778
26	5	550	8,071	644	-4,053	-18,996	-605	-139	-14,523
27	6	552	18,354	598	-4,245	-15,350	-706	-137	-927
28	7	549	14,398	617	-4,310	-4,935	-663	-145	5,519
29	6	553	15,609	589	-4,340	-4,578	-668	-149	7,022
30	6	550	11,960	567	-4,184	-8,404	-641	-153	-299
31	6	556	20,974	489	-4,688	-10,338	-777	-157	6,065
32	6	556	24,922	424	-5,418	-10,673	-908	-161	8,748
33	6	545	15,668	430	-5,453	-11,506	-912	-166	-1,389
34	6	554	12,389	558	-5,053	-10,908	-757	-171	-3,382
35	6	553	18,045	500	-5,154	-10,771	-902	-175	2,100
36	6	545	11,034	573	-4,907	-13,378	-736	-176	-7,040
37	6	545	9,932	648	-4,503	-19,204	-670	-163	-13,409
38	7	554	10,605	689	-4,289	-18,789	-645	-152	-12,020
39	9	549	7,905	790	-3,949	-19,288	-614	-140	-14,738
40	15	556	9,935	1,038	-3,678	-19,008	-842	-131	-12,113
41	23	549	12,714	1,048	-3,631	-19,250	-882	-128	-9,557
42	36	550	7,618	1,170	-3,278	-19,363	-934	-121	-14,321
43	53	549	7,975	1,498	-2,948	-18,976	-1,172	-108	-13,129
44	65	552	18,357	1,481	-3,201	-11,372	-1,330	-103	4,449
45	61	545	16,490	1,422	-3,452	-5,271	-1,384	-107	8,303
46	47	556	18,714	1,356	-3,864	-4,335	-1,408	-107	10,960
47	34	545	19,422	1,281	-4,207	-4,607	-1,453	-107	10,906
Average (afy)	**11**	**551**	**14,034**	**640**	**-4,418**	**-10,926**	**-784**	**-122**	**-1,013**
Maximum (afy)	**65**	**558**	**24,922**	**1,498**	**-2,948**	**-4,227**	**-522**	**-71**	**14,744**
Minimum (afy)	**4**	**545**	**7,618**	**351**	**-5,526**	**-19,363**	**-1,453**	**-176**	**-14,738**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

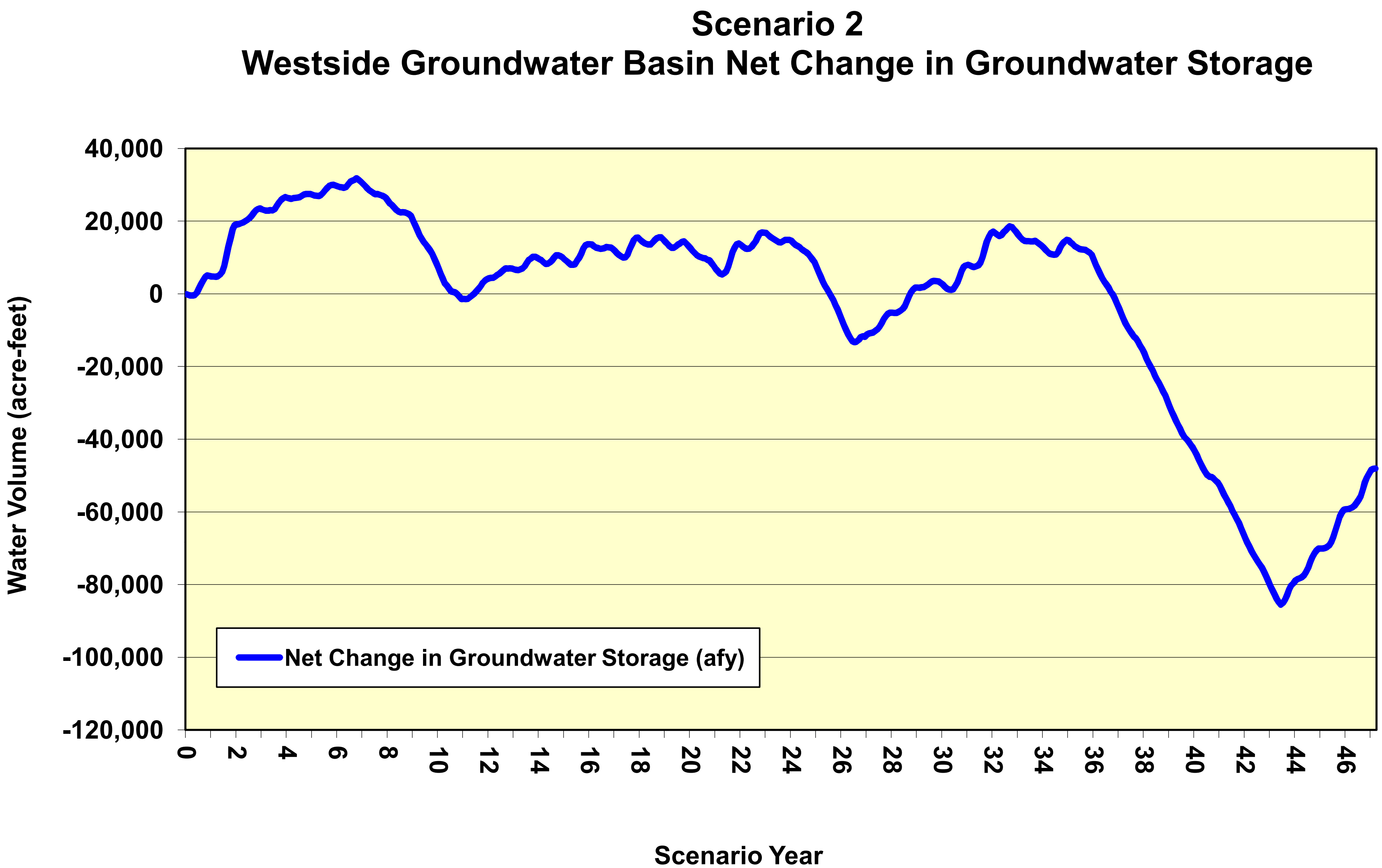
Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.



Note: Volume of some water balance components may be too small to be visible.



Scenario 2
Westside Groundwater Basin Change in Groundwater Storage
Change in Groundwater Storage (afy)
Water Volume (acre-feet)
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year



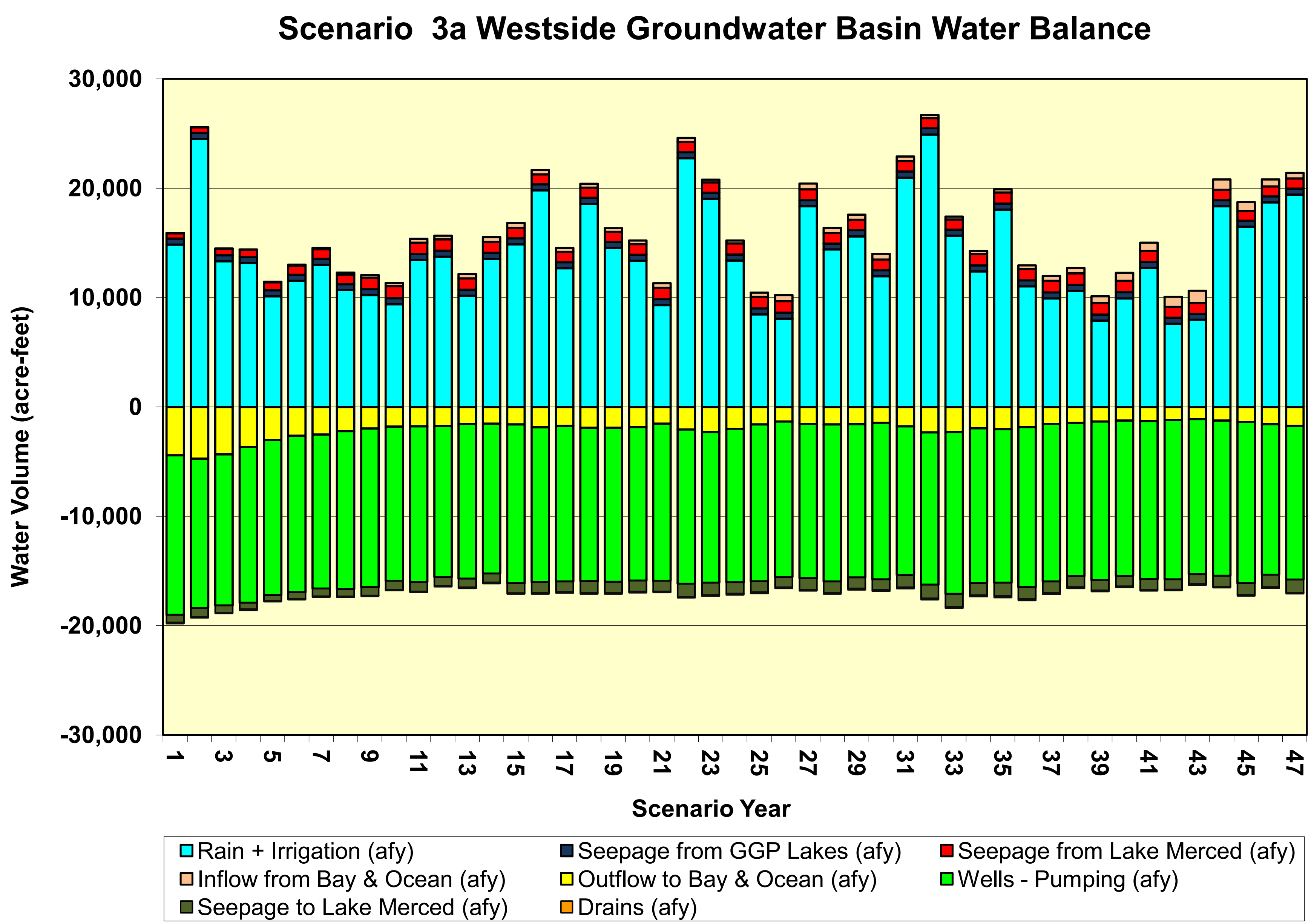
Scenario 2
Westside Groundwater Basin Net Change in Groundwater Storage
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
-100,000
-120,000
Water Volume (acre-feet)
Net Change in Groundwater Storage (afy)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
Scenario Year

Scenario 3a Westside Groundwater Basin Water Balance Summary

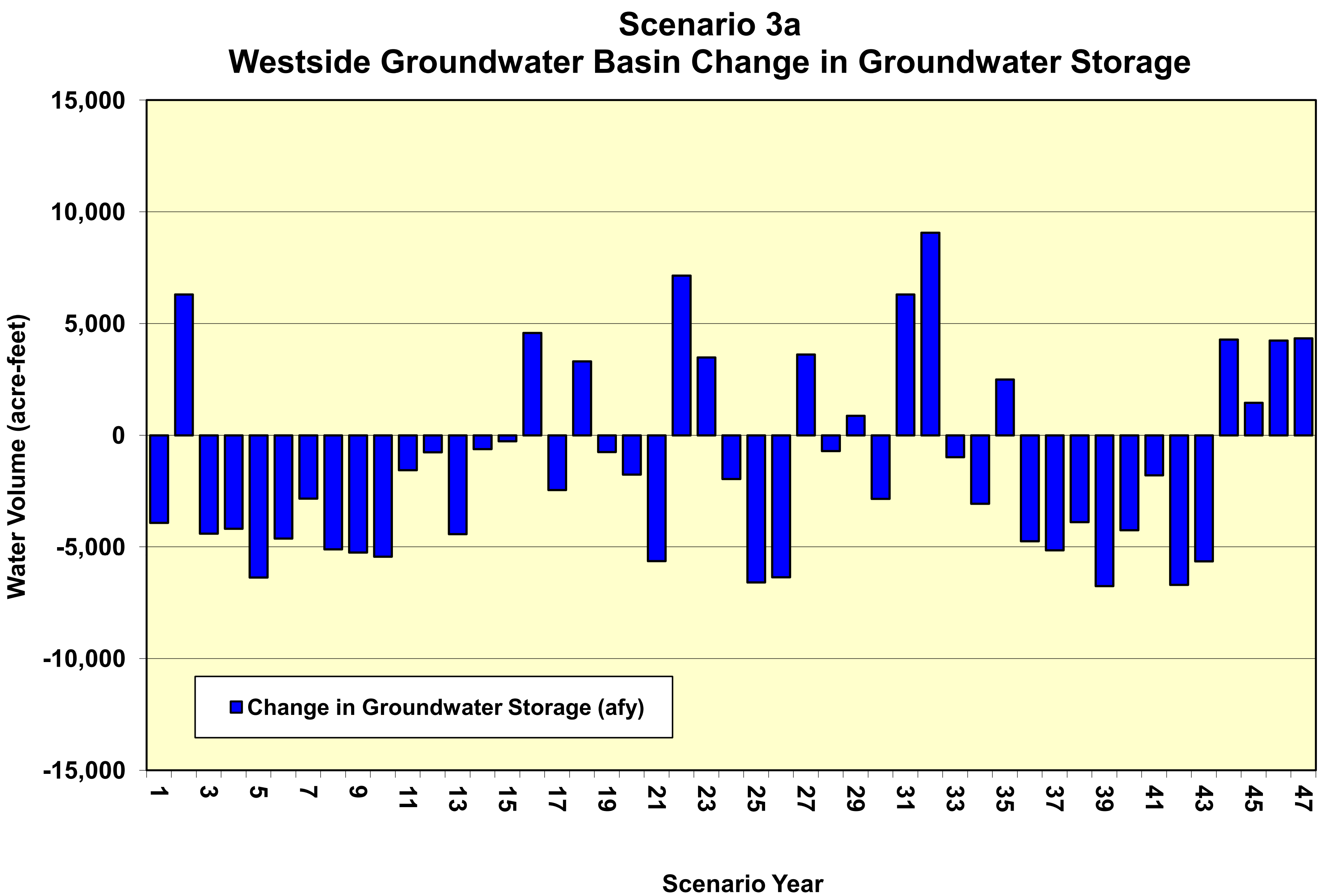
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	5	546	14,845	485	-4,415	-14,603	-712	-71	-3,919
2	7	558	24,505	517	-4,731	-13,674	-806	-72	6,303
3	11	552	13,329	601	-4,339	-13,820	-661	-73	-4,399
4	26	549	13,169	660	-3,649	-14,264	-605	-74	-4,188
5	53	549	10,129	718	-3,023	-14,179	-534	-74	-6,362
6	93	551	11,546	818	-2,639	-14,292	-628	-73	-4,624
7	127	552	12,988	881	-2,526	-14,091	-692	-72	-2,833
8	183	545	10,691	874	-2,213	-14,439	-678	-72	-5,109
9	243	549	10,235	1,035	-1,978	-14,488	-772	-70	-5,247
10	301	554	9,386	1,105	-1,802	-14,095	-814	-68	-5,432
11	349	549	13,455	1,031	-1,765	-14,254	-854	-68	-1,558
12	335	556	13,751	1,029	-1,752	-13,795	-818	-74	-766
13	409	553	10,162	1,035	-1,558	-14,136	-810	-76	-4,421
14	431	558	13,533	1,002	-1,539	-13,690	-835	-75	-616
15	463	549	14,876	941	-1,594	-14,528	-896	-81	-272
16	397	556	19,804	922	-1,872	-14,141	-999	-84	4,585
17	370	549	12,678	951	-1,721	-14,257	-930	-87	-2,447
18	361	554	18,568	928	-1,896	-14,037	-1,072	-92	3,313
19	314	553	14,531	943	-1,905	-14,084	-1,011	-96	-755
20	327	556	13,363	979	-1,836	-14,047	-1,006	-99	-1,763
21	432	548	9,310	1,031	-1,520	-14,385	-957	-93	-5,634
22	346	554	22,751	945	-2,056	-14,103	-1,193	-94	7,150
23	253	556	19,036	945	-2,299	-13,777	-1,125	-101	3,489
24	273	549	13,397	1,010	-1,985	-14,045	-1,047	-105	-1,952
25	380	549	8,479	1,057	-1,608	-14,338	-1,000	-107	-6,589
26	544	550	8,071	1,071	-1,343	-14,201	-955	-96	-6,359
27	522	552	18,354	997	-1,550	-14,106	-1,060	-96	3,614
28	469	549	14,398	961	-1,589	-14,381	-1,014	-104	-710
29	463	553	15,609	964	-1,574	-14,025	-1,014	-108	869
30	529	550	11,960	980	-1,435	-14,335	-979	-112	-2,841
31	425	556	20,974	959	-1,778	-13,604	-1,117	-115	6,301
32	291	556	24,922	933	-2,327	-13,939	-1,246	-117	9,072
33	258	545	15,668	938	-2,315	-14,773	-1,183	-120	-982
34	293	554	12,389	1,038	-1,949	-14,175	-1,097	-124	-3,068
35	302	553	18,045	1,014	-2,046	-14,037	-1,207	-127	2,496
36	337	545	11,034	1,035	-1,844	-14,629	-1,094	-128	-4,745
37	426	545	9,932	1,067	-1,557	-14,409	-1,035	-120	-5,151
38	495	554	10,605	1,058	-1,474	-13,994	-1,017	-113	-3,885
39	613	549	7,905	1,058	-1,333	-14,494	-948	-105	-6,755
40	729	556	9,935	1,037	-1,255	-14,213	-936	-99	-4,245
41	757	549	12,714	1,001	-1,297	-14,456	-963	-98	-1,793
42	949	550	7,618	974	-1,204	-14,576	-915	-95	-6,699
43	1,123	549	7,975	988	-1,115	-14,201	-872	-86	-5,640
44	957	552	18,357	943	-1,250	-14,180	-1,006	-85	4,287
45	806	545	16,490	891	-1,369	-14,746	-1,069	-93	1,457
46	637	556	18,714	904	-1,572	-13,786	-1,113	-96	4,243
47	508	545	19,422	938	-1,734	-14,055	-1,184	-99	4,340
Average (afy)	**403**	**551**	**14,034**	**940**	**-1,982**	**-14,189**	**-946**	**-93**	**-1,282**
Maximum (afy)	**1,123**	**558**	**24,922**	**1,105**	**-1,115**	**-13,604**	**-534**	**-68**	**9,072**
Minimum (afy)	**5**	**545**	**7,618**	**485**	**-4,731**	**-14,773**	**-1,246**	**-128**	**-6,755**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.



Note: Volume of some water balance components may be too small to be visible.


Scenario 3a
Westside Groundwater Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
Change in Groundwater Storage (afy)
1
3
5
7
9
11
13
15
17
19
21
23
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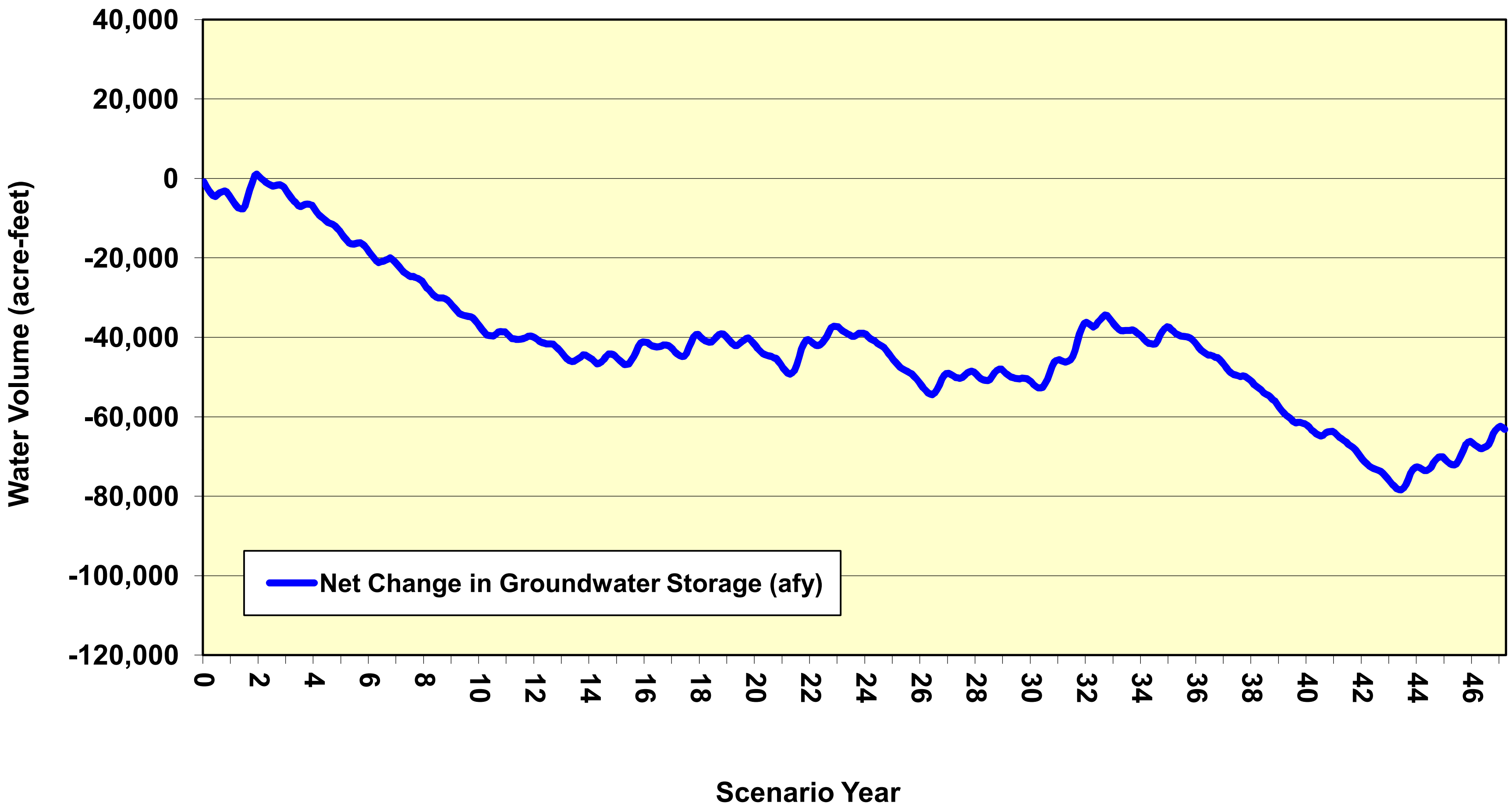
47
Scenario Year

Scenario 3a
Westside Groundwater Basin Net Change in Groundwater Storage

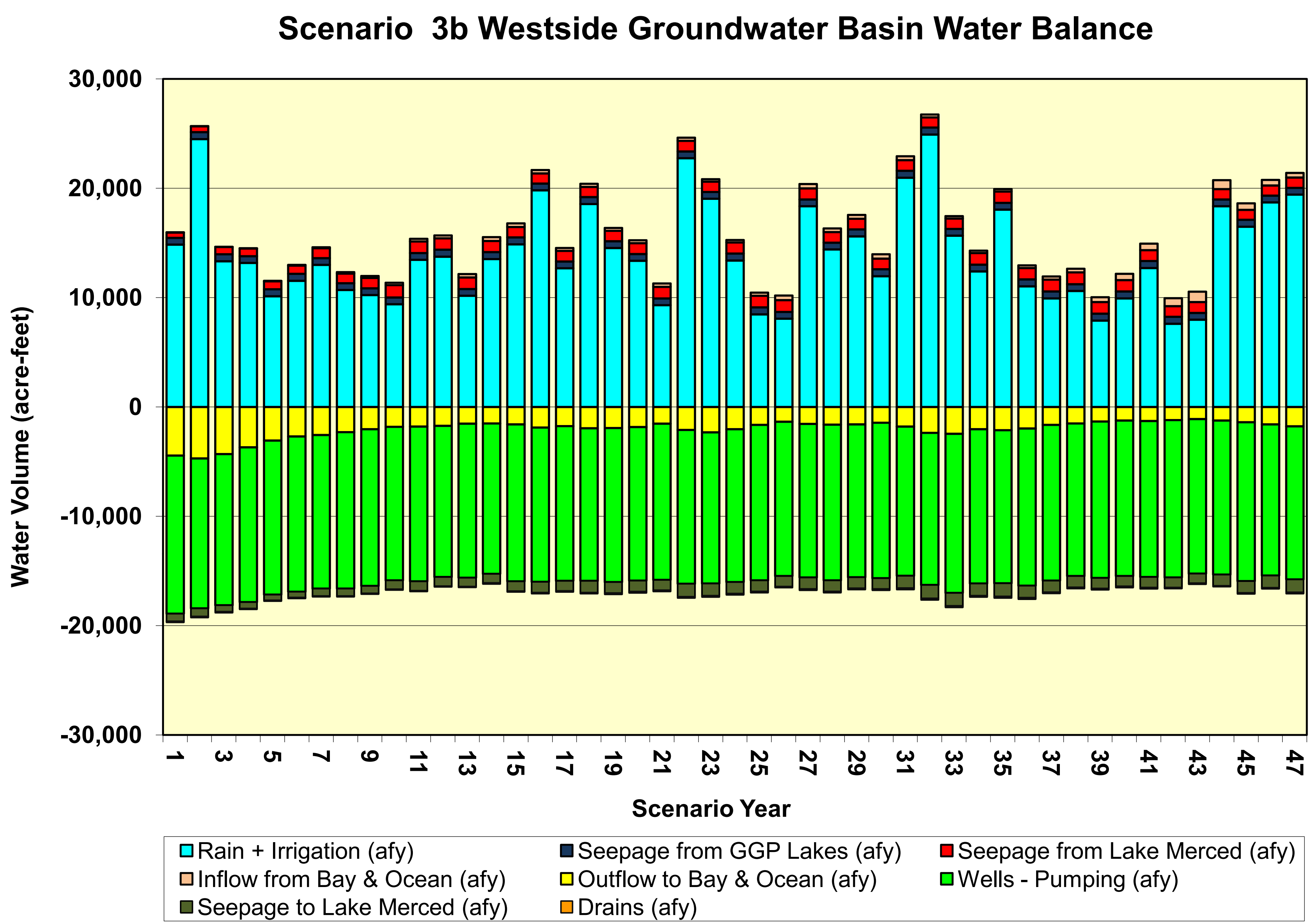


Scenario 3b Westside Groundwater Basin Water Balance Summary

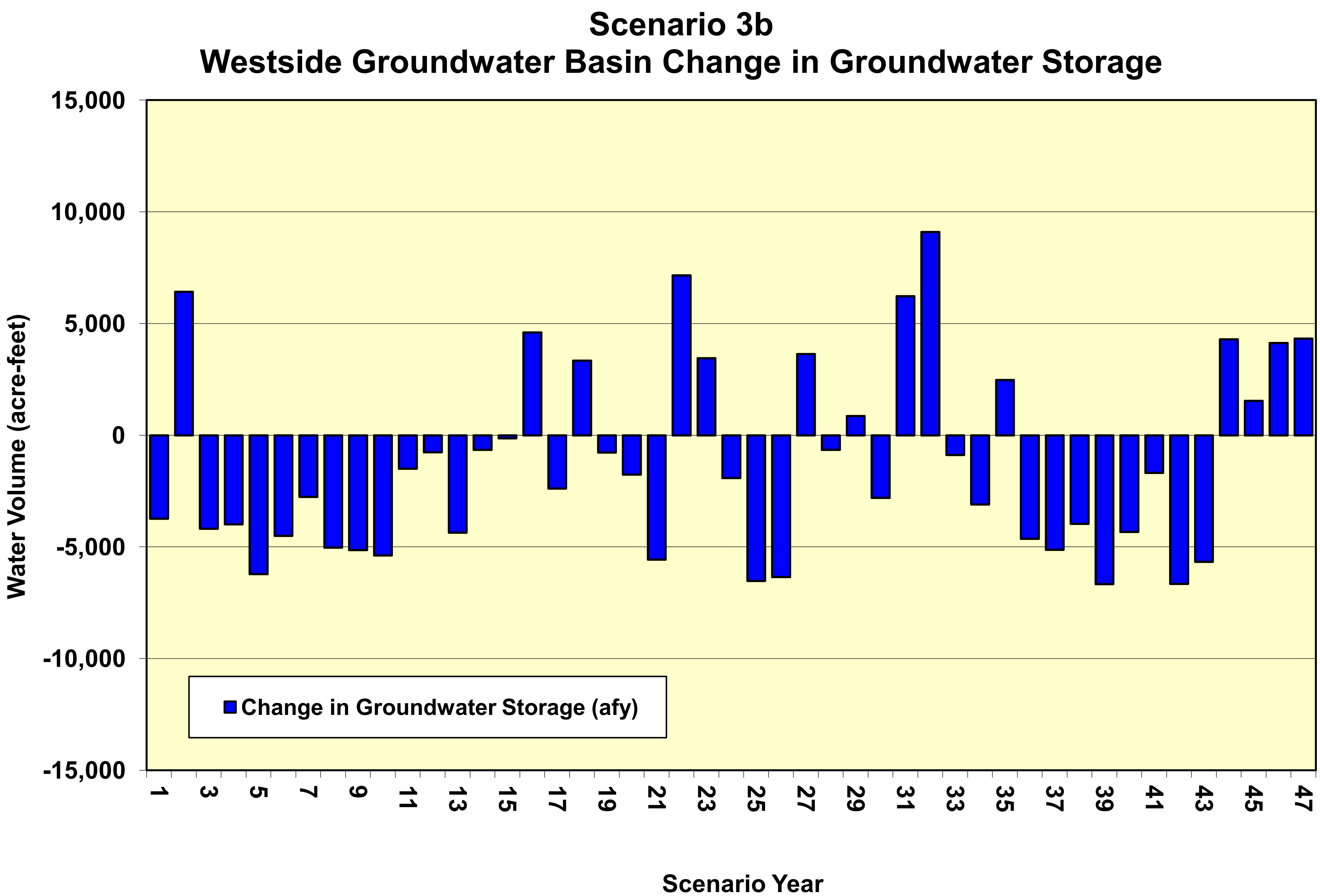
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	5	626	14,845	485	-4,455	-14,452	-713	-71	-3,730
2	6	628	24,505	532	-4,703	-13,711	-761	-72	6,423
3	9	626	13,329	664	-4,316	-13,809	-609	-73	-4,179
4	22	626	13,169	705	-3,687	-14,160	-591	-74	-3,990
5	44	626	10,129	747	-3,082	-14,074	-531	-74	-6,216
6	74	628	11,546	757	-2,702	-14,191	-541	-73	-4,502
7	101	626	12,988	896	-2,569	-14,034	-694	-72	-2,758
8	133	626	10,691	890	-2,312	-14,298	-684	-72	-5,025
9	175	626	10,235	951	-2,040	-14,332	-681	-70	-5,136
10	221	628	9,386	1,116	-1,817	-14,032	-818	-68	-5,385
11	255	626	13,455	1,045	-1,791	-14,149	-863	-68	-1,491
12	266	626	13,751	1,043	-1,737	-13,815	-827	-74	-766
13	314	626	10,162	1,048	-1,540	-14,073	-820	-76	-4,359
14	357	628	13,533	1,015	-1,509	-13,752	-846	-75	-649
15	342	626	14,876	953	-1,601	-14,340	-906	-81	-132
16	309	626	19,804	933	-1,893	-14,088	-1,008	-84	4,600
17	278	626	12,678	964	-1,756	-14,143	-940	-88	-2,380
18	278	628	18,568	939	-1,940	-13,957	-1,082	-92	3,342
19	253	626	14,531	955	-1,937	-14,078	-1,022	-96	-767
20	261	626	13,363	992	-1,840	-14,048	-1,017	-99	-1,763
21	315	626	9,310	1,044	-1,538	-14,266	-968	-93	-5,571
22	284	628	22,751	955	-2,099	-14,063	-1,203	-94	7,158
23	217	626	19,036	955	-2,329	-13,813	-1,135	-101	3,456
24	219	626	13,397	1,022	-2,045	-13,972	-1,058	-105	-1,915
25	277	626	8,479	1,069	-1,639	-14,218	-1,011	-107	-6,524
26	405	628	8,071	1,083	-1,350	-14,119	-966	-96	-6,345
27	409	626	18,354	1,008	-1,560	-14,032	-1,071	-96	3,638
28	342	626	14,398	971	-1,615	-14,241	-1,024	-104	-647
29	349	626	15,609	975	-1,590	-13,978	-1,024	-108	858
30	384	628	11,960	991	-1,453	-14,214	-990	-112	-2,806
31	350	626	20,974	969	-1,791	-13,655	-1,128	-115	6,231
32	252	626	24,922	943	-2,362	-13,905	-1,257	-117	9,102
33	200	626	15,668	949	-2,462	-14,544	-1,194	-120	-877
34	224	628	12,389	1,051	-2,035	-14,120	-1,108	-124	-3,095
35	238	626	18,045	1,025	-2,132	-13,984	-1,218	-127	2,473
36	240	626	11,034	1,047	-1,962	-14,388	-1,106	-128	-4,636
37	292	626	9,932	1,079	-1,641	-14,249	-1,047	-120	-5,127
38	347	628	10,605	1,069	-1,514	-13,955	-1,028	-113	-3,960
39	446	626	7,905	1,070	-1,341	-14,307	-960	-105	-6,666
40	572	626	9,935	1,048	-1,253	-14,212	-947	-99	-4,329
41	582	626	12,714	1,011	-1,298	-14,251	-974	-98	-1,688
42	723	628	7,618	984	-1,207	-14,383	-926	-95	-6,657
43	937	626	7,975	1,000	-1,114	-14,119	-883	-86	-5,665
44	803	626	18,357	954	-1,247	-14,091	-1,019	-86	4,297
45	610	626	16,490	901	-1,391	-14,525	-1,080	-93	1,539
46	508	626	18,714	914	-1,587	-13,825	-1,125	-96	4,130
47	416	618	19,422	949	-1,765	-14,011	-1,196	-99	4,333
Average (afy)	**312**	**626**	**14,034**	**950**	**-2,012**	**-14,106**	**-949**	**-93**	**-1,237**
Maximum (afy)	**937**	**628**	**24,922**	**1,116**	**-1,114**	**-13,655**	**-531**	**-68**	**9,102**
Minimum (afy)	**5**	**618**	**7,618**	**485**	**-4,703**	**-14,544**	**-1,257**	**-128**	**-6,666**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.



Note: Volume of some water balance components may be too small to be visible.


Scenario 3b
Westside Groundwater Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
Change in Groundwater Storage (afy)
1
3
5
7
9
11
13
15
17
19
21
23
25
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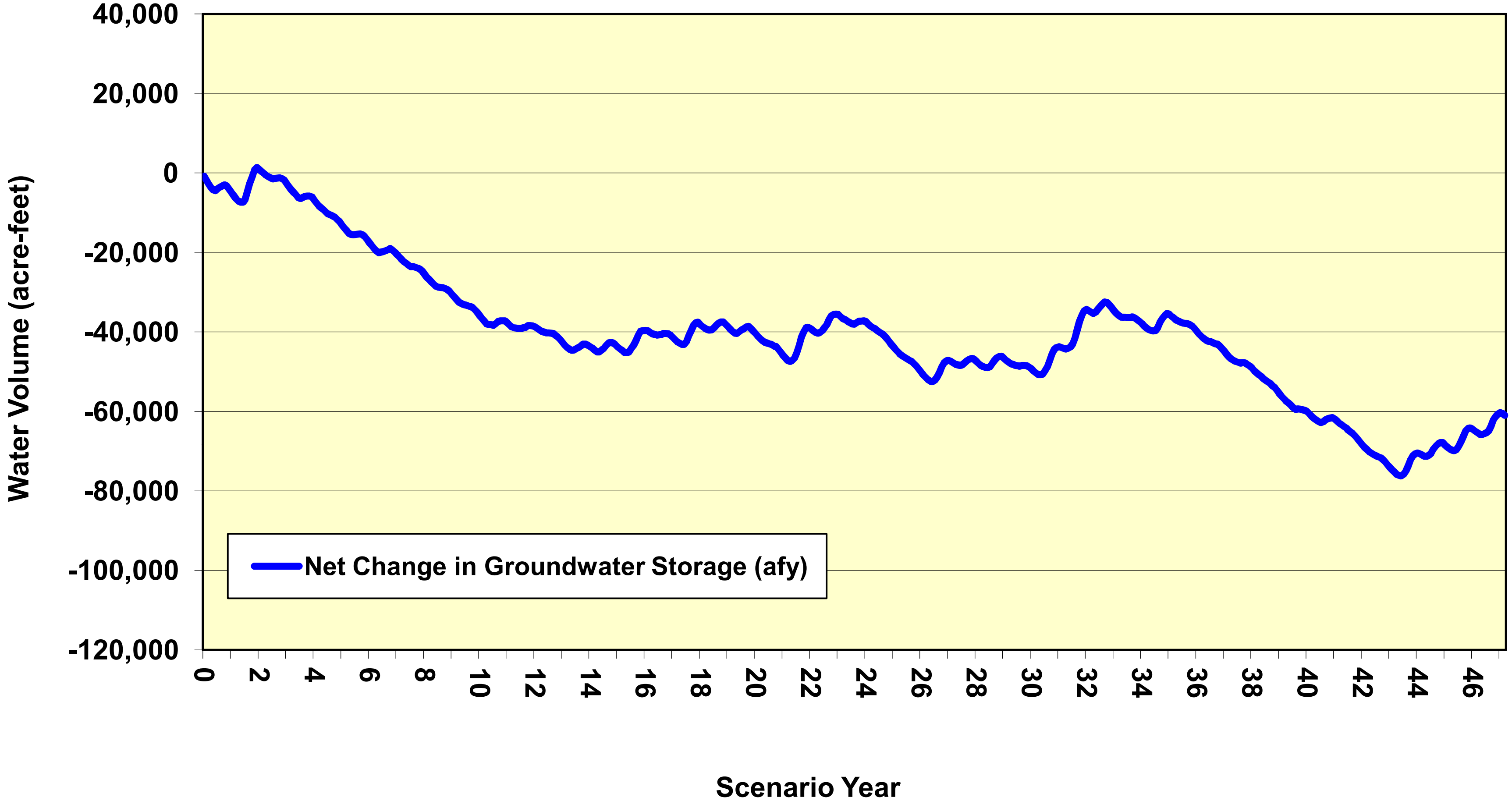
47
Scenario Year

Scenario 3b
Westside Groundwater Basin Net Change in Groundwater Storage

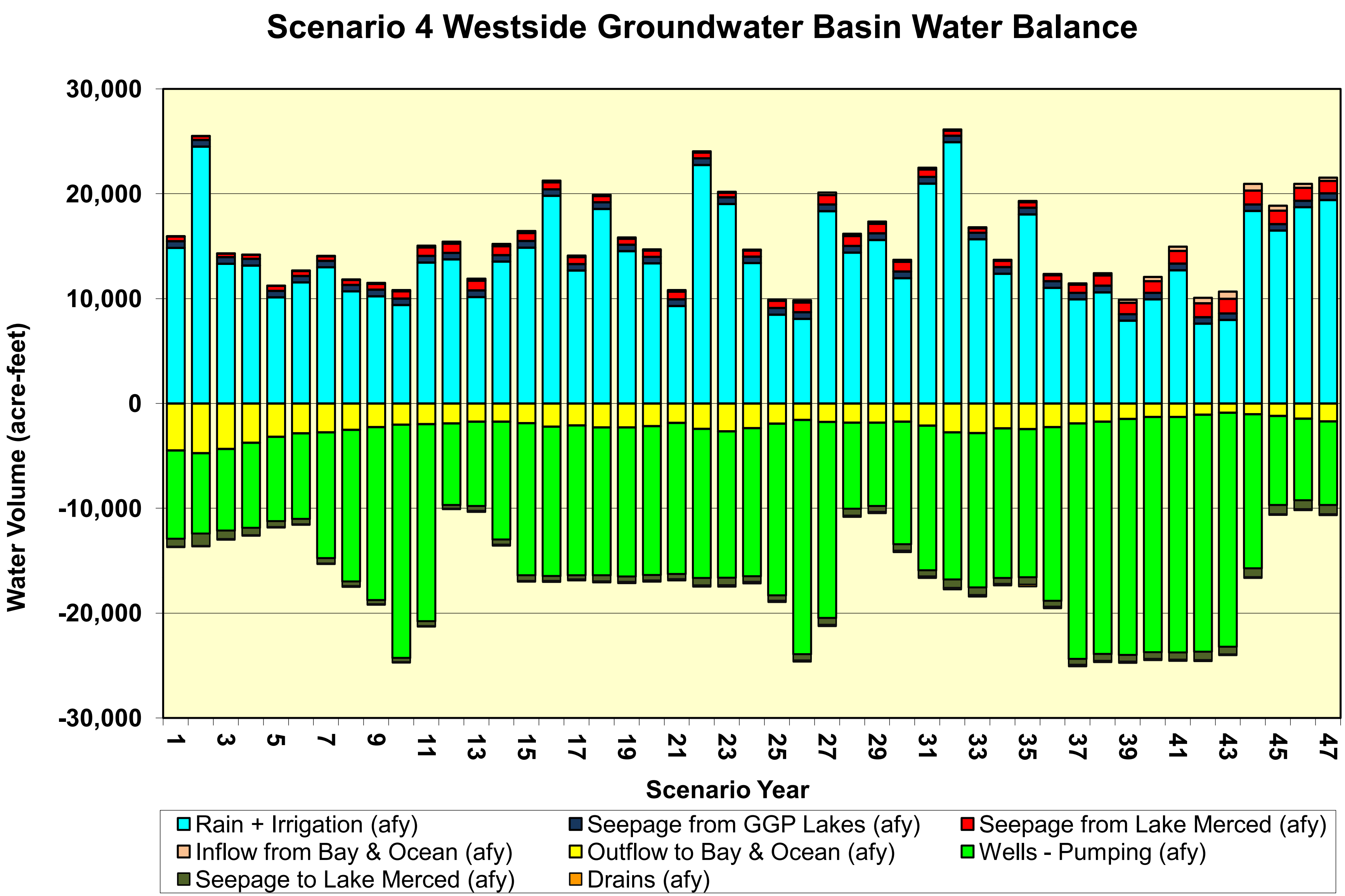


Scenario 4 Westside Groundwater Basin Water Balance Summary

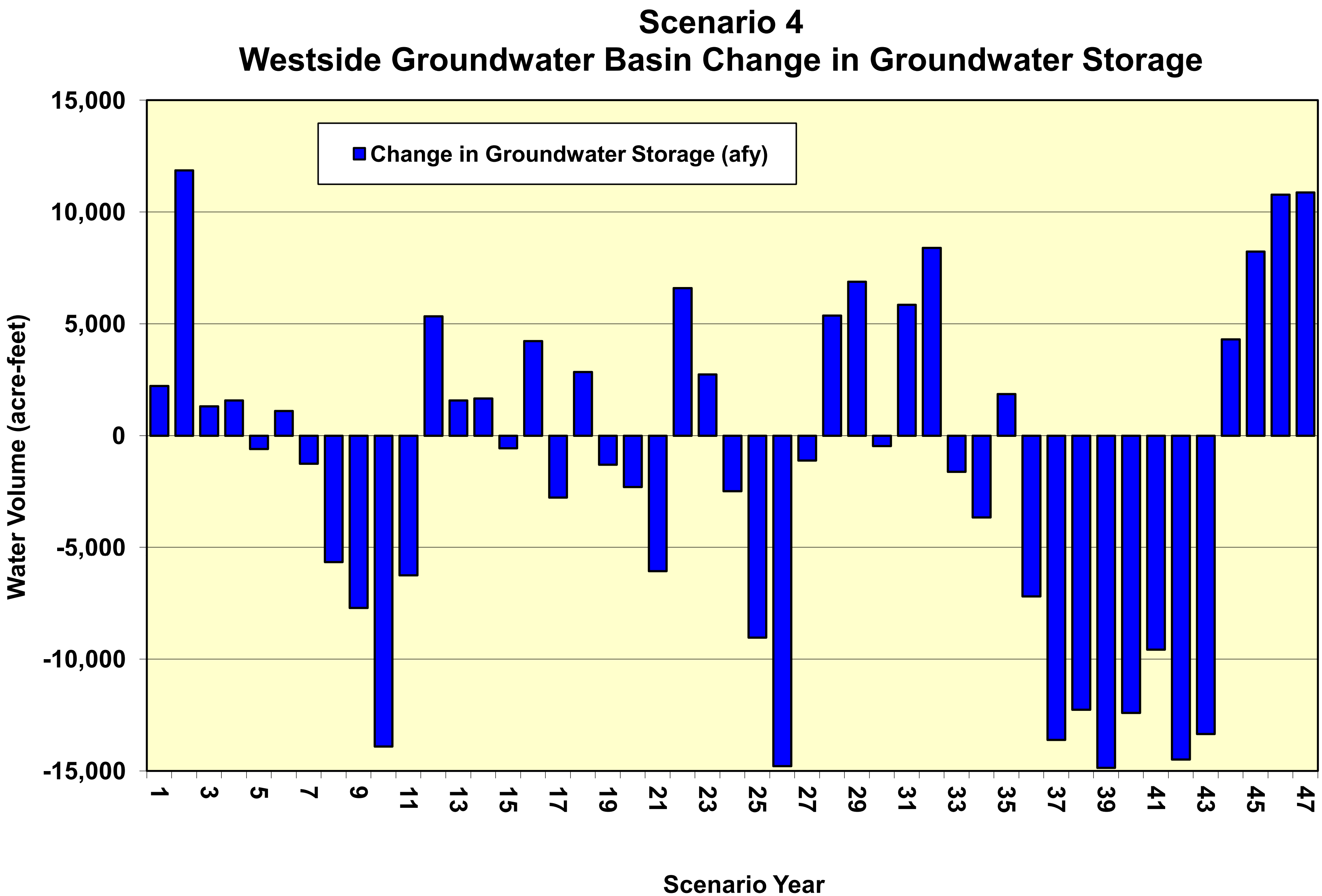
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	5	626	14,845	460	-4,466	-8,435	-737	-71	2,226
2	5	628	24,505	363	-4,735	-7,671	-1,156	-72	11,867
3	5	626	13,329	336	-4,339	-7,771	-803	-74	1,309
4	9	626	13,169	394	-3,732	-8,135	-676	-75	1,579
5	17	626	10,129	460	-3,166	-8,046	-543	-77	-600
6	31	628	11,546	471	-2,834	-8,167	-495	-77	1,103
7	41	626	12,988	422	-2,750	-12,007	-492	-78	-1,250
8	57	626	10,691	465	-2,513	-14,458	-440	-81	-5,653
9	85	626	10,235	558	-2,243	-16,509	-374	-84	-7,707
10	122	628	9,386	687	-2,009	-22,245	-384	-85	-13,901
11	170	626	13,455	797	-1,957	-18,815	-433	-87	-6,245
12	191	626	13,751	870	-1,899	-7,778	-325	-94	5,341
13	204	626	10,162	921	-1,728	-8,045	-462	-98	1,579
14	213	628	13,533	846	-1,740	-11,230	-485	-99	1,666
15	190	626	14,876	752	-1,878	-14,502	-517	-110	-565
16	166	626	19,804	665	-2,203	-14,243	-468	-117	4,230
17	139	626	12,678	666	-2,085	-14,299	-375	-125	-2,774
18	138	628	18,568	584	-2,278	-14,107	-559	-131	2,842
19	117	626	14,531	567	-2,274	-14,232	-500	-137	-1,303
20	118	626	13,363	594	-2,166	-14,202	-488	-142	-2,297
21	151	626	9,310	731	-1,836	-14,427	-477	-135	-6,057
22	136	628	22,751	546	-2,417	-14,217	-693	-136	6,597
23	91	626	19,036	444	-2,653	-13,958	-703	-145	2,738
24	90	626	13,397	555	-2,345	-14,123	-537	-150	-2,486
25	124	626	8,479	686	-1,907	-16,392	-491	-152	-9,029
26	213	628	8,071	936	-1,563	-22,336	-584	-140	-14,778
27	247	626	18,354	900	-1,758	-18,694	-647	-138	-1,110
28	216	626	14,398	955	-1,819	-8,218	-646	-146	5,366
29	200	626	15,609	914	-1,823	-7,947	-543	-150	6,886
30	195	628	11,960	919	-1,719	-11,707	-589	-154	-467
31	170	626	20,974	721	-2,117	-13,794	-567	-158	5,854
32	111	626	24,922	475	-2,736	-14,052	-783	-162	8,400
33	79	626	15,668	428	-2,826	-14,713	-713	-167	-1,618
34	90	628	12,389	591	-2,365	-14,276	-547	-171	-3,661
35	99	626	18,045	537	-2,447	-14,135	-685	-176	1,864
36	100	626	11,034	588	-2,258	-16,566	-536	-177	-7,188
37	137	626	9,932	773	-1,898	-22,469	-541	-164	-13,603
38	197	628	10,605	988	-1,719	-22,165	-641	-153	-12,261
39	277	626	7,905	1,082	-1,457	-22,529	-614	-141	-14,852
40	386	626	9,935	1,119	-1,280	-22,433	-622	-131	-12,399
41	415	626	12,714	1,216	-1,278	-22,470	-669	-128	-9,573
42	511	628	7,618	1,320	-1,075	-22,607	-761	-121	-14,486
43	681	626	7,975	1,390	-866	-22,321	-718	-108	-13,342
44	629	626	18,357	1,334	-1,018	-14,704	-814	-103	4,307
45	479	626	16,490	1,277	-1,188	-8,494	-844	-107	8,239
46	384	626	18,714	1,228	-1,445	-7,789	-831	-107	10,780
47	300	618	19,422	1,190	-1,706	-7,982	-857	-107	10,878
Average (AFY)	**186**	**626**	**14,034**	**760**	**-2,181**	**-14,264**	**-603**	**-122**	**-1,565**
Maximum (AFY)	**681**	**628**	**24,922**	**1,390**	**-866**	**-7,671**	**-325**	**-71**	**11,867**
Minimum (AFY)	**5**	**618**	**7,618**	**336**	**-4,735**	**-22,607**	**-1,156**	**-177**	**-14,852**

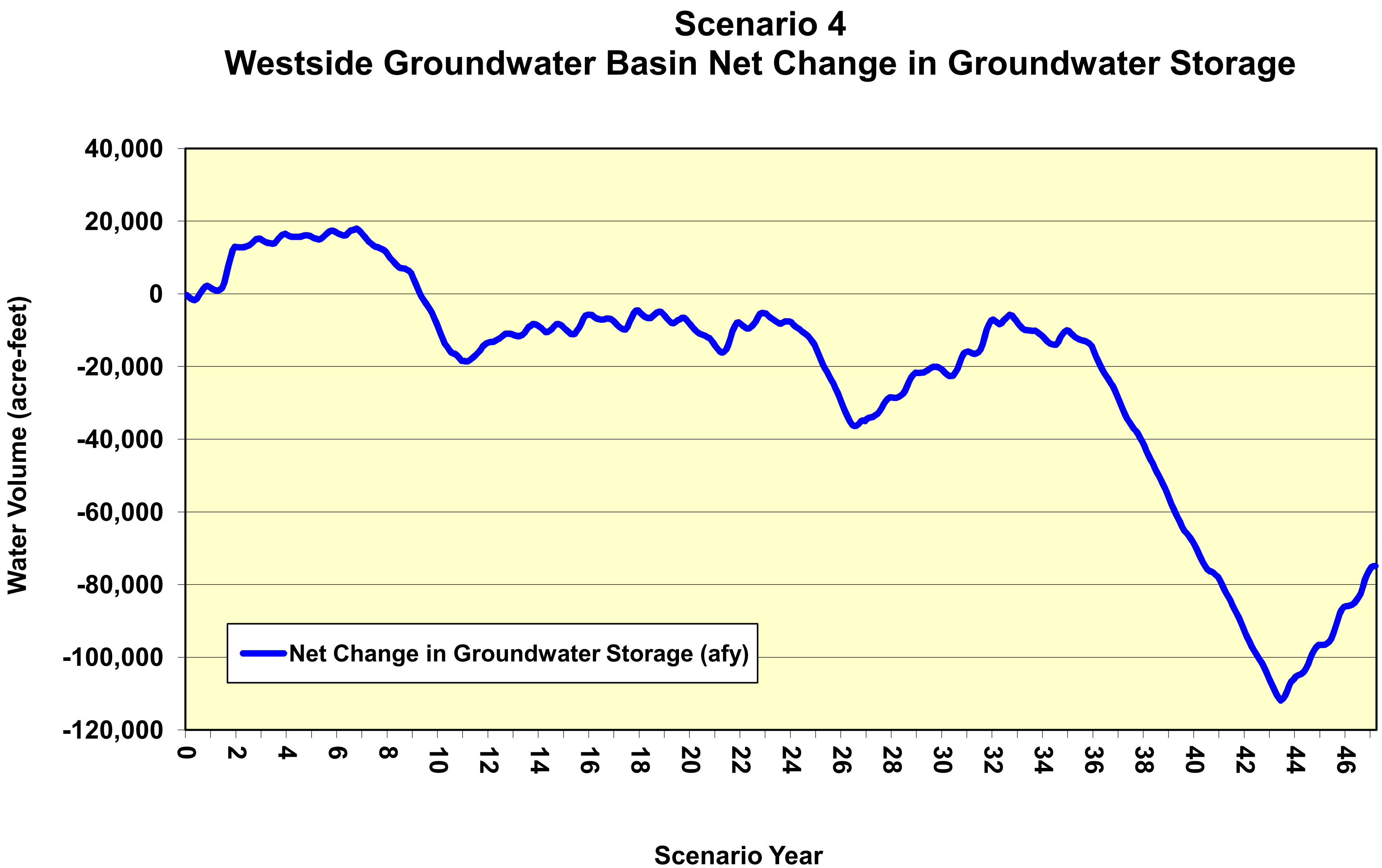
Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.



Note: Volume of some water balance components may be too small to be visible.


Scenario 4
Westside Groundwater Basin Change in Groundwater Storage
Change in Groundwater Storage (afy)
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year



Scenario 4
Westside Groundwater Basin Net Change in Groundwater Storage
Water Volume (acre-feet)
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
-100,000
-120,000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
Net Change in Groundwater Storage (afy)
Scenario Year

Attachment 10.1-D

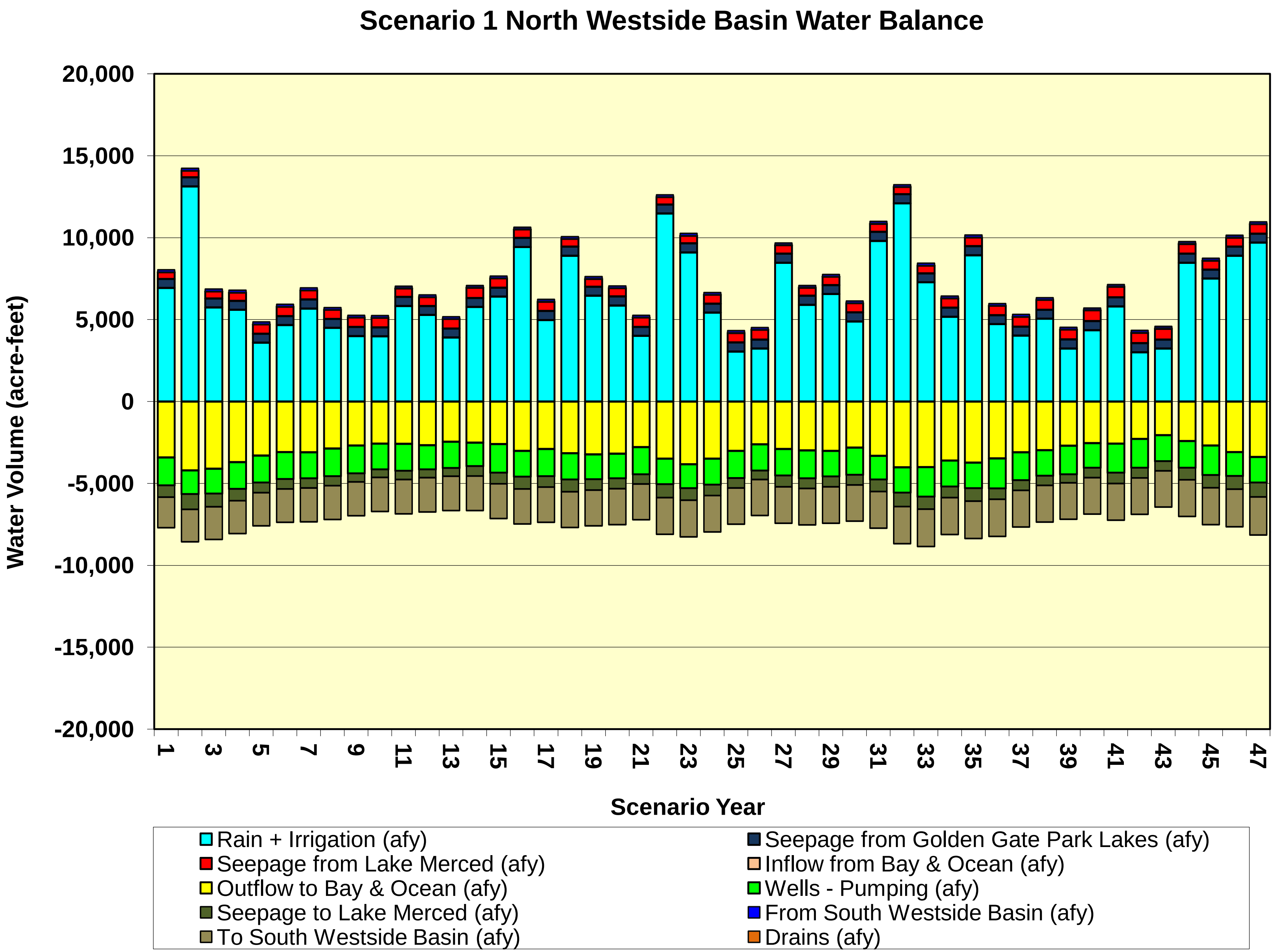
Model Scenario Water Balance Results – North and South Westside Basins

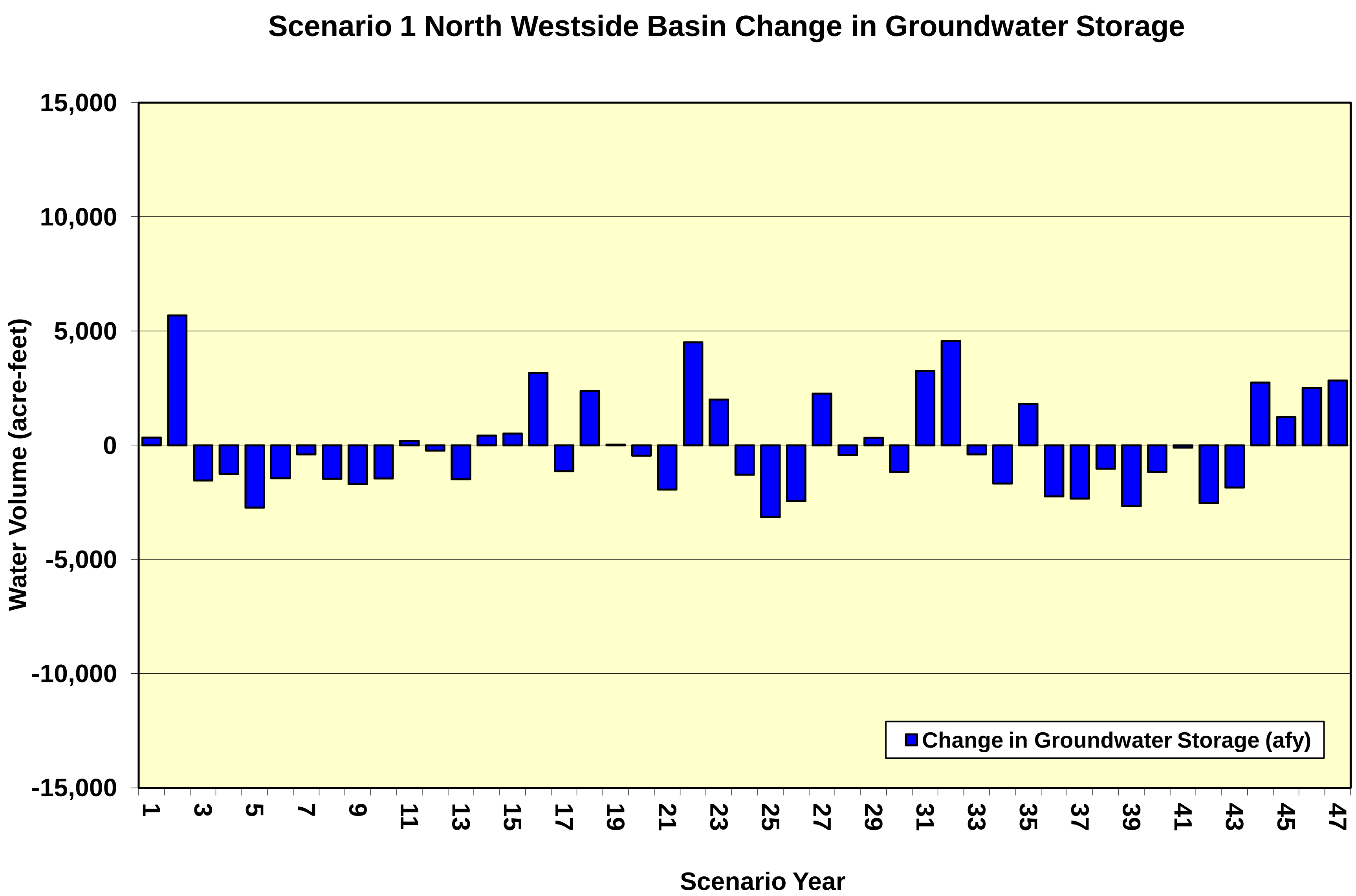
Scenario 1 North Westside Basin Water Balance Summary

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From South to North Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From North to South Westside Basin (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	2	546	6,941	421	134	-3,406	-1,716	-711	-1,870	0	341
2	2	558	13,135	406	138	-4,193	-1,457	-933	-1,972	0	5,684
3	2	552	5,749	425	146	-4,100	-1,523	-800	-1,986	0	-1,535
4	2	549	5,610	499	142	-3,703	-1,635	-707	-2,004	0	-1,248
5	2	549	3,598	572	138	-3,291	-1,648	-625	-2,022	0	-2,726
6	2	551	4,673	572	134	-3,079	-1,649	-601	-2,041	0	-1,438
7	2	552	5,687	562	132	-3,103	-1,586	-582	-2,065	0	-401
8	3	545	4,503	557	131	-2,862	-1,703	-562	-2,071	0	-1,459
9	3	549	4,009	573	129	-2,682	-1,709	-509	-2,067	0	-1,703
10	3	554	3,982	587	126	-2,558	-1,590	-479	-2,075	0	-1,450
11	4	549	5,843	524	124	-2,580	-1,651	-527	-2,093	0	195
12	4	556	5,286	540	124	-2,661	-1,486	-492	-2,099	0	-228
13	5	553	3,915	580	124	-2,457	-1,597	-506	-2,095	0	-1,479
14	7	558	5,773	626	123	-2,505	-1,431	-608	-2,111	0	432
15	8	549	6,407	574	123	-2,587	-1,760	-675	-2,117	0	521
16	8	556	9,441	518	125	-3,009	-1,578	-739	-2,149	0	3,172
17	5	549	4,984	569	129	-2,893	-1,663	-666	-2,144	0	-1,131
18	5	554	8,904	478	127	-3,153	-1,604	-754	-2,178	0	2,380
19	4	553	6,466	472	130	-3,227	-1,522	-648	-2,190	0	38
20	4	556	5,871	501	130	-3,178	-1,513	-629	-2,194	0	-453
21	4	548	4,017	570	128	-2,779	-1,663	-584	-2,182	0	-1,940
22	4	554	11,482	454	126	-3,486	-1,564	-820	-2,237	0	4,513
23	3	556	9,106	464	133	-3,821	-1,465	-733	-2,244	0	2,000
24	3	549	5,433	540	135	-3,483	-1,595	-650	-2,225	0	-1,291
25	3	549	3,062	582	131	-3,010	-1,669	-590	-2,207	0	-3,149
26	4	550	3,238	600	126	-2,610	-1,603	-548	-2,197	0	-2,440
27	5	552	8,480	526	124	-2,899	-1,621	-681	-2,224	0	2,263
28	5	549	5,916	493	127	-2,986	-1,697	-615	-2,222	0	-429
29	5	553	6,566	505	128	-3,004	-1,571	-625	-2,227	0	330
30	5	550	4,895	557	128	-2,805	-1,671	-615	-2,212	0	-1,167
31	5	556	9,806	499	127	-3,311	-1,443	-739	-2,240	0	3,259
32	3	556	12,107	443	133	-4,011	-1,556	-836	-2,269	0	4,570
33	3	545	7,280	475	139	-3,996	-1,811	-761	-2,274	0	-400
34	3	554	5,178	572	138	-3,604	-1,582	-671	-2,255	0	-1,667
35	3	553	8,941	532	135	-3,733	-1,561	-779	-2,279	0	1,811
36	3	545	4,727	575	136	-3,463	-1,838	-662	-2,260	0	-2,236
37	3	545	4,032	604	132	-3,095	-1,711	-606	-2,242	0	-2,337
38	3	554	5,061	591	128	-2,967	-1,564	-586	-2,241	0	-1,022
39	4	549	3,248	605	126	-2,695	-1,744	-525	-2,225	0	-2,656
40	6	556	4,359	666	122	-2,529	-1,513	-599	-2,229	0	-1,160
41	8	549	5,814	652	122	-2,563	-1,779	-663	-2,234	0	-95
42	12	550	3,017	643	121	-2,280	-1,762	-615	-2,217	0	-2,531
43	17	549	3,238	665	118	-2,045	-1,603	-580	-2,210	0	-1,850
44	19	552	8,481	593	117	-2,403	-1,640	-726	-2,243	0	2,750
45	16	545	7,522	541	122	-2,677	-1,804	-774	-2,261	0	1,230
46	13	556	8,902	557	125	-3,081	-1,459	-812	-2,290	0	2,512
47	8	545	9,712	582	129	-3,384	-1,565	-875	-2,313	0	2,840
Average (afy)	**5**	**551**	**6,264**	**546**	**129**	**-3,063**	**-1,619**	**-660**	**-2,170**	**0**	**-17**
Maximum (afy)	**19**	**558**	**13,135**	**666**	**146**	**-2,045**	**-1,431**	**-479**	**-1,870**	**0**	**5,684**
Minimum (afy)	**2**	**545**	**3,017**	**406**	**117**	**-4,193**	**-1,838**	**-933**	**-2,313**	**0**	**-3,149**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.


Scenario 1 North Westside Basin Water Balance
Water Volume (acre-feet)
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Rain + Irrigation (afy)
Seepage from Golden Gate Park Lakes (afy)
Seepage from Lake Merced (afy)
Inflow from Bay & Ocean (afy)
Outflow to Bay & Ocean (afy)
Wells - Pumping (afy)
Seepage to Lake Merced (afy)
From South Westside Basin (afy)
To South Westside Basin (afy)
Drains (afy)



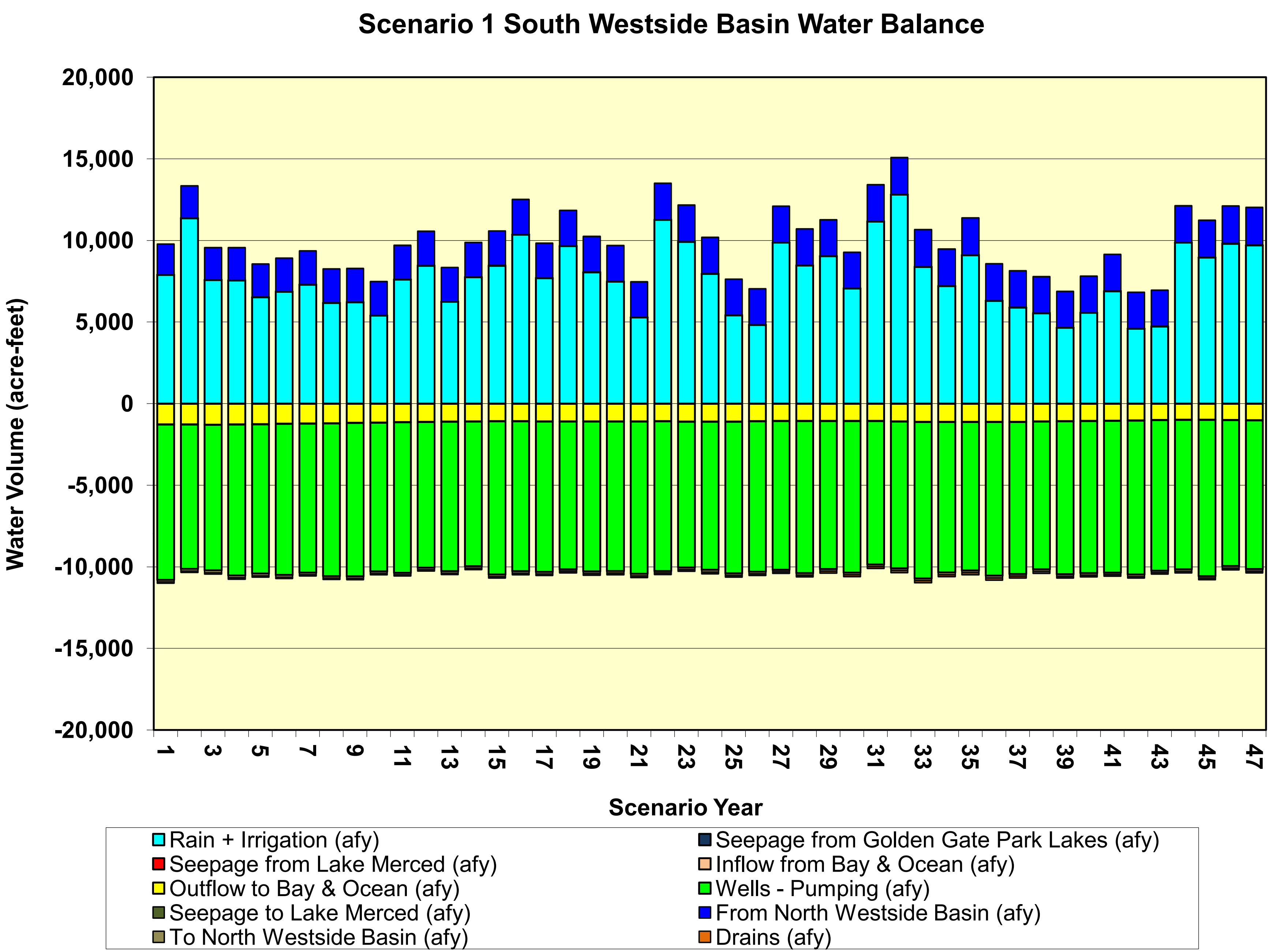
Scenario 1 North Westside Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Change in Groundwater Storage (afy)

Scenario 1 South Westside Basin Water Balance Summary

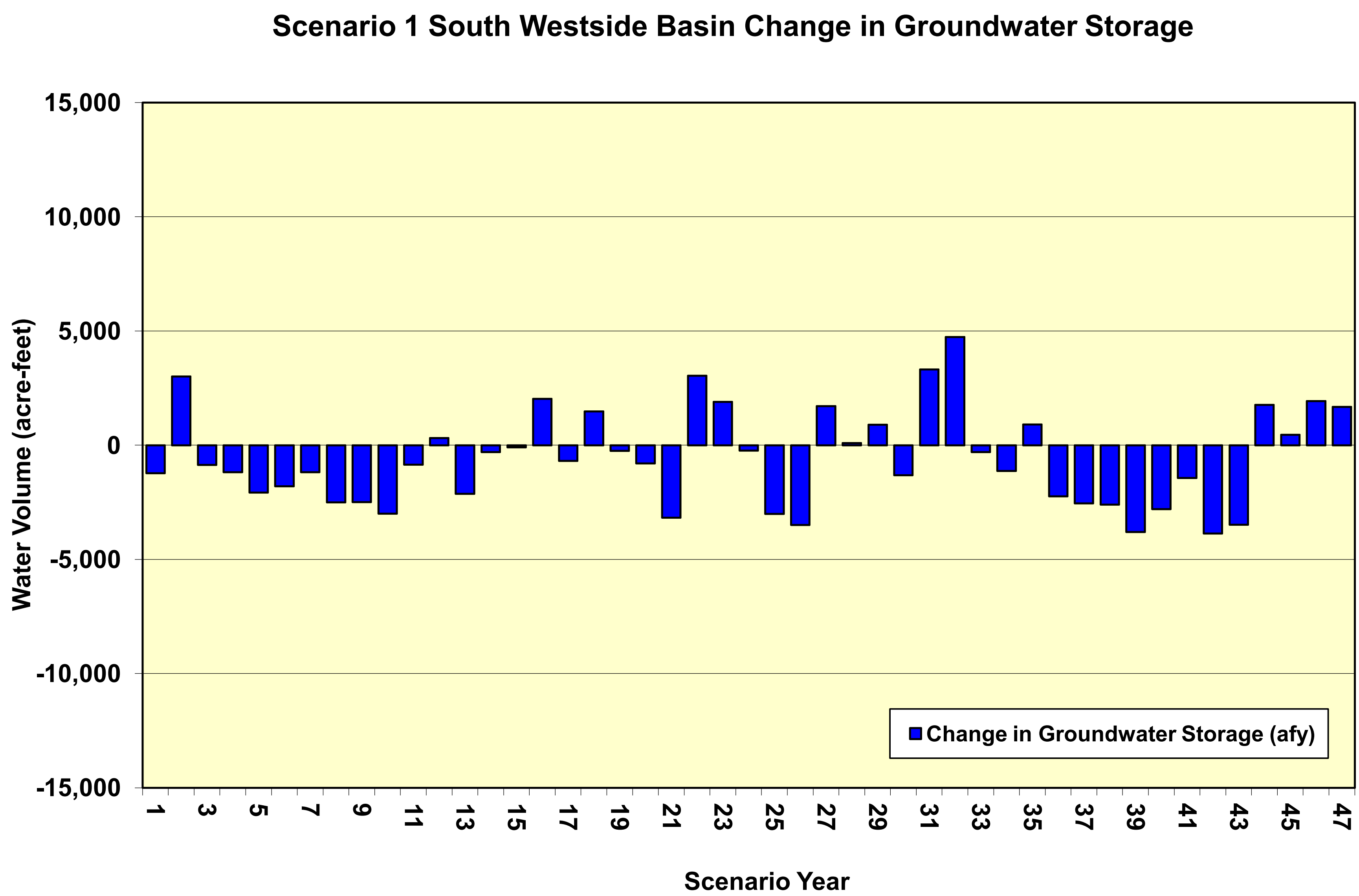
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From North to South Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From South to North Westside Basin (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	3	0	7,904	0	1,870	-1,276	-9,513	0	-134	-71	-1,217
2	3	0	11,370	0	1,972	-1,278	-8,842	0	-138	-72	3,014
3	3	0	7,580	0	1,986	-1,291	-8,922	0	-146	-73	-862
4	3	0	7,559	0	2,004	-1,277	-9,252	0	-142	-74	-1,180
5	3	0	6,531	0	2,022	-1,257	-9,157	0	-138	-74	-2,071
6	3	0	6,873	0	2,041	-1,233	-9,268	0	-134	-73	-1,791
7	3	0	7,302	0	2,065	-1,215	-9,131	0	-132	-72	-1,180
8	3	0	6,188	0	2,071	-1,199	-9,362	0	-131	-71	-2,502
9	3	0	6,225	0	2,067	-1,178	-9,405	0	-129	-70	-2,486
10	3	0	5,405	0	2,075	-1,154	-9,130	0	-126	-68	-2,996
11	3	0	7,611	0	2,093	-1,133	-9,228	0	-124	-68	-847
12	3	0	8,465	0	2,099	-1,118	-8,934	0	-124	-74	317
13	3	0	6,247	0	2,095	-1,103	-9,164	0	-124	-76	-2,121
14	4	0	7,760	0	2,111	-1,086	-8,884	0	-123	-75	-294
15	4	0	8,469	0	2,117	-1,078	-9,394	0	-123	-81	-86
16	4	0	10,364	0	2,149	-1,079	-9,188	0	-125	-84	2,041
17	4	0	7,695	0	2,144	-1,085	-9,220	0	-129	-88	-679
18	5	0	9,663	0	2,178	-1,084	-9,059	0	-127	-92	1,483
19	5	0	8,066	0	2,190	-1,092	-9,188	0	-130	-96	-246
20	5	0	7,492	0	2,194	-1,091	-9,159	0	-130	-100	-789
21	5	0	5,293	0	2,182	-1,081	-9,348	0	-128	-93	-3,169
22	6	0	11,269	0	2,237	-1,080	-9,165	0	-126	-94	3,047
23	6	0	9,930	0	2,244	-1,100	-8,937	0	-133	-101	1,908
24	6	0	7,964	0	2,225	-1,107	-9,075	0	-135	-106	-228
25	6	0	5,416	0	2,207	-1,096	-9,294	0	-131	-107	-2,998
26	7	0	4,834	0	2,197	-1,076	-9,224	0	-126	-96	-3,484
27	7	0	9,875	0	2,224	-1,062	-9,111	0	-124	-96	1,713
28	8	0	8,482	0	2,222	-1,066	-9,310	0	-127	-105	104
29	8	0	9,043	0	2,227	-1,064	-9,078	0	-128	-109	898
30	8	0	7,065	0	2,212	-1,060	-9,290	0	-128	-112	-1,306
31	8	0	11,168	0	2,240	-1,060	-8,786	0	-127	-115	3,327
32	8	0	12,815	0	2,269	-1,086	-9,008	0	-133	-118	4,747
33	8	0	8,388	0	2,274	-1,119	-9,587	0	-139	-121	-296
34	8	0	7,212	0	2,255	-1,121	-9,218	0	-138	-125	-1,126
35	8	0	9,104	0	2,279	-1,118	-9,102	0	-135	-128	910
36	8	0	6,306	0	2,260	-1,122	-9,417	0	-136	-129	-2,230
37	8	0	5,900	0	2,242	-1,110	-9,324	0	-132	-121	-2,537
38	8	0	5,544	0	2,241	-1,094	-9,056	0	-128	-114	-2,598
39	8	0	4,657	0	2,225	-1,079	-9,375	0	-126	-106	-3,796
40	9	0	5,576	0	2,229	-1,059	-9,327	0	-122	-100	-2,794
41	9	0	6,900	0	2,234	-1,044	-9,302	0	-122	-100	-1,424
42	10	0	4,601	0	2,217	-1,030	-9,440	0	-121	-96	-3,859
43	11	0	4,737	0	2,210	-1,007	-9,224	0	-118	-87	-3,478
44	12	0	9,876	0	2,243	-990	-9,166	0	-117	-87	1,772
45	13	0	8,968	0	2,261	-994	-9,567	0	-122	-95	465
46	14	0	9,812	0	2,290	-1,002	-8,953	0	-125	-98	1,938
47	15	0	9,710	0	2,313	-1,013	-9,116	0	-129	-101	1,678
Average (afy)	**6**	**0**	**7,770**	**0**	**2,170**	**-1,110**	**-9,196**	**0**	**-129**	**-94**	**-581**
Maximum (afy)	**15**	**0**	**12,815**	**0**	**2,313**	**-990**	**-8,786**	**0**	**-117**	**-68**	**4,747**
Minimum (afy)	**3**	**0**	**4,601**	**0**	**1,870**	**-1,291**	**-9,587**	**0**	**-146**	**-129**	**-3,859**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.



Scenario 1 South Westside Basin Water Balance
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Rain + Irrigation (afy)
Seepage from Golden Gate Park Lakes (afy)
Seepage from Lake Merced (afy)
Inflow from Bay & Ocean (afy)
Outflow to Bay & Ocean (afy)
Wells - Pumping (afy)
Seepage to Lake Merced (afy)
From North Westside Basin (afy)
To North Westside Basin (afy)
Drains (afy)



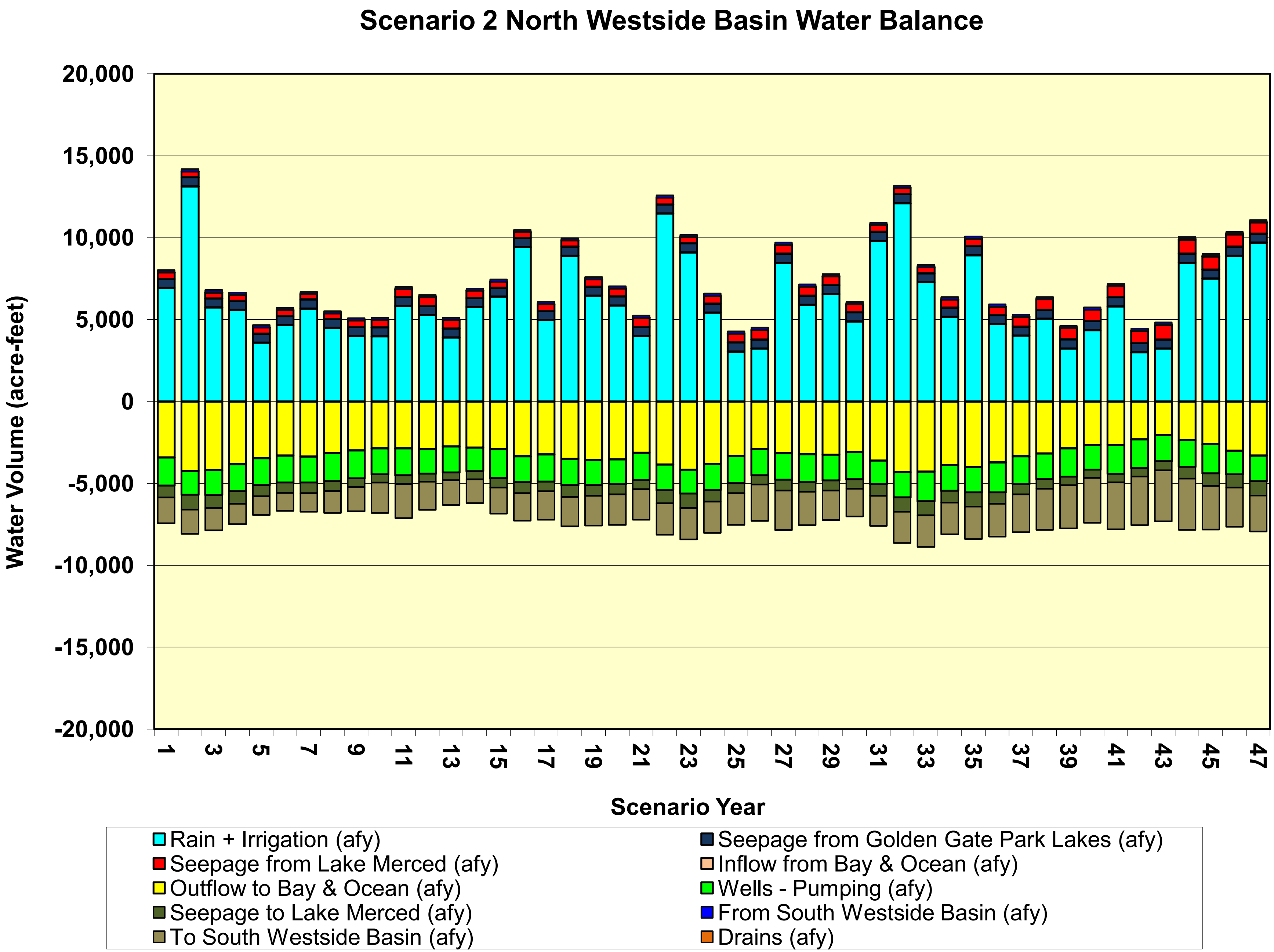
Scenario 1 South Westside Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
Change in Groundwater Storage (afy)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year

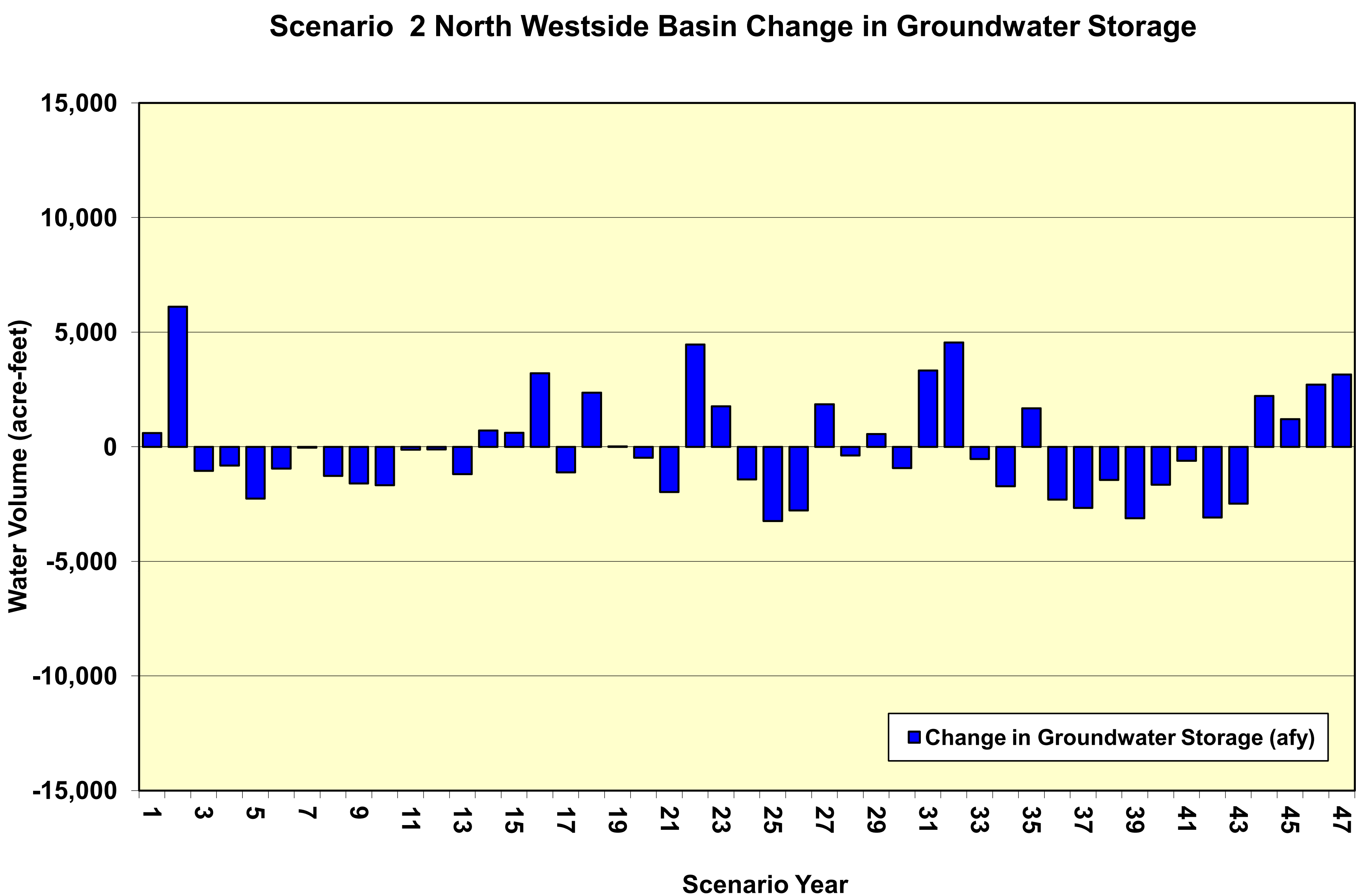
Scenario 2 North Westside Basin Water Balance Summary

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From South to North Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From North to South Westside Basin (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	2	546	6,941	409	134	-3,414	-1,716	-713	-1,587	0	601
2	2	558	13,135	363	139	-4,234	-1,457	-897	-1,487	0	6,122
3	2	552	5,749	360	146	-4,188	-1,523	-789	-1,354	0	-1,044
4	2	549	5,610	358	143	-3,834	-1,635	-762	-1,248	0	-817
5	2	549	3,598	389	140	-3,458	-1,648	-666	-1,160	0	-2,253
6	2	551	4,673	368	136	-3,289	-1,649	-641	-1,093	0	-943
7	2	552	5,687	325	134	-3,356	-1,586	-655	-1,130	0	-28
8	2	545	4,503	344	134	-3,142	-1,703	-616	-1,329	0	-1,261
9	2	549	4,009	399	131	-2,974	-1,709	-542	-1,464	0	-1,598
10	2	554	3,982	461	129	-2,854	-1,590	-496	-1,856	0	-1,668
11	3	549	5,843	474	127	-2,850	-1,651	-536	-2,077	0	-118
12	3	556	5,286	534	126	-2,910	-1,486	-491	-1,723	0	-104
13	2	553	3,915	519	126	-2,730	-1,597	-474	-1,502	0	-1,189
14	2	558	5,773	448	124	-2,811	-1,431	-506	-1,445	0	713
15	2	549	6,407	371	125	-2,913	-1,760	-573	-1,587	0	620
16	2	556	9,441	352	127	-3,341	-1,578	-665	-1,683	0	3,211
17	2	549	4,984	425	131	-3,231	-1,663	-584	-1,725	0	-1,113
18	2	554	8,904	389	129	-3,496	-1,604	-717	-1,793	0	2,371
19	2	553	6,466	447	133	-3,575	-1,522	-649	-1,828	0	27
20	2	556	5,871	487	132	-3,527	-1,513	-627	-1,853	0	-472
21	2	548	4,017	549	130	-3,126	-1,663	-563	-1,859	0	-1,964
22	2	554	11,482	427	128	-3,834	-1,564	-803	-1,925	0	4,468
23	2	556	9,106	388	136	-4,160	-1,465	-869	-1,926	0	1,769
24	2	549	5,433	471	138	-3,798	-1,595	-712	-1,907	0	-1,419
25	2	549	3,062	547	133	-3,314	-1,669	-611	-1,928	0	-3,229
26	3	550	3,238	594	128	-2,900	-1,603	-553	-2,234	0	-2,776
27	4	552	8,480	544	125	-3,148	-1,621	-658	-2,415	0	1,864
28	4	549	5,916	564	129	-3,205	-1,697	-608	-2,028	0	-374
29	3	553	6,566	538	129	-3,239	-1,571	-618	-1,796	0	565
30	2	550	4,895	507	129	-3,067	-1,671	-583	-1,691	0	-928
31	2	556	9,806	426	128	-3,590	-1,443	-717	-1,836	0	3,331
32	2	556	12,107	383	134	-4,294	-1,556	-872	-1,910	0	4,550
33	2	545	7,280	380	140	-4,269	-1,811	-857	-1,935	0	-524
34	2	554	5,178	510	139	-3,869	-1,582	-706	-1,946	0	-1,720
35	2	553	8,941	447	136	-3,993	-1,561	-854	-1,982	0	1,689
36	2	545	4,727	525	137	-3,714	-1,838	-684	-2,002	0	-2,300
37	2	545	4,032	597	134	-3,334	-1,711	-617	-2,306	0	-2,657
38	4	554	5,061	635	129	-3,168	-1,564	-588	-2,501	0	-1,439
39	5	549	3,248	693	126	-2,849	-1,744	-517	-2,626	0	-3,113
40	10	556	4,359	700	122	-2,640	-1,513	-502	-2,744	0	-1,650
41	17	549	5,814	689	121	-2,631	-1,779	-526	-2,863	0	-609
42	29	550	3,017	748	120	-2,306	-1,762	-508	-2,969	0	-3,082
43	44	549	3,238	893	116	-2,030	-1,603	-565	-3,118	0	-2,477
44	53	552	8,481	853	114	-2,345	-1,640	-709	-3,136	0	2,223
45	46	545	7,522	794	118	-2,587	-1,804	-757	-2,663	0	1,214
46	30	556	8,902	750	121	-2,989	-1,459	-803	-2,390	0	2,718
47	15	545	9,712	693	125	-3,301	-1,565	-872	-2,191	0	3,161
Average (afy)	**7**	**551**	**6,264**	**512**	**130**	**-3,273**	**-1,619**	**-656**	**-1,952**	**0**	**-35**
Maximum (afy)	**53**	**558**	**13,135**	**893**	**146**	**-2,030**	**-1,431**	**-474**	**-1,093**	**0**	**6,122**
Minimum (afy)	**2**	**545**	**3,017**	**325**	**114**	**-4,294**	**-1,838**	**-897**	**-3,136**	**0**	**-3,229**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.


Scenario 2 North Westside Basin Water Balance
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Rain + Irrigation (afy)
Seepage from Golden Gate Park Lakes (afy)
Seepage from Lake Merced (afy)
Inflow from Bay & Ocean (afy)
Outflow to Bay & Ocean (afy)
Wells - Pumping (afy)
Seepage to Lake Merced (afy)
From South Westside Basin (afy)
To South Westside Basin (afy)
Drains (afy)

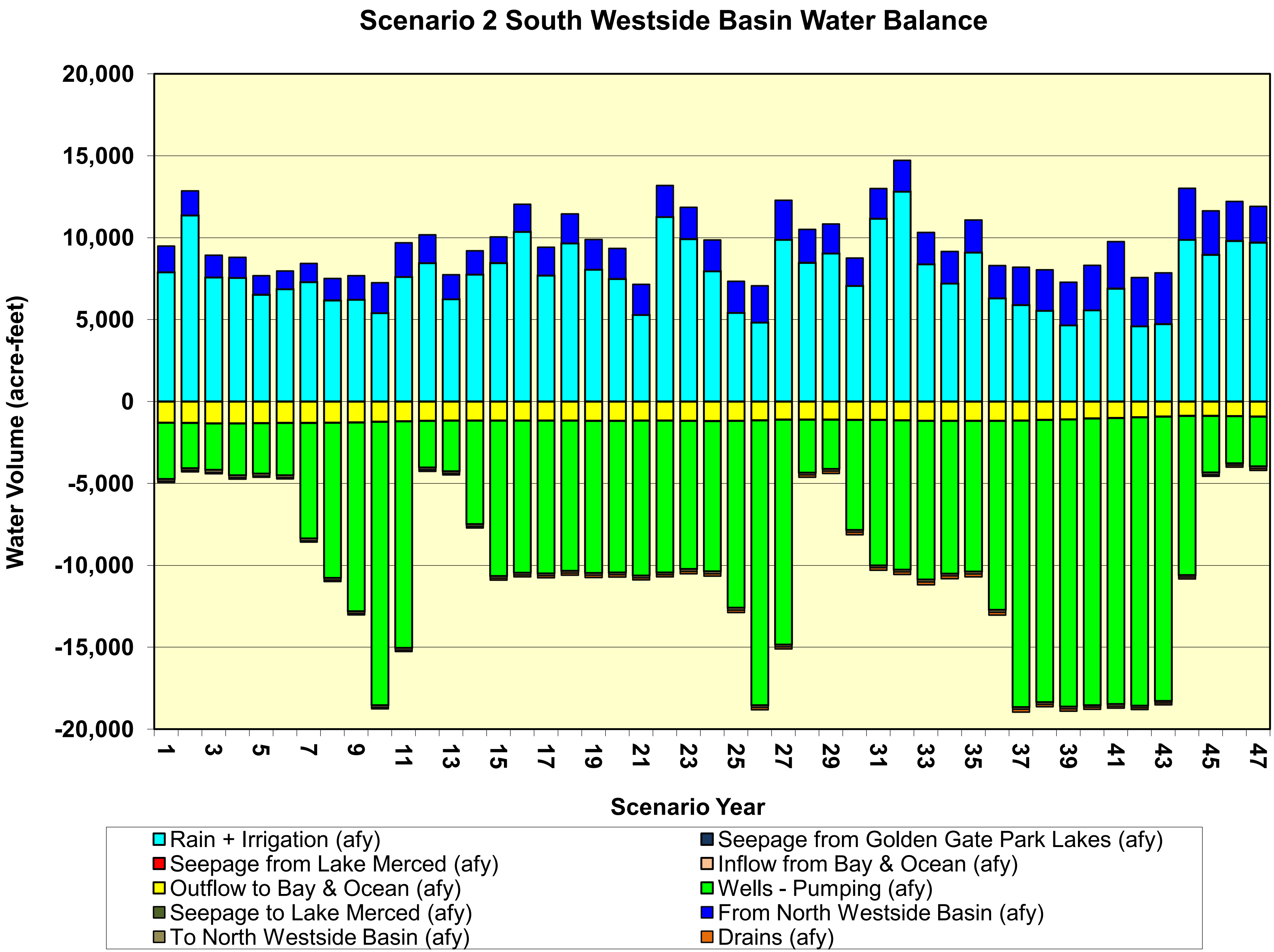

Scenario 2 North Westside Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
Change in Groundwater Storage (afy)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year

Scenario 2 South Westside Basin Water Balance Summary

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From North to South Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From South to North Westside Basin (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	3	0	7,904	0	1,587	-1,283	-3,441	0	-134	-71	4,566
2	3	0	11,370	0	1,487	-1,298	-2,770	0	-139	-72	8,581
3	3	0	7,580	0	1,354	-1,325	-2,850	0	-146	-74	4,542
4	3	0	7,559	0	1,248	-1,326	-3,180	0	-143	-75	4,085
5	3	0	6,531	0	1,160	-1,319	-3,085	0	-140	-77	3,073
6	3	0	6,873	0	1,093	-1,309	-3,196	0	-136	-77	3,251
7	3	0	7,302	0	1,130	-1,303	-7,061	0	-134	-78	-142
8	2	0	6,188	0	1,329	-1,291	-9,470	0	-134	-81	-3,456
9	2	0	6,225	0	1,464	-1,269	-11,528	0	-131	-84	-5,321
10	2	0	5,405	0	1,856	-1,237	-17,299	0	-129	-85	-11,488
11	2	0	7,611	0	2,077	-1,196	-13,847	0	-127	-87	-5,567
12	2	0	8,465	0	1,723	-1,170	-2,862	0	-126	-94	5,937
13	2	0	6,247	0	1,502	-1,163	-3,092	0	-126	-98	3,273
14	2	0	7,760	0	1,445	-1,159	-6,328	0	-124	-99	1,497
15	2	0	8,469	0	1,587	-1,157	-9,502	0	-125	-109	-836
16	2	0	10,364	0	1,683	-1,159	-9,296	0	-127	-117	1,350
17	2	0	7,695	0	1,725	-1,165	-9,328	0	-131	-124	-1,326
18	2	0	9,663	0	1,793	-1,164	-9,167	0	-129	-130	867
19	2	0	8,066	0	1,828	-1,172	-9,296	0	-133	-136	-842
20	2	0	7,492	0	1,853	-1,171	-9,267	0	-132	-141	-1,365
21	2	0	5,293	0	1,859	-1,161	-9,456	0	-130	-134	-3,727
22	2	0	11,269	0	1,925	-1,159	-9,273	0	-128	-135	2,500
23	2	0	9,930	0	1,926	-1,179	-9,045	0	-136	-144	1,354
24	2	0	7,964	0	1,907	-1,185	-9,183	0	-138	-149	-781
25	2	0	5,416	0	1,928	-1,173	-11,417	0	-133	-151	-5,528
26	2	0	4,834	0	2,234	-1,144	-17,393	0	-128	-139	-11,734
27	3	0	9,875	0	2,415	-1,109	-13,730	0	-125	-137	-2,809
28	3	0	8,482	0	2,028	-1,100	-3,238	0	-129	-145	5,901
29	3	0	9,043	0	1,796	-1,104	-3,006	0	-129	-149	6,453
30	3	0	7,065	0	1,691	-1,112	-6,733	0	-129	-153	632
31	3	0	11,168	0	1,836	-1,117	-8,895	0	-128	-157	2,711
32	4	0	12,815	0	1,910	-1,142	-9,116	0	-134	-162	4,174
33	3	0	8,388	0	1,935	-1,174	-9,695	0	-140	-166	-850
34	3	0	7,212	0	1,946	-1,176	-9,326	0	-139	-171	-1,651
35	3	0	9,104	0	1,982	-1,173	-9,210	0	-136	-176	395
36	3	0	6,306	0	2,002	-1,178	-11,540	0	-137	-176	-4,720
37	3	0	5,900	0	2,306	-1,158	-17,493	0	-134	-163	-10,738
38	4	0	5,544	0	2,501	-1,121	-17,225	0	-129	-152	-10,578
39	4	0	4,657	0	2,626	-1,082	-17,544	0	-126	-140	-11,607
40	5	0	5,576	0	2,744	-1,037	-17,496	0	-122	-130	-10,461
41	6	0	6,900	0	2,863	-997	-17,471	0	-121	-128	-8,948
42	8	0	4,601	0	2,969	-959	-17,601	0	-120	-120	-11,223
43	10	0	4,737	0	3,118	-911	-17,373	0	-116	-107	-10,642
44	12	0	9,876	0	3,136	-868	-9,733	0	-114	-103	2,205
45	14	0	8,968	0	2,663	-867	-3,467	0	-118	-107	7,086
46	17	0	9,812	0	2,390	-888	-2,875	0	-121	-107	8,227
47	19	0	9,710	0	2,191	-919	-3,043	0	-125	-107	7,725
Average (afy)	**4**	**0**	**7,770**	**0**	**1,952**	**-1,145**	**-9,307**	**0**	**-130**	**-122**	**-978**
Maximum (afy)	**19**	**0**	**12,815**	**0**	**3,136**	**-867**	**-2,770**	**0**	**-114**	**-71**	**8,581**
Minimum (afy)	**2**	**0**	**4,601**	**0**	**1,093**	**-1,326**	**-17,601**	**0**	**-146**	**-176**	**-11,734**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.


Scenario 2 South Westside Basin Water Balance
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
Water Volume (acre-feet)
1
3
5
7
9
11
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15
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23
25
27
29
31
33
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37
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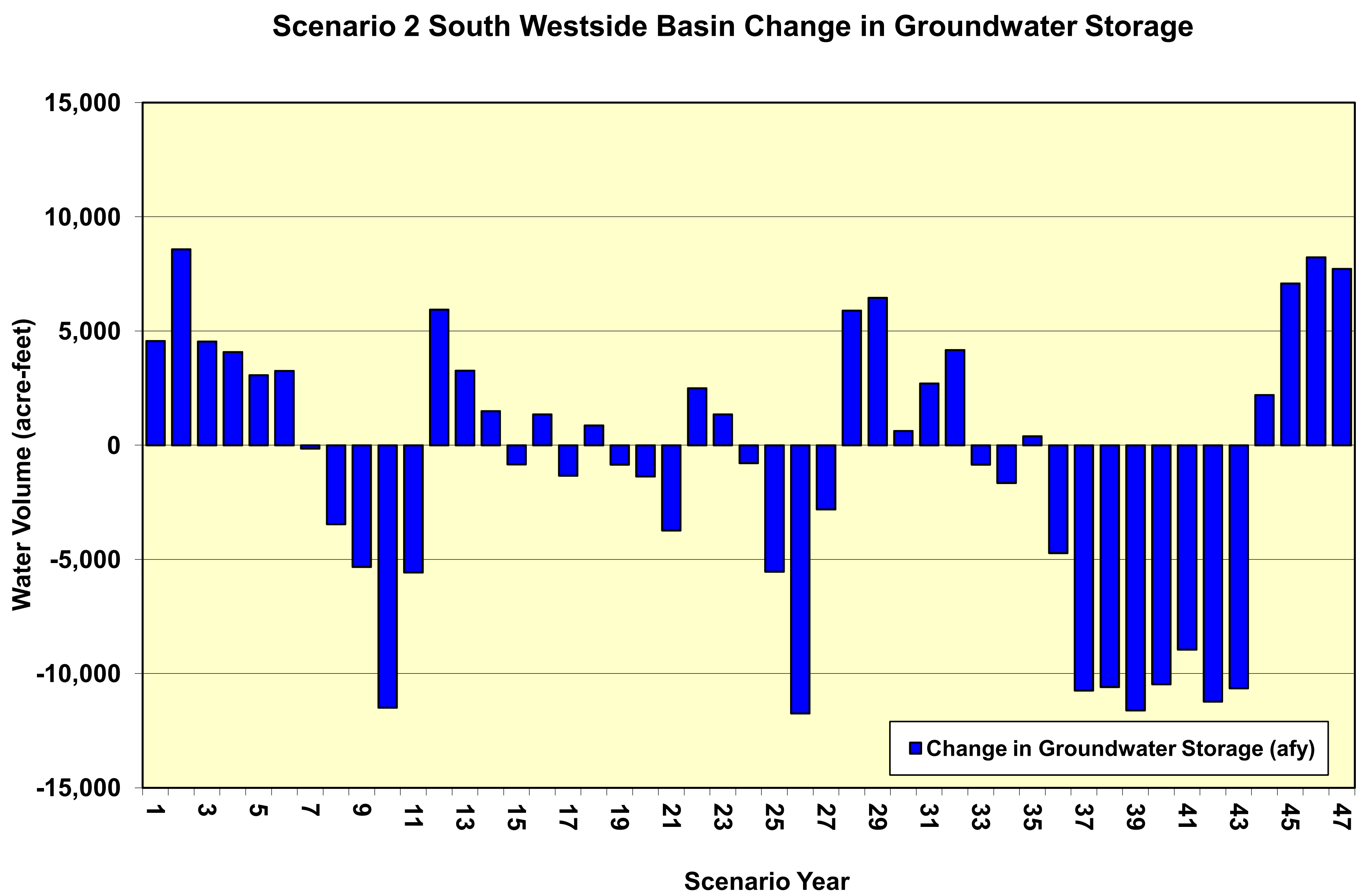
41
43
45
47
Scenario Year
Rain + Irrigation (afy)
Seepage from Golden Gate Park Lakes (afy)
Seepage from Lake Merced (afy)
Inflow from Bay & Ocean (afy)
Outflow to Bay & Ocean (afy)
Wells - Pumping (afy)
Seepage to Lake Merced (afy)
From North Westside Basin (afy)
To North Westside Basin (afy)
Drains (afy)



Scenario 2 South Westside Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
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27
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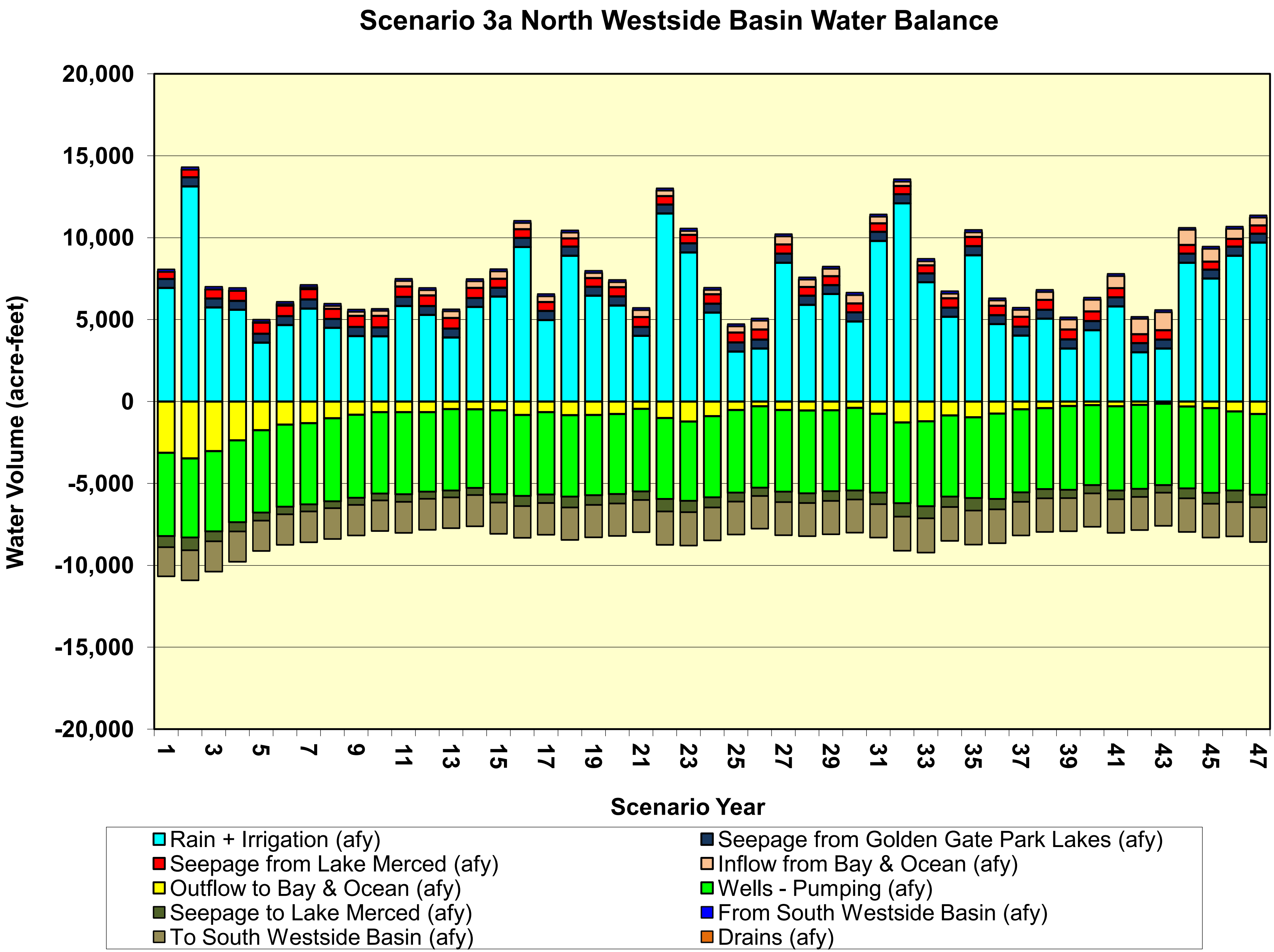
31
33
35
37
39
41
43
45
47
Scenario Year
Change in Groundwater Storage (afy)

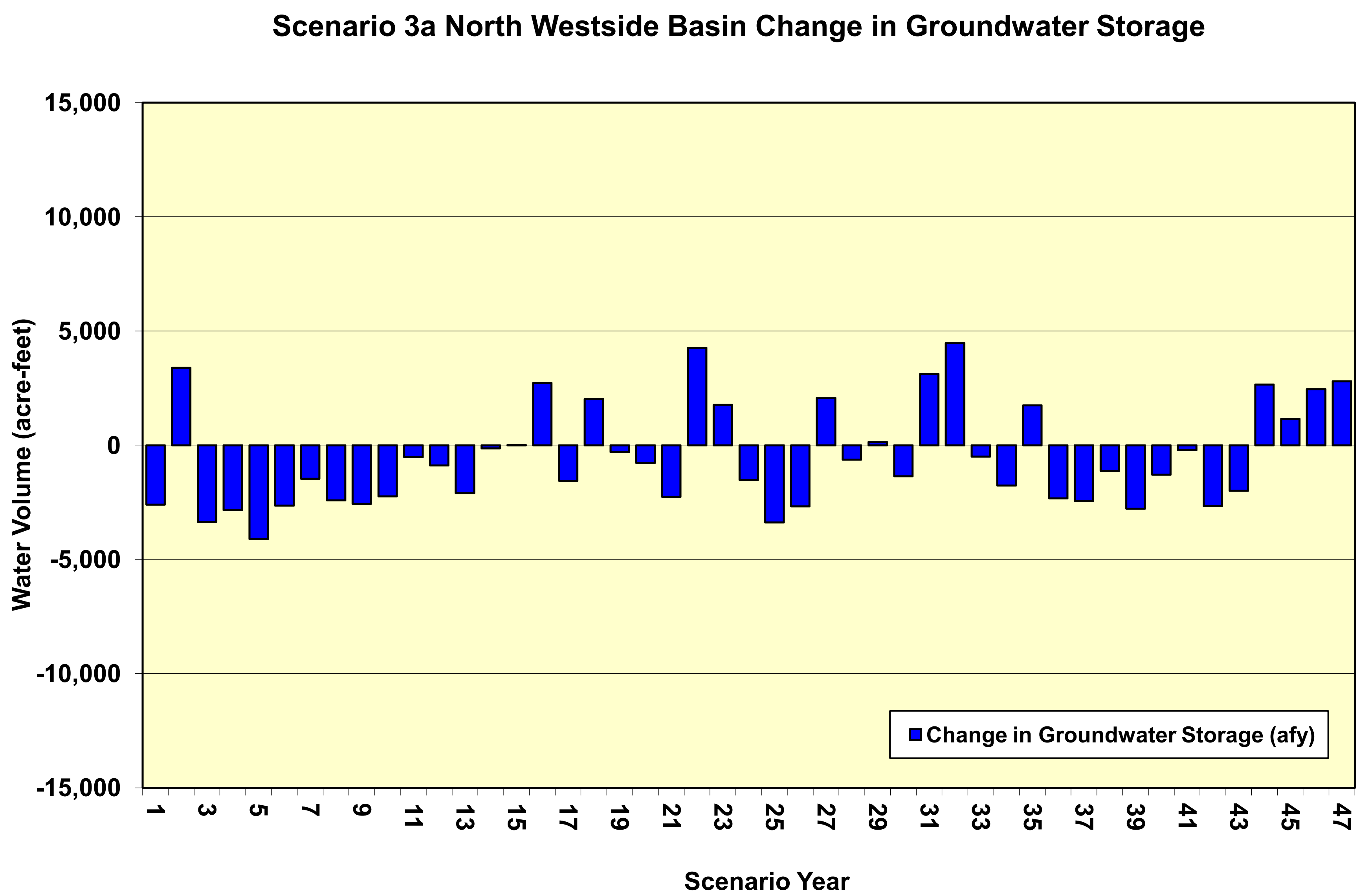
Scenario 3a North Westside Basin Water Balance Summary

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From South to North Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From North to South Westside Basin (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	2	546	6,941	445	134	-3,124	-5,090	-670	-1,777	0	-2,594
2	3	558	13,135	478	139	-3,474	-4,832	-772	-1,836	0	3,400
3	8	552	5,749	560	147	-3,026	-4,898	-612	-1,840	0	-3,360
4	23	549	5,610	617	143	-2,360	-5,010	-560	-1,847	0	-2,834
5	51	549	3,598	674	140	-1,752	-5,022	-487	-1,852	0	-4,101
6	91	551	4,673	650	135	-1,401	-5,024	-461	-1,858	0	-2,644
7	126	552	5,687	628	133	-1,313	-4,960	-440	-1,871	0	-1,458
8	182	545	4,503	616	133	-1,014	-5,078	-418	-1,874	0	-2,405
9	245	549	4,009	684	130	-799	-5,083	-422	-1,872	0	-2,559
10	302	554	3,982	707	128	-650	-4,965	-417	-1,875	0	-2,234
11	346	549	5,843	635	126	-640	-5,025	-461	-1,890	0	-517
12	334	556	5,286	640	126	-640	-4,861	-429	-1,894	0	-881
13	410	553	3,915	638	126	-458	-4,972	-412	-1,888	0	-2,089
14	426	558	5,773	605	124	-464	-4,806	-440	-1,903	0	-127
15	461	549	6,407	542	125	-526	-5,134	-500	-1,908	0	15
16	390	556	9,441	525	127	-814	-4,953	-606	-1,938	0	2,727
17	369	549	4,984	543	131	-637	-5,038	-519	-1,932	0	-1,551
18	354	554	8,904	515	129	-831	-4,978	-663	-1,966	0	2,019
19	310	553	6,466	529	132	-822	-4,896	-595	-1,977	0	-300
20	324	556	5,871	553	132	-754	-4,888	-579	-1,981	0	-766
21	431	548	4,017	595	130	-447	-5,037	-520	-1,968	0	-2,251
22	335	554	11,482	517	128	-1,006	-4,938	-771	-2,026	0	4,273
23	246	556	9,106	519	135	-1,217	-4,840	-699	-2,037	0	1,770
24	270	549	5,433	572	137	-885	-4,969	-606	-2,019	0	-1,518
25	380	549	3,062	607	133	-517	-5,044	-548	-2,001	0	-3,379
26	542	550	3,238	621	128	-279	-4,977	-503	-1,991	0	-2,672
27	511	552	8,480	559	125	-513	-4,995	-629	-2,021	0	2,069
28	465	549	5,916	531	129	-537	-5,071	-583	-2,025	0	-626
29	455	553	6,566	538	130	-528	-4,946	-588	-2,032	0	147
30	524	550	4,895	549	130	-389	-5,045	-548	-2,019	0	-1,352
31	411	556	9,806	529	129	-748	-4,818	-692	-2,048	0	3,126
32	279	556	12,107	502	134	-1,274	-4,931	-820	-2,078	0	4,475
33	251	545	7,280	497	141	-1,207	-5,186	-737	-2,082	0	-497
34	287	554	5,178	582	140	-843	-4,957	-638	-2,065	0	-1,762
35	292	553	8,941	556	137	-959	-4,935	-753	-2,085	0	1,746
36	334	545	4,727	574	138	-734	-5,212	-630	-2,067	0	-2,325
37	422	545	4,032	607	134	-464	-5,086	-573	-2,053	0	-2,435
38	485	554	5,061	603	130	-404	-4,938	-560	-2,051	0	-1,120
39	615	549	3,248	605	128	-272	-5,118	-495	-2,034	0	-2,775
40	720	556	4,359	594	124	-220	-4,887	-493	-2,037	0	-1,283
41	750	549	5,814	565	123	-278	-5,154	-531	-2,045	0	-206
42	946	550	3,017	546	123	-195	-5,137	-485	-2,031	0	-2,665
43	1115	549	3,238	567	120	-132	-4,977	-450	-2,024	0	-1,995
44	937	552	8,481	527	119	-292	-5,014	-597	-2,053	0	2,659
45	792	545	7,522	477	124	-402	-5,179	-656	-2,069	0	1,155
46	616	556	8,902	487	127	-604	-4,833	-697	-2,098	0	2,457
47	489	545	9,712	502	131	-755	-4,939	-752	-2,121	0	2,811
Average (afy)	**397**	**551**	**6,264**	**568**	**131**	**-885**	**-4,993**	**-575**	**-1,978**	**0**	**-520**
Maximum (afy)	**1115**	**558**	**13,135**	**707**	**147**	**-132**	**-4,806**	**-412**	**-1,777**	**0**	**4,475**
Minimum (afy)	**2**	**545**	**3,017**	**445**	**119**	**-3,474**	**-5,212**	**-820**	**-2,121**	**0**	**-4,101**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.


Scenario 3a North Westside Basin Water Balance
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Rain + Irrigation (afy)
Seepage from Golden Gate Park Lakes (afy)
Seepage from Lake Merced (afy)
Inflow from Bay & Ocean (afy)
Outflow to Bay & Ocean (afy)
Wells - Pumping (afy)
Seepage to Lake Merced (afy)
From South Westside Basin (afy)
To South Westside Basin (afy)
Drains (afy)



Scenario 3a North Westside Basin Change in Groundwater Storage
Water Volume (acre-feet)
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
1
3
5
7
9
11
13
15
17
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33
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41
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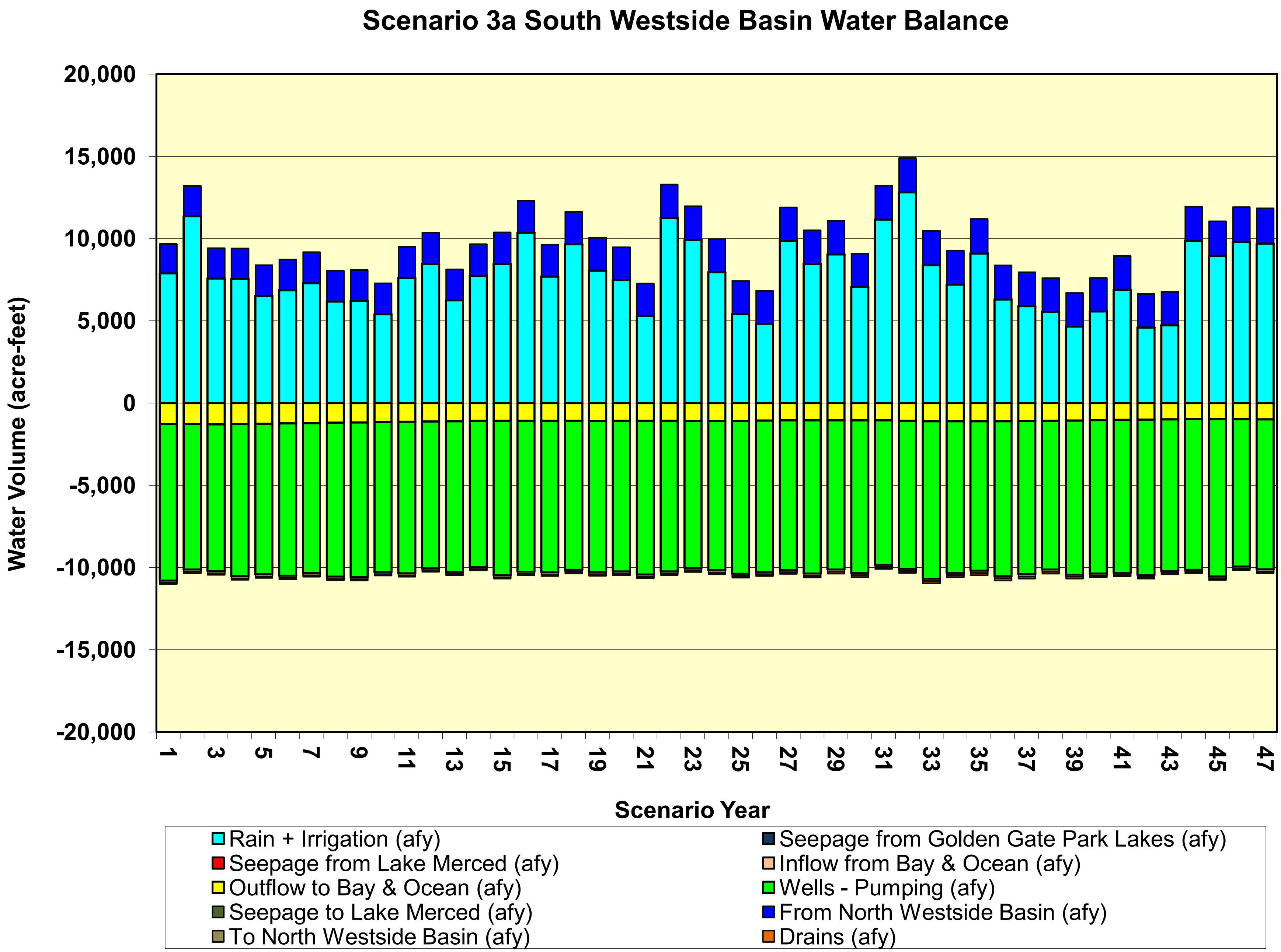
45
47
Scenario Year
Change in Groundwater Storage (afy)

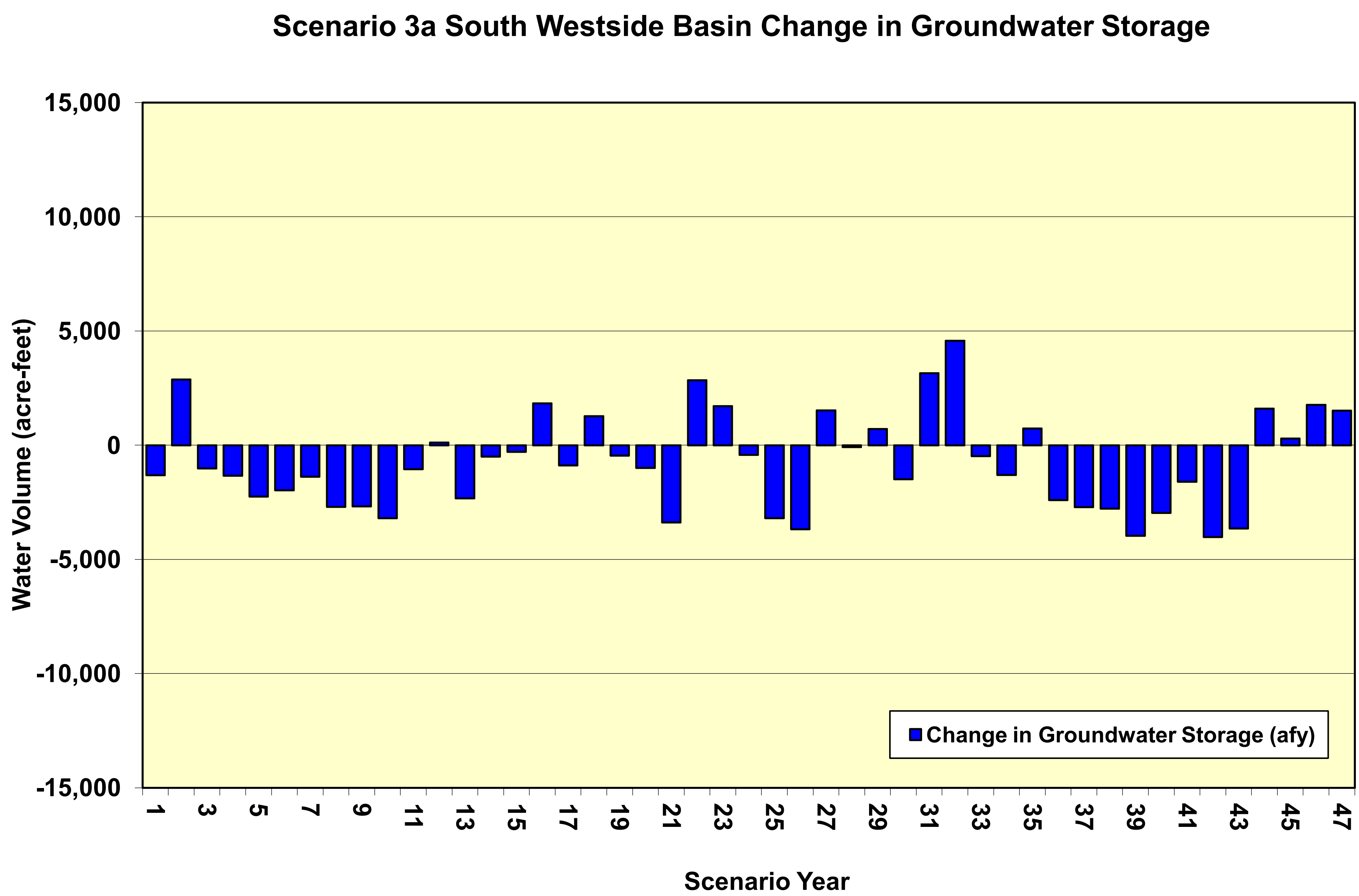
Scenario 3a South Westside Basin Water Balance Summary

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From North to South Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From South to North Westside Basin (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	3	0	7,904	0	1,777	-1,276	-9,513	0	-134	-71	-1,310
2	3	0	11,370	0	1,836	-1,277	-8,842	0	-139	-72	2,879
3	3	0	7,580	0	1,840	-1,289	-8,922	0	-147	-73	-1,008
4	3	0	7,559	0	1,847	-1,275	-9,252	0	-143	-74	-1,336
5	3	0	6,531	0	1,852	-1,255	-9,157	0	-140	-74	-2,240
6	3	0	6,873	0	1,858	-1,230	-9,268	0	-135	-73	-1,972
7	3	0	7,302	0	1,871	-1,211	-9,131	0	-133	-72	-1,372
8	3	0	6,188	0	1,874	-1,195	-9,362	0	-133	-71	-2,696
9	3	0	6,225	0	1,872	-1,172	-9,405	0	-130	-70	-2,678
10	3	0	5,405	0	1,875	-1,148	-9,130	0	-128	-68	-3,191
11	3	0	7,611	0	1,890	-1,126	-9,228	0	-126	-68	-1,045
12	3	0	8,465	0	1,894	-1,111	-8,934	0	-126	-74	117
13	3	0	6,247	0	1,888	-1,096	-9,164	0	-126	-76	-2,322
14	4	0	7,760	0	1,903	-1,078	-8,884	0	-124	-75	-495
15	4	0	8,469	0	1,908	-1,069	-9,394	0	-125	-81	-288
16	4	0	10,364	0	1,938	-1,070	-9,188	0	-127	-84	1,838
17	4	0	7,695	0	1,932	-1,076	-9,220	0	-131	-88	-882
18	5	0	9,663	0	1,966	-1,074	-9,059	0	-129	-92	1,280
19	5	0	8,066	0	1,977	-1,081	-9,188	0	-132	-96	-450
20	5	0	7,492	0	1,981	-1,080	-9,159	0	-132	-100	-993
21	5	0	5,293	0	1,968	-1,069	-9,348	0	-130	-92	-3,372
22	6	0	11,269	0	2,026	-1,067	-9,165	0	-128	-94	2,847
23	6	0	9,930	0	2,037	-1,087	-8,937	0	-135	-101	1,713
24	6	0	7,964	0	2,019	-1,093	-9,075	0	-137	-105	-422
25	6	0	5,416	0	2,001	-1,082	-9,294	0	-133	-106	-3,191
26	7	0	4,834	0	1,991	-1,061	-9,224	0	-128	-96	-3,677
27	7	0	9,875	0	2,021	-1,046	-9,111	0	-125	-96	1,524
28	8	0	8,482	0	2,025	-1,049	-9,310	0	-129	-104	-78
29	8	0	9,043	0	2,032	-1,047	-9,078	0	-130	-108	719
30	8	0	7,065	0	2,019	-1,043	-9,290	0	-130	-112	-1,482
31	8	0	11,168	0	2,048	-1,042	-8,786	0	-129	-115	3,153
32	8	0	12,815	0	2,078	-1,067	-9,008	0	-134	-117	4,574
33	8	0	8,388	0	2,082	-1,099	-9,587	0	-141	-121	-469
34	8	0	7,212	0	2,065	-1,100	-9,218	0	-140	-124	-1,297
35	8	0	9,104	0	2,085	-1,097	-9,102	0	-137	-127	736
36	8	0	6,306	0	2,067	-1,101	-9,417	0	-138	-128	-2,402
37	8	0	5,900	0	2,053	-1,088	-9,324	0	-134	-120	-2,705
38	8	0	5,544	0	2,051	-1,071	-9,056	0	-130	-112	-2,766
39	8	0	4,657	0	2,034	-1,056	-9,375	0	-128	-104	-3,965
40	9	0	5,576	0	2,037	-1,036	-9,327	0	-124	-99	-2,963
41	10	0	6,900	0	2,045	-1,020	-9,302	0	-123	-99	-1,590
42	10	0	4,601	0	2,031	-1,006	-9,440	0	-123	-94	-4,020
43	11	0	4,737	0	2,024	-982	-9,224	0	-120	-86	-3,640
44	13	0	9,876	0	2,053	-964	-9,166	0	-119	-86	1,607
45	14	0	8,968	0	2,069	-968	-9,567	0	-124	-93	299
46	15	0	9,812	0	2,098	-975	-8,953	0	-127	-97	1,773
47	16	0	9,710	0	2,121	-986	-9,116	0	-131	-99	1,514
Average (afy)	**7**	**0**	**7,770**	**0**	**1,978**	**-1,096**	**-9,196**	**0**	**-131**	**-93**	**-761**
Maximum (afy)	**16**	**0**	**12,815**	**0**	**2,121**	**-964**	**-8,786**	**0**	**-119**	**-68**	**4,574**
Minimum (afy)	**3**	**0**	**4,601**	**0**	**1,777**	**-1,289**	**-9,587**	**0**	**-147**	**-128**	**-4,020**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.


Scenario 3a South Westside Basin Water Balance
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Rain + Irrigation (afy)
Seepage from Golden Gate Park Lakes (afy)
Seepage from Lake Merced (afy)
Inflow from Bay & Ocean (afy)
Outflow to Bay & Ocean (afy)
Wells - Pumping (afy)
Seepage to Lake Merced (afy)
From North Westside Basin (afy)
To North Westside Basin (afy)
Drains (afy)

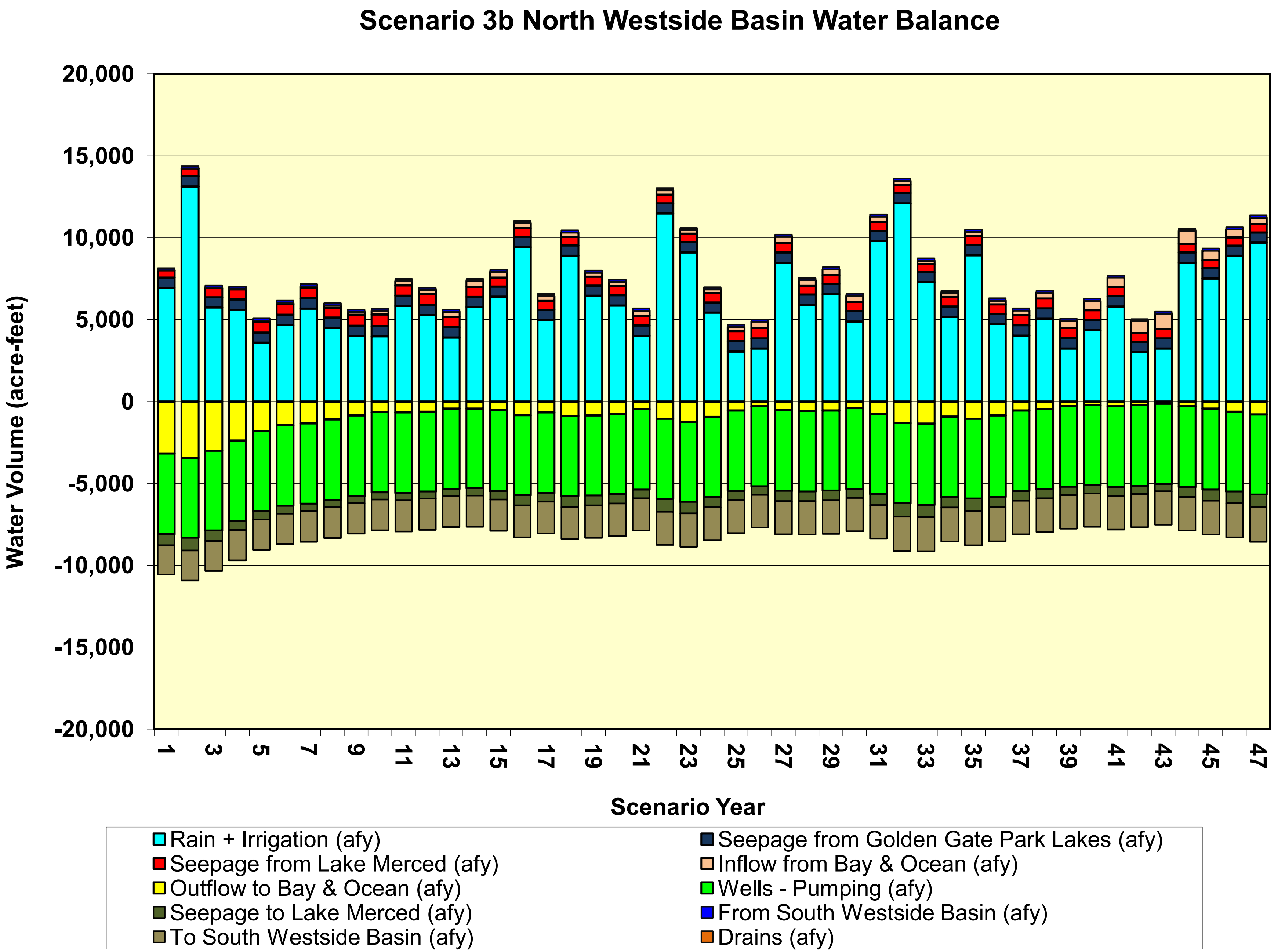

Scenario 3a South Westside Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Change in Groundwater Storage (afy)

Scenario 3b North Westside Basin Water Balance Summary

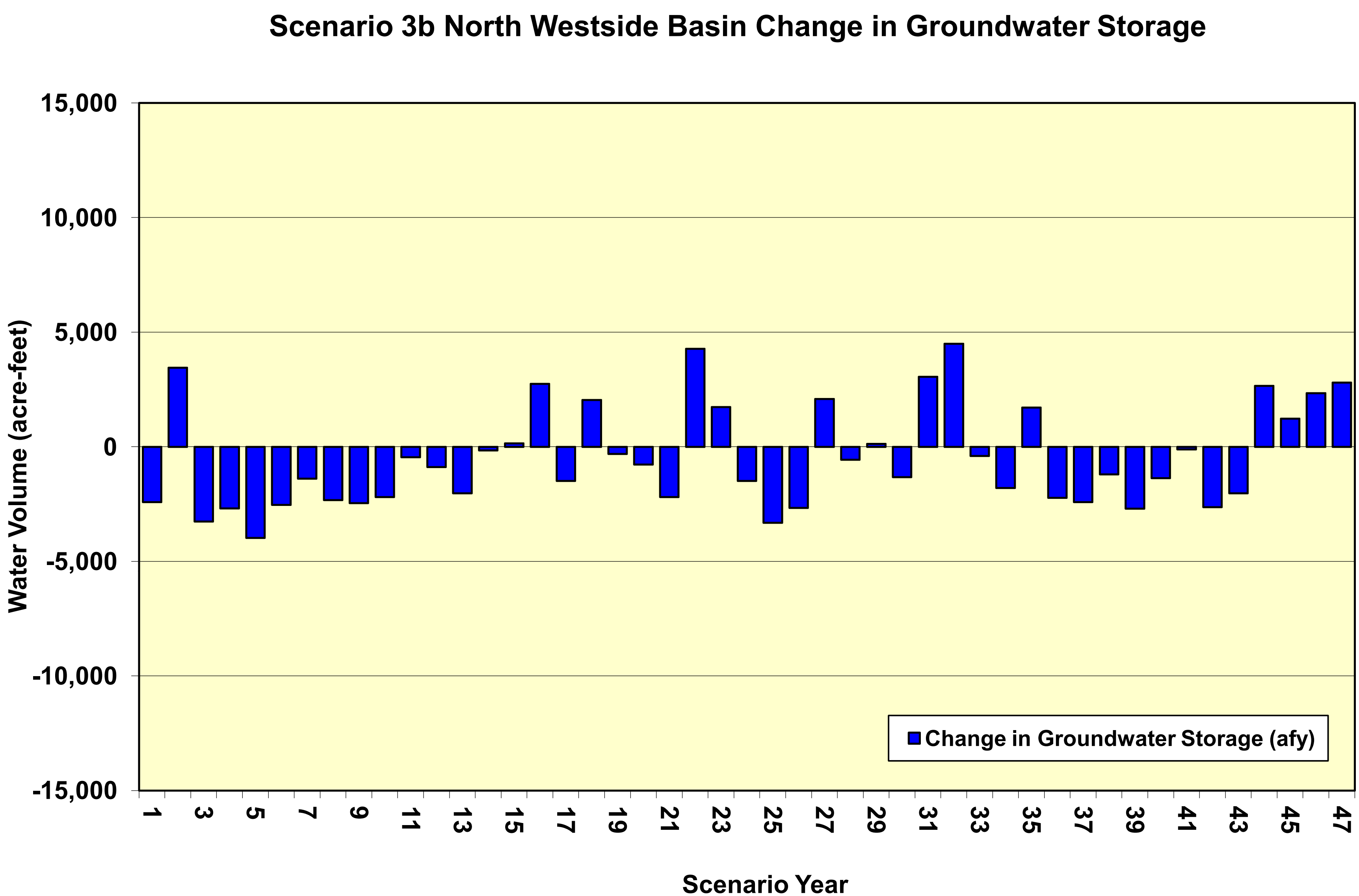
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From South to North Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From North to South Westside Basin (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	2	626	6,941	444	134	-3,164	-4,939	-672	-1,777	0	-2,404
2	3	628	13,135	476	139	-3,443	-4,869	-777	-1,837	0	3,454
3	7	626	5,749	556	147	-2,990	-4,887	-618	-1,841	0	-3,252
4	20	626	5,610	614	143	-2,377	-4,905	-565	-1,848	0	-2,683
5	42	626	3,598	672	140	-1,788	-4,918	-492	-1,853	0	-3,973
6	74	628	4,673	651	135	-1,444	-4,924	-466	-1,860	0	-2,533
7	101	626	5,687	626	133	-1,337	-4,903	-444	-1,874	0	-1,385
8	134	626	4,503	615	133	-1,093	-4,936	-423	-1,877	0	-2,318
9	177	626	4,009	671	130	-845	-4,927	-415	-1,875	0	-2,448
10	223	628	3,982	707	128	-649	-4,902	-422	-1,878	0	-2,184
11	256	626	5,843	637	126	-653	-4,921	-468	-1,893	0	-447
12	267	626	5,286	641	126	-611	-4,881	-435	-1,898	0	-878
13	318	626	3,915	640	126	-428	-4,909	-419	-1,892	0	-2,025
14	357	628	5,773	607	124	-424	-4,867	-447	-1,907	0	-155
15	342	626	6,407	545	125	-523	-4,946	-507	-1,912	0	156
16	305	626	9,441	528	127	-827	-4,900	-613	-1,942	0	2,745
17	278	626	4,984	547	131	-662	-4,924	-526	-1,936	0	-1,484
18	275	628	8,904	519	129	-867	-4,898	-670	-1,970	0	2,050
19	251	626	6,466	533	132	-844	-4,890	-603	-1,981	0	-310
20	258	626	5,871	557	132	-749	-4,889	-587	-1,985	0	-765
21	315	626	4,017	600	130	-457	-4,918	-527	-1,972	0	-2,187
22	276	628	11,482	521	128	-1,044	-4,898	-778	-2,030	0	4,283
23	211	626	9,106	524	135	-1,240	-4,876	-706	-2,041	0	1,739
24	216	626	5,433	577	137	-937	-4,897	-613	-2,023	0	-1,481
25	276	626	3,062	613	133	-540	-4,924	-555	-2,005	0	-3,315
26	405	628	3,238	626	128	-280	-4,895	-511	-1,995	0	-2,657
27	400	626	8,480	563	125	-520	-4,921	-636	-2,025	0	2,092
28	338	626	5,916	535	129	-559	-4,931	-589	-2,029	0	-563
29	343	626	6,566	543	130	-540	-4,900	-595	-2,037	0	138
30	381	628	4,895	554	130	-404	-4,925	-555	-2,023	0	-1,319
31	340	626	9,806	534	129	-758	-4,868	-699	-2,052	0	3,057
32	242	626	12,107	506	134	-1,308	-4,896	-827	-2,082	0	4,503
33	192	626	7,280	502	141	-1,350	-4,957	-743	-2,086	0	-395
34	218	628	5,178	588	140	-923	-4,902	-645	-2,069	0	-1,788
35	230	626	8,941	562	137	-1,041	-4,882	-760	-2,090	0	1,722
36	235	626	4,727	580	137	-848	-4,971	-637	-2,071	0	-2,221
37	288	626	4,032	613	134	-542	-4,925	-581	-2,057	0	-2,412
38	342	628	5,061	608	130	-440	-4,899	-567	-2,055	0	-1,193
39	445	626	3,248	611	128	-277	-4,932	-502	-2,038	0	-2,692
40	568	626	4,359	600	124	-216	-4,885	-500	-2,041	0	-1,365
41	575	626	5,814	570	123	-278	-4,949	-538	-2,049	0	-105
42	723	628	3,017	551	123	-196	-4,943	-492	-2,035	0	-2,625
43	933	626	3,238	573	120	-129	-4,895	-457	-2,028	0	-2,019
44	783	626	8,481	532	119	-288	-4,926	-605	-2,057	0	2,666
45	598	626	7,522	482	124	-423	-4,958	-663	-2,073	0	1,234
46	490	626	8,902	492	127	-616	-4,871	-704	-2,102	0	2,345
47	399	618	9,712	507	131	-786	-4,896	-759	-2,125	0	2,801
Average (afy)	**307**	**626**	**6,264**	**571**	**131**	**-908**	**-4,910**	**-581**	**-1,981**	**0**	**-481**
Maximum (afy)	**933**	**628**	**13,135**	**707**	**147**	**-129**	**-4,867**	**-415**	**-1,777**	**0**	**4,503**
Minimum (afy)	**2**	**618**	**3,017**	**444**	**119**	**-3,443**	**-4,971**	**-827**	**-2,125**	**0**	**-3,973**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.



Scenario 3b North Westside Basin Water Balance
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Rain + Irrigation (afy)
Seepage from Golden Gate Park Lakes (afy)
Seepage from Lake Merced (afy)
Inflow from Bay & Ocean (afy)
Outflow to Bay & Ocean (afy)
Wells - Pumping (afy)
Seepage to Lake Merced (afy)
From South Westside Basin (afy)
To South Westside Basin (afy)
Drains (afy)



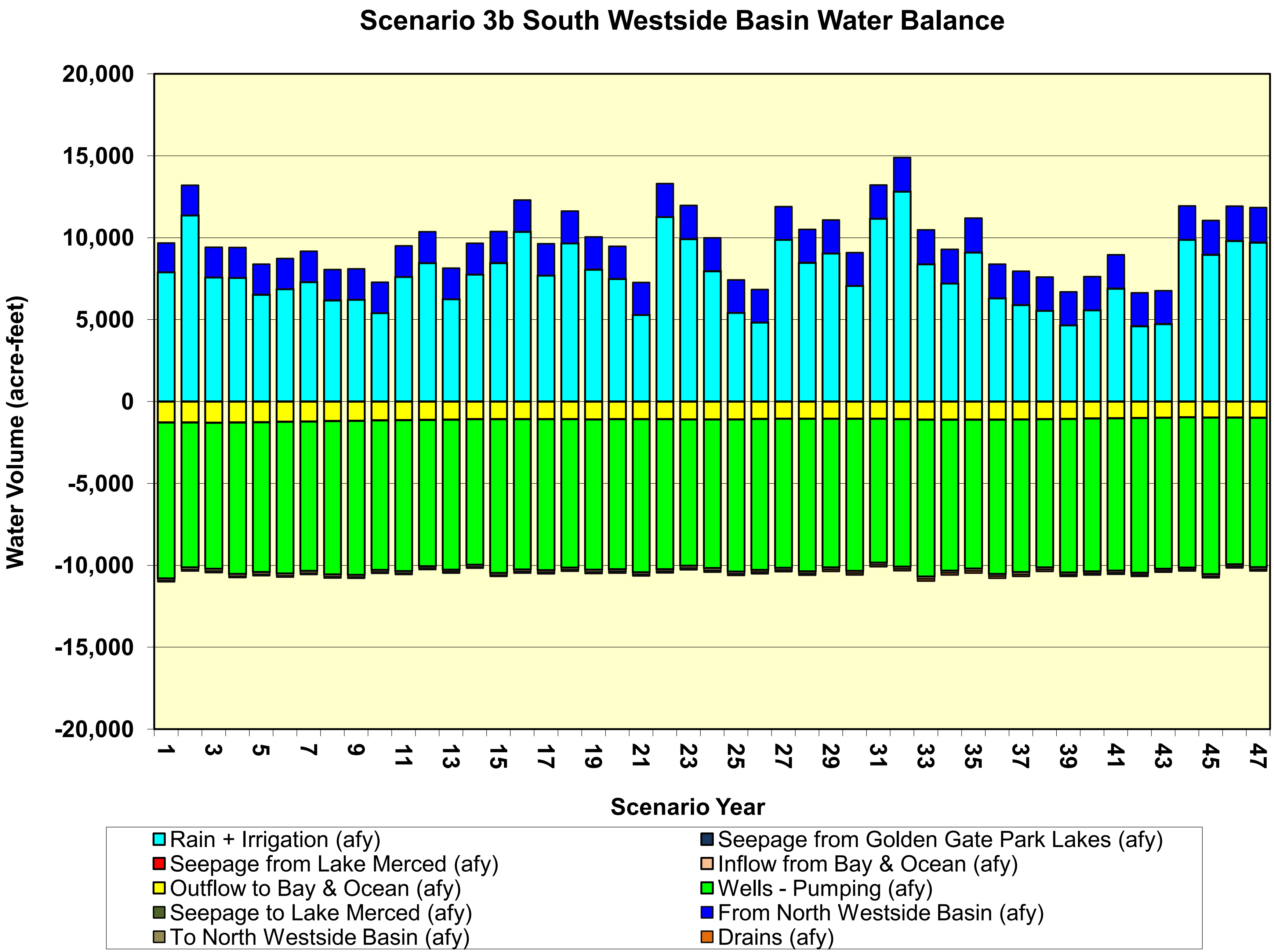
Scenario 3b North Westside Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
Change in Groundwater Storage (afy)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year

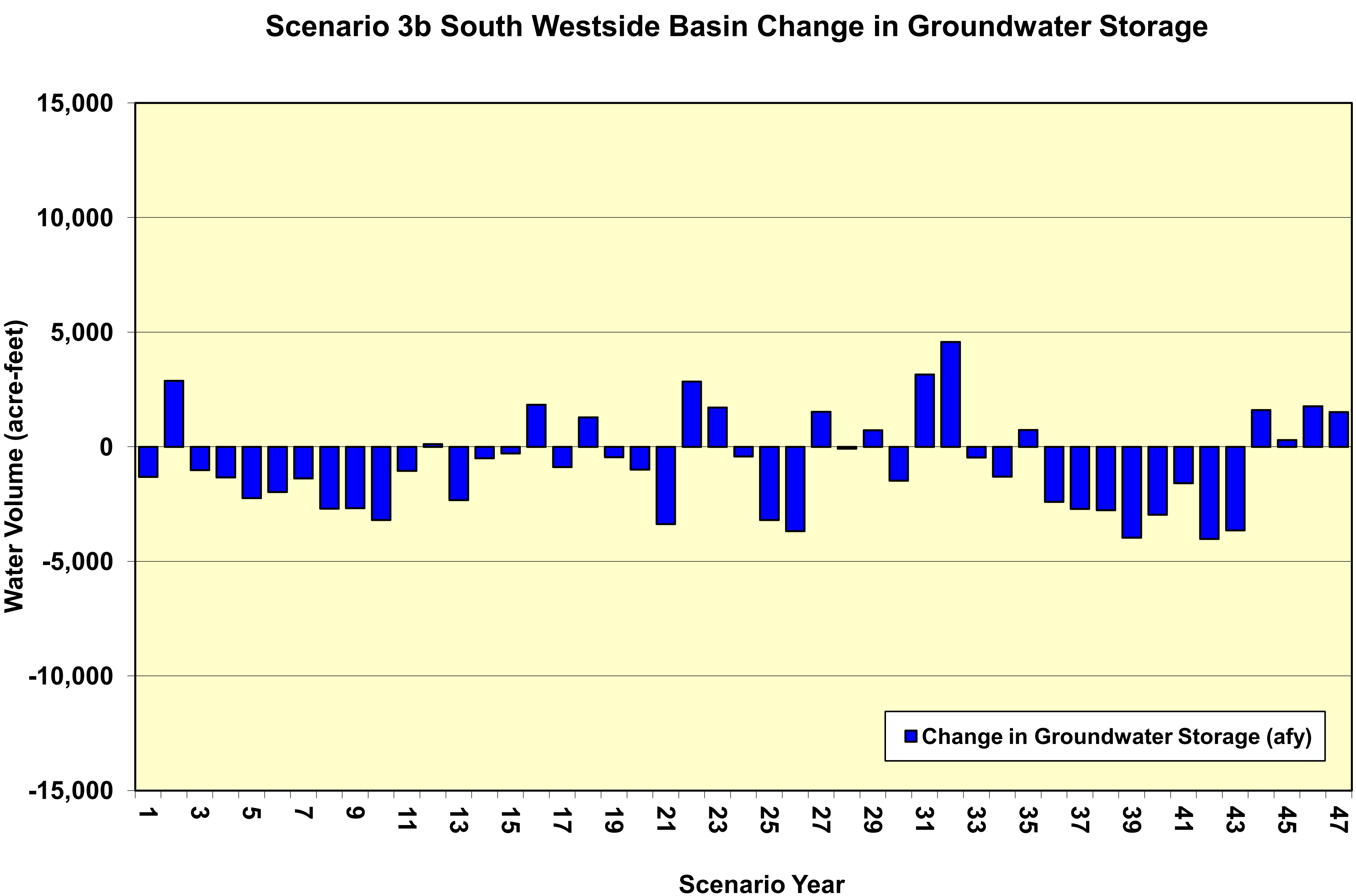
Scenario 3b South Westside Basin Water Balance Summary

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From North to South Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From South to North Westside Basin (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	3	0	7,904	0	1,777	-1,276	-9,513	0	-134	-71	-1,310
2	3	0	11,370	0	1,837	-1,277	-8,842	0	-139	-72	2,879
3	3	0	7,580	0	1,841	-1,289	-8,922	0	-147	-73	-1,007
4	3	0	7,559	0	1,848	-1,275	-9,252	0	-143	-74	-1,335
5	3	0	6,531	0	1,853	-1,255	-9,157	0	-140	-74	-2,238
6	3	0	6,873	0	1,860	-1,230	-9,268	0	-135	-73	-1,969
7	3	0	7,302	0	1,874	-1,211	-9,131	0	-133	-72	-1,369
8	3	0	6,188	0	1,877	-1,195	-9,362	0	-133	-71	-2,693
9	3	0	6,225	0	1,875	-1,172	-9,405	0	-130	-70	-2,675
10	3	0	5,405	0	1,878	-1,148	-9,130	0	-128	-68	-3,188
11	3	0	7,611	0	1,893	-1,126	-9,228	0	-126	-68	-1,042
12	3	0	8,465	0	1,898	-1,112	-8,934	0	-126	-74	120
13	3	0	6,247	0	1,892	-1,096	-9,164	0	-126	-76	-2,318
14	4	0	7,760	0	1,907	-1,078	-8,884	0	-124	-75	-491
15	4	0	8,469	0	1,912	-1,070	-9,394	0	-125	-81	-284
16	4	0	10,364	0	1,942	-1,070	-9,188	0	-127	-84	1,842
17	4	0	7,695	0	1,936	-1,076	-9,220	0	-131	-88	-878
18	5	0	9,663	0	1,970	-1,074	-9,059	0	-129	-92	1,284
19	5	0	8,066	0	1,981	-1,081	-9,188	0	-132	-96	-446
20	5	0	7,492	0	1,985	-1,080	-9,159	0	-132	-100	-989
21	5	0	5,293	0	1,972	-1,069	-9,348	0	-130	-92	-3,368
22	6	0	11,269	0	2,030	-1,067	-9,165	0	-128	-94	2,851
23	6	0	9,930	0	2,041	-1,087	-8,937	0	-135	-101	1,717
24	6	0	7,964	0	2,023	-1,093	-9,075	0	-137	-105	-418
25	6	0	5,416	0	2,005	-1,082	-9,294	0	-133	-106	-3,187
26	7	0	4,834	0	1,995	-1,061	-9,224	0	-128	-96	-3,673
27	7	0	9,875	0	2,025	-1,046	-9,111	0	-125	-96	1,528
28	8	0	8,482	0	2,029	-1,050	-9,310	0	-129	-104	-75
29	8	0	9,043	0	2,037	-1,047	-9,078	0	-130	-108	723
30	8	0	7,065	0	2,023	-1,043	-9,290	0	-130	-112	-1,478
31	8	0	11,168	0	2,052	-1,042	-8,786	0	-129	-115	3,157
32	8	0	12,815	0	2,082	-1,067	-9,008	0	-134	-117	4,578
33	8	0	8,388	0	2,086	-1,099	-9,587	0	-141	-121	-465
34	8	0	7,212	0	2,069	-1,101	-9,218	0	-140	-124	-1,293
35	8	0	9,104	0	2,090	-1,097	-9,102	0	-137	-127	740
36	8	0	6,306	0	2,071	-1,101	-9,417	0	-137	-128	-2,398
37	8	0	5,900	0	2,057	-1,089	-9,324	0	-134	-120	-2,701
38	8	0	5,544	0	2,055	-1,072	-9,056	0	-130	-112	-2,762
39	8	0	4,657	0	2,038	-1,057	-9,375	0	-128	-104	-3,961
40	9	0	5,576	0	2,041	-1,036	-9,327	0	-124	-99	-2,959
41	10	0	6,900	0	2,049	-1,020	-9,302	0	-123	-99	-1,586
42	10	0	4,601	0	2,035	-1,006	-9,440	0	-123	-94	-4,016
43	11	0	4,737	0	2,028	-982	-9,224	0	-120	-86	-3,636
44	13	0	9,876	0	2,057	-965	-9,166	0	-119	-86	1,610
45	14	0	8,968	0	2,073	-969	-9,567	0	-124	-93	303
46	15	0	9,812	0	2,102	-976	-8,953	0	-127	-97	1,776
47	16	0	9,710	0	2,125	-987	-9,116	0	-131	-99	1,518
Average (afy)	**7**	**0**	**7,770**	**0**	**1,981**	**-1,096**	**-9,196**	**0**	**-131**	**-93**	**-757**
Maximum (afy)	**16**	**0**	**12,815**	**0**	**2,125**	**-965**	**-8,786**	**0**	**-119**	**-68**	**4,578**
Minimum (afy)	**3**	**0**	**4,601**	**0**	**1,777**	**-1,289**	**-9,587**	**0**	**-147**	**-128**	**-4,016**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.


Scenario 3b South Westside Basin Water Balance
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Rain + Irrigation (afy)
Seepage from Golden Gate Park Lakes (afy)
Seepage from Lake Merced (afy)
Inflow from Bay & Ocean (afy)
Outflow to Bay & Ocean (afy)
Wells - Pumping (afy)
Seepage to Lake Merced (afy)
From North Westside Basin (afy)
To North Westside Basin (afy)
Drains (afy)



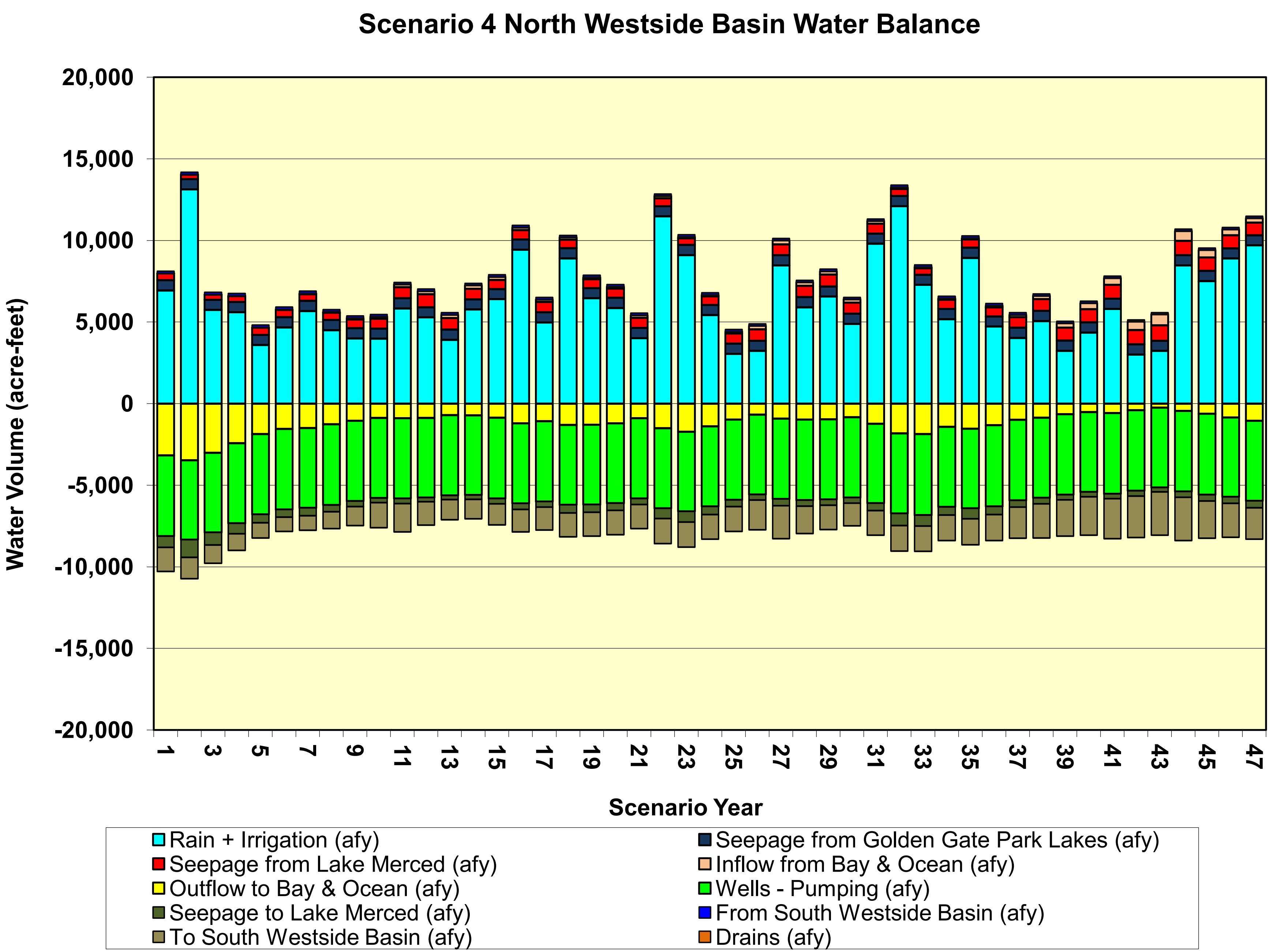
Scenario 3b South Westside Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Change in Groundwater Storage (afy)

Scenario 4 North Westside Basin Water Balance Summary

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From South to North Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From North to South Westside Basin (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	2	626	6,941	416	134	-3,172	-4,939	-694	-1,480	0	-2,165
2	2	628	13,135	282	139	-3,462	-4,869	-1,089	-1,306	0	3,460
3	2	626	5,749	305	147	-3,004	-4,887	-762	-1,130	0	-2,954
4	6	626	5,610	365	146	-2,415	-4,905	-645	-1,022	0	-2,235
5	15	626	3,598	439	146	-1,858	-4,918	-519	-939	0	-3,409
6	29	628	4,673	450	147	-1,551	-4,924	-473	-880	0	-1,901
7	39	626	5,687	404	138	-1,483	-4,903	-475	-895	0	-862
8	56	626	4,503	449	134	-1,266	-4,936	-417	-1,041	0	-1,892
9	84	626	4,009	526	131	-1,042	-4,927	-343	-1,152	0	-2,089
10	122	628	3,982	604	128	-868	-4,902	-298	-1,527	0	-2,133
11	169	626	5,843	670	125	-891	-4,921	-305	-1,744	0	-427
12	189	626	5,286	800	123	-873	-4,881	-252	-1,441	0	-423
13	204	626	3,915	712	122	-705	-4,909	-256	-1,242	0	-1,534
14	211	628	5,773	641	120	-722	-4,867	-281	-1,187	0	316
15	188	626	6,407	559	121	-857	-4,946	-328	-1,293	0	477
16	162	626	9,441	576	123	-1,204	-4,900	-382	-1,376	0	3,065
17	138	626	4,984	630	127	-1,073	-4,924	-337	-1,408	0	-1,236
18	135	628	8,904	524	125	-1,302	-4,898	-502	-1,457	0	2,157
19	115	626	6,466	534	127	-1,292	-4,890	-465	-1,474	0	-253
20	117	626	5,871	559	126	-1,197	-4,889	-453	-1,484	0	-723
21	151	626	4,017	627	123	-885	-4,918	-371	-1,479	0	-2,108
22	132	628	11,482	487	121	-1,503	-4,898	-640	-1,537	0	4,271
23	89	626	9,106	406	128	-1,712	-4,876	-668	-1,527	0	1,572
24	89	626	5,433	524	130	-1,391	-4,897	-503	-1,507	0	-1,496
25	124	626	3,062	610	126	-967	-4,924	-411	-1,526	0	-3,281
26	214	628	3,238	694	120	-665	-4,895	-339	-1,830	0	-2,836
27	242	626	8,480	660	117	-916	-4,921	-413	-2,020	0	1,855
28	213	626	5,916	688	120	-972	-4,931	-377	-1,678	0	-395
29	197	626	6,566	732	121	-963	-4,900	-360	-1,487	0	532
30	193	628	4,895	677	121	-826	-4,925	-347	-1,392	0	-976
31	164	626	9,806	600	121	-1,225	-4,868	-451	-1,511	0	3,262
32	106	626	12,107	429	127	-1,825	-4,896	-749	-1,558	0	4,367
33	76	626	7,280	393	134	-1,866	-4,957	-672	-1,554	0	-540
34	87	628	5,178	557	132	-1,415	-4,902	-510	-1,556	0	-1,802
35	95	626	8,941	496	128	-1,529	-4,882	-648	-1,587	0	1,640
36	97	626	4,727	553	129	-1,323	-4,971	-498	-1,599	0	-2,258
37	135	626	4,032	656	125	-993	-4,925	-418	-1,901	0	-2,663
38	195	628	5,061	723	120	-866	-4,899	-372	-2,095	0	-1,505
39	276	626	3,248	783	117	-642	-4,932	-315	-2,221	0	-3,059
40	383	626	4,359	803	113	-522	-4,885	-305	-2,343	0	-1,770
41	409	626	5,814	850	111	-566	-4,949	-304	-2,456	0	-464
42	508	628	3,017	878	110	-396	-4,943	-317	-2,541	0	-3,056
43	675	626	3,238	938	106	-242	-4,895	-264	-2,655	0	-2,474
44	611	626	8,481	872	104	-450	-4,926	-359	-2,656	0	2,304
45	463	626	7,522	818	108	-612	-4,958	-387	-2,290	0	1,291
46	364	626	8,902	793	111	-839	-4,871	-397	-2,077	0	2,613
47	279	618	9,712	767	116	-1,051	-4,896	-439	-1,920	0	3,185
Average (afy)	**182**	**626**	**6,264**	**606**	**125**	**-1,221**	**-4,910**	**-449**	**-1,617**	**0**	**-395**
Maximum (afy)	**675**	**628**	**13,135**	**938**	**147**	**-242**	**-4,867**	**-252**	**-880**	**0**	**4,367**
Minimum (afy)	**2**	**618**	**3,017**	**282**	**104**	**-3,462**	**-4,971**	**-1,089**	**-2,656**	**0**	**-3,409**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.


Scenario 4 North Westside Basin Water Balance
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
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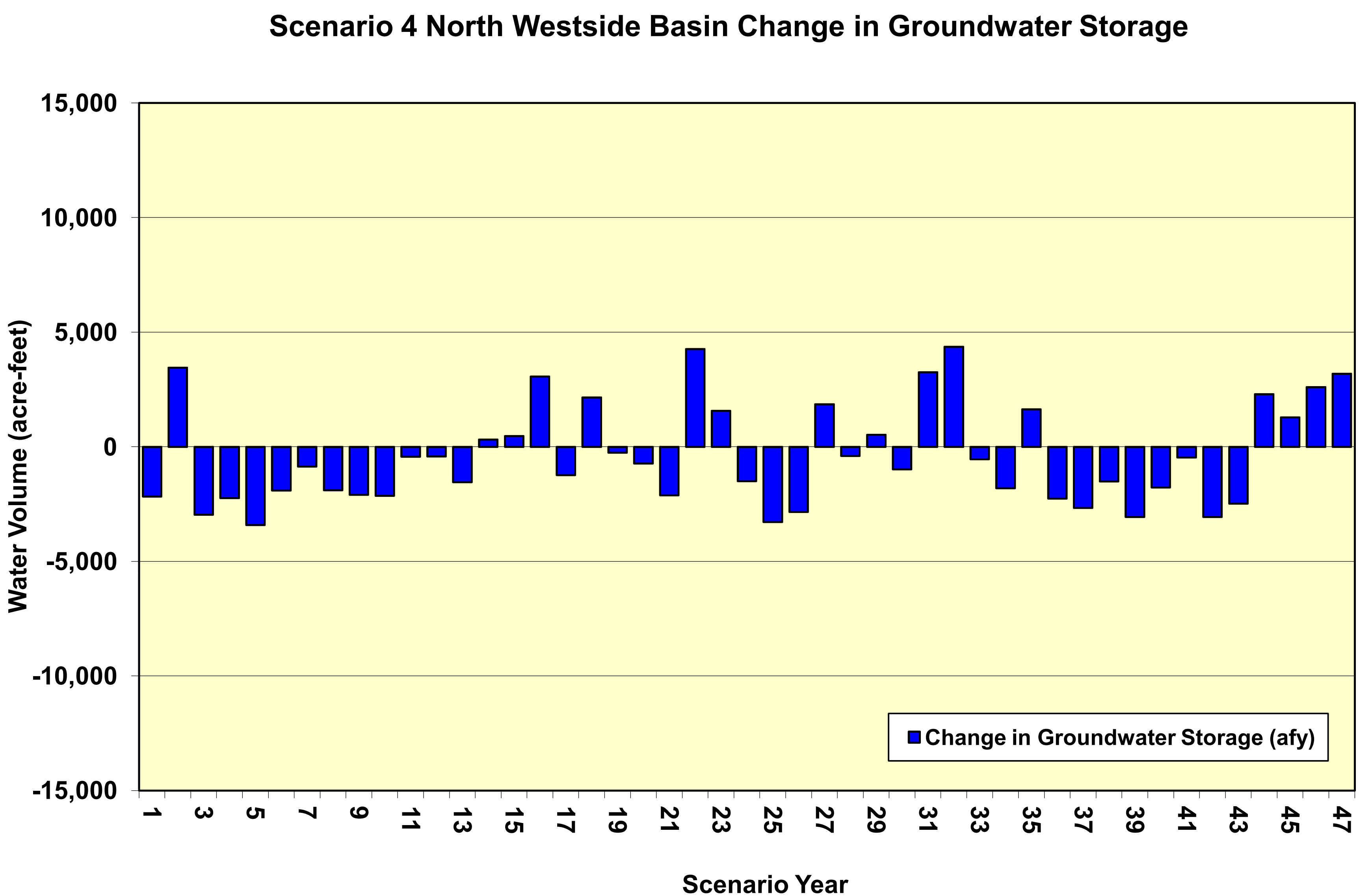
45
47
Scenario Year
Rain + Irrigation (afy)
Seepage from Golden Gate Park Lakes (afy)
Seepage from Lake Merced (afy)
Inflow from Bay & Ocean (afy)
Outflow to Bay & Ocean (afy)
Wells - Pumping (afy)
Seepage to Lake Merced (afy)
From South Westside Basin (afy)
To South Westside Basin (afy)
Drains (afy)



Scenario 4 North Westside Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
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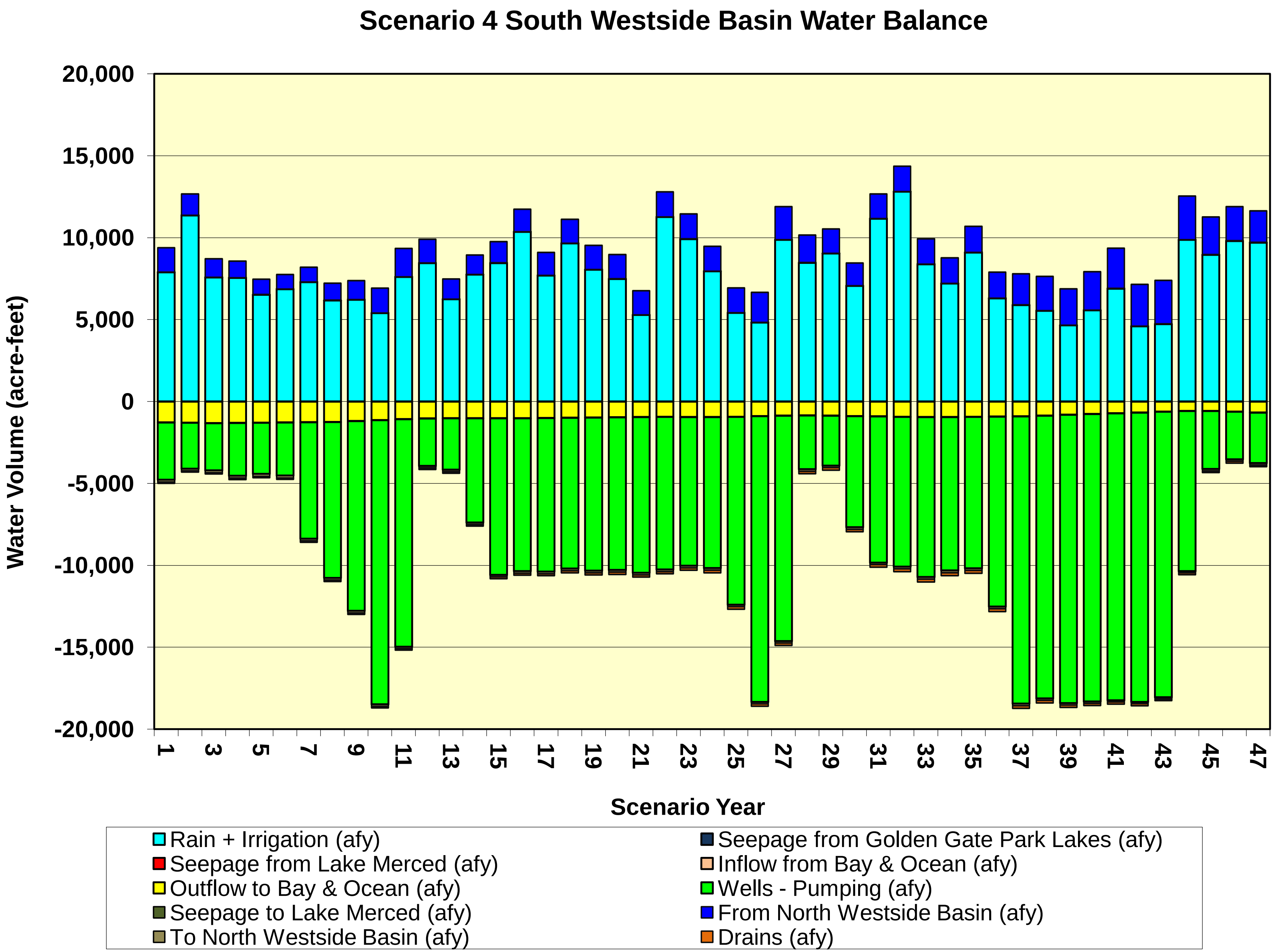
43
45
47
Scenario Year
Change in Groundwater Storage (afy)

Scenario 4 South Westside Basin Water Balance Summary

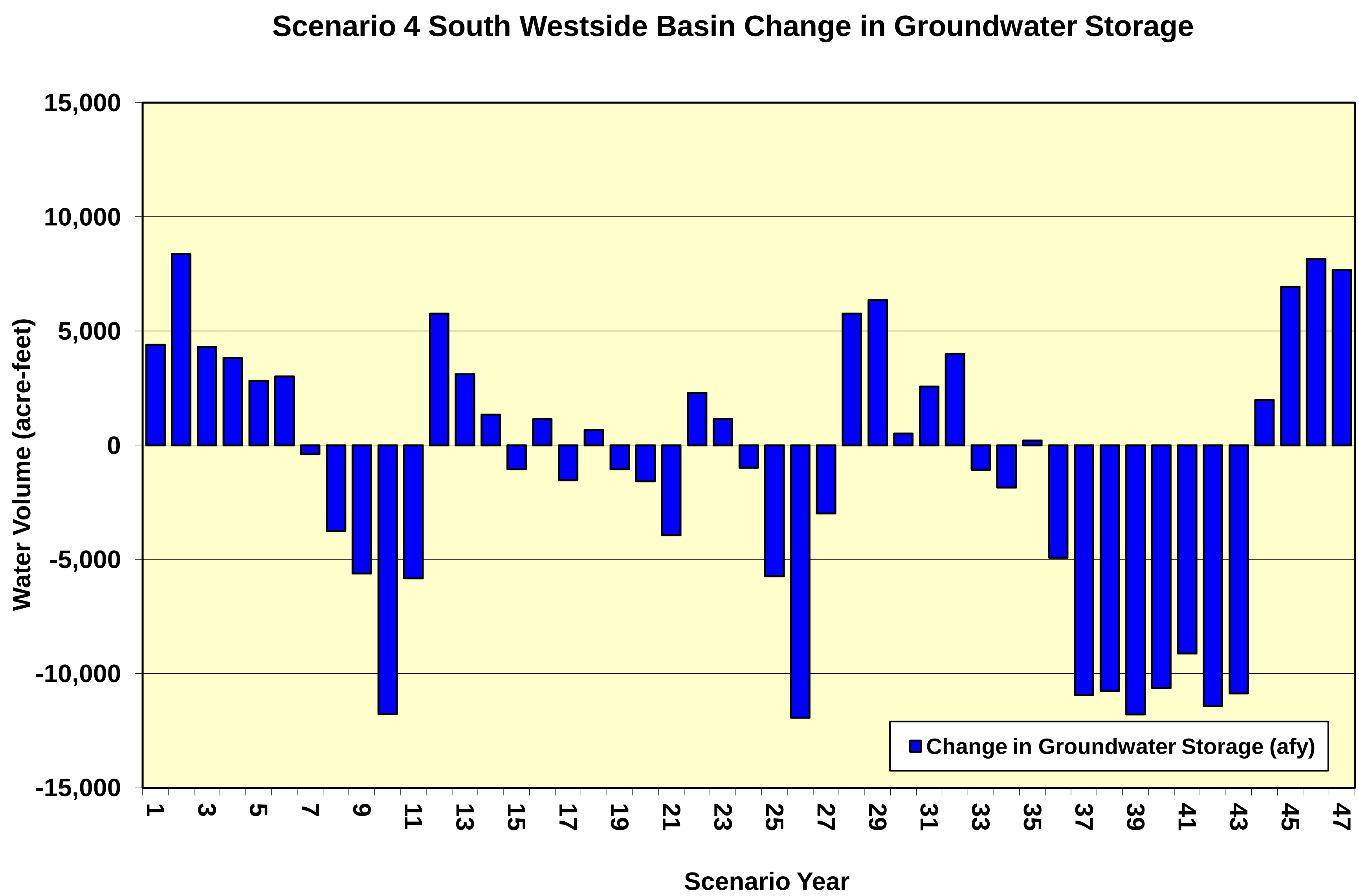
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From North to South Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From South to North Westside Basin (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	3	0	7,904	0	1,480	-1,281	-3,496	0	-134	-71	4,405
2	3	0	11,370	0	1,306	-1,291	-2,802	0	-139	-72	8,374
3	3	0	7,580	0	1,130	-1,312	-2,884	0	-147	-74	4,297
4	3	0	7,559	0	1,022	-1,305	-3,228	0	-146	-75	3,830
5	3	0	6,531	0	939	-1,293	-3,128	0	-146	-77	2,829
6	3	0	6,873	0	880	-1,276	-3,243	0	-147	-77	3,012
7	3	0	7,302	0	895	-1,266	-7,105	0	-138	-78	-388
8	2	0	6,188	0	1,041	-1,240	-9,522	0	-134	-81	-3,746
9	2	0	6,225	0	1,152	-1,193	-11,582	0	-131	-84	-5,611
10	2	0	5,405	0	1,527	-1,134	-17,343	0	-128	-85	-11,756
11	2	0	7,611	0	1,744	-1,067	-13,894	0	-125	-87	-5,817
12	2	0	8,465	0	1,441	-1,025	-2,898	0	-123	-95	5,768
13	2	0	6,247	0	1,242	-1,017	-3,136	0	-122	-98	3,118
14	2	0	7,760	0	1,187	-1,022	-6,362	0	-120	-100	1,345
15	2	0	8,469	0	1,293	-1,022	-9,556	0	-121	-110	-1,046
16	2	0	10,364	0	1,376	-1,013	-9,343	0	-123	-118	1,145
17	2	0	7,695	0	1,408	-1,002	-9,375	0	-127	-125	-1,525
18	2	0	9,663	0	1,457	-985	-9,209	0	-125	-131	672
19	2	0	8,066	0	1,474	-979	-9,342	0	-127	-137	-1,044
20	2	0	7,492	0	1,484	-965	-9,313	0	-126	-142	-1,569
21	2	0	5,293	0	1,479	-944	-9,509	0	-123	-135	-3,938
22	2	0	11,269	0	1,537	-933	-9,319	0	-121	-136	2,299
23	2	0	9,930	0	1,527	-945	-9,082	0	-128	-145	1,159
24	2	0	7,964	0	1,507	-944	-9,226	0	-130	-150	-976
25	2	0	5,416	0	1,526	-927	-11,468	0	-126	-152	-5,728
26	2	0	4,834	0	1,830	-892	-17,441	0	-120	-140	-11,927
27	3	0	9,875	0	2,020	-852	-13,773	0	-117	-138	-2,983
28	3	0	8,482	0	1,678	-843	-3,287	0	-120	-146	5,766
29	3	0	9,043	0	1,487	-862	-3,048	0	-121	-150	6,353
30	3	0	7,065	0	1,392	-890	-6,783	0	-121	-154	513
31	4	0	11,168	0	1,511	-907	-8,926	0	-121	-158	2,571
32	4	0	12,815	0	1,558	-928	-9,156	0	-127	-162	4,002
33	4	0	8,388	0	1,554	-950	-9,757	0	-134	-167	-1,062
34	3	0	7,212	0	1,556	-941	-9,373	0	-132	-172	-1,846
35	3	0	9,104	0	1,587	-927	-9,253	0	-128	-176	210
36	3	0	6,306	0	1,599	-923	-11,595	0	-129	-176	-4,914
37	3	0	5,900	0	1,901	-895	-17,544	0	-125	-163	-10,924
38	4	0	5,544	0	2,095	-852	-17,266	0	-120	-153	-10,748
39	4	0	4,657	0	2,221	-807	-17,598	0	-117	-140	-11,780
40	5	0	5,576	0	2,343	-757	-17,547	0	-113	-130	-10,623
41	7	0	6,900	0	2,456	-713	-17,521	0	-111	-128	-9,110
42	8	0	4,601	0	2,541	-671	-17,664	0	-110	-120	-11,414
43	10	0	4,737	0	2,655	-620	-17,426	0	-106	-107	-10,857
44	12	0	9,876	0	2,656	-576	-9,778	0	-104	-103	1,983
45	15	0	8,968	0	2,290	-578	-3,536	0	-108	-107	6,944
46	17	0	9,812	0	2,077	-614	-2,917	0	-111	-107	8,156
47	19	0	9,710	0	1,920	-666	-3,086	0	-116	-107	7,674
Average (afy)	**4**	**0**	**7,770**	**0**	**1,617**	**-958**	**-9,354**	**0**	**-125**	**-122**	**-1,168**
Maximum (afy)	**19**	**0**	**12,815**	**0**	**2,656**	**-576**	**-2,802**	**0**	**-104**	**-71**	**8,374**
Minimum (afy)	**2**	**0**	**4,601**	**0**	**880**	**-1,312**	**-17,664**	**0**	**-147**	**-176**	**-11,927**

Key:
afy - acre-feet per year
GGP - Golden Gate Park

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.



Scenario 4 South Westside Basin Water Balance
Water Volume (acre-feet)
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Rain + Irrigation (afy)
Seepage from Golden Gate Park Lakes (afy)
Seepage from Lake Merced (afy)
Inflow from Bay & Ocean (afy)
Outflow to Bay & Ocean (afy)
Wells - Pumping (afy)
Seepage to Lake Merced (afy)
From North Westside Basin (afy)
To North Westside Basin (afy)
Drains (afy)



Scenario 4 South Westside Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Change in Groundwater Storage (afy)

Attachment 10.1-E

Model Scenario Water Balance Results – San Francisco, Daly City, Colma, South San Francisco, and San Bruno Water Budget Zones

Scenario 1 - Summary of Zone Budget Analyses in Subareas

Daly City — Zone 1

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	538	Storage	308	Storage	-230
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	4253	Pumpage	-4253
Drains	0	Drains	0	Drains	0
Recharge	1155	Recharge	0	Recharge	1155
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 2	660	To Zone 2	82	Zone 2	578
From Zone 8	2183	To Zone 8	71	Zone 8	2112
From Zone 11	199	To Zone 11	0	Zone 11	199

Colma — Zone 2

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	436	Storage	334	Storage	-103
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	716	Pumpage	-716
Drains	0	Drains	0	Drains	0
Recharge	917	Recharge	0	Recharge	917
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 1	82	To Zone 1	659	Zone 1	-577
From Zone 3	479	To Zone 3	468	Zone 3	11
From Zone 11	269	To Zone 11	0	Zone 11	269

Cal Water — Zone 3

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	393	Storage	253	Storage	-140
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	1535	Pumpage	-1535
Drains	0	Drains	0	Drains	0
Recharge	1453	Recharge	0	Recharge	1453
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 2	467	To Zone 2	478	Zone 2	-12
From Zone 4	376	To Zone 4	1023	Zone 4	-647
From Zone 5	180	To Zone 5	139	Zone 5	41
From Zone 11	562	To Zone 11	0	Zone 11	562

San Bruno — Zone 4

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	213	Storage	229	Storage	15
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	2104	Pumpage	-2104
Drains	0	Drains	0	Drains	0
Recharge	796	Recharge	0	Recharge	796
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 3	1023	To Zone 3	373	Zone 3	650
From Zone 5	498	To Zone 5	308	Zone 5	190
From Zone 6	870	To Zone 6	387	Zone 6	484
From Zone 11	3	To Zone 11	0	Zone 11	3

Bay Plain/Bay — Zone 5

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	59	Storage	68	Storage	9
Constant Head	6	Constant Head	110	Constant Head	-103
Pumpage	0	Pumpage	0	Pumpage	0
Drains	0	Drains	93	Drains	-93
Recharge	332	Recharge	0	Recharge	332
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 3	139	To Zone 3	179	Zone 3	-40
From Zone 4	308	To Zone 4	498	Zone 4	-190
From Zone 6	283	To Zone 6	265	Zone 6	18
From Zone 7	112	To Zone 7	26	Zone 7	86

Millbrae — Zone 6

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	168	Storage	153	Storage	-15
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	110	Pumpage	-110
Drains	0	Drains	0	Drains	0
Recharge	557	Recharge	0	Recharge	557
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 4	387	To Zone 4	870	Zone 4	-484
From Zone 5	265	To Zone 5	283	Zone 5	-18
From Zone 7	65	To Zone 7	25	Zone 7	40

Burlingame — Zone 7

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	361	Storage	290	Storage	-70
Constant Head	0	Constant Head	12	Constant Head	-12
Pumpage	0	Pumpage	468	Pumpage	-468
Drains	0	Drains	0	Drains	0
Recharge	537	Recharge	0	Recharge	537
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 5	26	To Zone 5	112	Zone 5	-86
From Zone 6	25	To Zone 6	65	Zone 6	-40

Lake Merced/GGP — Zone 8

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	1652	Storage	1497	Storage	-155
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	551	Pumpage	1618	Pumpage	-1067
Drains	0	Drains	0	Drains	0
Recharge	5979	Recharge	0	Recharge	5979
Lake Seepage	544	Lake Seepage	649	Lake Seepage	-105
From Zone 1	71	To Zone 1	2175	Zone 1	-2104
From Zone 10	257	To Zone 10	3139	Zone 10	-2882
From Zone 11	24	To Zone 11	1	Zone 11	23

Ocean — Zone 10

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	50	Storage	44	Storage	-7
Constant Head	5	Constant Head	4055	Constant Head	-4050
Pumpage	0	Pumpage	0	Pumpage	0
Drains	0	Drains	0	Drains	0
Recharge	0	Recharge	0	Recharge	0
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 8	3139	To Zone 8	257	Zone 8	2882
From Zone 11	1182	To Zone 11	21	Zone 11	1161

Thornton Beach — Zone 11

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	594	Storage	480	Storage	-114
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	0	Pumpage	0
Drains	0	Drains	0	Drains	0
Recharge	2101	Recharge	0	Recharge	2101
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 1	0	To Zone 1	199	Zone 1	-199
From Zone 2	0	To Zone 2	269	Zone 2	-269
From Zone 3	0	To Zone 3	562	Zone 3	-562
From Zone 4	0	To Zone 4	3	Zone 4	-3
From Zone 8	1	To Zone 8	24	Zone 8	-23
From Zone 10	21	To Zone 10	1180	Zone 10	-1159

Subareas 1, 2, 3, 4, and 8

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	3233	Storage	2620	Storage	-613
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	551	Pumpage	10227	Pumpage	-9676
Drains	0	Drains	0	Drains	0
Recharge	10301	Recharge	0	Recharge	10301
Lake Seepage	544	Lake Seepage	649	Lake Seepage	-105
Ocean	257	Ocean	3139	Ocean	-2882
Bay Plain/Bay	678	Bay Plain/Bay	447	Bay Plain/Bay	231
Millbrae	870	Millbrae	387	Millbrae	484
Thornton Beach	1057	Thornton Beach	1	Thornton Beach	1056

Notes: (1) The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flow out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced. Negative storage values represent losses of storage from the aquifer, while positive storage values represent gains in storage in the aquifer.

(2) Water balance components represent annual average values on a water year basis, from October to September. The first three months of the simulation period, which represent July through September conditions, are omitted from the annual averages because they represent only a partial water year. The volumes presented represent the 47 complete water years for the simulation period.

(3) Volumes are calculated using the USGS program ZONEBUDGET (Harbaugh, 1990). As noted in Harbaugh (1990), ZONEBUDGET tabulates boundary conditions differently from how they are reported in the MODFLOW output file. Also, ZONEBUDGET calculates volumes using the volumetric flow rate rather than the cumulative volume. Therefore, the water balance presented in Attachment 10.1-C, calculated using the cumulative volume as reported in the MODFLOW output file, may differ from the results reported on this table. However, the volumes calculated by the two methods are correct with respect to each method.

(4) [green] The five water budget areas that are collectively referred to as "Developed Subbasin" as defined by HydroFocus (2011): San Francisco (Lake Merced and Golden Gate Park), Daly City, Colma, South San Francisco, and San Bruno.

[pink] The five water budget areas that are adjacent to the Developed Subbasin as defined by HydroFocus (2011): San Francisco Bay Plain, Millbrae, Burlingame, Pacific Ocean, and Thornton Beach (across the Serra Fault).

Scenario 2 - Summary of Zone Budget Analyses in Subareas

Daly City — Zone 1

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	1116	Storage	705	Storage	-411
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	3921	Pumpage	-3921
Drains	0	Drains	0	Drains	0
Recharge	1155	Recharge	0	Recharge	1155
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 2	461	To Zone 2	207	Zone 2	254
From Zone 8	1958	To Zone 8	63	Zone 8	1895
From Zone 11	184	To Zone 11	0	Zone 11	184

Colma — Zone 2

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	737	Storage	457	Storage	-280
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	1198	Pumpage	-1198
Drains	0	Drains	0	Drains	0
Recharge	917	Recharge	0	Recharge	917
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 1	216	To Zone 1	482	Zone 1	-266
From Zone 3	560	To Zone 3	566	Zone 3	-7
From Zone 11	268	To Zone 11	0	Zone 11	268

Cal Water — Zone 3

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	926	Storage	552	Storage	-374
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	2120	Pumpage	-2120
Drains	0	Drains	1	Drains	-1
Recharge	1453	Recharge	0	Recharge	1453
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 2	565	To Zone 2	558	Zone 2	8
From Zone 4	404	To Zone 4	725	Zone 4	-322
From Zone 5	168	To Zone 5	130	Zone 5	38
From Zone 11	576	To Zone 11	0	Zone 11	576

San Bruno — Zone 4

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	496	Storage	412	Storage	-84
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	1836	Pumpage	-1836
Drains	0	Drains	0	Drains	0
Recharge	796	Recharge	0	Recharge	796
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 3	725	To Zone 3	398	Zone 3	328
From Zone 5	449	To Zone 5	282	Zone 5	167
From Zone 6	787	To Zone 6	350	Zone 6	437
From Zone 11	3	To Zone 11	0	Zone 11	3

Bay Plain/Bay — Zone 5

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	131	Storage	121	Storage	-10
Constant Head	4	Constant Head	122	Constant Head	-118
Pumpage	0	Pumpage	0	Pumpage	0
Drains	0	Drains	122	Drains	-122
Recharge	332	Recharge	0	Recharge	332
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 3	130	To Zone 3	166	Zone 3	-35
From Zone 4	282	To Zone 4	449	Zone 4	-167
From Zone 6	254	To Zone 6	243	Zone 6	11
From Zone 7	110	To Zone 7	20	Zone 7	90

Millbrae — Zone 6

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	225	Storage	188	Storage	-37
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	179	Pumpage	-179
Drains	0	Drains	0	Drains	0
Recharge	557	Recharge	0	Recharge	557
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 4	350	To Zone 4	787	Zone 4	-437
From Zone 5	243	To Zone 5	254	Zone 5	-11
From Zone 7	60	To Zone 7	28	Zone 7	32

Burlingame — Zone 7

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	360	Storage	293	Storage	-67
Constant Head	0	Constant Head	13	Constant Head	-13
Pumpage	0	Pumpage	468	Pumpage	-468
Drains	0	Drains	0	Drains	0
Recharge	537	Recharge	0	Recharge	537
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 5	20	To Zone 5	110	Zone 5	-90
From Zone 6	28	To Zone 6	60	Zone 6	-32

Lake Merced/GGP — Zone 8

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	1704	Storage	1523	Storage	-181
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	551	Pumpage	1618	Pumpage	-1067
Drains	0	Drains	0	Drains	0
Recharge	5979	Recharge	0	Recharge	5979
Lake Seepage	496	Lake Seepage	645	Lake Seepage	-149
From Zone 1	63	To Zone 1	1923	Zone 1	-1859
From Zone 10	228	To Zone 10	3333	Zone 10	-3104
From Zone 11	21	To Zone 11	2	Zone 11	20

Ocean — Zone 10

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	54	Storage	44	Storage	-10
Constant Head	6	Constant Head	4319	Constant Head	-4313
Pumpage	0	Pumpage	0	Pumpage	0
Drains	0	Drains	0	Drains	0
Recharge	0	Recharge	0	Recharge	0
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 8	3333	To Zone 8	228	Zone 8	3104
From Zone 11	1220	To Zone 11	21	Zone 11	1199

Thornton Beach — Zone 11

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	634	Storage	497	Storage	-136
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	0	Pumpage	0
Drains	0	Drains	0	Drains	0
Recharge	2101	Recharge	0	Recharge	2101
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 1	0	To Zone 1	184	Zone 1	-184
From Zone 2	0	To Zone 2	267	Zone 2	-267
From Zone 3	0	To Zone 3	574	Zone 3	-574
From Zone 4	0	To Zone 4	3	Zone 4	-3
From Zone 8	1	To Zone 8	22	Zone 8	-20
From Zone 10	21	To Zone 10	1211	Zone 10	-1190

Subareas 1, 2, 3, 4, and 8

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	4979	Storage	3649	Storage	-1330
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	551	Pumpage	10692	Pumpage	-10141
Drains	0	Drains	1	Drains	-1
Recharge	10301	Recharge	0	Recharge	10301
Lake Seepage	496	Lake Seepage	645	Lake Seepage	-149
Ocean	228	Ocean	3333	Ocean	-3104
Bay Plain/Bay	617	Bay Plain/Bay	412	Bay Plain/Bay	205
Millbrae	787	Millbrae	350	Millbrae	437
Thornton Beach	1052	Thornton Beach	2	Thornton Beach	1051

Notes: (1) The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flow out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced. Negative storage values represent losses of storage from the aquifer, while positive storage values represent gains in storage in the aquifer.

(2) Water balance components represent annual average values on a water year basis, from October to September. The first three months of the simulation period, which represent July through September conditions, are omitted from the annual averages because they represent only a partial water year. The volumes presented represent the 47 complete water years for the simulation period.

(3) Volumes are calculated using the USGS program ZONEBUDGET (Harbaugh, 1990). As noted in Harbaugh (1990), ZONEBUDGET tabulates boundary conditions differently from how they are reported in the MODFLOW output file. Also, ZONEBUDGET calculates volumes using the volumetric flow rate rather than the cumulative volume. Therefore, the water balance presented in Attachment 10.1-C, calculated using the cumulative volume as reported in the MODFLOW output file, may differ from the results reported on this table. However, the volumes calculated by the two methods are correct with respect to each method.

(4) [green] The five water budget areas that are collectively referred to as "Developed Subbasin" as defined by HydroFocus (2011): San Francisco (Lake Merced and Golden Gate Park), Daly City, Colma, South San Francisco, and San Bruno.
[pink] The five water budget areas that are adjacent to the Developed Subbasin as defined by HydroFocus (2011): San Francisco Bay Plain, Millbrae, Burlingame, Pacific Ocean, and Thornton Beach (across the Serra Fault).

Scenario 3a - Summary of Zone Budget Analyses in Subareas

IN (acre-feet/year)

Daly City	Zone 1	Colma	Zone 2	Cal Water	Zone 3	San Bruno	Zone 4	Bay Plain/Bay	Zone 5
Storage	613	Storage	458	Storage	413	Storage	216	Storage	60
Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	7
Pumpage	0	Pumpage	0	Pumpage	0	Pumpage	0	Pumpage	0
Drains	0	Drains	0	Drains	0	Drains	0	Drains	0
Recharge	1155	Recharge	917	Recharge	1453	Recharge	796	Recharge	332
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 2	754	From Zone 1	86	From Zone 2	443	From Zone 3	1016	From Zone 3	137
From Zone 8	1983	From Zone 3	501	From Zone 4	378	From Zone 5	499	From Zone 4	308
From Zone 11	209	From Zone 11	275	From Zone 5	180	From Zone 6	872	From Zone 6	284
				From Zone 11	566	From Zone 11	3	From Zone 7	112

Millbrae	Zone 6	Burlingame	Zone 7	Lake Merced/GGP	Zone 8	Ocean	Zone 10	Thornton Beach	Zone 11	Subareas 1, 2, 3, 4, and 8	
Storage	168	Storage	361	Storage	2079	Storage	58	Storage	599	Storage	3779
Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	381	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	0	Pumpage	551	Pumpage	0	Pumpage	0	Pumpage	551
Drains	0	Drains	0	Drains	0	Drains	0	Drains	0	Drains	0
Recharge	557	Recharge	537	Recharge	5979	Recharge	0	Recharge	2101	Recharge	10301
Lake Seepage	0	Lake Seepage	0	Lake Seepage	573	Lake Seepage	0	Lake Seepage	0	Lake Seepage	573
From Zone 4	388	From Zone 5	26	From Zone 1	67	From Zone 8	904	From Zone 1	0	Ocean	560
From Zone 5	266	From Zone 6	25	From Zone 10	560	From Zone 11	1166	From Zone 2	0	Bay Plain/Bay	679
From Zone 7	65			From Zone 11	30			From Zone 3	0	Millbrae	872
								From Zone 4	0	Thornton Beach	1084
								From Zone 8	0		
								From Zone 10	23		

OUT (acre-feet/year)

Daly City	Zone 1	Colma	Zone 2	Cal Water	Zone 3	San Bruno	Zone 4	Bay Plain/Bay	Zone 5
Storage	285	Storage	318	Storage	242	Storage	225	Storage	67
Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	110
Pumpage	4253	Pumpage	716	Pumpage	1535	Pumpage	2104	Pumpage	0
Drains	0	Drains	0	Drains	0	Drains	0	Drains	93
Recharge	0	Recharge	0	Recharge	0	Recharge	0	Recharge	0
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
To Zone 2	86	To Zone 1	749	To Zone 2	499	To Zone 3	375	To Zone 3	179
To Zone 8	67	To Zone 3	446	To Zone 4	1016	To Zone 5	308	To Zone 4	499
To Zone 11	0	To Zone 11	0	To Zone 5	137	To Zone 6	388	To Zone 6	266
				To Zone 11	0	To Zone 11	0	To Zone 7	26

Millbrae	Zone 6	Burlingame	Zone 7	Lake Merced/GGP	Zone 8	Ocean	Zone 10	Thornton Beach	Zone 11	Subareas 1, 2, 3, 4, and 8	
Storage	152	Storage	290	Storage	1407	Storage	40	Storage	477	Storage	2478
Constant Head	0	Constant Head	12	Constant Head	0	Constant Head	1885	Constant Head	0	Constant Head	0
Pumpage	110	Pumpage	468	Pumpage	4990	Pumpage	0	Pumpage	0	Pumpage	13599
Drains	0	Drains	0	Drains	0	Drains	0	Drains	0	Drains	0
Recharge	0	Recharge	0	Recharge	0	Recharge	0	Recharge	0	Recharge	0
Lake Seepage	0	Lake Seepage	0	Lake Seepage	566	Lake Seepage	0	Lake Seepage	0	Lake Seepage	566
To Zone 4	872	To Zone 5	112	To Zone 1	1974	To Zone 8	560	To Zone 1	209	Ocean	904
To Zone 5	284	To Zone 6	65	To Zone 10	904	To Zone 11	23	To Zone 2	275	Bay Plain/Bay	446
To Zone 7	25			To Zone 11	0			To Zone 3	566	Millbrae	388
								To Zone 4	3	Thornton Beach	0
								To Zone 8	31		
								To Zone 10	1163		

NET (acre-feet/year)

Daly City	Zone 1	Colma	Zone 2	Cal Water	Zone 3	San Bruno	Zone 4	Bay Plain/Bay	Zone 5
Storage	-328	Storage	-140	Storage	-170	Storage	9	Storage	6
Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	-103
Pumpage	-4253	Pumpage	-716	Pumpage	-1535	Pumpage	-2104	Pumpage	0
Drains	0	Drains	0	Drains	0	Drains	0	Drains	-93
Recharge	1155	Recharge	917	Recharge	1453	Recharge	796	Recharge	332
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
Zone 2	668	Zone 1	-663	Zone 2	-57	Zone 3	641	Zone 3	-42
Zone 8	1915	Zone 3	56	Zone 4	-638	Zone 5	191	Zone 4	-191
Zone 11	209	Zone 11	275	Zone 5	43	Zone 6	485	Zone 6	18
				Zone 11	566	Zone 11	3	Zone 7	86

Millbrae	Zone 6	Burlingame	Zone 7	Lake Merced/GGP	Zone 8	Ocean	Zone 10	Thornton Beach	Zone 11	Subareas 1, 2, 3, 4, and 8	
Storage	-16	Storage	-71	Storage	-672	Storage	-18	Storage	-122	Storage	-1301
Constant Head	0	Constant Head	-12	Constant Head	0	Constant Head	-1505	Constant Head	0	Constant Head	0
Pumpage	-110	Pumpage	-468	Pumpage	-4439	Pumpage	0	Pumpage	0	Pumpage	-13048
Drains	0	Drains	0	Drains	0	Drains	0	Drains	0	Drains	0
Recharge	557	Recharge	537	Recharge	5979	Recharge	0	Recharge	2101	Recharge	10301
Lake Seepage	0	Lake Seepage	0	Lake Seepage	8	Lake Seepage	0	Lake Seepage	0	Lake Seepage	8
Zone 4	-485	Zone 5	-86	Zone 1	-1907	Zone 8	344	Zone 1	-209	Ocean	-344
Zone 5	-18	Zone 6	-40	Zone 10	-344	Zone 11	1143	Zone 2	-275	Bay Plain/Bay	234
Zone 7	40			Zone 11	30			Zone 3	-566	Millbrae	485
								Zone 4	-3	Thornton Beach	1083
								Zone 8	-30		
								Zone 10	-1140		

Notes: (1) The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flow out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced. Negative storage values represent losses of storage from the aquifer, while positive storage values represent gains in storage in the aquifer.

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[pink] The five water budget areas that are adjacent to the Developed Subbasin as defined by HydroFocus (2011): San Francisco Bay Plain, Millbrae, Burlingame, Pacific Ocean, and Thornton Beach (across the Serra Fault).

Scenario 3b - Summary of Zone Budget Analyses in Subareas

Daly City — Zone 1

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	611	Storage	286	Storage	-326
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	4253	Pumpage	-4253
Drains	0	Drains	0	Drains	0
Recharge	1155	Recharge	0	Recharge	1155
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 2	752	To Zone 2	86	Zone 2	667
From Zone 8	1987	To Zone 8	67	Zone 8	1919
From Zone 11	209	To Zone 11	0	Zone 11	209

Colma — Zone 2

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	457	Storage	318	Storage	-139
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	716	Pumpage	-716
Drains	0	Drains	0	Drains	0
Recharge	917	Recharge	0	Recharge	917
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 1	86	To Zone 1	748	Zone 1	-661
From Zone 3	501	To Zone 3	446	Zone 3	55
From Zone 11	275	To Zone 11	0	Zone 11	275

Cal Water — Zone 3

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	412	Storage	243	Storage	-170
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	1535	Pumpage	-1535
Drains	0	Drains	0	Drains	0
Recharge	1453	Recharge	0	Recharge	1453
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 2	443	To Zone 2	499	Zone 2	-56
From Zone 4	378	To Zone 4	1016	Zone 4	-638
From Zone 5	180	To Zone 5	137	Zone 5	43
From Zone 11	566	To Zone 11	0	Zone 11	566

San Bruno — Zone 4

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	216	Storage	226	Storage	9
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	2104	Pumpage	-2104
Drains	0	Drains	0	Drains	0
Recharge	796	Recharge	0	Recharge	796
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 3	1016	To Zone 3	375	Zone 3	642
From Zone 5	499	To Zone 5	308	Zone 5	191
From Zone 6	872	To Zone 6	388	Zone 6	485
From Zone 11	3	To Zone 11	0	Zone 11	3

Bay Plain/Bay — Zone 5

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	60	Storage	67	Storage	6
Constant Head	7	Constant Head	110	Constant Head	-103
Pumpage	0	Pumpage	0	Pumpage	0
Drains	0	Drains	93	Drains	-93
Recharge	332	Recharge	0	Recharge	332
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 3	137	To Zone 3	179	Zone 3	-42
From Zone 4	308	To Zone 4	499	Zone 4	-191
From Zone 6	284	To Zone 6	266	Zone 6	18
From Zone 7	112	To Zone 7	26	Zone 7	86

Millbrae — Zone 6

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	168	Storage	152	Storage	-16
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	110	Pumpage	-110
Drains	0	Drains	0	Drains	0
Recharge	557	Recharge	0	Recharge	557
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 4	388	To Zone 4	872	Zone 4	-485
From Zone 5	266	To Zone 5	284	Zone 5	-18
From Zone 7	65	To Zone 7	25	Zone 7	40

Burlingame — Zone 7

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	361	Storage	290	Storage	-70
Constant Head	0	Constant Head	12	Constant Head	-12
Pumpage	0	Pumpage	468	Pumpage	-468
Drains	0	Drains	0	Drains	0
Recharge	537	Recharge	0	Recharge	537
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 5	26	To Zone 5	112	Zone 5	-86
From Zone 6	25	To Zone 6	65	Zone 6	-40

Lake Merced/GGP — Zone 8

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	1922	Storage	1292	Storage	-630
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	626	Pumpage	4906	Pumpage	-4281
Drains	0	Drains	0	Drains	0
Recharge	5979	Recharge	0	Recharge	5979
Lake Seepage	576	Lake Seepage	572	Lake Seepage	4
From Zone 1	67	To Zone 1	1978	Zone 1	-1910
From Zone 10	466	To Zone 10	919	Zone 10	-453
From Zone 11	30	To Zone 11	0	Zone 11	30

Ocean — Zone 10

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	44	Storage	26	Storage	-17
Constant Head	294	Constant Head	1908	Constant Head	-1614
Pumpage	0	Pumpage	0	Pumpage	0
Drains	0	Drains	0	Drains	0
Recharge	0	Recharge	0	Recharge	0
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 8	919	To Zone 8	466	Zone 8	453
From Zone 11	1166	To Zone 11	22	Zone 11	1143

Thornton Beach — Zone 11

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	599	Storage	477	Storage	-122
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	0	Pumpage	0
Drains	0	Drains	0	Drains	0
Recharge	2101	Recharge	0	Recharge	2101
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0
From Zone 1	0	To Zone 1	209	Zone 1	-209
From Zone 2	0	To Zone 2	275	Zone 2	-275
From Zone 3	0	To Zone 3	566	Zone 3	-566
From Zone 4	0	To Zone 4	3	Zone 4	-3
From Zone 8	0	To Zone 8	30	Zone 8	-30
From Zone 10	23	To Zone 10	1163	Zone 10	-1141

Subareas 1, 2, 3, 4, and 8

IN (acre-feet/year)		OUT (acre-feet/year)		NET (acre-feet/year)	
Storage	3619	Storage	2363	Storage	-1256
Constant Head	0	Constant Head	0	Constant Head	0
Pumpage	626	Pumpage	13515	Pumpage	-12890
Drains	0	Drains	0	Drains	0
Recharge	10301	Recharge	0	Recharge	10301
Lake Seepage	576	Lake Seepage	572	Lake Seepage	4
Ocean	466	Ocean	919	Ocean	-453
Bay Plain/Bay	679	Bay Plain/Bay	446	Bay Plain/Bay	234
Millbrae	872	Millbrae	388	Millbrae	485
Thornton Beach	1083	Thornton Beach	0	Thornton Beach	1083

Notes: (1) The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flow out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced. Negative storage values represent losses of storage from the aquifer, while positive storage values represent gains in storage in the aquifer.

(2) Water balance components represent annual average values on a water year basis, from October to September. The first three months of the simulation period, which represent July through September conditions, are omitted from the annual averages because they represent only a partial water year. The volumes presented represent the 47 complete water years for the simulation period.

(3) Volumes are calculated using the USGS program ZONEBUDGET (Harbaugh, 1990). As noted in Harbaugh (1990), ZONEBUDGET tabulates boundary conditions differently from how they are reported in the MODFLOW output file. Also, ZONEBUDGET calculates volumes using the volumetric flow rate rather than the cumulative volume. Therefore, the water balance presented in Attachment 10.1-C, calculated using the cumulative volume as reported in the MODFLOW output file, may differ from the results reported on this table. However, the volumes calculated by the two methods are correct with respect to each method.

(4) [green] The five water budget areas that are collectively referred to as "Developed Subbasin" as defined by HydroFocus (2011): San Francisco (Lake Merced and Golden Gate Park), Daly City, Colma, South San Francisco, and San Bruno.

[pink] The five water budget areas that are adjacent to the Developed Subbasin as defined by HydroFocus (2011): San Francisco Bay Plain, Millbrae, Burlingame, Pacific Ocean, and Thornton Beach (across the Serra Fault).

Scenario 4 - Summary of Zone Budget Analyses in Subareas

Daly City — Zone 1

IN (acre-feet/year)	Storage	1050
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	1155
	Lake Seepage	0
	From Zone 2	367
	From Zone 8	1614
	From Zone 11	175
OUT (acre-feet/year)	Storage	659
	Constant Head	0
	Pumpage	3421
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 2	237
	To Zone 8	55
	To Zone 11	0
NET (acre-feet/year)	Storage	-391
	Constant Head	0
	Pumpage	-3421
	Drains	0
	Recharge	1155
	Lake Seepage	0
	Zone 2	130
	Zone 8	1559
	Zone 11	175

Colma — Zone 2

IN (acre-feet/year)	Storage	736
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	917
	Lake Seepage	0
	From Zone 1	248
	From Zone 3	539
	From Zone 11	245
OUT (acre-feet/year)	Storage	468
	Constant Head	0
	Pumpage	1243
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 1	382
	To Zone 3	593
	To Zone 11	0
NET (acre-feet/year)	Storage	-267
	Constant Head	0
	Pumpage	-1243
	Drains	0
	Recharge	917
	Lake Seepage	0
	Zone 1	-135
	Zone 3	-54
	Zone 11	245

Cal Water — Zone 3

IN (acre-feet/year)	Storage	931
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	1453
	Lake Seepage	0
	From Zone 2	593
	From Zone 4	401
	From Zone 5	169
	From Zone 11	524
OUT (acre-feet/year)	Storage	558
	Constant Head	0
	Pumpage	2120
	Drains	1
	Recharge	0
	Lake Seepage	0
	To Zone 2	536
	To Zone 4	717
	To Zone 5	132
	To Zone 11	0
NET (acre-feet/year)	Storage	-372
	Constant Head	0
	Pumpage	-2120
	Drains	-1
	Recharge	1453
	Lake Seepage	0
	Zone 2	57
	Zone 4	-317
	Zone 5	37
	Zone 11	524

San Bruno — Zone 4

IN (acre-feet/year)	Storage	497
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	796
	Lake Seepage	0
	From Zone 3	717
	From Zone 5	450
	From Zone 6	789
	From Zone 11	3
OUT (acre-feet/year)	Storage	410
	Constant Head	0
	Pumpage	1836
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 3	395
	To Zone 5	282
	To Zone 6	351
	To Zone 11	0
NET (acre-feet/year)	Storage	-87
	Constant Head	0
	Pumpage	-1836
	Drains	0
	Recharge	796
	Lake Seepage	0
	Zone 3	323
	Zone 5	168
	Zone 6	438
	Zone 11	3

Bay Plain/Bay — Zone 5

IN (acre-feet/year)	Storage	131
	Constant Head	4
	Pumpage	0
	Drains	0
	Recharge	332
	Lake Seepage	0
	From Zone 3	132
	From Zone 4	282
	From Zone 6	254
	From Zone 7	110
OUT (acre-feet/year)	Storage	121
	Constant Head	121
	Pumpage	0
	Drains	122
	Recharge	0
	Lake Seepage	0
	To Zone 3	166
	To Zone 4	450
	To Zone 6	244
	To Zone 7	20
NET (acre-feet/year)	Storage	-10
	Constant Head	-117
	Pumpage	0
	Drains	-122
	Recharge	332
	Lake Seepage	0
	Zone 3	-35
	Zone 4	-168
	Zone 6	10
	Zone 7	90

Millbrae — Zone 6

IN (acre-feet/year)	Storage	226
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	557
	Lake Seepage	0
	From Zone 4	351
	From Zone 5	244
	From Zone 7	60
OUT (acre-feet/year)	Storage	188
	Constant Head	0
	Pumpage	179
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 4	789
	To Zone 5	254
	To Zone 7	28
NET (acre-feet/year)	Storage	-38
	Constant Head	0
	Pumpage	-179
	Drains	0
	Recharge	557
	Lake Seepage	0
	Zone 4	-438
	Zone 5	-10
	Zone 7	32

Burlingame — Zone 7

IN (acre-feet/year)	Storage	360
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	537
	Lake Seepage	0
	From Zone 5	20
	From Zone 6	28
OUT (acre-feet/year)	Storage	293
	Constant Head	13
	Pumpage	468
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 5	110
	To Zone 6	60
NET (acre-feet/year)	Storage	-67
	Constant Head	-13
	Pumpage	-468
	Drains	0
	Recharge	537
	Lake Seepage	0
	Zone 5	-90
	Zone 6	-32

Lake Merced/GGP — Zone 8

IN (acre-feet/year)	Storage	1881
	Constant Head	0
	Pumpage	626
	Drains	0
	Recharge	5979
	Lake Seepage	592
	From Zone 1	55
	From Zone 10	346
	From Zone 11	24
OUT (acre-feet/year)	Storage	1325
	Constant Head	0
	Pumpage	4906
	Drains	0
	Recharge	0
	Lake Seepage	452
	To Zone 1	1578
	To Zone 10	1241
	To Zone 11	1
NET (acre-feet/year)	Storage	-556
	Constant Head	0
	Pumpage	-4281
	Drains	0
	Recharge	5979
	Lake Seepage	141
	Zone 1	-1523
	Zone 10	-895
	Zone 11	23

Ocean — Zone 10

IN (acre-feet/year)	Storage	46
	Constant Head	169
	Pumpage	0
	Drains	0
	Recharge	0
	Lake Seepage	0
	From Zone 8	1241
	From Zone 11	1031
OUT (acre-feet/year)	Storage	28
	Constant Head	2093
	Pumpage	0
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 8	346
	To Zone 11	21
NET (acre-feet/year)	Storage	-19
	Constant Head	-1924
	Pumpage	0
	Drains	0
	Recharge	0
	Lake Seepage	0
	Zone 8	895
	Zone 11	1010

Thornton Beach — Zone 11

IN (acre-feet/year)	Storage	833
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	2101
	Lake Seepage	0
	From Zone 1	0
	From Zone 2	0
	From Zone 3	0
	From Zone 4	0
	From Zone 8	1
	From Zone 10	21
OUT (acre-feet/year)	Storage	486
	Constant Head	0
	Pumpage	484
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 1	175
	To Zone 2	244
	To Zone 3	522
	To Zone 4	3
	To Zone 8	24
	To Zone 10	1017
NET (acre-feet/year)	Storage	-346
	Constant Head	0
	Pumpage	-484
	Drains	0
	Recharge	2101
	Lake Seepage	0
	Zone 1	-175
	Zone 2	-244
	Zone 3	-522
	Zone 4	-3
	Zone 8	-23
	Zone 10	-996

Subareas 1, 2, 3, 4, and 8

IN (acre-feet/year)	Storage	5095
	Constant Head	0
	Pumpage	626
	Drains	0
	Recharge	10301
	Lake Seepage	592
	Ocean	346
	Bay Plain/Bay	619
	Millbrae	789
	Thornton Beach	970
OUT (acre-feet/year)	Storage	3422
	Constant Head	0
	Pumpage	13526
	Drains	1
	Recharge	0
	Lake Seepage	452
	Ocean	1241
	Bay Plain/Bay	413
	Millbrae	351
	Thornton Beach	1
NET (acre-feet/year)	Storage	-1674
	Constant Head	0
	Pumpage	-12901
	Drains	-1
	Recharge	10301
	Lake Seepage	141
	Ocean	-895
	Bay Plain/Bay	205
	Millbrae	438
	Thornton Beach	969

Notes: (1) The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flow out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced. Negative storage values represent losses of storage from the aquifer, while positive storage values represent gains in storage in the aquifer.

(2) Water balance components represent annual average values on a water year basis, from October to September. The first three months of the simulation period, which represent July through September conditions, are omitted from the annual averages because they represent only a partial water year. The volumes presented represent the 47 complete water years for the simulation period.

(3) Volumes are calculated using the USGS program ZONEBUDGET (Harbaugh, 1990). As noted in Harbaugh (1990), ZONEBUDGET tabulates boundary conditions differently from how they are reported in the MODFLOW output file. Also, ZONEBUDGET calculates volumes using the volumetric flow rate rather than the cumulative volume. Therefore, the water balance presented in Attachment 10.1-C, calculated using the cumulative volume as reported in the MODFLOW output file, may differ from the results reported on this table. However, the volumes calculated by the two methods are correct with respect to each method.

(4) [green] The five water budget areas that are collectively referred to as "Developed Subbasin" as defined by HydroFocus (2011): San Francisco (Lake Merced and Golden Gate Park), Daly City, Colma, South San Francisco, and San Bruno.

[pink] The five water budget areas that are adjacent to the Developed Subbasin as defined by HydroFocus (2011): San Francisco Bay Plain, Millbrae, Burlingame, Pacific Ocean, and Thornton Beach (across the Serra Fault).

Attachment 10.1-F

Model Scenario Groundwater Elevation Contour Maps for Selected Time Periods

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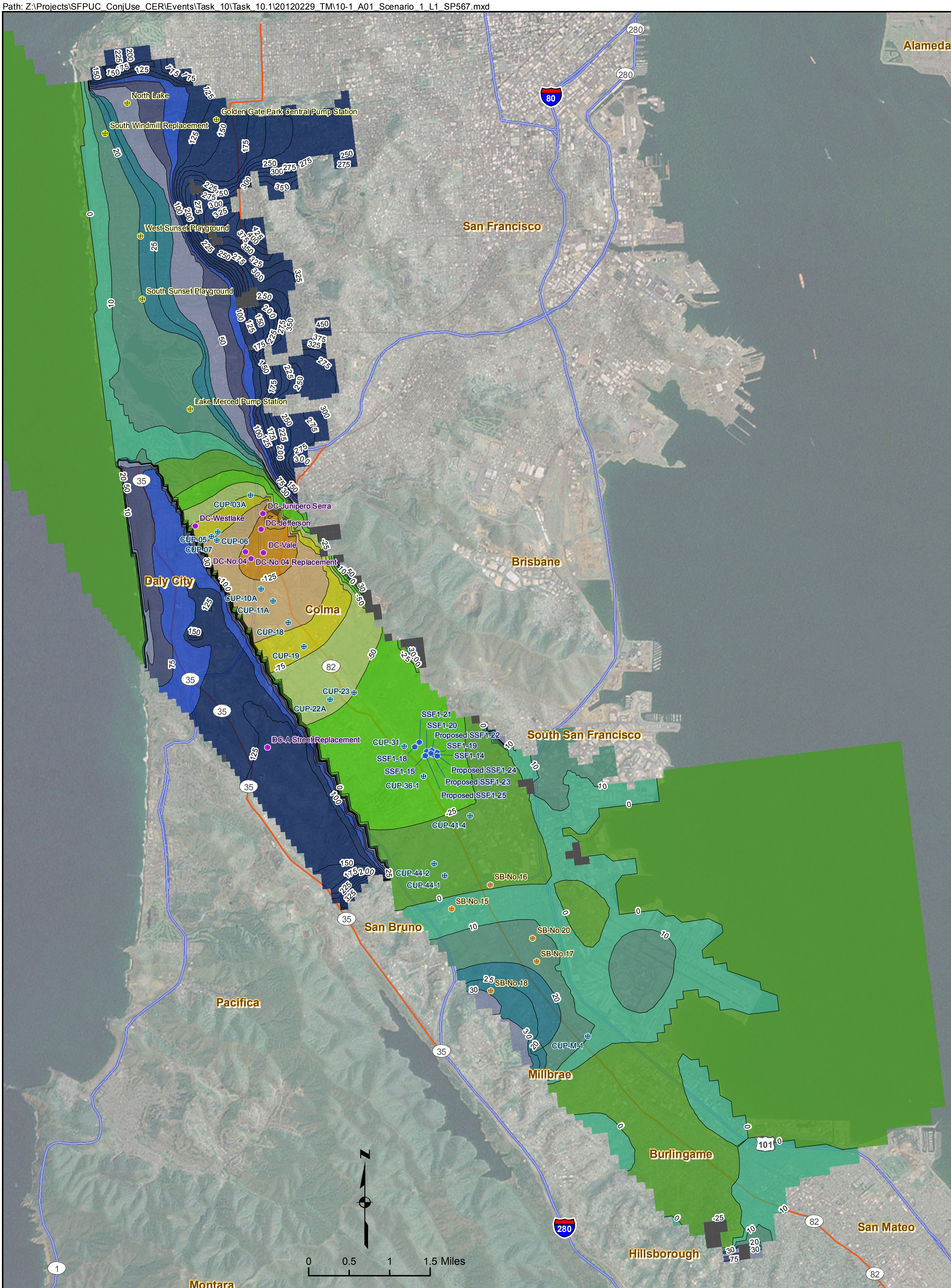

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Simulated Groundwater Elevation (feet NGVD29)

Model Simulated Groundwater Elevation (feet NGVD29)

- 100 -500
- 75 - 100
- 50 - 75
- 30 - 50
- 20 - 30
- 10 - 20
- 0 - 10
- -25 - 0
- -50 - -25
- -75 - -50
- -100 - -75
- -125 - -100
- -200 - -125
- Dry Cell

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Model Simulated Groundwater Elevation Contour Map

SCENARIO 1, LAYER 1
End of Hydrologic Sequence

Scenario Year 47

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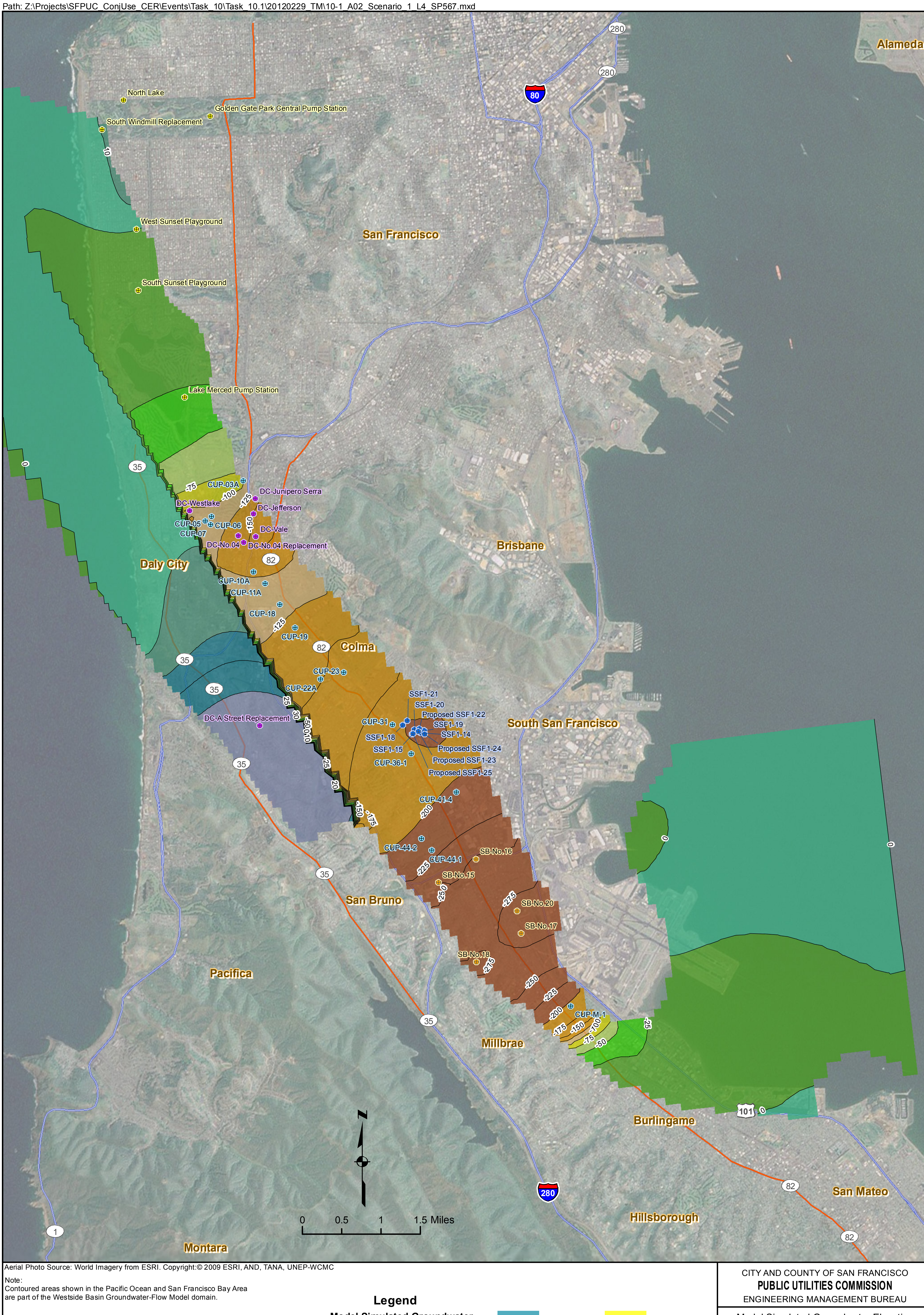

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Simulated Groundwater Elevation (feet NGVD29)

Model Simulated Groundwater Elevation (feet NGVD29)

- 100 - 150
- 75 - 100
- 50 - 75
- 30 - 50
- 20 - 30
- 10 - 20
- 0 - 10
- -25 - 0
- -50 - -25
- -75 - -50
- -100 - -75
- -125 - -100
- -200 - -125
- -300 - -200

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Model Simulated Groundwater Elevation Contour Map

SCENARIO 1, LAYER 4
End of Hydrologic Sequence

Scenario Year 47

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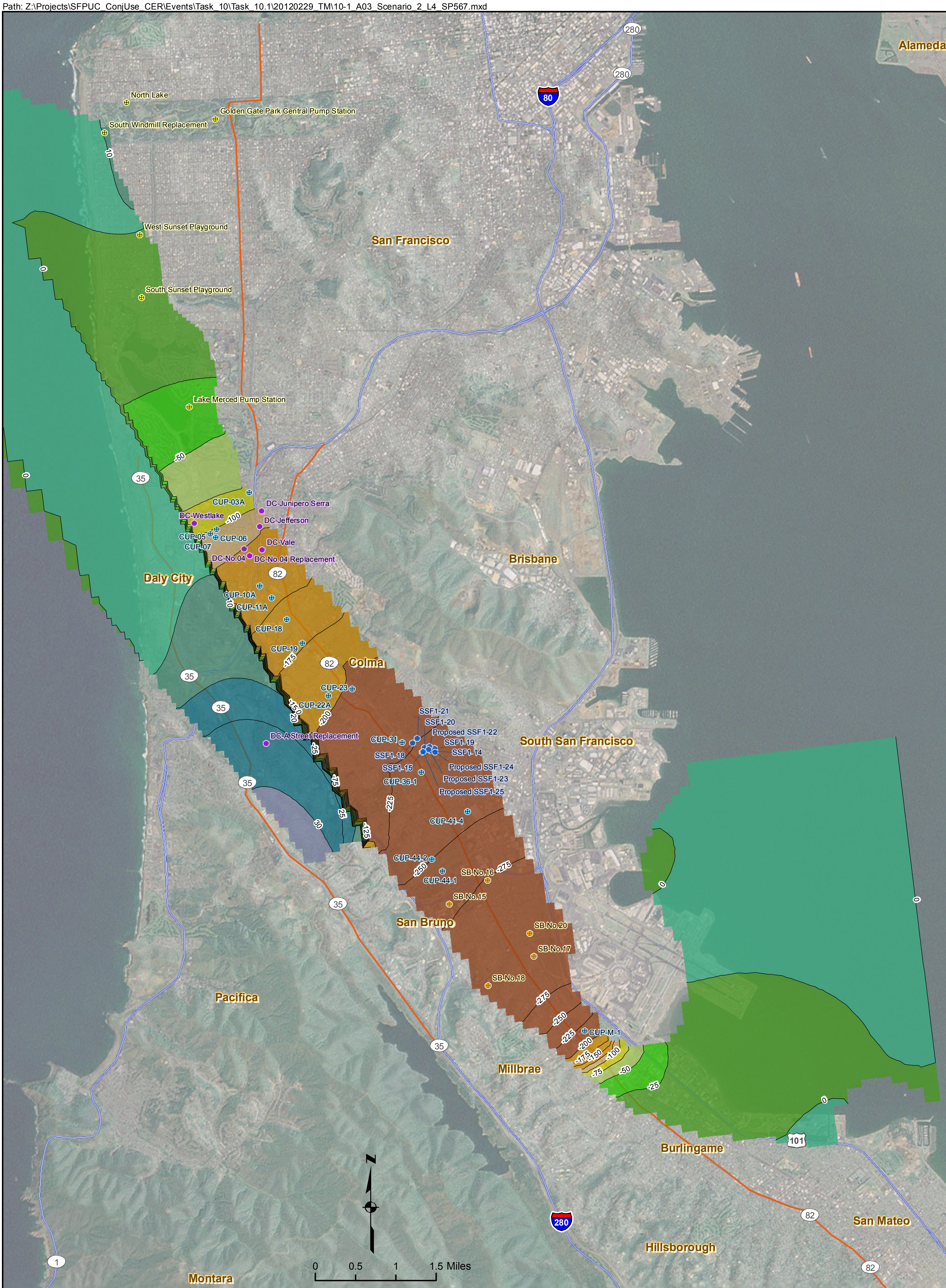

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Simulated Groundwater Elevation (feet NGVD29)

Model Simulated Groundwater Elevation (feet NGVD29)

- 100 - 150
- 75 - 100
- 50 - 75
- 30 - 50
- 20 - 30
- 10 - 20
- 0 - 10
- -25 - 0
- -50 - -25
- -75 - -50
- -100 - -75
- -125 - -100
- -200 - -125
- -300 - -200

CITY AND COUNTY OF SAN FRANCISCO
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Model Simulated Groundwater Elevation Contour Map

SCENARIO 2, LAYER 4
End of Hydrologic Sequence

Scenario Year 47

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Date
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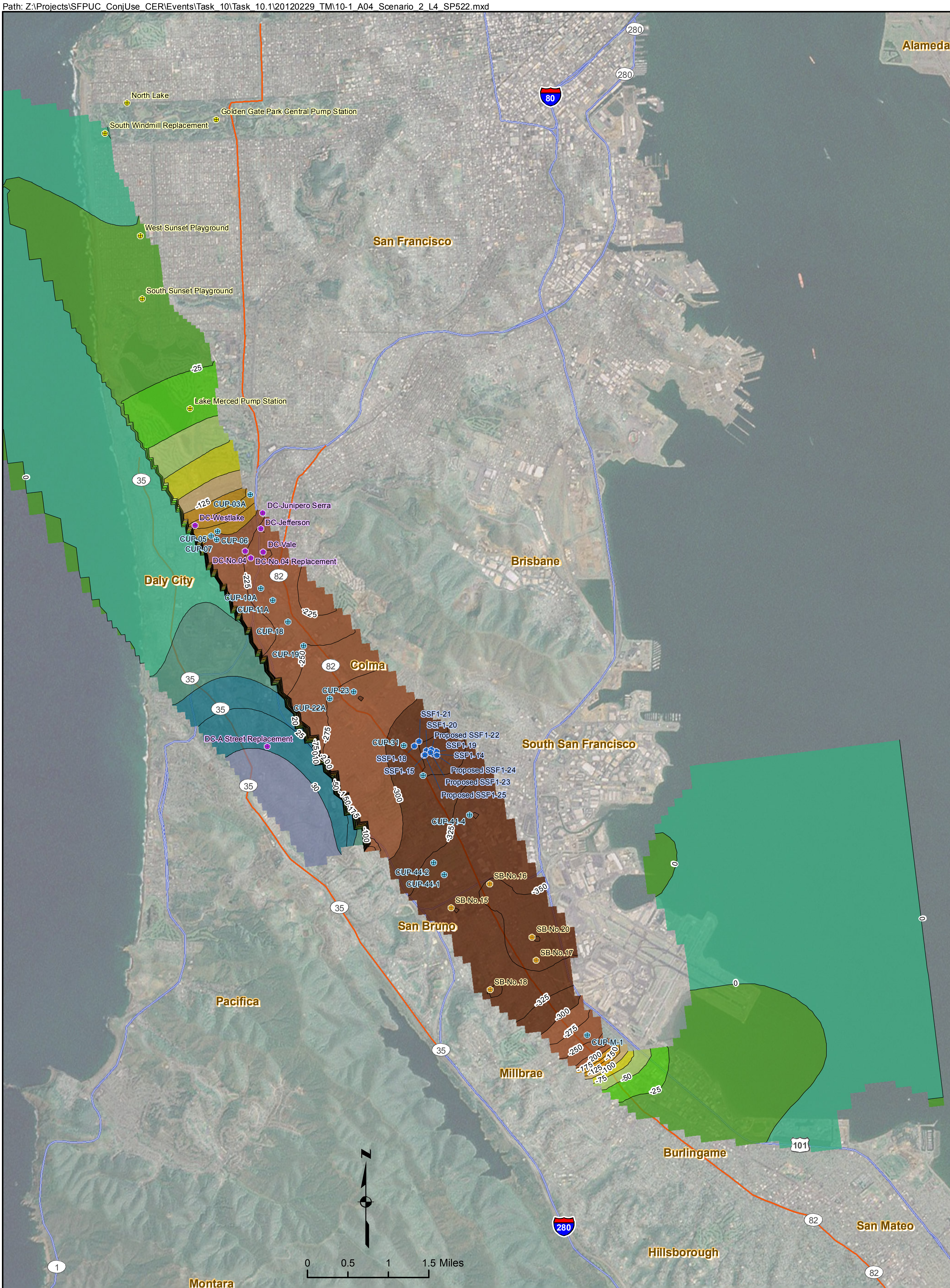

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Simulated Groundwater Elevation (feet NGVD29)

Model Simulated Groundwater Elevation (feet NGVD29)

- 75 - 100
- 50 - 75
- 30 - 50
- 20 - 30
- 10 - 20
- 0 - 10
- -25 - 0
- -50 - -25
- -75 - -50
- -100 - -75
- -125 - -100
- -200 - -125
- -300 - -200
- -400 - -300

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Model Simulated Groundwater Elevation Contour Map

SCENARIO 2, LAYER 4
End of Design Drought

Scenario Year 44

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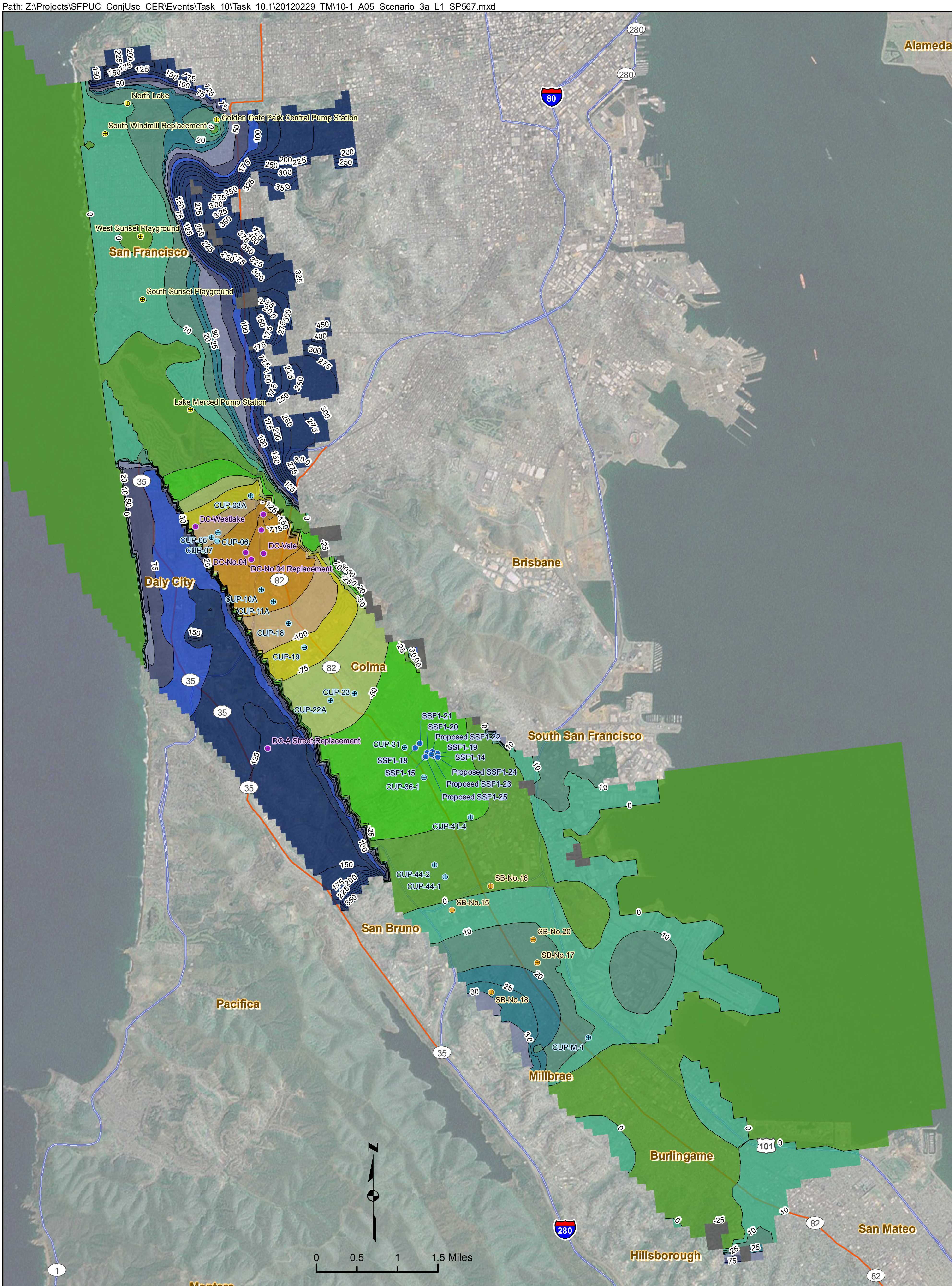

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Simulated Groundwater Elevation (feet NGVD29)

Model Simulated Groundwater Elevation (feet NGVD29)

- 100 - 500
- 75 - 100
- 50 - 75
- 30 - 50
- 20 - 30
- 10 - 20
- 0 - 10
- -25 - 0
- -50 - -25
- -75 - -50
- -100 - -75
- -125 - -100
- -200 - -125
- Dry Cells

CITY AND COUNTY OF SAN FRANCISCO
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Model Simulated Groundwater Elevation Contour Map

SCENARIO 3A, LAYER 1
End of Hydrologic Sequence

Scenario Year 47

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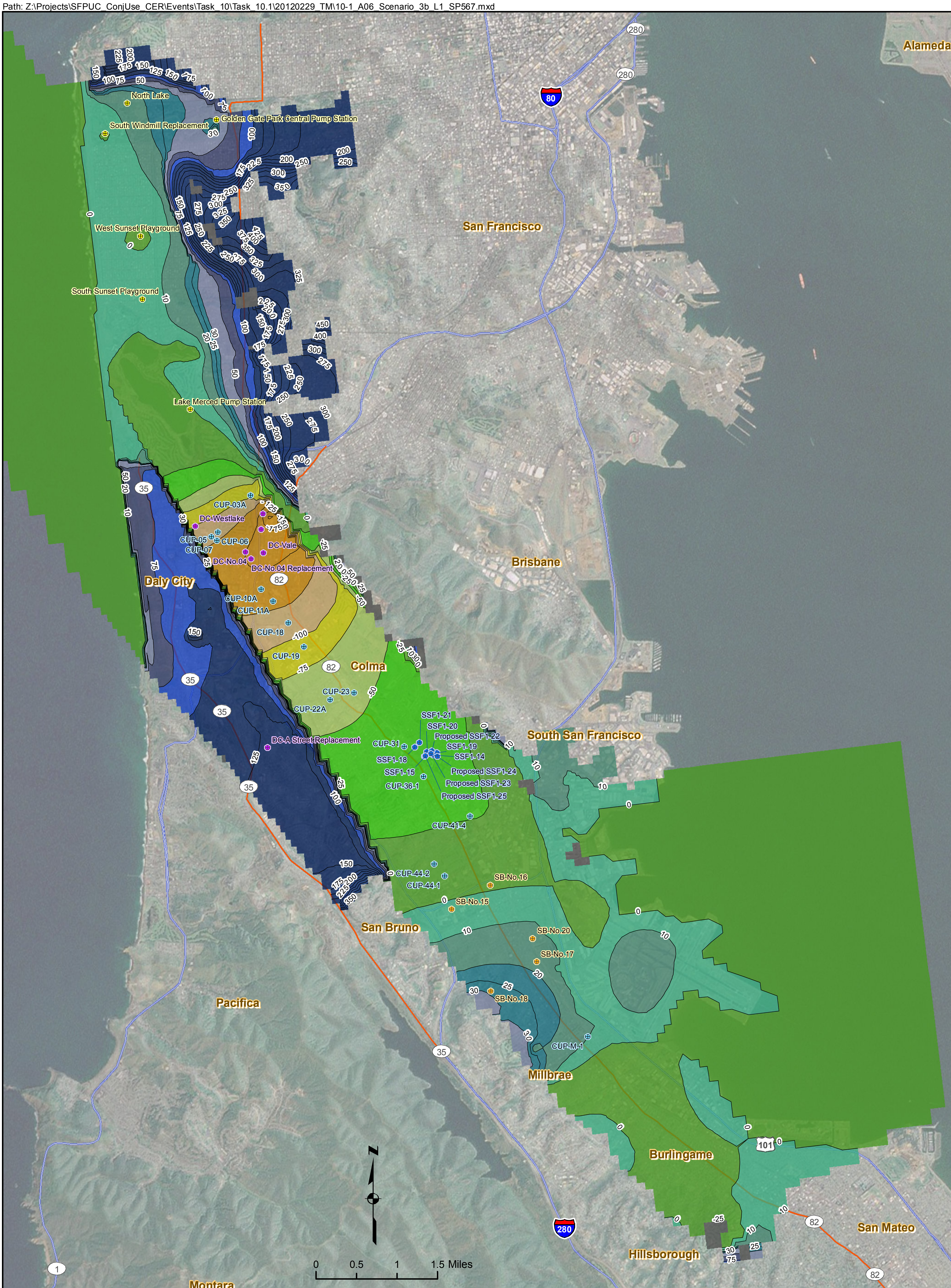

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Simulated Groundwater Elevation (feet NGVD29)

Model Simulated Groundwater Elevation (feet NGVD29)

100 - 500	20 - 30	-75 - -50
75 - 100	10 - 20	-100 - -75
50 - 75	0 - 10	-125 - -100
30 - 50	-25 - 0	-200 - -125
	-50 - -25	Dry Cells

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Model Simulated Groundwater Elevation Contour Map

SCENARIO 3B, LAYER 1
End of Hydrologic Sequence

Scenario Year 47

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Date
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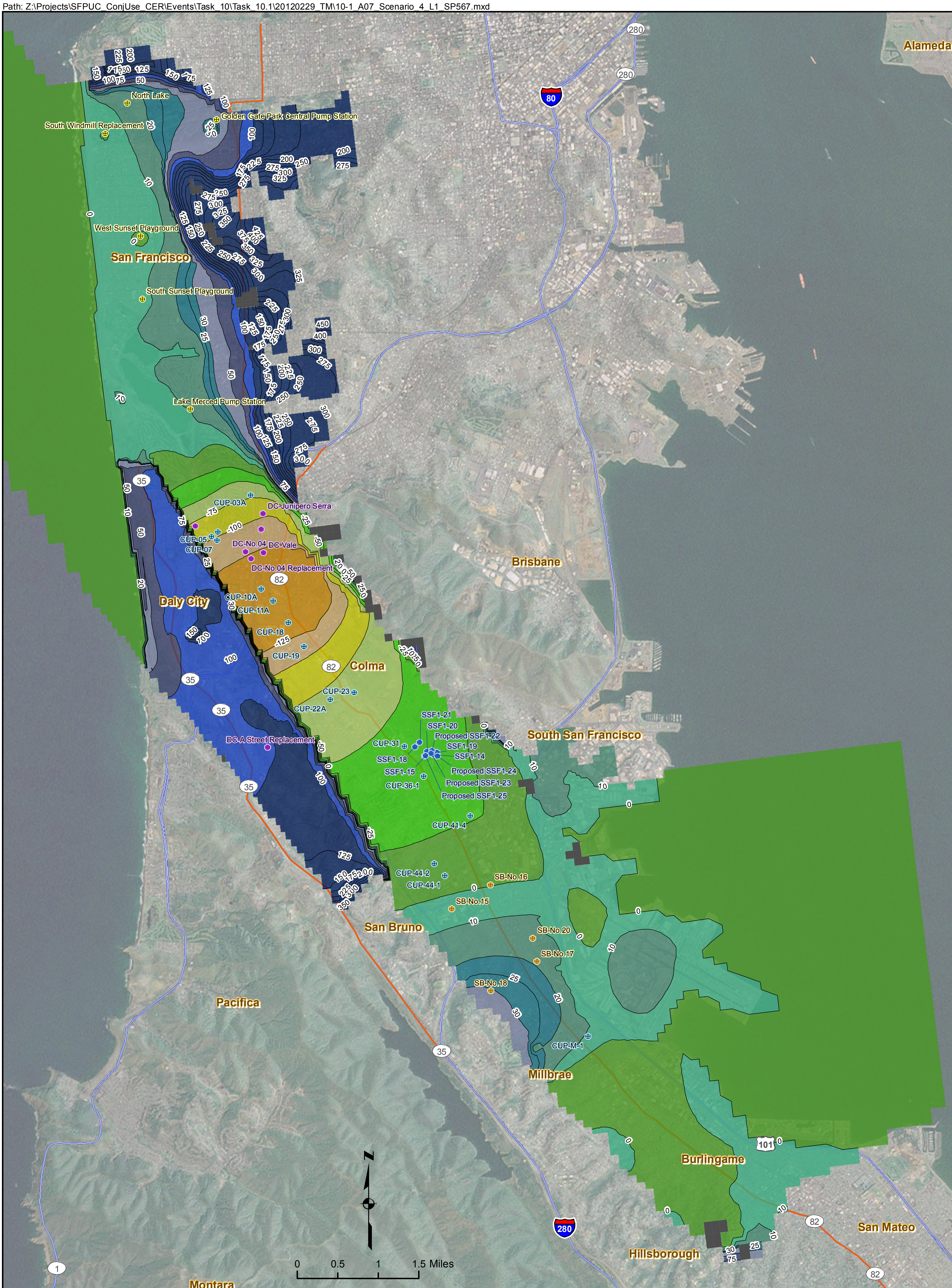

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Simulated Groundwater Elevation (feet NGVD29)

Model Simulated Groundwater Elevation (feet NGVD29)

- 100 - 500
- 75 - 100
- 50 - 75
- 30 - 50
- 20 - 30
- 10 - 20
- 0 - 10
- -25 - 0
- -50 - -25
- -75 - -50
- -100 - -75
- -125 - -100
- -200 - -125
- Dry Cells

CITY AND COUNTY OF SAN FRANCISCO
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Model Simulated Groundwater Elevation Contour Map

SCENARIO 4, LAYER 1
End of Hydrologic Sequence

Scenario Year 47

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Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Date
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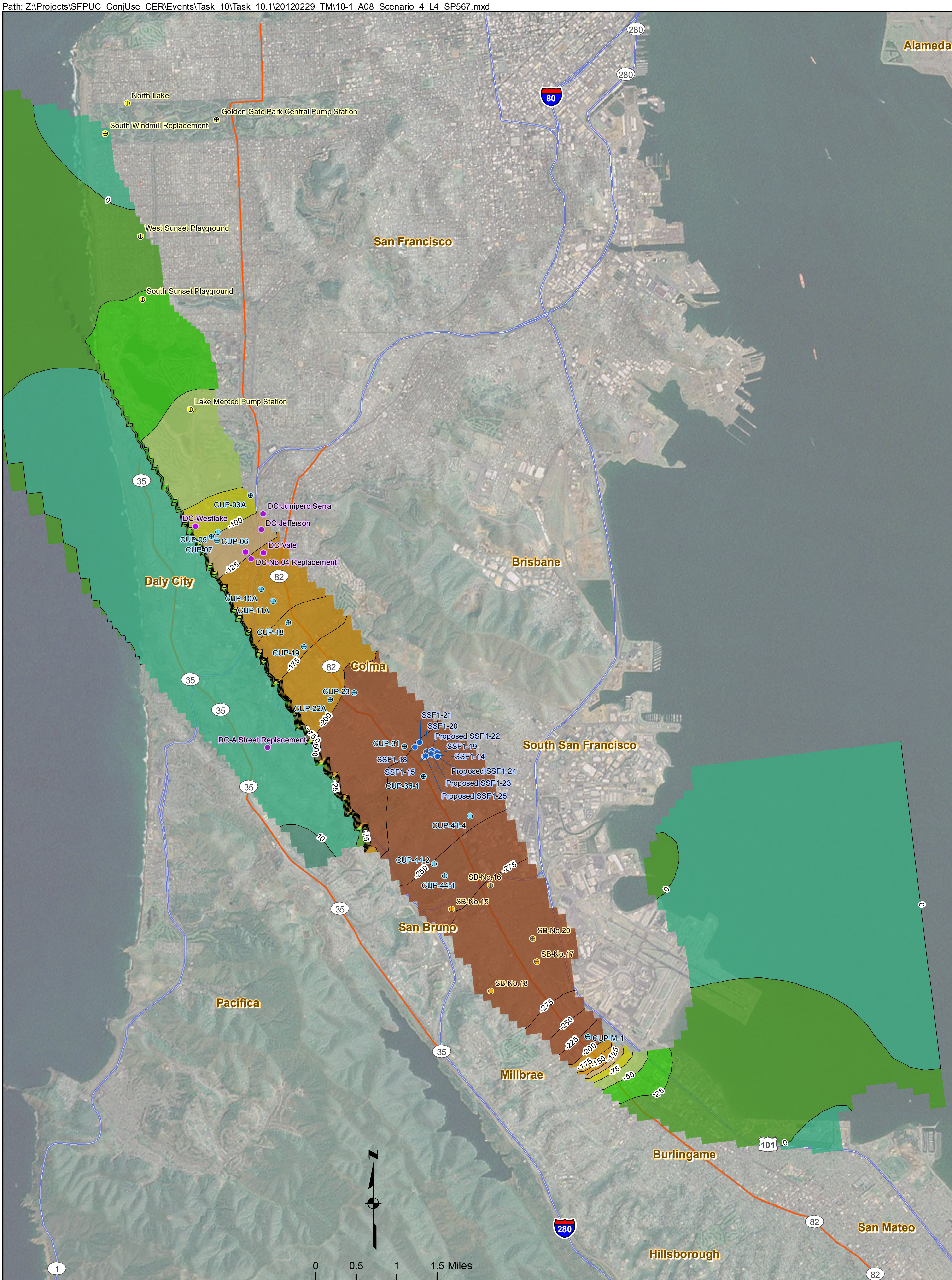

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Simulated Groundwater Elevation (feet NGVD29)

Model Simulated Groundwater Elevation (feet NGVD29)

- 100 - 150
- 75 - 100
- 50 - 75
- 30 - 50
- 20 - 30
- 10 - 20
- 0 - 10
- -25 - 0
- -50 - -25
- -75 - -50
- -100 - -75
- -125 - -100
- -200 - -125
- -300 - -200

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
ENGINEERING MANAGEMENT BUREAU

Model Simulated Groundwater Elevation Contour Map

SCENARIO 4, LAYER 4
End of Hydrologic Sequence

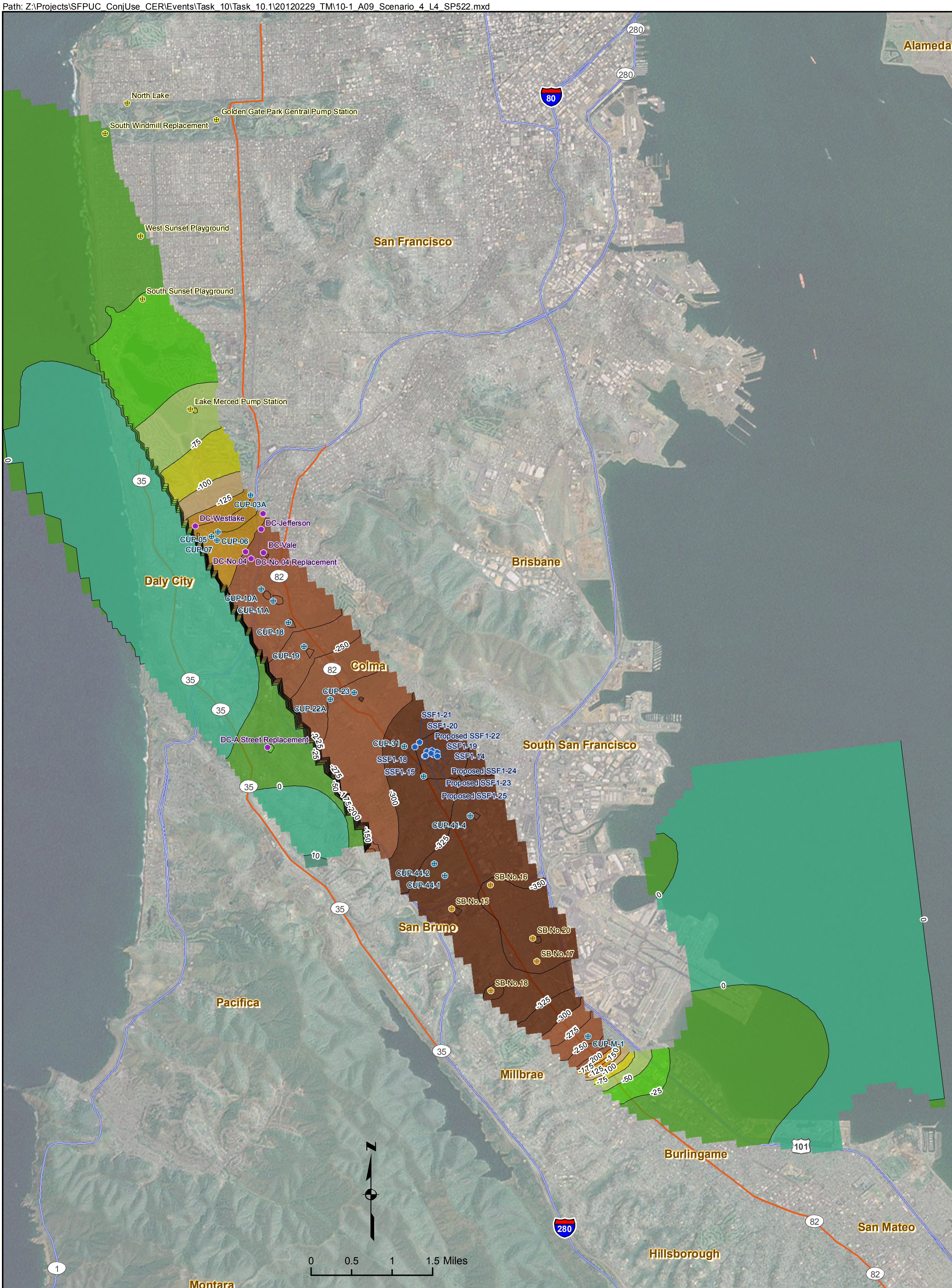
Scenario Year 47

Kennedy/Jenks Consultants
303 Second Street, Suite 300 South
San Francisco, CA 94107

Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Date
April 2012

Path: Z:\Projects\SFPUC_ConjUse_CER\Events\Task_10\Task_10.1\20120229_TM\10-1_A09_Scenario_4_L4_SP522.mxd



Aerial Photo Source: World Imagery from ESRI. Copyright:© 2009 ESRI, AND, TANA, UNEP-WCMC

Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Simulated Groundwater Elevation (feet NGVD29)

Model Simulated Groundwater Elevation (feet NGVD29)

- 75 - 100
- 50 - 75
- 30 - 50
- 20 - 30
- 10 - 20
- 0 - 10
- -25 - 0
- -50 - -25
- -75 - -50
- -100 - -75
- -125 - -100
- -200 - -125
- -300 - -200
- -400 - -300

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
ENGINEERING MANAGEMENT BUREAU

Model Simulated Groundwater Elevation Contour Map

SCENARIO 4, LAYER 4
End of Design Drought

Scenario Year 44

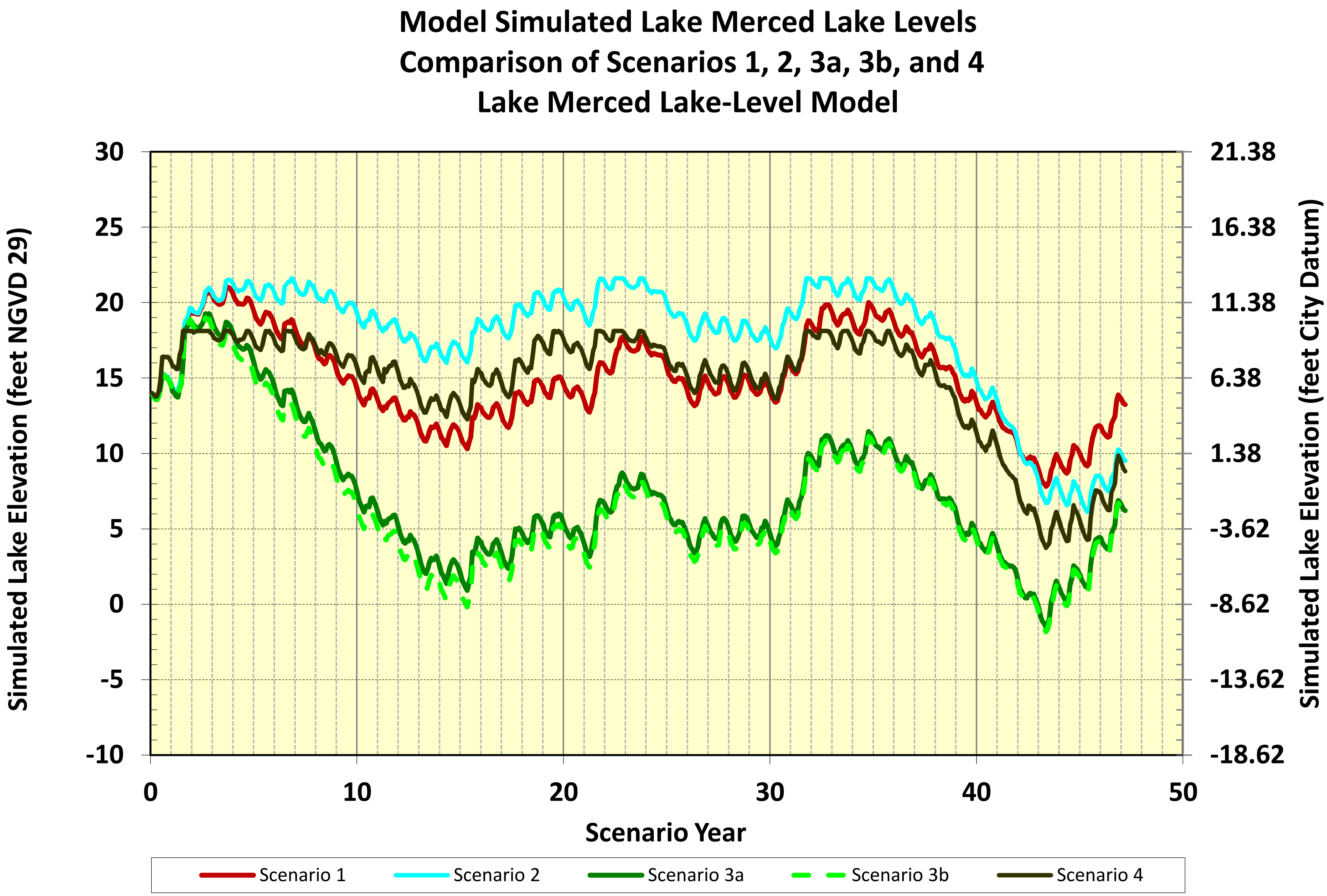
Kennedy/Jenks Consultants
303 Second Street, Suite 300 South
San Francisco, CA 94107

Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Date
April 2012

Attachment 10.1-G

Model Scenario Lake Hydrographs from Lake Merced Lake-Level Model

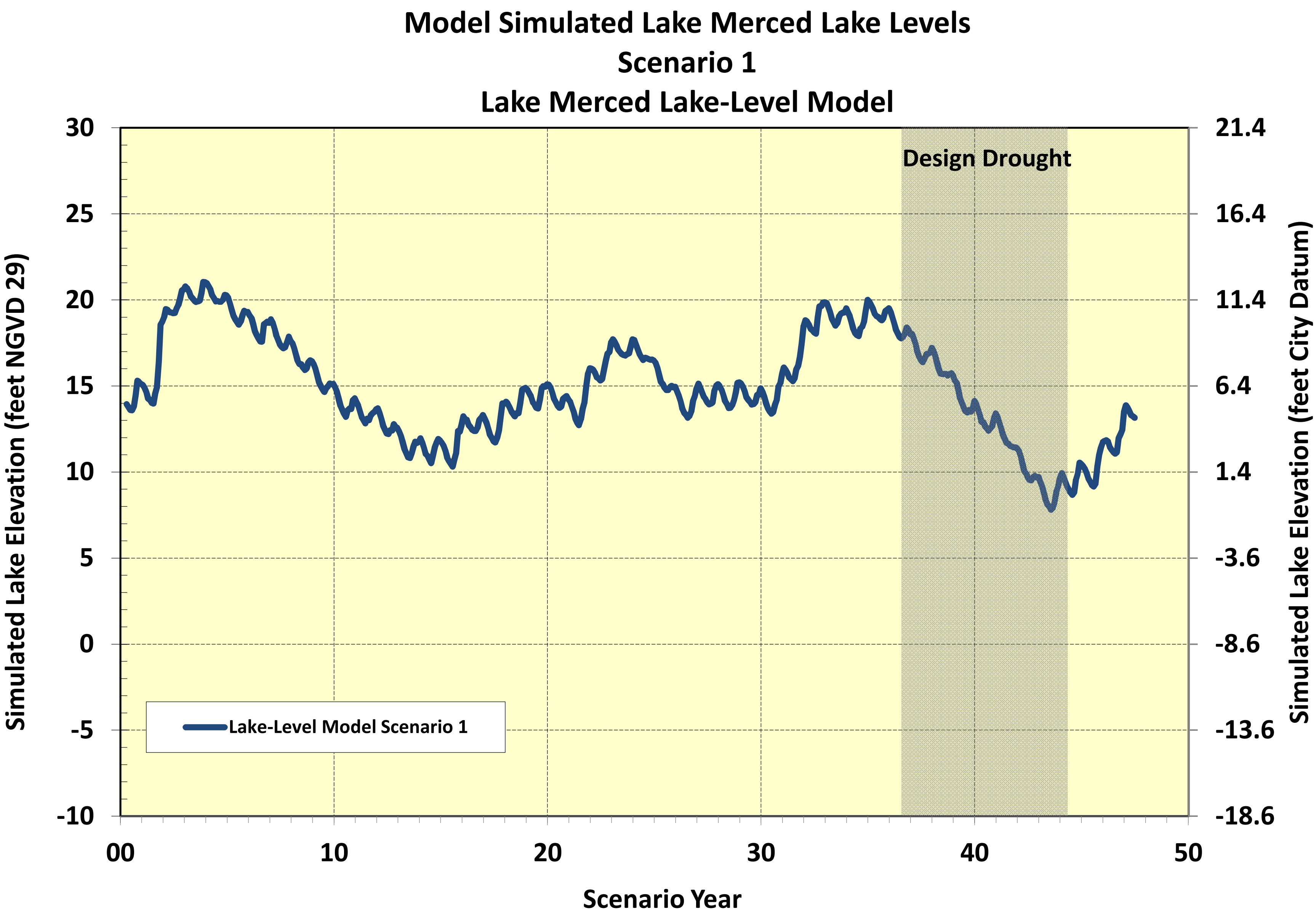


Model Simulated Lake Merced Lake Levels
Comparison of Scenarios 1, 2, 3a, 3b, and 4
Lake Merced Lake-Level Model
Simulated Lake Elevation (feet NGVD 29)
Simulated Lake Elevation (feet City Datum)
30
25
20
15
10
5
0
-5
-10
21.38
16.38
11.38
6.38
1.38
-3.62
-8.62
-13.62
-18.62
0
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

Lake Merced Lake-Level Model Water Balance
Scenario 1
SFPUC GSR and SFGW Projects Technical Analysis

Assumptions: (in feet City Datum)		Initial Lake Level 5.7		Wetland Source None		VG Stormwater No		Number of Wells No Wells		Diversion Elevation 13.0		Spillway Elevation 13.0	
		Lake Merced Natural Hydrology						Lake Merced Lake Level Management				Summary	
Historical Water Year	Scenario Year	Precipitation (af)	Stormwater Runoff (af)	Evaporation (af)	Transpiration (af)	Groundwater Inflow-Outflow (af)	Natural Hydrology Subtotal (af)	Lake Additions from Engineered Wetland (af)	Lake Additions from Vista Grande Canal Stormflow (af)	Lake Additions from Wells (af)	Flow over the Spillway (af)	Annual (Sept to Sept) Change in Lake Level (feet)	Lake Merced Change in Storage (af)
1996	0	1	0	-241	-49	78	-211	0	0	0	0	-	-
1997	1	499	189	-718	-144	289	116	0	0	0	0	0.41	116
1998	2	1,186	668	-680	-134	518	1,559	0	0	0	0	5.22	1,559
1999	3	484	134	-648	-129	382	224	0	0	0	0	0.72	224
2000	4	481	132	-702	-135	211	-13	0	0	0	0	-0.04	-13
2001	5	300	70	-673	-133	57	-378	0	0	0	0	-1.22	-378
2002	6	382	104	-671	-132	29	-288	0	0	0	0	-0.94	-288
2003	7	514	198	-702	-136	20	-106	0	0	0	0	-0.33	-106
1959	8	360	103	-688	-136	10	-352	0	0	0	0	-1.16	-352
1960	9	320	96	-658	-134	-65	-441	0	0	0	0	-1.47	-441
1961	10	369	108	-648	-134	-108	-412	0	0	0	0	-1.41	-412
1962	11	418	146	-599	-128	0	-163	0	0	0	0	-0.56	-163
1963	12	492	170	-651	-136	-48	-173	0	0	0	0	-0.60	-173
1964	13	316	101	-604	-131	-73	-391	0	0	0	0	-1.38	-391
1965	14	501	189	-584	-128	-19	-41	0	0	0	0	-0.14	-41
1966	15	416	157	-612	-133	99	-73	0	0	0	0	-0.25	-73
1967	16	717	354	-601	-130	217	557	0	0	0	0	2.00	557
1968	17	369	125	-649	-136	100	-191	0	0	0	0	-0.67	-191
1969	18	616	257	-608	-131	273	408	0	0	0	0	1.44	408
1970	19	536	203	-644	-133	178	141	0	0	0	0	0.50	141
1971	20	481	160	-610	-128	129	32	0	0	0	0	0.11	32
1972	21	310	95	-614	-130	16	-324	0	0	0	0	-1.12	-324
1973	22	810	338	-625	-131	360	752	0	0	0	0	2.59	752
1974	23	721	239	-642	-131	270	457	0	0	0	0	1.53	457
1975	24	433	125	-642	-130	112	-103	0	0	0	0	-0.34	-103
1976	25	236	55	-651	-134	10	-483	0	0	0	0	-1.61	-483
1977	26	289	79	-647	-132	-50	-462	0	0	0	0	-1.58	-462
1978	27	646	239	-683	-138	148	211	0	0	0	0	0.74	211
1979	28	418	145	-652	-135	123	-101	0	0	0	0	-0.34	-101
1980	29	556	192	-641	-132	120	94	0	0	0	0	0.33	94
1981	30	382	125	-630	-133	59	-197	0	0	0	0	-0.67	-197
1982	31	778	290	-622	-130	236	551	0	0	0	0	1.89	551
1983	32	939	381	-719	-141	388	848	0	0	0	0	2.83	848
1984	33	523	184	-736	-141	290	121	0	0	0	0	0.40	121
1985	34	469	126	-723	-140	100	-169	0	0	0	0	-0.55	-169
1986	35	723	244	-741	-142	243	327	0	0	0	0	1.07	327
1987	36	326	91	-731	-140	91	-363	0	0	0	0	-1.18	-363
1988	37	360	96	-731	-141	4	-412	0	0	0	0	-1.35	-412
1989	38	460	137	-699	-140	-3	-246	0	0	0	0	-0.81	-246
1990	39	276	75	-703	-141	-80	-573	0	0	0	0	-1.94	-573
1991	40	410	140	-663	-137	-67	-317	0	0	0	0	-1.09	-317
1992	41	431	151	-716	-146	7	-273	0	0	0	0	-0.96	-273
1976	42	182	47	-624	-136	-26	-557	0	0	0	0	-2.01	-557
1977	43	264	90	-589	-132	-84	-452	0	0	0	0	-1.69	-452
1978	44	583	274	-632	-140	126	210	0	0	0	0	0.81	210
2004	45	437	198	-616	-137	233	115	0	0	0	0	0.44	115
2005	46	681	317	-599	-132	255	522	0	0	0	0	1.94	522
2006	47	693	331	-624	-133	288	556	0	0	0	0	1.98	556
Average (af)		**481**	**176**	**-648**	**-133**	**110**	**-22**	**0**	**0**	**0**	**0**	**-0.05**	**-18**
Maximum (af)		**1,186**	**668**	**-241**	**-49**	**518**	**1,559**	**0**	**0**	**0**	**0**	**5.22**	**1,559**
Minimum (af)		**1**	**0**	**-741**	**-146**	**-108**	**-573**	**0**	**0**	**0**	**0**	**-2.01**	**-573**

Key:
af - acre-feet
VG - Vista Grande

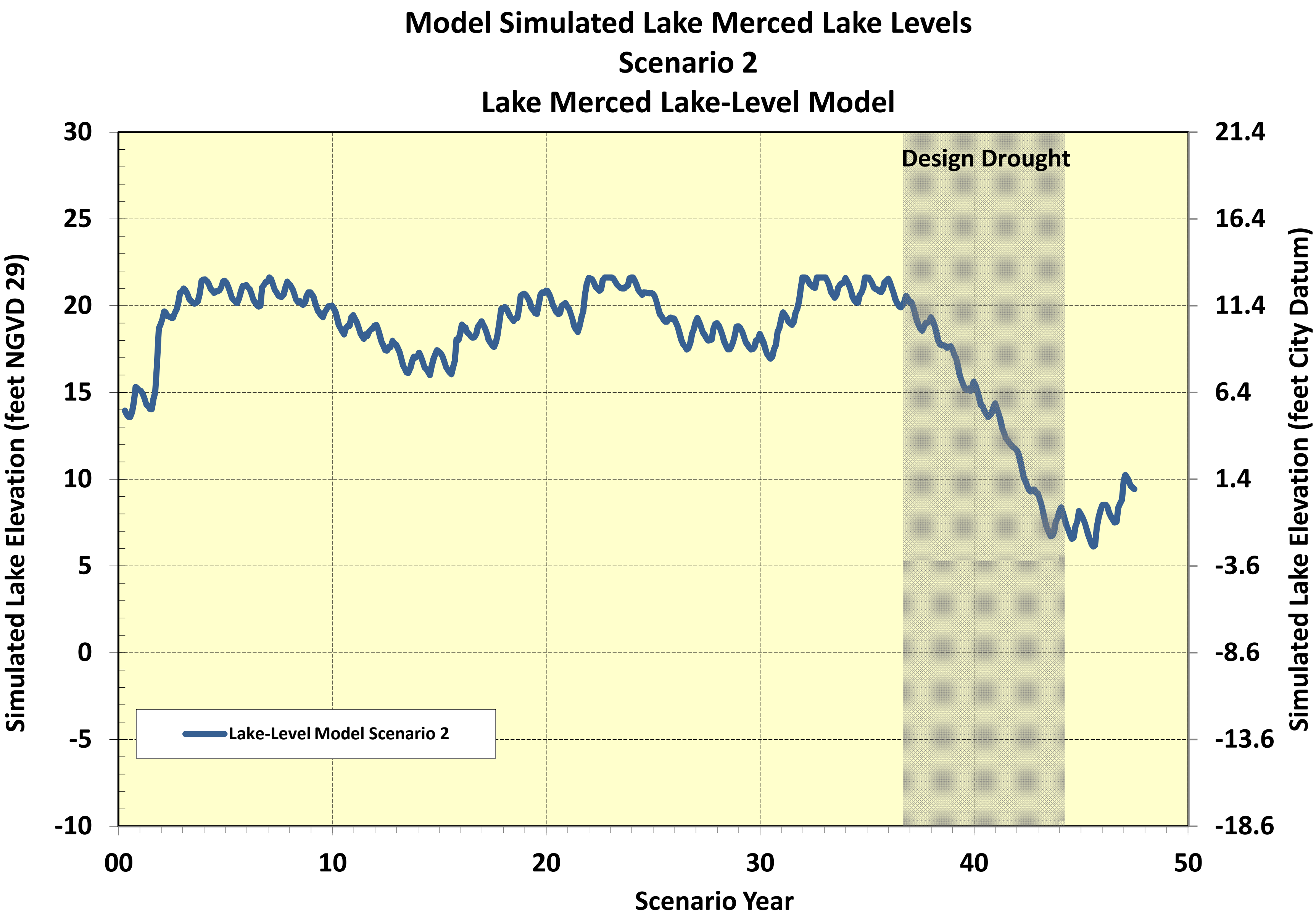


Model Simulated Lake Merced Lake Levels
Scenario 1
Lake Merced Lake-Level Model
Design Drought
Lake-Level Model Scenario 1
Simulated Lake Elevation (feet NGVD 29)
Simulated Lake Elevation (feet City Datum)
Scenario Year
30
25
20
15
10
5
0
-5
-10
21.4
16.4
11.4
6.4
1.4
-3.6
-8.6
-13.6
-18.6
00
10
20
30
40
50

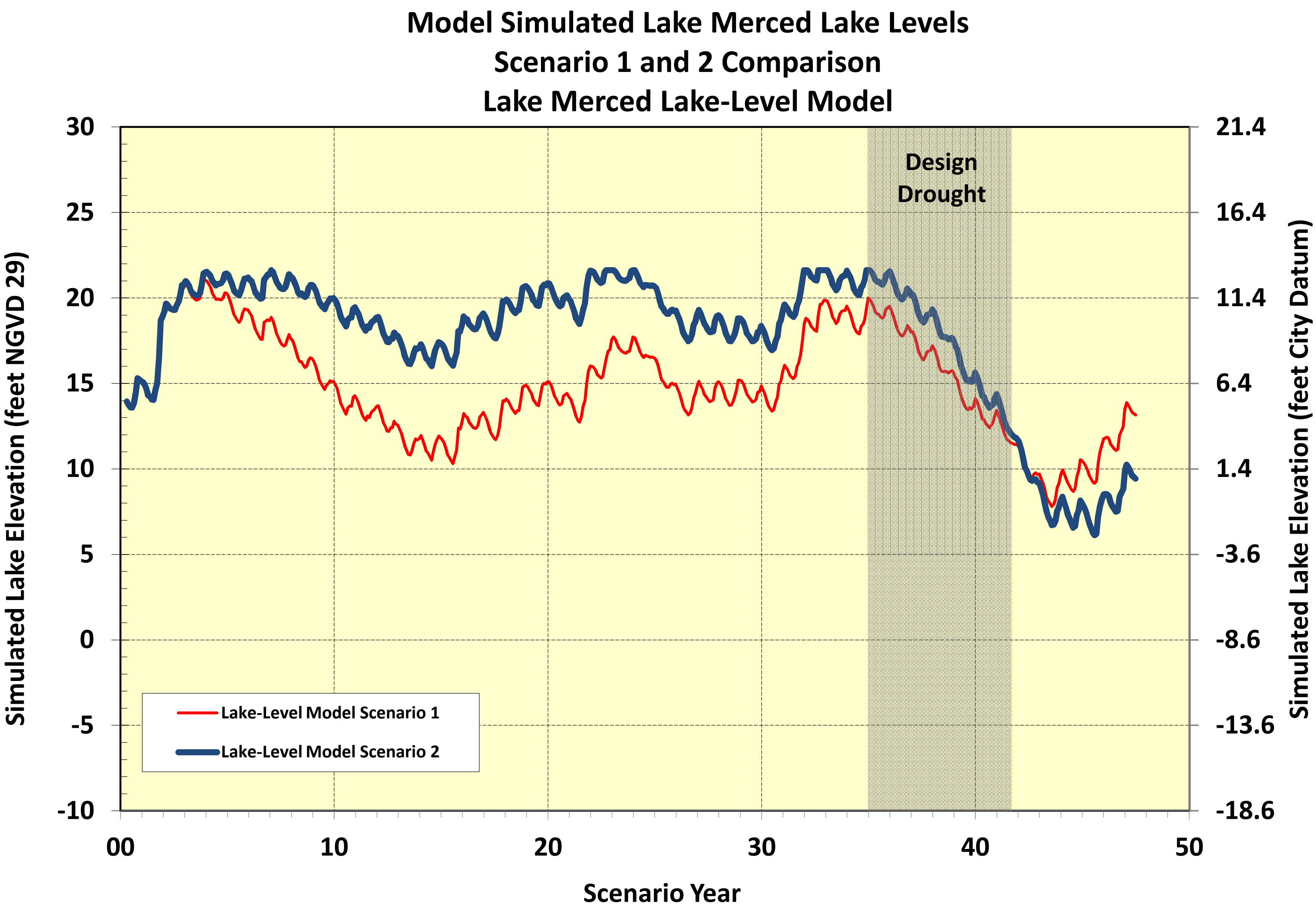
Lake Merced Lake-Level Model Water Balance
Scenario 2
SFPUC GSR and SFGW Projects Technical Analysis

Assumptions: (in feet City Datum)		Initial Lake Level 5.7		Wetland Source None		VG Stormwater No		Number of Wells No Wells		Diversion Elevation 13.0		Spillway Elevation 13.0	
		Lake Merced Natural Hydrology						Lake Merced Lake Level Management				Summary	
Historical Water Year	Scenario Year	Precipitation (af)	Stormwater Runoff (af)	Evaporation (af)	Transpiration (af)	Groundwater Inflow-Outflow (af)	Natural Hydrology Subtotal (af)	Lake Additions from Engineered Wetland (af)	Lake Additions from Vista Grande Canal Stormflow (af)	Lake Additions from Wells (af)	Flow over the Spillway (af)	Annual (Sept to Sept) Change in Lake Level (feet)	Lake Merced Change in Storage (af)
1996	0	1	0	-241	-49	78	-211	0	0	0	0	-	-
1997	1	499	189	-718	-144	303	129	0	0	0	0	0.46	129
1998	2	1,188	667	-681	-134	526	1,565	0	0	0	0	5.24	1,565
1999	3	485	133	-650	-129	433	273	0	0	0	0	0.88	273
2000	4	482	131	-705	-135	403	176	0	0	0	0	0.56	176
2001	5	303	69	-680	-133	279	-162	0	0	0	0	-0.51	-162
2002	6	389	100	-685	-132	273	-55	0	0	0	0	-0.17	-55
2003	7	528	190	-720	-136	329	191	0	0	0	-19	0.55	210
1959	8	374	95	-714	-136	275	-106	0	0	0	0	-0.34	-106
1960	9	335	88	-690	-134	144	-257	0	0	0	0	-0.82	-257
1961	10	389	99	-686	-134	38	-295	0	0	0	0	-0.95	-295
1962	11	445	131	-638	-128	62	-129	0	0	0	0	-0.42	-129
1963	12	526	151	-696	-136	-43	-198	0	0	0	0	-0.64	-198
1964	13	338	90	-647	-131	-45	-394	0	0	0	0	-1.30	-394
1965	14	539	168	-628	-128	57	7	0	0	0	0	0.03	7
1966	15	451	137	-660	-133	200	-5	0	0	0	0	-0.01	-5
1967	16	776	318	-649	-130	309	624	0	0	0	0	2.07	624
1968	17	398	110	-701	-136	163	-166	0	0	0	0	-0.54	-166
1969	18	665	228	-653	-131	325	435	0	0	0	0	1.42	435
1970	19	575	181	-688	-133	204	139	0	0	0	0	0.45	139
1971	20	513	142	-652	-128	141	16	0	0	0	0	0.06	16
1972	21	330	85	-657	-130	16	-357	0	0	0	0	-1.15	-357
1973	22	864	304	-662	-131	369	745	0	0	0	0	2.39	745
1974	23	763	214	-672	-131	478	652	0	0	0	-604	0.15	1,255
1975	24	450	115	-669	-130	245	12	0	0	0	-137	-0.39	149
1976	25	249	50	-682	-134	68	-450	0	0	0	0	-1.44	-450
1977	26	303	72	-680	-132	-39	-476	0	0	0	0	-1.54	-476
1978	27	682	217	-718	-138	108	151	0	0	0	0	0.50	151
1979	28	439	133	-684	-135	45	-201	0	0	0	0	-0.65	-201
1980	29	583	176	-669	-132	79	36	0	0	0	0	0.12	36
1981	30	400	115	-658	-133	74	-201	0	0	0	0	-0.66	-201
1982	31	813	268	-647	-130	288	592	0	0	0	0	1.94	592
1983	32	976	358	-743	-141	483	934	0	0	0	-257	2.17	1,190
1984	33	537	176	-752	-141	482	302	0	0	0	-496	-0.61	798
1985	34	477	122	-737	-140	199	-80	0	0	0	0	-0.25	-80
1986	35	740	234	-755	-142	403	480	0	0	0	-248	0.74	728
1987	36	332	88	-746	-140	163	-302	0	0	0	0	-0.96	-302
1988	37	367	93	-746	-141	22	-404	0	0	0	0	-1.30	-404
1989	38	471	130	-715	-140	-44	-297	0	0	0	0	-0.96	-297
1990	39	283	72	-719	-141	-176	-682	0	0	0	0	-2.26	-682
1991	40	420	135	-677	-137	-196	-455	0	0	0	0	-1.54	-455
1992	41	439	147	-727	-146	-166	-454	0	0	0	0	-1.57	-454
1976	42	184	46	-627	-136	-236	-770	0	0	0	0	-2.77	-770
1977	43	260	92	-579	-132	-326	-686	0	0	0	0	-2.61	-686
1978	44	566	284	-611	-140	-151	-51	0	0	0	0	-0.19	-51
2004	45	414	212	-584	-137	-38	-132	0	0	0	0	-0.51	-132
2005	46	635	344	-556	-132	52	343	0	0	0	0	1.37	343
2006	47	645	361	-582	-133	172	463	0	0	0	0	1.78	463
Average (af)		**496**	**168**	**-667**	**-133**	**142**	**-4**	**0**	**0**	**0**	**-37**	**-0.13**	**39**
Maximum (af)		**1,188**	**667**	**-241**	**-49**	**526**	**1,565**	**0**	**0**	**0**	**0**	**5.24**	**1,565**
Minimum (af)		**1**	**0**	**-755**	**-146**	**-326**	**-770**	**0**	**0**	**0**	**-604**	**-2.77**	**-770**

Key:
af - acre-feet
VG - Vista Grande



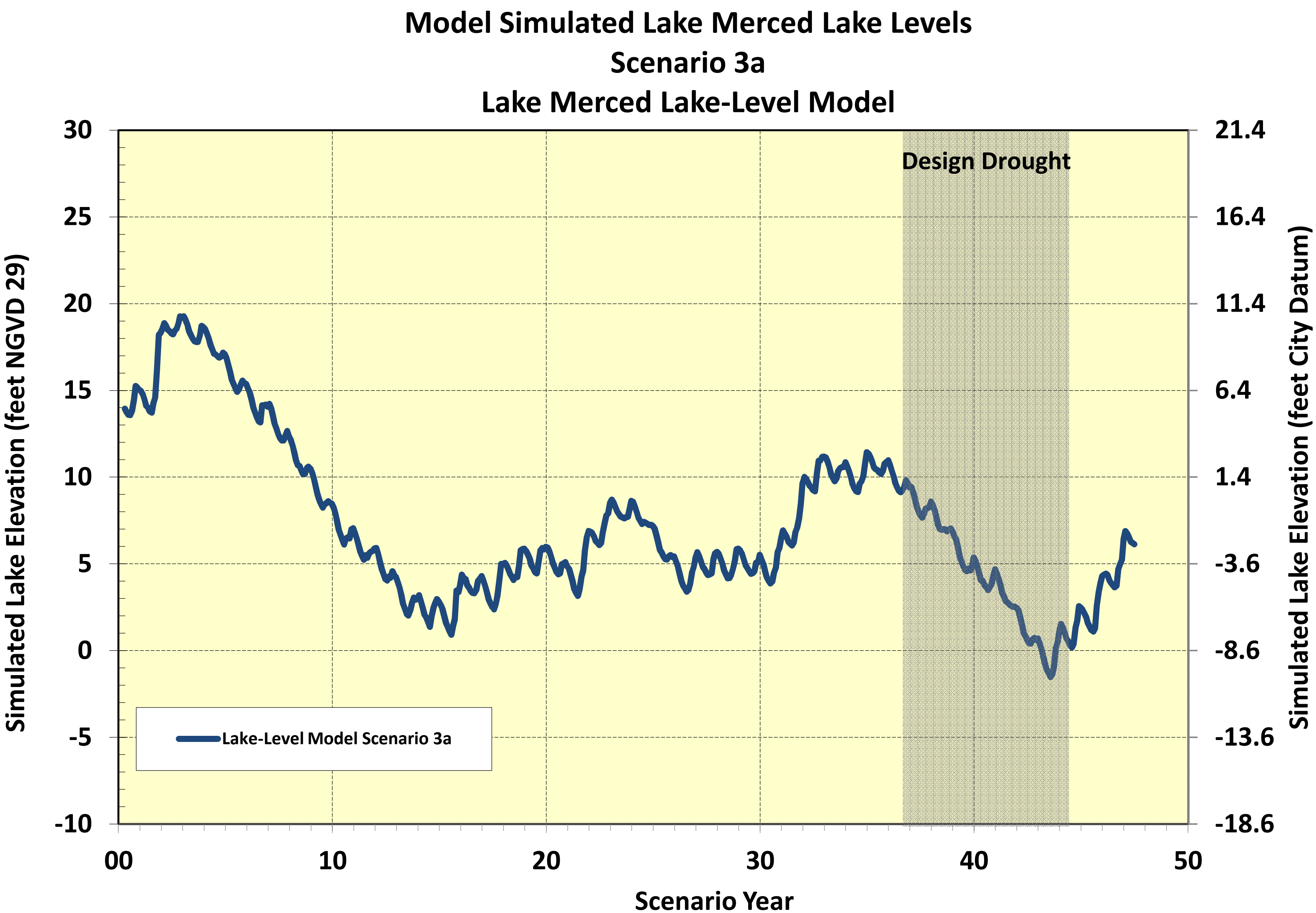
Model Simulated Lake Merced Lake Levels
Scenario 2
Lake Merced Lake-Level Model
Design Drought
Lake-Level Model Scenario 2
Simulated Lake Elevation (feet NGVD 29)
Simulated Lake Elevation (feet City Datum)
Scenario Year
30
25
20
15
10
5
0
-5
-10
21.4
16.4
11.4
6.4
1.4
-3.6
-8.6
-13.6
-18.6
00
10
20
30
40
50


Model Simulated Lake Merced Lake Levels
Scenario 1 and 2 Comparison
Lake Merced Lake-Level Model
Design
Drought
Simulated Lake Elevation (feet NGVD 29)
Simulated Lake Elevation (feet City Datum)
Scenario Year
Lake-Level Model Scenario 1
Lake-Level Model Scenario 2
30
25
20
15
10
5
0
-5
-10
21.4
16.4
11.4
6.4
1.4
-3.6
-8.6
-13.6
-18.6
00
10
20
30
40
50

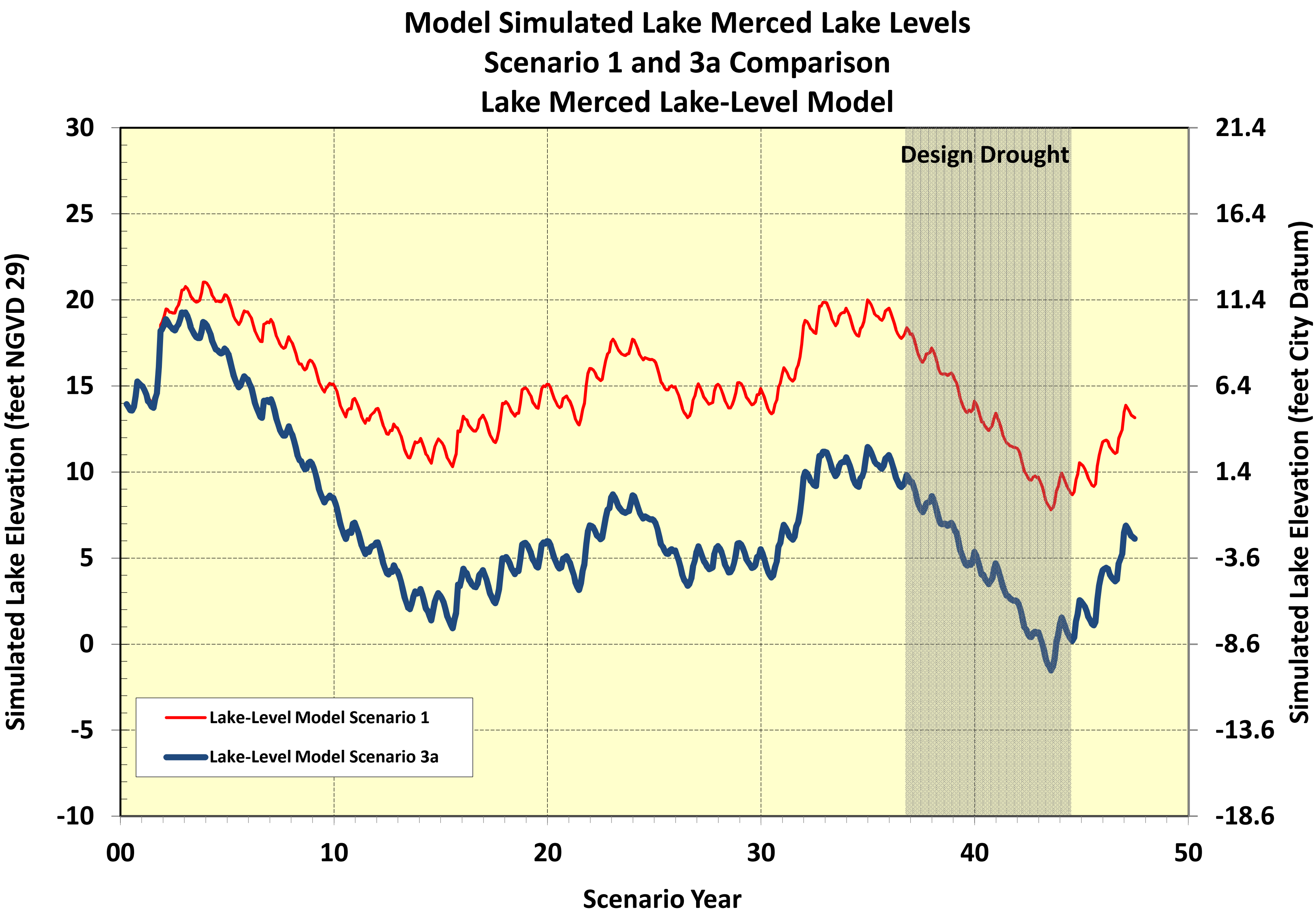
Lake Merced Lake-Level Model Water Balance
Scenario 3a
SFPUC GSR and SFGW Projects Technical Analysis

Assumptions:		**Initial Lake Level**		**Wetland Source**		**VG Stormwater**		**Number of Wells**		**Diversion Elevation**		**Spillway Elevation**	
(in feet City Datum)		**5.7**		**None**		**No**		**No Wells**		**13.0**		**13.0**	
		Lake Merced Natural Hydrology						**Lake Merced Lake Level Management**				**Summary**	
Historical Water Year	**Scenario Year**	**Precipitation (af)**	**Stormwater Runoff (af)**	**Evaporation (af)**	**Transpiration (af)**	**Groundwater Inflow-Outflow (af)**	**Natural Hydrology Subtotal (af)**	**Lake Additions from Engineered Wetland (af)**	**Lake Additions from Vista Grande Canal Stormflow (af)**	**Lake Additions from Wells (af)**	**Flow over the Spillway (af)**	**Annual (Sept to Sept) Change in Lake Level (feet)**	**Lake Merced Change in Storage (af)**
1996	0	1	0	-241	-49	76	-213	0	0	0	0	-	-
1997	1	499	189	-717	-144	226	54	0	0	0	0	0.20	54
1998	2	1,180	672	-677	-134	289	1,331	0	0	0	0	4.50	1,331
1999	3	478	137	-639	-129	60	-93	0	0	0	0	-0.30	-93
2000	4	471	137	-686	-135	-56	-268	0	0	0	0	-0.88	-268
2001	5	291	75	-649	-133	-184	-601	0	0	0	0	-2.00	-601
2002	6	366	112	-640	-132	-190	-485	0	0	0	0	-1.65	-485
2003	7	487	214	-661	-136	-189	-286	0	0	0	0	-0.98	-286
1959	8	336	115	-640	-136	-196	-521	0	0	0	0	-1.84	-521
1960	9	291	111	-597	-134	-262	-591	0	0	0	0	-2.18	-591
1961	10	326	130	-571	-134	-291	-540	0	0	0	0	-2.09	-540
1962	11	361	179	-517	-128	-177	-282	0	0	0	0	-1.13	-282
1963	12	419	210	-549	-136	-211	-267	0	0	0	0	-1.12	-267
1964	13	260	129	-487	-131	-225	-455	0	0	0	0	-2.01	-455
1965	14	386	255	-448	-128	-166	-103	0	0	0	0	-0.47	-103
1966	15	314	214	-462	-133	-45	-112	0	0	0	0	-0.51	-112
1967	16	548	458	-479	-130	76	474	0	0	0	0	2.32	474
1968	17	294	165	-518	-136	-22	-217	0	0	0	0	-0.94	-217
1969	18	487	334	-491	-131	144	343	0	0	0	0	1.57	343
1970	19	441	258	-533	-133	68	102	0	0	0	0	0.46	102
1971	20	395	208	-507	-128	27	-4	0	0	0	0	0.01	-4
1972	21	250	125	-495	-130	-74	-324	0	0	0	0	-1.39	-324
1973	22	656	434	-521	-131	248	685	0	0	0	0	2.94	685
1974	23	615	303	-551	-131	180	416	0	0	0	0	1.65	416
1975	24	372	156	-551	-130	36	-116	0	0	0	0	-0.45	-116
1976	25	201	69	-551	-134	-57	-472	0	0	0	0	-1.87	-472
1977	26	235	103	-524	-132	-116	-435	0	0	0	0	-1.83	-435
1978	27	519	315	-555	-138	63	205	0	0	0	0	0.91	205
1979	28	338	191	-530	-135	53	-83	0	0	0	0	-0.33	-83
1980	29	455	250	-527	-132	50	95	0	0	0	0	0.42	95
1981	30	310	164	-511	-133	-1	-171	0	0	0	0	-0.71	-171
1982	31	642	372	-521	-130	158	522	0	0	0	0	2.19	522
1983	32	806	464	-627	-141	314	815	0	0	0	0	3.18	815
1984	33	459	220	-652	-141	245	132	0	0	0	0	0.51	132
1985	34	413	155	-638	-140	58	-152	0	0	0	0	-0.55	-152
1986	35	640	294	-659	-142	193	326	0	0	0	0	1.21	326
1987	36	290	111	-648	-140	59	-328	0	0	0	0	-1.20	-328
1988	37	313	120	-637	-141	-32	-377	0	0	0	0	-1.41	-377
1989	38	397	170	-602	-140	-41	-216	0	0	0	0	-0.83	-216
1990	39	235	94	-593	-141	-110	-514	0	0	0	0	-2.07	-514
1991	40	337	178	-544	-137	-101	-267	0	0	0	0	-1.12	-267
1992	41	350	196	-581	-146	-38	-219	0	0	0	0	-0.94	-219
1976	42	138	63	-469	-136	-58	-463	0	0	0	0	-2.23	-463
1977	43	188	124	-415	-132	-116	-351	0	0	0	0	-1.88	-351
1978	44	390	392	-451	-140	63	254	0	0	0	0	1.60	254
2004	45	326	265	-467	-137	178	165	0	0	0	0	0.87	165
2005	46	535	405	-488	-132	210	530	0	0	0	0	2.57	530
2006	47	588	396	-537	-133	246	560	0	0	0	0	2.37	560
Average (af)		**409**	**217**	**-553**	**-133**	**2**	**-65**	**0**	**0**	**0**	**0**	**-0.21**	**-62**
Maximum (af)		**1,180**	**672**	**-241**	**-49**	**314**	**1,331**	**0**	**0**	**0**	**0**	**4.50**	**1,331**
Minimum (af)		**1**	**0**	**-717**	**-146**	**-291**	**-601**	**0**	**0**	**0**	**0**	**-2.23**	**-601**

Key:
af - acre-feet
VG - Vista Grande



Model Simulated Lake Merced Lake Levels
Scenario 3a
Lake Merced Lake-Level Model
Design Drought
Lake-Level Model Scenario 3a
Simulated Lake Elevation (feet NGVD 29)
Simulated Lake Elevation (feet City Datum)
Scenario Year
30
25
20
15
10
5
0
-5
-10
21.4
16.4
11.4
6.4
1.4
-3.6
-8.6
-13.6
-18.6
00
10
20
30
40
50

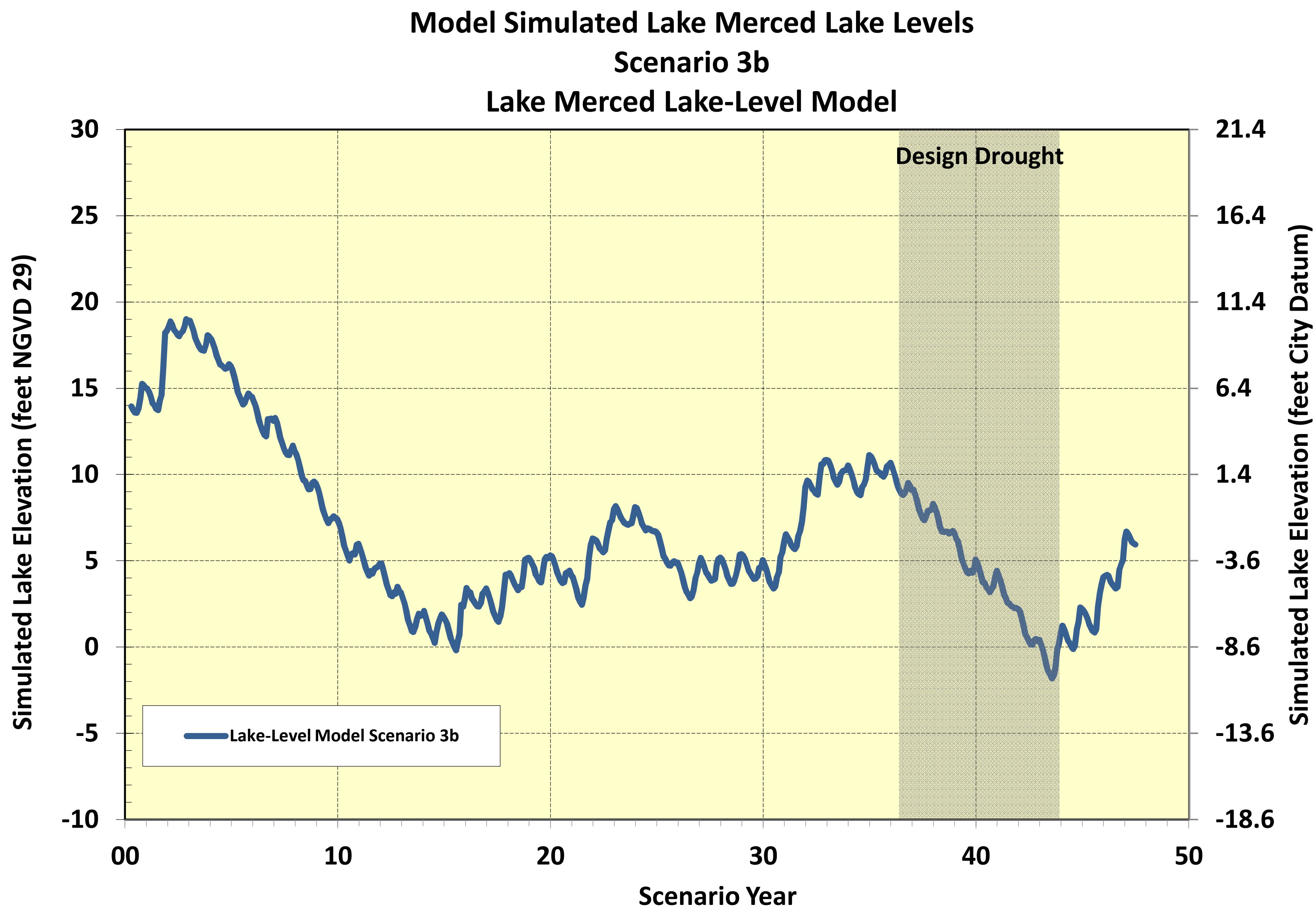

Model Simulated Lake Merced Lake Levels
Scenario 1 and 3a Comparison
Lake Merced Lake-Level Model
Design Drought
Simulated Lake Elevation (feet NGVD 29)
Simulated Lake Elevation (feet City Datum)
Scenario Year
30
25
20
15
10
5
0
-5
-10
21.4
16.4
11.4
6.4
1.4
-3.6
-8.6
-13.6
-18.6
00
10
20
30
40
50
Lake-Level Model Scenario 1
Lake-Level Model Scenario 3a

Lake Merced Lake-Level Model Water Balance
Scenario 3b
SFPUC GSR and SFGW Projects Technical Analysis

Assumptions: (in feet City Datum)	Initial Lake Level	Wetland Source	VG Stormwater	Number of Wells	Diversion Elevation	Spillway Elevation
	5.7	None	No	No Wells	13.0	13.0

		Lake Merced Natural Hydrology						Lake Merced Lake Level Management				Summary	
Historical Water Year	Scenario Year	Precipitation (af)	Stormwater Runoff (af)	Evaporation (af)	Transpiration (af)	Groundwater Inflow-Outflow (af)	Natural Hydrology Subtotal (af)	Lake Additions from Engineered Wetland (af)	Lake Additions from Vista Grande Canal Stormflow (af)	Lake Additions from Wells (af)	Flow over the Spillway (af)	Annual (Sept to Sept) Change in Lake Level (feet)	Lake Merced Change in Storage (af)
1996	0	1	0	-241	-49	76	-213	0	0	0	0	-	-
1997	1	499	189	-717	-144	229	57	0	0	0	0	0.21	57
1998	2	1,180	672	-677	-134	229	1,270	0	0	0	0	4.30	1,270
1999	3	477	138	-637	-129	-54	-206	0	0	0	0	-0.66	-206
2000	4	466	140	-680	-135	-113	-323	0	0	0	0	-1.06	-323
2001	5	287	76	-643	-133	-216	-629	0	0	0	0	-2.11	-629
2002	6	361	115	-632	-132	-216	-505	0	0	0	0	-1.74	-505
2003	7	480	218	-651	-136	-202	-292	0	0	0	0	-1.02	-292
1959	8	330	118	-629	-136	-206	-523	0	0	0	0	-1.89	-523
1960	9	285	114	-584	-134	-270	-589	0	0	0	0	-2.22	-589
1961	10	318	134	-556	-134	-297	-535	0	0	0	0	-2.13	-535
1962	11	348	186	-500	-128	-182	-276	0	0	0	0	-1.13	-276
1963	12	403	220	-528	-136	-216	-257	0	0	0	0	-1.12	-257
1964	13	247	135	-457	-131	-229	-434	0	0	0	0	-2.07	-434
1965	14	366	266	-426	-128	-169	-91	0	0	0	0	-0.44	-91
1966	15	300	221	-438	-133	-47	-96	0	0	0	0	-0.48	-96
1967	16	524	473	-456	-130	75	486	0	0	0	0	2.46	486
1968	17	278	174	-490	-136	-24	-198	0	0	0	0	-0.90	-198
1969	18	462	349	-477	-131	143	348	0	0	0	0	1.71	348
1970	19	425	268	-517	-133	67	110	0	0	0	0	0.52	110
1971	20	387	213	-494	-128	25	3	0	0	0	0	0.03	3
1972	21	247	126	-483	-130	-75	-316	0	0	0	0	-1.40	-316
1973	22	637	446	-513	-131	248	687	0	0	0	0	3.05	687
1974	23	603	310	-543	-131	180	418	0	0	0	0	1.71	418
1975	24	367	159	-544	-130	35	-113	0	0	0	0	-0.44	-113
1976	25	200	69	-544	-134	-59	-467	0	0	0	0	-1.88	-467
1977	26	233	104	-517	-132	-117	-429	0	0	0	0	-1.84	-429
1978	27	510	321	-547	-138	63	209	0	0	0	0	0.95	209
1979	28	337	191	-526	-135	53	-80	0	0	0	0	-0.33	-80
1980	29	450	252	-519	-132	49	101	0	0	0	0	0.44	101
1981	30	306	166	-505	-133	-1	-167	0	0	0	0	-0.70	-167
1982	31	625	383	-513	-130	159	524	0	0	0	0	2.28	524
1983	32	799	468	-621	-141	314	819	0	0	0	0	3.22	819
1984	33	458	221	-649	-141	245	134	0	0	0	0	0.52	134
1985	34	409	157	-634	-140	58	-150	0	0	0	0	-0.55	-150
1986	35	633	298	-654	-142	193	328	0	0	0	0	1.23	328
1987	36	287	113	-643	-140	58	-325	0	0	0	0	-1.20	-325
1988	37	313	120	-633	-141	-32	-374	0	0	0	0	-1.42	-374
1989	38	394	172	-598	-140	-41	-213	0	0	0	0	-0.82	-213
1990	39	234	95	-591	-141	-110	-514	0	0	0	0	-2.07	-514
1991	40	333	180	-538	-137	-101	-263	0	0	0	0	-1.11	-263
1992	41	341	201	-569	-146	-37	-211	0	0	0	0	-0.92	-211
1976	42	135	64	-462	-136	-58	-457	0	0	0	0	-2.23	-457
1977	43	186	125	-399	-132	-116	-336	0	0	0	0	-1.92	-336
1978	44	390	392	-450	-140	65	257	0	0	0	0	1.62	257
2004	45	322	268	-466	-137	179	166	0	0	0	0	0.90	166
2005	46	535	405	-488	-132	211	531	0	0	0	0	2.58	531
2006	47	578	402	-531	-133	247	563	0	0	0	0	2.44	563
Average (af)		**402**	**221**	**-544**	**-133**	**-5**	**-67**	**0**	**0**	**0**	**0**	**-0.22**	**-63**
Maximum (af)		**1,180**	**672**	**-241**	**-49**	**314**	**1,270**	**0**	**0**	**0**	**0**	**4.30**	**1,270**
Minimum (af)		**1**	**0**	**-717**	**-146**	**-297**	**-629**	**0**	**0**	**0**	**0**	**-2.23**	**-629**

Key:
af - acre-feet
VG - Vista Grande



Model Simulated Lake Merced Lake Levels
Scenario 3b
Lake Merced Lake-Level Model
Design Drought
Lake-Level Model Scenario 3b
Simulated Lake Elevation (feet NGVD 29)
Simulated Lake Elevation (feet City Datum)
Scenario Year
30
25
20
15
10
5
0
-5
-10
21.4
16.4
11.4
6.4
1.4
-3.6
-8.6
-13.6
-18.6
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10
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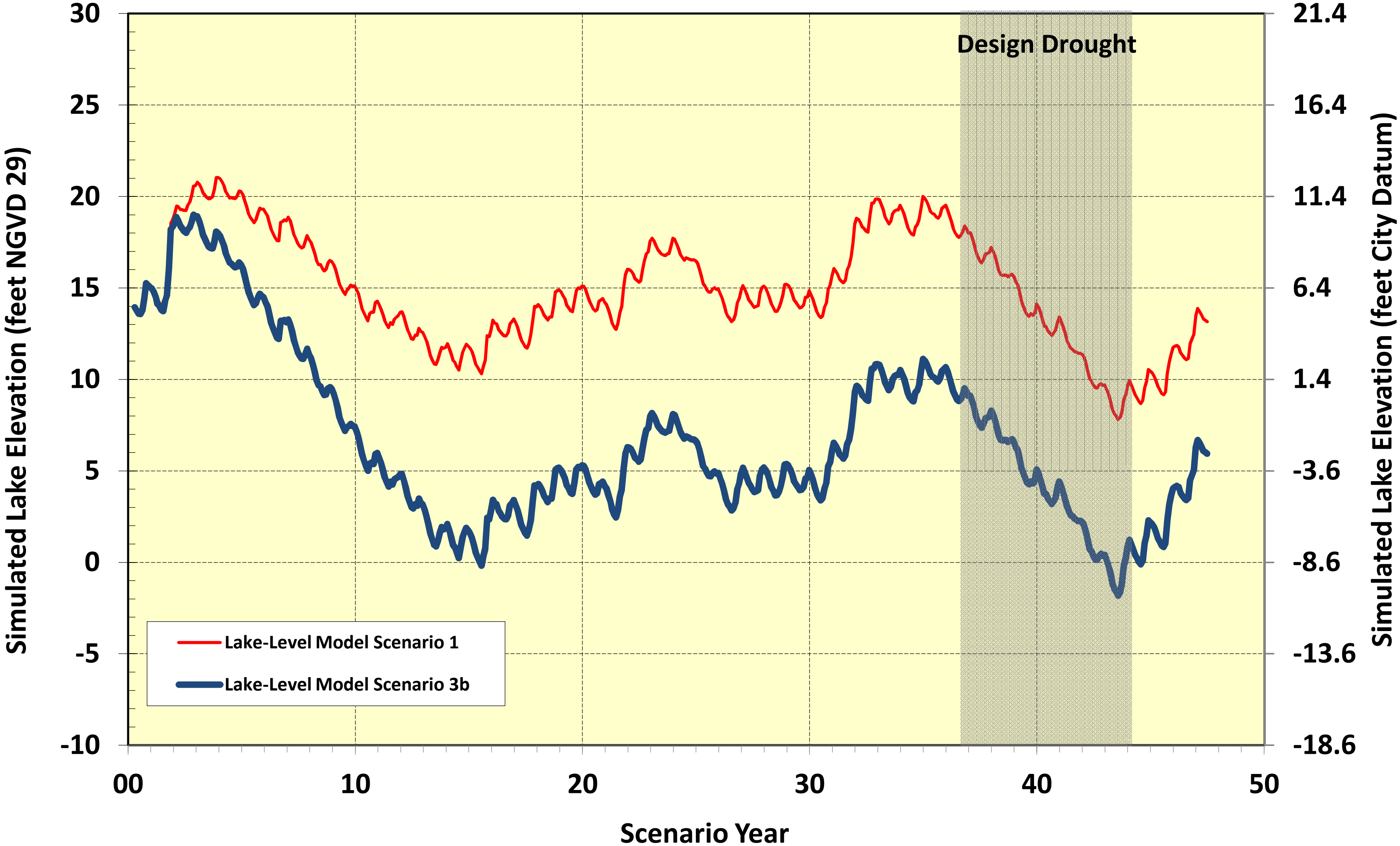
30
40
50

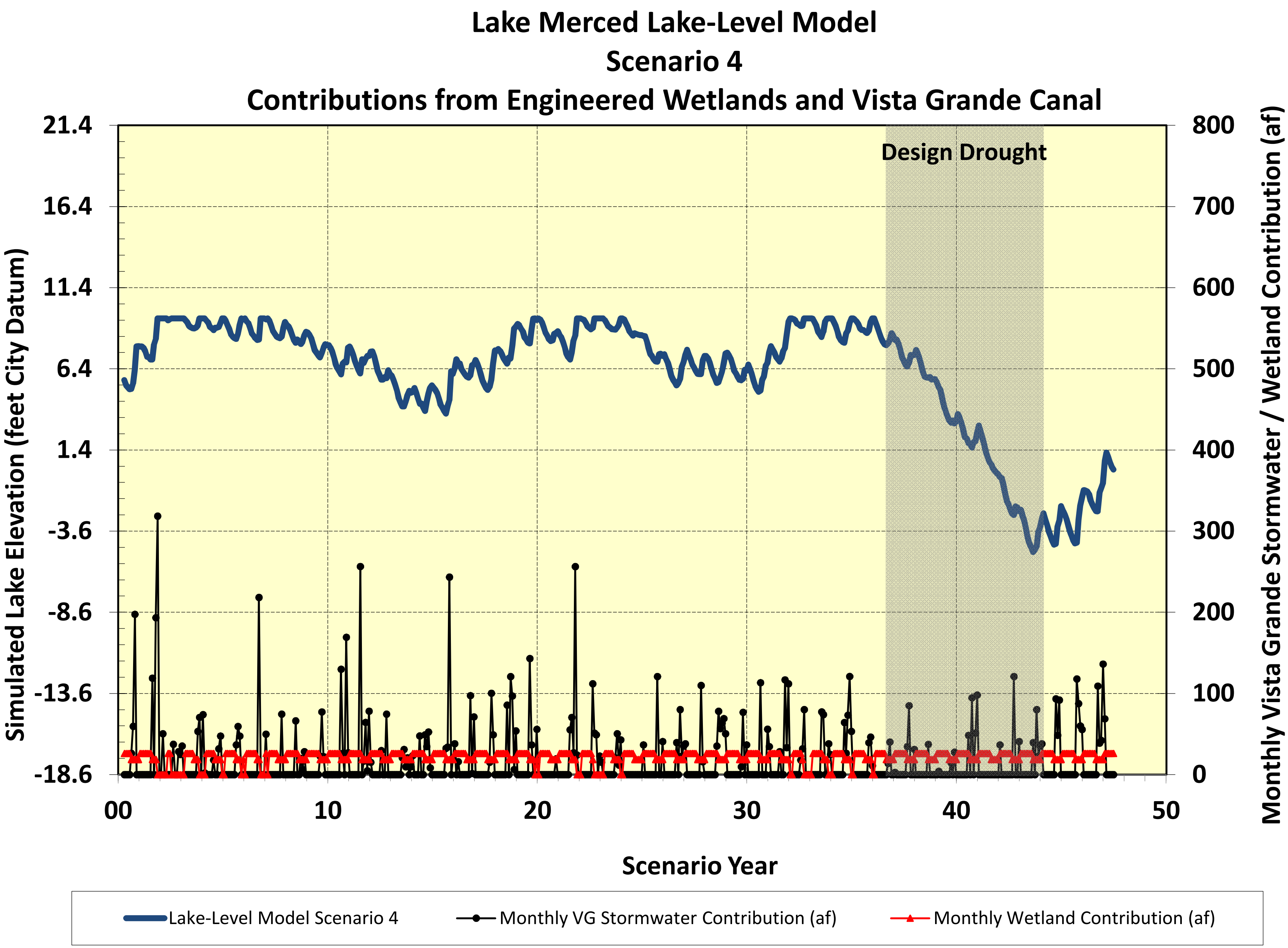
Model Simulated Lake Merced Lake Levels
Scenario 1 and 3b Comparison
Lake Merced Lake-Level Model

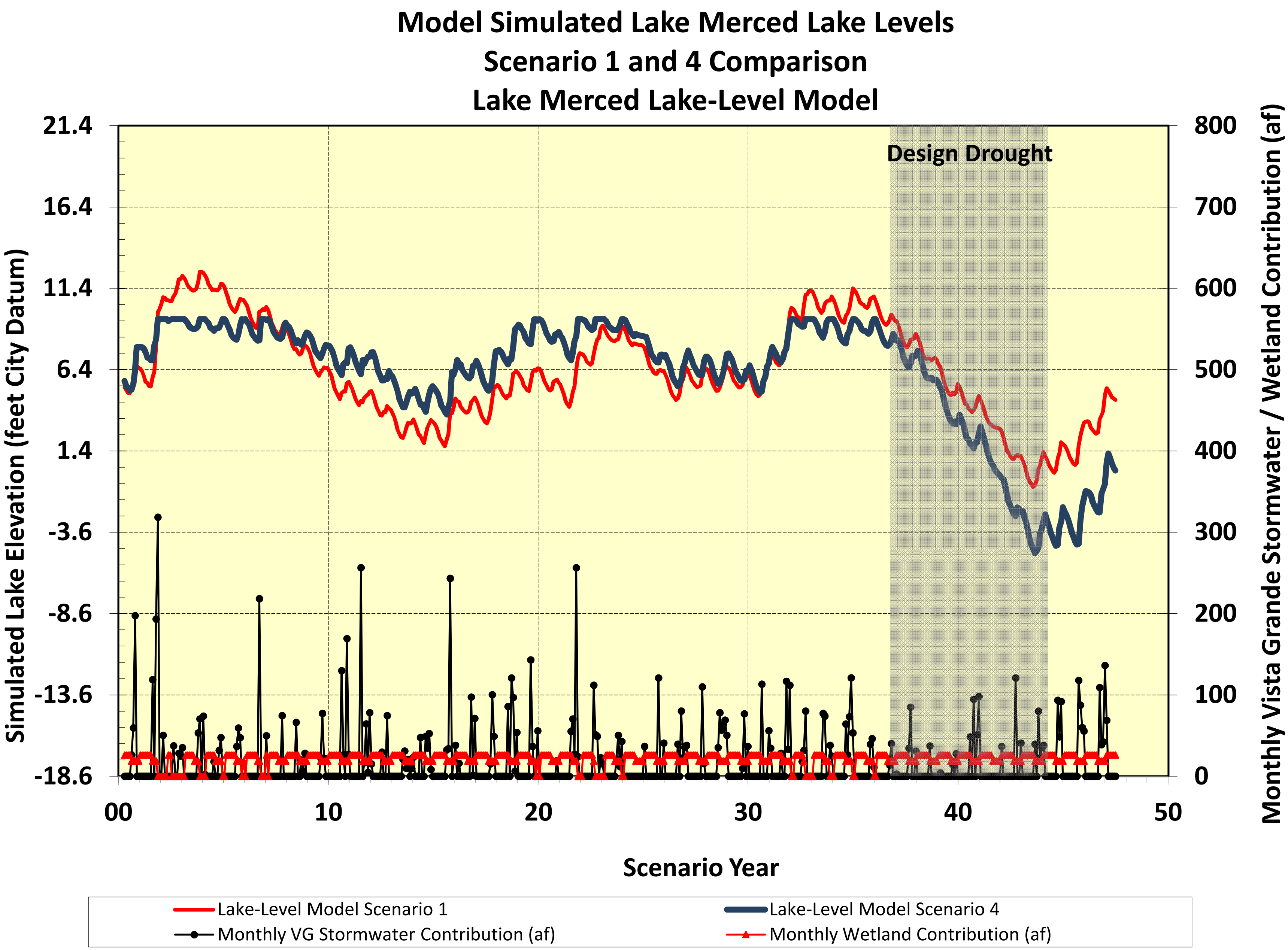


Lake Merced Lake-Level Model Water Balance
Scenario 4
SFPUC GSR and SFGW Projects Technical Analysis

Assumptions:		Initial Lake Level		Wetland Source		VG Stormwater		Number of Wells		Diversion Elevation		Spillway Elevation	
(in feet City Datum)		5.7		Baseflow		Yes		No Wells		9.5		9.5	
		Lake Merced Natural Hydrology						Lake Merced Lake Level Management				Summary	
Historical Water Year	Scenario Year	Precipitation (AF)	Stormwater Runoff (af)	Evaporation (af)	Transpiration (af)	Groundwater Inflow-Outflow (af)	Natural Hydrology Subtotal (af)	Lake Additions from Engineered Wetland (af)	Lake Additions from Vista Grande Canal Stormflow (af)	Lake Additions from Wells (af)	Flow over the Spillway (af)	Annual (Sept to Sept) Change in Lake Level (feet)	Lake Merced Change in Storage (af)
1996	0	1	0	-241	-49	49	-239	78	0	0	0	-	-
1997	1	504	176	-729	-144	165	-28	277	283	0	0	1.82	532
1998	2	1,205	489	-678	-134	608	1,490	135	681	0	-1,547	2.53	3,852
1999	3	476	138	-634	-129	411	262	105	126	0	-678	-0.60	1,171
2000	4	469	134	-683	-135	191	-24	187	200	0	-397	-0.11	760
2001	5	293	74	-658	-133	12	-413	232	97	0	-64	-0.48	-20
2002	6	377	106	-663	-132	-58	-370	232	144	0	-10	-0.01	15
2003	7	512	172	-697	-136	-29	-178	194	268	0	-252	0.12	537
1959	8	360	102	-690	-136	-113	-476	277	141	0	0	-0.19	-59
1960	9	323	94	-665	-134	-250	-631	277	55	0	0	-0.99	-300
1961	10	374	106	-659	-134	-382	-695	277	122	0	0	-0.99	-296
1962	11	427	141	-614	-128	-490	-664	277	353	0	0	-0.11	-35
1963	12	508	161	-673	-136	-687	-827	277	436	0	0	-0.38	-114
1964	13	325	97	-622	-131	-532	-863	277	104	0	0	-1.65	-482
1965	14	515	182	-600	-128	-429	-461	277	163	0	0	-0.07	-21
1966	15	430	149	-632	-133	-302	-488	277	145	0	0	-0.22	-67
1967	16	741	297	-621	-130	-310	-23	277	384	0	0	2.22	638
1968	17	380	120	-670	-136	-381	-687	277	170	0	0	-0.81	-241
1969	18	634	233	-626	-131	-113	-2	277	165	0	0	1.51	439
1970	19	553	184	-666	-133	-198	-260	277	364	0	0	1.29	380
1971	20	497	151	-633	-128	-206	-319	232	236	0	-92	0.20	240
1972	21	322	89	-638	-130	-313	-671	277	19	0	0	-1.25	-375
1973	22	838	296	-642	-131	12	374	213	433	0	-464	1.86	1,484
1974	23	735	231	-649	-131	168	354	149	251	0	-750	0.02	1,504
1975	24	436	123	-644	-130	-95	-311	232	126	0	-169	-0.40	215
1976	25	239	54	-658	-134	-257	-756	277	37	0	0	-1.47	-443
1977	26	291	78	-653	-132	-439	-855	277	162	0	0	-1.41	-417
1978	27	655	233	-691	-138	-351	-292	277	216	0	0	0.69	200
1979	28	422	140	-659	-135	-389	-620	277	126	0	0	-0.73	-217
1980	29	561	189	-647	-132	-496	-526	277	353	0	0	0.37	104
1981	30	385	123	-634	-133	-410	-668	277	123	0	0	-0.91	-269
1982	31	779	282	-624	-130	-248	60	277	204	0	0	1.85	540
1983	32	943	338	-718	-141	193	615	224	291	0	-470	2.20	1,599
1984	33	519	166	-726	-141	211	30	176	130	0	-542	-0.68	878
1985	34	463	129	-714	-140	-137	-400	213	214	0	-126	-0.32	154
1986	35	715	235	-730	-142	20	98	232	338	0	-442	0.75	1,110
1987	36	321	94	-720	-140	-123	-568	232	97	0	-29	-0.88	-210
1988	37	354	99	-719	-141	-299	-706	277	57	0	0	-1.24	-373
1989	38	453	140	-689	-140	-432	-668	277	151	0	0	-0.81	-241
1990	39	270	78	-688	-141	-527	-1,009	277	42	0	0	-2.38	-691
1991	40	402	141	-646	-137	-545	-784	277	42	0	0	-1.65	-465
1992	41	413	161	-688	-146	-633	-893	277	292	0	0	-1.18	-324
1976	42	171	51	-586	-136	-574	-1,074	277	37	0	0	-2.92	-761
1977	43	243	99	-538	-132	-676	-1,004	277	162	0	0	-2.34	-565
1978	44	525	309	-572	-140	-524	-403	277	216	0	0	0.41	90
2004	45	391	226	-556	-137	-437	-513	277	234	0	0	0.02	-3
2005	46	610	340	-540	-132	-403	-124	277	321	0	0	1.99	474
2006	47	632	333	-573	-133	-371	-112	277	395	0	0	2.21	560
Average (af)		**479**	**168**	**-644**	**-133**	**-229**	**-366**	**248**	**198**	**0**	**-128**	**-0.16**	**216**
Maximum (af)		**1,205**	**489**	**-241**	**-49**	**608**	**1,490**	**277**	**681**	**0**	**0**	**2.53**	**3,852**
Minimum (af)		**1**	**0**	**-730**	**-146**	**-687**	**-1,074**	**78**	**0**	**0**	**-1,547**	**-2.92**	**-1,547**

Key:
af - acre-feet
VG - Vista Grande


Lake Merced Lake-Level Model
Scenario 4
Contributions from Engineered Wetlands and Vista Grande Canal
Design Drought
Simulated Lake Elevation (feet City Datum)
Monthly Vista Grande Stormwater / Wetland Contribution (af)
Scenario Year
21.4
16.4
11.4
6.4
1.4
-3.6
-8.6
-13.6
-18.6
800
700
600
500
400
300
200
100
0
00
10
20
30
40
50
Lake-Level Model Scenario 4
Monthly VG Stormwater Contribution (af)
Monthly Wetland Contribution (af)



Model Simulated Lake Merced Lake Levels
Scenario 1 and 4 Comparison
Lake Merced Lake-Level Model
Design Drought
Simulated Lake Elevation (feet City Datum)
21.4
16.4
11.4
6.4
1.4
-3.6
-8.6
-13.6
-18.6
Monthly Vista Grande Stormwater / Wetland Contribution (af)
800
700
600
500
400
300
200
100
0
00
10
20
30
40
50
Scenario Year
Lake-Level Model Scenario 1
Lake-Level Model Scenario 4
Monthly VG Stormwater Contribution (af)
Monthly Wetland Contribution (af)

Attachment 10.1-H

Lake Merced Lake-Level Model Development Technical Memorandum

17 April 2012

Technical Memorandum
Attachment H to Task 10.1 Technical Memorandum

San Francisco Public Utilities Commission

Lake Merced Lake-Level Model Development
Regional Groundwater Storage and Recovery Project and
San Francisco Groundwater Supply Project

Prepared for: Greg Bartow and Jeff Gilman, SFPUC

Prepared by: Michael Maley and Sevim Onsoy, Kennedy/Jenks Consultants

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1. Introduction

This Technical Memorandum (TM) was prepared to document work performed by Kennedy/Jenks Consultants (Kennedy/Jenks) for the San Francisco Public Utilities Commission (SFPUC) pursuant to the amended Task Order (TO) authorizations CUW30103-TO-1.12 of the Regional Groundwater Storage and Recovery (GSR) Project and CUW30102-TO-2.7 of the San Francisco Groundwater Supply (SFGW) Project. These projects are funded by the SFPUC's Water System Improvement Program (WSIP).

1.1. Objective

SFPUC is currently undertaking engineering and environmental studies for the GSR and SFGW Projects that includes evaluating the potential effects of these projects on Lake Merced. The Lake Merced Lake-Level Model is one the tools used to evaluate these effects.

The Lake Merced Lake-Level Model is a spreadsheet-based water-balance that applies a rule-based approach for the water balance. The model sums up the inflows and outflows from Lake Merced on a monthly time scale. The water balance components are each calculated independently. The sum represents the net change in water volume in the lake for that month. Based on this net change in water volume, a new lake level is calculated. The advantage of a rule-based approach is that once the rules are defined, they enhance the ability to then adapt the model for use in project simulations.

This technical memorandum documents the model calibration to historical lake levels over a 70-year period from 1939 to 2009. Calibrating the model over this long historical range allows for the historical analysis to be tested over a variety of hydrological conditions including wet, normal and dry precipitation years, flood events, and periods of high and low lake levels. The calibration process defines the level of confidence in the capability of the model to subsequently simulate future-case scenarios. A well calibrated model demonstrates a stronger conceptual understanding of the key hydrological factors that control lake levels. An improved historical calibration also increases confidence in the model's ability to forecast future conditions and reduces uncertainty in the model's applications to future conditions.

The setup and modifications to the Lake-Level Model necessary to apply the model for the GSR and SFGW projects is also documented herein, but the results of the modeling are presented in the main body of the Task 10.1 Technical Memorandum.

1.2. Previous Studies

Several previous studies have been conducted to evaluate Lake Merced. EDAW and Talavera & Richardson (2004) conducted a study to understand the cause for declining water levels and to develop plans to restore levels. Several detailed studies were conducted by Luhdorff & Scalmanini Consulting Engineers (LSCE) (LSCE 2002, 2004, and 2007) to provide a description of the aquifers underlying the lake to evaluate the lake-aquifer relationships. The Lake Merced Water Level Restoration Alternatives Analysis Report (AAR) (Metcalf & Eddy, Inc., 2008) identified preferred alternatives to meet recommended lake level elevations through a combination of treated stormwater from the Vista Grande Canal (VGC) and groundwater. A draft Conceptual Engineering Report (CER) was prepared to provide the first phase of the conceptual engineering design for an engineered wetland for stormwater treatment (Kennedy/Jenks, 2009a). The City of Daly City prepared the Vista Grande Drainage Basin Alternatives Analysis in 2011 (Jacobs Associates, 2011a, 2011b; City of Daly City, 2012) to evaluate alternatives to reduce flooding and erosion along Lake Merced, and provide lake level augmentation.

Previous Lake Merced lake-level modeling studies have been conducted to characterize the water balance of Lake Merced and to estimate supplemental water necessary to raise and maintain lake levels. As a part of the EDAW study, a numerical groundwater model was developed to provide preliminary estimates of the volumes of water needed for maintaining lake levels within different target lake levels (EDAW and Talavera & Richardson, 2004). LSCE (2008) developed a spreadsheet-based analytical water-balance model to evaluate changes in lake levels in Lake Merced. This model was updated to support the draft Conceptual Engineering Report (CER) for the conceptual engineering design to increase and maintain Lake Merced Levels (Kennedy/Jenks, 2009a). The Kennedy/Jenks (2009b) model was modified for the Vista Grande Drainage Basin Alternatives Analysis in 2011 (Brown and Caldwell, 2010; Jacobs Associates, 2011a, 2011b) to evaluate lake-levels changes from diversions of stormwater from the VGC.

2. Physical Setting

This section provides a summary of the climatic, hydrological, and hydrogeological data representative of the physical setting of Lake Merced.

2.1. Lake Merced

Lake Merced is a freshwater lake located in the southwest corner of San Francisco, consisting of four inter-connected freshwater lakes - North Lake, South Lake, East Lake and Impound Lake (Figure 1). Until the early 1900s, Lake Merced was one large body of water that was fed by local runoff and springs, with an outflow to the Pacific Ocean via a stream from North Lake. The springs that flowed into the lake were primarily located on the eastern side and in the southern portion of Lake Merced and resulted in flow through the lake from south to north.

Lake Merced does not have a natural outlet; however Lake Merced has an overflow structure, also known as spillway, near the midpoint of the southwest side of South Lake at 13 feet City Datum. All lake elevations in this memorandum reference the City Datum, which is 11.37 feet higher than the North American Vertical Datum 1988 (NAVD) and 8.62 feet higher than the National Geodetic Vertical Datum 1929 (NGVD) (LSCE, 2002). Lake Merced elevations have historically referenced a Lake Merced Gage Board that has a datum 17.50 feet higher than the City Datum, 8.88 feet higher than NGVD, and 6.13 feet higher than NAVD.

North and East lakes are joined through a narrow channel and these lakes are separated from South Lake by natural or man-made barriers. A conduit between North and South lakes allows water to flow between the two lakes when the lake elevation in either lake is approximately 3.35 feet City Datum. When lake levels drop below that elevation, the two lakes are separated and typically exhibit different elevations. South and Impound lakes are separated below an elevation of approximately 4.26 feet City Datum. When the lake elevation in either lake is above 5 feet City Datum, water flows freely, connecting the two lakes.

2.2. History of Lake Levels

Lake levels have been measured daily in South Lake since 1926. Figure 2 shows the historical measured Lake Merced water levels as measured at South Lake. Historically, lake water levels have fluctuated. Prior to the beginning of Hetch-Hetchy aqueduct water delivery in 1935, lake levels typically ranged from 0 to -10 feet City Datum. In the late 1930s to early 1940s, lake levels increased to over 13 feet City Datum which is approximately the spillway elevation and represents the maximum potential lake level.

Lake levels started to decline in the 1940s. During the 1940s to late 1950s, lake levels varied between 8 and 13 feet City Datum. Between the late 1950s and early 1980s, the lake experienced an overall long-term declining trend when lake levels ranged between 4 and 10 feet City Datum (Figure 2). Previous reports cite the primary reasons for the overall declining lake levels as drought, groundwater pumping, evaporation, and urbanization diverting stormwater into the City's combined sewer and stormwater system (Pezzetti and Bellows, 1998).

In the late 1980s and early 1990s, a major drought impacted the area. During this time, lake levels dropped significantly due to the drought and groundwater pumping. A lake level of about -3.2 feet City Datum observed in 1993 was the lowest since the 1930s (Figure 2).

Lake levels have been recovering since 1993. As of June 2009, the lake was at approximately 5.7 feet City Datum (Figure 2). Water level increases over the last 15 years are attributed to a combination of factors, including above average precipitation and direct recharge to the lake and the SFPUC water additions to the lake between 2002 and 2005. During the wet winters of 1997 and 1998, the lake level rose sharply.

Expanded lake-level monitoring was conducted from August 2001 to January 2004. This was during a time when the lake levels were near or below the hydraulic connections between the lakes. This condition caused the lakes to act more independently since the lake levels could not readily equilibrate. These measurements showed that the lake levels decrease progressively from north to south. North and East lakes had higher levels than South Lake, and South Lake was continuously higher than Impound Lake (LSCE, 2004). These observations reflected the predominant shallow groundwater gradient to the south and showed that lake levels separate at lower elevations and have distinct elevations.

2.3. Lake Merced Hydrological Conceptual Model

The hydrological conceptual model for Lake Merced provides a representation of the various inflow and outflow components for the overall lake system. The conceptual model also provides the basis for a representative water-balance model that can be used to develop future operations scenarios for managing the lake levels. The conceptual water-balance model described below consists of various key components that include inflows into and outflows from the lake systems.

Figure 3 demonstrates a schematic of the conceptual water-balance model with primary inflows and outflows that are pertinent for Lake Merced. The primary water balance components are defined as follows:

- Change in Lake Storage – Change in the volume of water in the lake. An increase in lake storage results in a rise in lake levels as water is added to the lake. Conversely, a decrease in lake storage results in a decline in lake levels as water is lost from the lake
- Direct Precipitation – Inflow to Lake Merced resulting from rainfall that falls directly onto Lake Merced surface.
- Stormwater Runoff – Inflow to Lake Merced resulting from runoff of precipitation that falls on the areas surrounding Lake Merced or from overflow from VGC during storm events. Stormwater runoff depends on the extent of drainage area that contributes to the runoff, the amount of precipitation, topography and surface conditions in the drainage areas.
- Evaporation – Outflow from Lake Merced resulting from evaporation, or the conversion of water at the lake surface into water vapor that is lost to the atmosphere. Evaporation is considered as the single largest water loss from the lake. Evaporation loss depends

on lake surface area that is subject to evaporation and evaporation rates that vary as a function of climate conditions (temperature, fog, wind).

- Transpiration – Outflow from Lake Merced resulting from transpiration, or the uptake of water from the lake by plants. The primary plant for consideration of transpiration is the California bulrush (*Scirpus californicus*), or tule. Transpiration loss from the lake is dependent upon the area covered by tules and on transpiration rates.
- Groundwater Inflow and Outflow – The net inflow or outflow of groundwater from the lake. Lake Merced is hydraulically connected to the Shallow Aquifer of the groundwater system (LSCE, 2002; LSCE, 2004); thus, groundwater inflow into and outflow from the lake system is an important water balance component. The direction and magnitude of the groundwater flux into or out of the lake is controlled by the relative difference of lake and groundwater levels.
- Singular Events – The net inflow or outflow to the lake resulting from man-made lake water additions or extractions. These are termed singular events because they are determined by arbitrary operating decisions; therefore, they cannot be estimated independently.

This conceptual water-balance model can be formulated mathematically as follows to track the inflow and outflow of water from the lake over time:

Change in Lake Storage = Direct Precipitation + Stormwater Runoff – Evaporation – Transpiration + Groundwater Inflow – Groundwater Outflow ± Singular Events

In this form, positive components represent inflows into the lake and negative components are outflows from the lake. When inflow exceeds outflow over a month period, the model outcome is a positive change in lake storage, indicating an increase in lake levels. Conversely, when outflow exceeds inflow, the model outcome is a negative change in lake storage, which indicates a decrease in lake levels.

2.4. Physical Lake Condition

As part of the modeling analysis presented here, the lake surface area was calculated as a function of lake level elevation derived from both bathymetric and surface contour data. Table 1 presents the estimated lake surface areas. The estimated lake surface area contours (feet, City Datum) along with the bathymetric contours (feet, City Datum) are shown in Figure 4. For the current lake level as of June 2009 at 5.7 feet City Datum, the total surface area of the lake, including the four lakes, was calculated to be approximately 296 acres. These values are incorporated into the model for converting lake storage into lake levels. This was a model improvement in an effort to refine the lake surface area estimates, which, in turn, improves water balance calculations.

Table 1 – Estimated Lake Merced Surface Area by Lake Levels

Lake Elevation (feet City Datum)	Estimated Lake Surface Area (Acres)
-13	106
-12	122
-11	157
-10	157
-9	193
-8	201
-7	209
-6	223
-5	234
-4	240
-3	250
-2	255
-1	261
0	267
1	273
2	279
3	284
4	288
5	292
6	296
7	300
8	304
9	307
10	310
11	313
12	316
13	319

Based on previous reports, estimates of the total lake surface area range from approximately 245 acres of open water (EIP Associates, 2000) to 276 acres (Yates et al., 1990) to 300 acres (EDAW and Talavera & Richardson, 2004). The variations are likely due to differences in lake levels and surrounding topography. Estimates of the capacity of the lake also vary greatly from a low of 768 million gallons to high of 1.93 billion gallons (Ecology and Environment, 1993). According to Camp Dresser and McKee (CDM) (1999), the volume of North and East lakes is approximately 280 million gallons, South Lake is approximately 700 million gallons and Impound Lake is approximately 26 million gallons, for a total of approximately 1 billion gallons of water in Lake Merced. Yates et al. (1990) estimates the lake's capacity at 1.2 billion gallons.

Based on the available lake bathymetry data discussed in previous reports, the maximum depth of North Lake is 24 feet with an average depth of 13 feet (Yates et al., 1990). South Lake has a maximum and average depth of 23 and 16 feet, respectively. The maximum and average depth of Impound Lake is 12 and 8 feet, respectively. The maximum water level at Lake Merced is controlled by an overflow structure near the midpoint of the southwest end of South Lake at approximately 13 feet City Datum. The bottom topography of the lake is reported to be generally flat and smooth. Only one reference was found to indicate modifications to the bottom of South Lake when dredging was conducted to remove lead shot in the proximity of the Pacific Rod and Gun Club (Ecology and Environment, 1993).

2.5. History of Lake Additions

SFPUC has added water to Lake Merced periodically to help maintain lake levels. These primarily have been diversions of Regional Water System water into South Lake at the Lake Merced Pump Station. Table 2 presents a summary of the known lake water additions based on information provided by the SFPUC (personal comm., Betsey Eagon) and gathered from previous documents (LSCE, 2002; LSCE, 2004). Additional lake water additions are known to have occurred, but records are not available at the time of this study to quantify the volume of water added (personal comm., Greg Bartow, 2009).

Table 2 – Records of Water Additions to Lake Merced

Calendar Year	Volume (AF)	Data Source
1965 -1969	740	LSCE
1978	1,200	LSCE
1992	840	LSCE
1994	920	LSCE
1997	129	SFPUC
2000	71	SFPUC
2002	345	SFPUC & LSCE
2003	816	SFPUC & LSCE
2004	2	SFPUC
2005	96	SFPUC

In the summer of 2003, decreasing lake levels from north to south changed as North and South lakes reached equilibrium in response to the SFPUC's intentional water additions to the lake (LSCE, 2004). Three water additions to the lake were made using the SFPUC Regional Water System water to evaluate the feasibility of direct water addition to the lake as a practical way to manage lake levels. The additions occurred between October 2002 and October 2003. During the first addition in October 2002, the total volume of water added to the lake was 345 af (Table 2). The impact from the first addition was notable in South Lake, with a measurable 1-1/2 foot rise to an elevation of 1.28 feet City Datum. No definitive response was seen in either North Lake or Impound Lake. The second water addition occurred in April 2003, by adding approximately 111 af to the lake. Similar to the first addition, the impact of the second addition was evident in South Lake and no measurable response was seen in North Lake and Impound Lake. During the third addition between July 25 and October 17, 2003, South Lake rose to a level of 3.35 feet City Datum where it began to spill to North Lake and East Lake, and the lakes reached equilibrium. Approximately 705 af was added during the third addition.

Groundwater monitoring during the 2002 and 2003 water additions also demonstrated that the Shallow Aquifer is in full hydraulic connection with Lake Merced (LSCE, 2004). Groundwater level response after October 2002 event was evident in shallow groundwater monitoring wells in the lake vicinity, located immediately adjacent to South Lake. The third addition provided a significant response in all the shallow monitoring wells around the lake.

2.6. Climate

Two weather stations with long-term climatological records were evaluated for this study. These include the Lake Merced Pump Station precipitation gauge operated by SFPUC adjacent to Lake Merced, and the Mission Dolores station located about 5 miles northeast of Lake Merced. The Lake Merced Pump Station gauge is considered to provide representative precipitation data for Lake Merced. Records go back to 1948 but continuous data begins in 1958 (WRCC, 2012a). The Mission Dolores station has a long-term record with continuous climate data records going back to 1914 for both precipitation and temperature (WRCC, 2012b).

2.6.1. Rainfall

The close proximity of Lake Merced to the Pacific Ocean results in distinct maritime Mediterranean climate primarily influenced by wind, fog, and precipitation. Based on the historical precipitation data from Lake Merced Pump Station, the majority of annual rainfall occurs from late October through March (Table 3). Precipitation typically declines during the late season and becomes minimal during the summer. Average annual rainfall (based on a water year of October through September) at the Lake Merced Pump Station gauge is approximately 20.7 inches with a record high of 47.6 inches in 1998 and a record low of 9.5 inches in 1976 (Figure 5). The long term historical record uses a combination of data from the Mission Dolores Station (1914 to 1958) combined with the Lake Merced Pump Station data. The long-term average for Mission Dolores is approximately 21.1 inches which is only slightly higher than Lake Merced Pump Station and, therefore, it is considered reasonable to include this data. The combined precipitation data set is provided in Appendix A.

2.6.2. Temperature

The maritime Mediterranean climate is characterized by cool, foggy summers and mild, rainy winters. In summer and fall, locations adjacent to the ocean, such as Lake Merced, are often enclosed in fog with cool temperature in the 50s and 60s ^{o}F. Lake Merced area often experiences its warmest weather in late September and early October as a result of less fog and occasional off-shore breezes (Table 4). Average monthly temperature from the Mission Dolores station ranges from 51 ^{o}F in January to nearly 63 ^{o}F in September, based on data from January 1914 to April 2009 (Table 4). The highest average monthly temperature was 69.4 ^{o}F in September 1984 and the lowest was 43.6 ^{o}F in January 1937 (see Appendix A).

Table 3 – Summary of Rainfall Data (inches) from Lake Merced Pump Station Precipitation Gauge Based on Records from October 1958 to September 2009

	Monthly Rainfall Data Statistics (October 1958 – September 2009)		
Month	**Average**	**Minimum**	**Maximum**
Jan	4.22	0.42	11.67
Feb	3.56	0.24	15.64
Mar	3.02	0.12	9.29
Apr	1.45	0.06	5.56
May	0.48	0.00	4.20
Jun	0.19	0.00	1.69
July	0.04	0.00	0.49
Aug	0.13	0.00	2.26
Sep	0.25	0.00	2.06
Oct	1.01	0.00	4.65
Nov	2.61	0.00	8.20
Dec	3.48	0.00	8.81

Table 4 – Summary of Temperature Data (°F) from the Mission Dolores, San Francisco, Weather Station Based on Records from January 1914 to April 2009

	Average Monthly Temperature Statistics (January 1914 – April 2009)		
Month	**Average**	**Minimum**	**Maximum**
Jan	51.0	43.6	56.6
Feb	53.9	48.3	58.9
Mar	55.2	50.9	60.7
Apr	56.3	50.7	62.6
May	57.5	53.3	62.7
Jun	59.5	56.2	65.9
July	59.8	56.0	66.0
Aug	60.6	56.4	66.6
Sep	62.7	58.3	69.4
Oct	61.8	56.9	66.7
Nov	57.4	51.9	61.0
Dec	52.1	47.2	57.5

2.6.3. Evapotranspiration

Fog is prevalent throughout the Lake Merced area and significantly affects sunshine and temperature conditions. This also affects evaporation, transpiration, and evapotranspiration rates. A United State Geological Survey (USGS) study was conducted at Lake Merced during 1987 and 1988 that collected pan evaporation measurements. These pan evaporation measurements were converted to equivalent lake evaporation and tule transpiration rates (Yates et al., 1990). A summary of the results of this study is provided in Table 5.

Evaporation rates for Lake Merced were assumed to be affected by temporal variations based on temperature conditions; however, these data are not available from Lake Merced. Reference evapotranspiration (ETo) data measured at the closest California Irrigation Management Information System (CIMIS) station at Castroville (http://wwwcimis.water.ca.gov/cimis/) were used as the basis to relate ETo to lake evaporation, similar to the approach taken by Yates (2003). Castroville was used because it represents a location with a similar climate near the ocean that is influenced by fog in the summertime. In this analysis, ETo data available from November 1982 to March 2009 at Castroville CIMIS station were used to estimate long-term lake evaporation.

A literature review indicated that evaporation is not directly measured by weather stations, but can be estimated based on ETo of cropped surfaces, using a procedure published by the Food and Agricultural Organization (FAO) Irrigation and Drainage Papers (FAO, 1977; FAO, 1998; Pruitt and Snyder, 1985). This approach is commonly applied in the literature, and it was used in this study to develop a time series of monthly lake evaporation from monthly ETo. Monthly ETo records at Castroville Station were multiplied by a coefficient of 0.735 to estimate monthly lake evaporation. This coefficient is within the typical range of 0.6 to 0.9 as reported by Yates (2003). The standard deviation was calculated for the estimated lake evaporation for each month to evaluate the seasonal variation in lake evaporation. The results of this analysis are provided in Table 6.

Table 5 – Monthly Evaporation Rates for Lake Merced (Yates et al., 1990)

Month	Pan Evaporation [(a)] (inches)	Lake Evaporation [(b)] (inches)	Tule Transpiration[(c)] (inches)
Jan	1.18	0.89	1.01
Feb	1.77	1.33	1.52
Mar	2.80	2.11	2.41
Apr	3.11	2.33	2.67
May	4.05	3.04	3.48
Jun	5.06	3.80	4.35
Jul	5.58	4.19	4.80
Aug	3.17	2.38	2.73
Sep	3.17	2.38	2.73
Oct	2.59	1.94	2.23
Nov	1.67	1.25	1.44
Dec	1.08	0.81	0.93
Total	**35.2**	**26.4**	**30.3**

Notes:

(a) Measurements at Lake Merced during Oct 1987 to Sept 1998 (Yates et al., 1990).
(b) Lake evaporation calculated as 75% of pan evaporation (Yates et al., 1990).
(c) Tule transpiration calculated as 86% of pan evaporation (Yates et al., 1990).

Table 6 – Summary of Evapotranspiration and Estimated Lake Evaporation Data from Castroville CIMIS Station Based on Records from November 1982 to March 2009

Month	Average Evapotranspiration	Average Estimated Lake Evaporation	Standard Deviation of Estimated Lake Evaporation
	(inches)	(inches)	(inches)
Jan	1.62	1.19	0.22
Feb	2.00	1.47	0.28
Mar	3.13	2.30	0.37
May	4.12	3.03	0.34
Apr	4.76	3.50	0.35
Jun	4.85	3.56	0.36
July	4.34	3.19	0.55
Aug	3.88	2.85	0.40
Sep	3.25	2.39	0.39
Oct	2.72	2.00	0.32
Nov	1.79	1.31	0.25
Dec	1.50	1.10	0.18

2.7. Hydrology

The original watershed that drained into Lake Merced has been estimated at approximately 6,320 acres; however, the current watershed is now estimated to be approximately 650 acres (SFSU, 2005; Pezzetti and Bellows, 1998). The current watershed is defined by the adjacent roadways that include Lake Merced Boulevard, Skyline Boulevard, and John Muir Boulevard.

A significant portion of stormwater that falls on the areas immediately surrounding the lake drains directly into the lake based on information provided by the SFPUC staff (personal comm., Greg Braswell). Overflow from VGC during storm events also has been discharged into the lake; thus, the lake has received additional stormwater runoff from the VGC overflows. Several catch basins draining into the lake are located primarily along the southern portion near the Impound Lake, and the majority of the stormwater drains located along the western shore of Lake Merced empty directly to the lake (Figure 6).

Much of the runoff from the original watershed is now diverted into the City's combined wastewater system, which had an effect on the surface runoff into the lake. The urbanization of the lake watershed diverts stormwater runoff away from the lake into the City's combined sewer and stormwater system and results in reduced recharge to the lake (SFSU, 2005). Runoff from the eastern and northern portions surrounding the lake is directed into the City's combined wastewater system. However, the development of the lake's watershed with impervious surfaces has tended to increase the runoff from these surfaces (SFSU, 2005).

Due to changes in the lake watershed hydrology, the flow through the lake has reversed over time, now flowing from north to south. The development of the urbanized watershed has also affected groundwater recharge to the Shallow Aquifer from precipitation, and in turn, reduced the amount of subsurface inflow to Lake Merced (SFPUC, 2008).

2.8. Groundwater

Lake Merced overlies the North Westside Basin, which is the northern portion of the greater Westside Groundwater Basin (Westside Basin). From north to south, the North Westside Basin underlies a portion of the Sunset District in San Francisco from Golden Gate Park to the San Francisco/San Mateo County line. From west to east, the North Westside Basin extends from the Pacific Ocean to inland bedrock exposures generally associated with Mount Sutro and Mount Davidson (LSCE, 2002; LSCE, 2004).

The groundwater aquifer system in the Lake Merced area is stratified consisting of three aquifer units: a shallow unconfined aquifer (Shallow Aquifer), an intermediate semi-confined aquifer (Primary Production Aquifer), and a deep confined aquifer (Deep Aquifer) (LSCE, 2002; LSCE, 2004; LSCE, 2005) (Figure 7). The Shallow Aquifer extends from the top of the zone of saturation (i.e., water table) to the top of the -100 foot clay in the Lake Merced area (LSCE, 2010). The thickness of the Shallow Aquifer varies from 100 to 150 feet. Beneath the unconfined aquifer lies a fairly extensive clay layer known locally as the -100 foot clay. This clay layer forms the top of the semi-confined Primary Production Aquifer that consists of a 250 to 300 foot thick sandy sequence. Beneath the Primary Production Aquifer is the confined Deep Aquifer consisting of a fine sand or loosely-consolidated sandstone.

Lake Merced is hydraulically connected to the unconfined Shallow Aquifer (LSCE, 2002; LSCE, 2004). Previous hydrogeological investigation also provided some evidence that the surface of the lake is essentially an exposed part of the water table that defines the upper boundary of the Shallow Aquifer (Yates et al., 1990). Groundwater monitoring during the SFPUC's 2002 and 2003 water additions to Lake Merced further demonstrated that the Shallow Aquifer is in full hydraulic connection with Lake Merced (LSCE, 2004).Groundwater level response after the October 2002 water addition was evident in shallow groundwater monitoring wells in the lake vicinity, located immediately adjacent to South Lake. The third addition between July 25 and October 17, 2003 provided a significant response in the shallow monitoring wells around the lake, suggesting increased seepage from the lake in response to water additions. Analysis by LSCE (2004) indicated that 70 to 80 percent of the volume of water added contributed to lake storage and the remaining 20 to 30 percent attributed to net outflow and evaporative losses during the addition period.

Interpretation of water level data and some anecdotal groundwater observations (e.g., spring discharge into Lake Merced) show that shallow groundwater previously flowed toward the ocean to the northwest of Lake Merced (LSCE, 2002). Interpretation of recent shallow water level data shows that shallow groundwater has a gradient potentially turned toward the pumping depression that expanded toward Daly City by 1970. At present (based on fall 2007 data), the direction of groundwater flow in the unconfined Shallow Aquifer is predominantly to the southwest, however, north of Lake Merced groundwater flow appears to be more westward toward the ocean (Figure 8). Groundwater elevations ranged from about 13.5 feet (NAVD 88) north of Lake Merced to 15.8 feet (NAVD 88) south of Lake Merced (SFPUC, 2008).

Groundwater levels in the Primary Production Aquifer ranged from 3.4 feet north of Lake Merced to -5.2 feet south of the lake (SFPUC, 2008). These are notably lower elevations than levels in the overlying Shallow Aquifer, suggesting semi-confined to confined conditions in the Primary Production Aquifer. As reported in the draft North Westside Groundwater Management Plan (LSCE, 2005), significant historical groundwater pumping south of Lake Merced toward Daly City has resulted in substantial pumping depression and decline in groundwater levels in the deeper portion of the aquifer. Over the period from the late 1940's to the 1970's, a significant reduction in water levels was seen in the Primary Production Aquifer near the southern end of Lake Merced. It appears that the decrease in groundwater levels in Daly City and South San Francisco resulted in a change in groundwater flow direction from northwesterly to southerly in the Lake Merced-northern San Mateo County area of the Westside Basin. As also reported in the previous studies (LSCE, 2002), general groundwater flow direction in the deeper portion of the aquifer exhibits a more pronounced north to south flow direction than in the Shallow Aquifer, likely due to greater pumping stresses in the deeper aquifer to the south. In addition, interpretation of deeper groundwater levels shows that the groundwater has a steeper gradient toward the pumping depression than the Shallow Aquifer (LSCE, 2002).

2.9. Groundwater Pumping

In the Westside Basin, municipal pumping mostly occurs south of Lake Merced, in Daly City and San Bruno, by the California Water Service Company (SFPUC, 2008). Historically, a significant amount of groundwater pumping (for municipal water supply and irrigation) has occurred from the Primary Production Aquifer and Deep Aquifer. Significant municipal pumping commenced in 1949, increased considerably through 1965, and for the most part has continued to the present day (SFPUC, 2008). Total municipal pumping in the Westside Basin was about 7,500 acre feet per year (AFY) from the mid-1970s to the mid-1980s, and then ranged generally between about 6,000 AFY and 8,000 AFY until 2001 (Figure 9). Between 2002 and 2005, municipal pumping was significantly reduced, as part of the conjunctive use pilot project which replaced the majority of groundwater pumping during normal and wet years with the SFPUC's system water.

In addition to municipal pumping in the Westside Basin, groundwater has been pumped for irrigation supply and other non-potable uses, mostly for golf courses around Lake Merced, the cemeteries in Colma, Golden Gate Park, and the San Francisco Zoo. Much of the groundwater pumping for irrigation is unmetered, and historical pumping records are scarce. Total pumping in the Westside Basin, including municipal pumping (metered) combined with irrigation (unmetered) pumping, was estimated to be nearly 15,000 AFY in the late 1960s and was reduced to about 7,500 AFY in 2007 (Figure 9). In 2005, groundwater use for golf course irrigation around Lake Merced reduced significantly as a result of initial deliveries of recycled water. The combination of the conjunctive use pilot project and recycled water deliveries for golf course irrigation resulted in reduced pumping of about 5,600 acre feet (af) in 2005 and 7,500 af in 2006. When the conjunctive use project ended in 2006, approximately 7,500 af of water was pumped based on metered municipal and estimated irrigation pumping.

Pumping in the Primary Production Aquifer and Deep Aquifer has a direct effect on the Shallow (unconfined) Aquifer in the Lake Merced vicinity and on the Lake itself, because the Shallow Aquifer is hydraulically connected to the Primary Production Aquifer and Deep Aquifer; the -100-foot clay is absent to the south of Lake Merced and the Primary Production Aquifer is semi-confined (LSCE, 2002; SFPUC, 2008). Qualitatively, it is generally agreed upon that pumping from the Primary Production Aquifer has led to an overall decline in the water level of Lake Merced. Additionally, pumping from the Shallow Aquifer is known to have occurred, but historical records are scarce. The water-level decline has not been quantified unequivocally due to the many uncertainties associated with incomplete groundwater withdrawal records, subsurface complexities, and urbanization. As reported in the previous studies (LSCE, 2002), greater pumping stresses to the south of Lake Merced have lowered groundwater levels and resulted in depressed aquifer conditions in the Primary Production and Deep Aquifers where most of the current municipal pumping is occurring. As also shown in the 2008 Annual Groundwater Monitoring Report of the Westside Basin (SFPUC, 2009), in the Primary Aquifer groundwater elevations decrease significantly from north of Lake Merced to south of Lake Merced and experience a prominent north to south flow direction, likely due to greater pumping to the south. Previous reports indicate water was pumped from the lake to irrigate Harding Park Golf Course (Yates et al., 1990), but pumping volumes are unknown.

3. Lake Merced Lake-Level Model

This section describes how the various water balance components from the hydrological conceptual model were incorporated into the spreadsheet based Lake Merced Lake-Level Model by characterizing each of the conceptual water balance components including data sources, assumptions, and parameters used for the historical analysis.

3.1. Model Setup

The Lake Merced Lake-Level Model includes monthly water balance calculations based on the conceptual model described above and is maintained as a spreadsheet-based water-balance model, similar to the original model setup by LSCE (LSCE, 2008). The model includes each component of the water balance needed to simulate lake hydrology, and tracks monthly flows into and out of Lake Merced. The water balance components are inputs to the conceptual model; change in lake storage (in acre-feet) and lake levels (in feet) are the model outputs.

The historical analysis was extended over a 70-year period from October 1939 through June 2009. Prior to 1935, Lake Merced was used as a water supply source for the City of San Francisco. Pumping from the lake and nearby groundwater pumping either directly or indirectly contributed to the substantial decline of lake levels through about 1932, but records are unavailable to quantify these activities. After Regional Water System delivery began around 1935, it took a period of several years for the lake levels to recover. Therefore, 1939 was considered an appropriate starting point for the model.

In addition, the spreadsheet model was made more user-friendly. This was done by setting up each water balance component as a separate spreadsheet tab so that the development of the water balance can be traced. Supporting data are also included in separate data tabs. The calculation of the lake level is done in a summary table that is linked to the individual water balance components so that the contribution of each water balance component in calculating the lake level is clearly shown.

A more detailed discussion of how each of the water balance components was incorporated into the Lake Merced Lake-Level Model is provided below.

3.2. Direct Precipitation

In the Lake Merced Lake-Level Model, precipitation includes only the water that falls directly onto the lake surface as rainfall. To calculate the volume for the water balance, the monthly rainfall was multiplied by the lake surface area in acres to estimate the total volume of rainfall entering the lake. The calculation is as follows:

*Direct Precipitation = Precipitation Rate * Lake Surface Area*

The data used in calculating the precipitation component of the water balance are shown below:

- Precipitation Rate is the monthly precipitation data. Precipitation data from the Mission Dolores weather station were used from 1939 to 1958, and from the Lake Merced Pump Station gauge from 1958 to 2009. Data were incorporated directly into the model.
- Lake Surface Area is the lake surface area in acres. The area of the lake surface varies with the lake level, as described above (Table 1). The calculation was based on the starting lake level for the month.

The precipitation contribution was calculated for each month. The total volume of precipitation is listed in the water balance components in acre-feet and is added to the water balance. Potential water losses due to evaporation and other mechanisms are handled separately by the model.

3.3. Stormwater Runoff

Historically, stormwater runoff was a major inflow into Lake Merced. However, much of the original watershed is now diverted away from Lake Merced and into the City's combined stormwater system (SFSU, 2005). Currently, stormwater runoff into Lake Merced is generally limited to only those areas immediately adjacent to the lake. Several catch basins draining into the lake are located primarily along the southern portion near the Impound Lake and the majority of the stormwater drains located along the western shore of Lake Merced empty directly to the lake (Figure 10).

Specific runoff measurements into Lake Merced were not available; therefore, the stormwater runoff contribution was calculated using a variation of the Rational Method (Chow, Maidment and Mays 1988). The stormwater runoff contribution was calculated for each month and total volume was listed in the water balance components in acre-feet. The formula for calculating stormwater runoff is as follows:

*Stormwater Runoff = (Precipitation Rate - Rainfall Threshold) * Runoff Coefficient * Drainage Area*

The data used in calculating the stormwater component of the water balance is discussed below:

- Precipitation Rate is the monthly precipitation data. Precipitation data from the Mission Dolores weather station from 1939 to 1958, and from the Lake Merced Pump Station gauge from 1958 to 2009.
- Rainfall Threshold is the minimum amount of monthly rainfall required to generate runoff and was defined for each category. The rainfall threshold was subtracted from the monthly precipitation data. If the threshold was greater than the monthly rainfall, then no stormwater runoff was generated.
- Runoff Coefficient is the percentage of the precipitation, minus the rainfall threshold, that reaches Lake Merced as stormwater runoff.

- Drainage Area is the surface area that is receiving precipitation and contributing stormwater runoff to Lake Merced.

The calculation of stormwater runoff contributions to the lake was based on four drainage (or catch basin) areas surrounding the lake that could potentially contribute stormwater runoff to the lake during the historical period. The surface area for each of these four drainage areas was estimated based on the locations of storm drains and site topography (Figure 10). The stormwater runoff was calculated separately for each of the following drainage (or catch basin) areas:

- Adjacent to Lake – Approximately 123 acres of unpaved, relatively pervious areas adjacent to Lake Merced within the boundary defined by John Muir Drive, Skyline Boulevard and Lake Merced Boulevard.
- Impervious Area – Approximately 31 acres of paved, hardpacked or relatively impervious areas (e.g., roads and parking lots) within the boundary defined by John Muir Drive, Skyline Boulevard and Lake Merced Boulevard.
- Harding Park – Approximately 183 acres that includes Harding Park Municipal Golf Course. This area generally allows precipitation to percolate into the soil, but stormwater runoff does occur during periods of high rainfall.
- Pre-1955 Catch Basin – Pre-1955 total catch basin areas were assumed to be 650 acres during model calibration, which is consistent with the size of the lake watershed. This assumes approximately 313 acres east of Lake Merced Boulevard that drained into Lake Merced before this area was connected to the City's combined sewer and stormwater system. It was assumed that pre-1955 runoff into Lake Merced was only for the period prior to 1955.
- Lake Bed – The surface area of Lake Merced changes with changing lake levels. When the lake level falls below 7.0 feet (City Datum), direct precipitation falling on the dry portion of the lake bed is treated as stormwater using the same assumptions as those for the areas adjacent to the lake. When the lake level rises above 7.0 feet (City Datum), the area available to contribute stormwater from the areas adjacent to the lake is reduced for the stormwater calculation. Because the calculation is dependent upon the calculation of the lake level, it is calculated separately from the other stormwater contributions, but is included in the stormwater for the water balance.

Prior to the mid-1950s, the total drainage area into Lake Merced was assumed to be larger, thus resulting in higher runoff before the combined sewer and stormwater system was established around the mid-1950s. For the purpose of this analysis, the combined system was assumed to be developed in 1955, based on inputs from the SFPUC.

For each of the drainage areas defined above, a runoff coefficient and rainfall threshold were developed that were reflective of average conditions of the topography and surface conditions. A potential range of runoff coefficients was developed for each area based on standard references (CalTrans, 1987; Chow, Maidment, and Mays, 1988). Table 7 summarizes the stormwater runoff parameters, including the estimated drainage areas, runoff coefficients, and thresholds associated with each drainage area.

The rainfall threshold was developed empirically based on model calibration. The rainfall threshold is an adaptation added to the Rational Method that was intended to account for the fact that light rainfall amounts do not generally generate stormwater runoff. The use of the rainfall threshold reduced the stormwater runoff in the lower precipitation months. Also, by using the rainfall threshold, the runoff coefficients were increased to the upper parts of their range. These were adjusted during model calibration. By using the combination of runoff coefficient and rainfall threshold, the Lake Merced Lake-Level Model was better able to capture the seasonal variations in lake levels.

Table 7 – Summary of Stormwater Runoff Components, Coefficients, and Thresholds

	Area (Acres)[a]	Runoff Coefficient [b]	Threshold (inches) [c]
Pre-1955 Catch Basin	313	0.42	1
Adjacent to Lake	123	0.7	0.5
Impervious Area	31	0.9	0.25
Harding Park	183	0.35	6
Total	**650**	**-**	**-**

Notes:

(a) Estimated based on locations of catch basin drains using the data provided by the SFPUC.
(b) Assumed based on average topography and surface conditions using reference values from Cal Trans Highway Design Manual (1987) and Chow, Maidment, and Mays (1988).
(c) Empirically developed as part of the model calibration.

An adjustment to the stormwater runoff was made based on the surface area of Lake Merced. As noted in Table 1, the surface area of the lake varies with lake level. The drainage area adjacent to the lake was based on an assumption of a lake surface area of 300 acres. If the lake surface area was greater than 300 acres, then there was the potential to double account for areas that received direct precipitation to the lake. If the lake surface area was less than 300 acres, then there was an area that would generate stormwater runoff that was not accounted for. This would potentially be an issue during periods of high precipitation at low lake levels. Therefore, the difference between the estimated lake level and the assumed 300-acre lake surface area for the drainage areas was calculated using the Adjacent to Lake conditions and was added or subtracted from the stormwater runoff water balance component as appropriate.

Flooding from the VGC was calculated separately as part of the stormwater runoff. VGC overflow occurs during storm events when surface water flow in the VGC exceeds its discharge capacity. The water tends to backup where the VGC goes from a surface water canal to a subsurface pipeline. During these periods, water in the VGC overflows from the canal and over John Muir Drive into Impound and South Lakes for a period of hours to days.

To estimate these flooding events, an empirical formula was developed based on model calibration. This formula is as follows:

*VGC Flood = (Precipitation Rate - Rainfall Threshold) * Flood Factor*

The data used in calculating the VGC flood component of the water balance is discussed below:

- Precipitation Rate is the monthly precipitation data. Precipitation data from the Mission Dolores weather station from 1939 to 1958, and from the Lake Merced Pump Station gauge from 1958 to 2009.
- Rainfall Threshold is the minimum amount of monthly rainfall required to generate runoff and was defined for each category. A rainfall threshold of 6.5 inches per month was developed for VGC flooding based on model calibration. The rainfall threshold was subtracted from the monthly precipitation data. If the threshold was greater than the monthly rainfall, then no stormwater runoff was generated.
- Flood Factor is an empirically-derived number based on the model calibration that is used to estimate the flood volume. A flood factor of 140 was developed for VGC flooding based on model calibration.

The VGC is assumed to have been developed in the mid-1950s. For the Lake Merced Lake-Level Model, estimates of VGC flooding are calculated for the period from 1955 to 2009. No flooding is assumed to have occurred prior to 1955. By using a relatively high rainfall threshold of 6.5 inches per month, VGC flooding occurs during 42 months during the period from 1955 through 2009. The primary objective in developing the flood factor was determining a consistent value that was representative for all time periods so that VGC flooding could be incorporated into future case simulations.

3.4. Evaporation

Evaporation accounts for water at the lake surface that is converted into water vapor and lost to the atmosphere. Previous studies conducted for Lake Merced consider evaporation as the single largest outflow from the lake (Yates et al., 1990; Yates, 2003). To estimate the total evaporation loss from the lake, the monthly evaporation rate was multiplied by the lake surface area. The calculation is as follows:

*Evaporation = Lake Evaporation Rate * Lake Surface Area*

The evaporation loss was calculated for each month. The total evaporation loss is listed in the water balance components in acre-feet and is subtracted from the water balance. The data used in calculating the evaporation component of the water balance are shown below:

- Lake Evaporation Rate is the estimated monthly evaporation rate for Lake Merced. The monthly evaporation rate varies as a function of the average temperature, based on the Mission Dolores weather station (Appendix A).
- Lake Surface Area is the lake surface area in acres. The lake surface area varies with changes in the lake level, as described above (Table 1). The calculation was based on the starting lake level for the month.

Variations in temperature conditions result in temporal variations in the lake evaporation rate. Table 8 presents estimated monthly lake evaporation data as a function of temperature conditions. An estimation of the lake evaporation rate was developed for three different relative temperature conditions that are defined as cool, normal, and warm, which are defined as follows:

- Normal temperature conditions were defined when the average monthly temperature was within one standard deviation of the long-term average temperature for the month (Table 4 and Appendix A). The normal lake evaporation rate (Table 8) is based on the estimated monthly average lake evaporation rate (Table 5).
- Cool temperature conditions were defined when the average monthly temperature was below one standard deviation of the long-term average temperature for the month (Table 4 and Appendix A). The cool lake evaporation rate (Table 8) is estimated to be the monthly average lake evaporation rate minus one standard deviation based on the monthly measured ET data from Castroville (Table 6).
- Warm temperature conditions were defined when the average monthly temperature was above one standard deviation of the long-term average temperature for the month (Table 4 and Appendix A). The warm lake evaporation rate (Table 8) is estimated to be the normal lake evaporation rate plus one standard deviation based on the monthly measured ET data from Castroville (Table 6).

Table 8 – Monthly Lake Evaporation based on Temperature Conditions

	Lake Evaporation Rate (1982-2007)		
	(inches)	(inches)	(inches)
Month	**Warm**	**Normal**	**Cool**
Jan	1.11	0.89	0.66
Feb	1.61	1.33	1.05
Mar	2.47	2.10	1.73
Apr	2.67	2.33	1.99
May	3.39	3.04	2.68
Jun	4.16	3.80	3.43
Jul	4.73	4.19	3.64
Aug	2.78	2.38	1.98
Sep	2.77	2.38	1.99
Oct	2.26	1.94	1.62
Nov	1.50	1.25	1.01
Dec	0.99	0.81	0.63
Total	**30.4**	**26.4**	**22.4**

3.5. Transpiration

According to the natural resources inventory of Lake Merced prepared by the SFPUC in 1998, tules border almost the entire lake. In the Lake Merced Lake-Level Model, transpiration water loss from the lake represents water uptake by tules in the immediate areas surrounding the lake. To estimate the total transpiration loss from the lake, the monthly transpiration rate was multiplied by the area covered by the vegetation. The calculation is as follows:

*Transpiration = Transpiration Rate * Tule Area*

The transpiration loss was calculated for each month. The total transpiration loss is listed in the water balance components in acre-feet and is subtracted from the water balance. The data used in calculating the transpiration component of the water balance are shown below:

- Transpiration Rate is the estimated monthly transpiration rate for Lake Merced based on Yates et al. (1990). The monthly evaporation rate is varied based on the average temperature from the Mission Dolores weather station (Appendix A).
- Tule Area is the area of the lake containing tules. Tules extend out up to 150 feet from the lake shore (SFSU, 2005). Thus, for the purpose of this analysis, the area covered by tules around the lake, reported to be 53 acres (Yates et al., 1990), was taken into account.

Monthly transpiration rates reported by Yates et al. (1990) for the Lake Merced area were assumed to reflect normal or average temperature conditions. Similar to the approach taken for lake evaporation, temporal distribution of transpiration data was identified based on monthly temperature conditions for three different relative temperature conditions that are defined as cool, normal, and warm, and which are defined as follows:

- Normal temperature conditions were defined when the average monthly temperature was within one standard deviation of the long-term average temperature for the month. The normal transpiration rate was based on the estimated monthly average lake evaporation rate (Tables 4 and 9).
- Cool temperature conditions were defined when the average monthly temperature was below one standard deviation of the long-term average temperature for the month. The cool lake transpiration rate was assumed to be ten percent less than the estimated monthly average lake evaporation rate for the month (Table 9).
- Warm temperature conditions were defined when the average monthly temperature was above one standard deviation of the long-term average temperature for the month. The warm lake transpiration rate was assumed to be ten percent greater than the estimated monthly average lake evaporation rate for the month (Table 9).

Table 9 – Monthly Transpiration Based on Temperature Conditions

	Transpiration		
	(inches)	**(inches)**	**(inches)**
Month	**warm**	**normal**	**cool**
Jan	1.11	1.01	0.92
Feb	1.67	1.52	1.38
Mar	2.65	2.41	2.19
Apr	2.94	2.67	2.43
May	3.83	3.48	3.16
Jun	4.79	4.35	3.95
Jul	5.28	4.80	4.36
Aug	3.00	2.73	2.48
Sep	3.00	2.73	2.48
Oct	2.45	2.23	2.03
Nov	1.58	1.44	1.31
Dec	1.02	0.93	0.85
Total	**33.33**	**30.30**	**27.55**

3.6. Groundwater Inflow/Outflow

Of the various water balance components, groundwater inflow and outflow from Lake Merced had the highest degree of uncertainty. Conceptually, the direction and magnitude of the groundwater flux into and out of the lake is controlled by the relative difference in lake and groundwater levels. However, consistent groundwater elevation data for the Shallow Aquifer do not exist prior to the late 1990s. Therefore, an empirical approach was applied for defining the water balance calculation for groundwater inflow and outflow.

This approach was initially applied for the previous lake level model (LSCE, 2008) to define a set monthly groundwater inflow or outflow depending upon climatic conditions. Climatic conditions were defined in terms of the total rainfall during the preceding 12-months starting with the month being calculated. The basic assumption for this approach is that during periods of below-average precipitation, there is typically less groundwater recharge to the aquifer which causes groundwater levels to decrease relative to lake levels. The lower groundwater levels cause either reduced groundwater discharge into the lake or increased lake water recharge to the groundwater aquifer depending on aquifer conditions. Alternatively, during periods of above-average precipitation, there is typically higher groundwater recharge to the aquifer which causes groundwater levels to increase relative to lake levels. These higher groundwater levels cause either increased groundwater discharge into the lake or decreased lake water recharge to the groundwater aquifer depending on aquifer conditions.

For the Lake Merced Lake-Level Model, climatic conditions were grouped into three categories based on the combined precipitation data from the Lake Merced Pump Station and Mission Dolores weather stations (Appendix A). By defining the climatic conditions based on the preceding 12-month period, the climatic conditions were allowed to vary on a month-to-month basis. The climatic conditions were defined as follows.

- Normal rainfall conditions were defined when the total precipitation for the preceding 12-months was between 16.5 and 25.5 inches.
- Dry rainfall conditions were defined when the total precipitation for the preceding 12-months was less than 16.5 inches.
- Wet rainfall conditions were defined when the total precipitation for the preceding 12-months was greater than 25.5 inches.

This approach was expanded for this version of the Lake Merced Lake-Level Model to represent a range of aquifer conditions. The Lake Merced Lake-Level Model is a spreadsheet-based water-balance model; therefore, it does not have a mechanism to predict reactions of groundwater and lake levels to pumping. To account for groundwater-lake interactions, assumptions were developed empirically during model calibration. The aquifer conditions were grouped into five categories that provided a qualitative representation of the regional groundwater conditions and the relative groundwater lake conditions. The aquifer conditions were defined in the Lake Merced Lake-Level Model per water year for the period from October through the following September. The aquifer condition category definitions include the following.

- Recovering aquifer conditions were defined as periods of high rainfall along with reduced groundwater pumping when lake levels rose significantly.
- Rising aquifer conditions were defined as periods of reduced groundwater pumping or when groundwater levels were generally higher than lake levels.
- Stable aquifer conditions were defined as periods of reduced groundwater pumping or when groundwater levels were generally similar to lake levels.
- Low aquifer conditions were defined as periods of moderate groundwater pumping or when groundwater levels were generally similar to or lower than lake levels.

- Stressed aquifer conditions were defined as periods of high groundwater pumping or when groundwater levels were generally lower than lake levels.
- Declining aquifer conditions were defined as periods of maximum groundwater pumping or when groundwater levels were generally lower than lake levels.

In the spreadsheet-based Lake Merced Lake-Level Model, a lookup table was set up to approximate the net groundwater flux. Table 10 summarizes the monthly groundwater inflow and outflow volumes relative to Lake Merced based on the assumptions discussed above. Positive numbers represent a net gain of water to the lake signifying an overall net discharge of groundwater into the lake. Conversely, negative numbers represent a net loss of water from the lake signifying an overall net discharge of lake water to the Shallow Aquifer.

Table 10 – Summary of GW Inflow/Outflow Assumptions

Aquifer Condition	Groundwater Inflow/Outflow (af per month)		
	Dry	Normal	Wet
Recovering	10	15	25
Rising	1	5	15
Stable	-5	1	10
Low	-10	-2	5
Stressed	-15	-10	1
Declining	-35	-30	-10

3.7. Singular Events

Man-made water additions to the lake and pumping from the lake have occurred in the past; however, records of these events are limited. These are characterized as singular events in the Lake Merced Lake-Level Model because they represent independent operational decisions.

Lake additions are the results of water additions by the SFPUC at the Lake Merced Pump Station. These were done periodically in the past to help maintain lake levels. The occurrence of recorded additions as identified based on SFPUC records and previously reported data is presented in Table 2 (LSCE, 2002). Other lake additions were known to have occurred in the past; however, the records for these events were not available. Similarly, pumping of water from the lake for golf course irrigation and other uses was known to occur; however, no records are available of the duration and extent of this pumping.

During calibration, singular events were kept within the range of recorded lake additions. Table 11 presents a summary of the estimated annual lake additions and extractions (singular events) by water year (defined as October through September).

For the Lake Merced Lake-Level Model, the available data were used in developing a history of lake additions and extractions. Additional lake additions and extractions were added to the model history during model calibration. During calibration, significant increases or decreases in lake levels that could not be ascribed to natural phenomenon were considered to represent these singular events. In the model, a volume of water was added for those months when the unexplained change in lake levels occurred until a sufficient lake level was achieved. Some modifications were made to known lake additions as shown in Table 2.

Although singular events are interpreted as representing lake additions or extractions, it is also possible that these may also represent, at least in part, necessary adjustments to compensate for natural variations in the lake hydrology. These potential natural variations may reflect unusual hydrological conditions that are not well represented by the rule-based approach.

Table 11 – Estimated Annual Man-Made Additions and Extractions (Singular Events) from Lake Merced

Water Year	Estimated Lake Addition/Extraction (acre-feet)	Water Year	Estimated Lake Addition/Extraction (acre-feet)	Water Year	Estimated Lake Addition/Extraction (acre-feet)
1940	0	1964	150	1988	-300
1941	0	1965	1,340	1989	0
1942	0	1966	250	1990	0
1943	0	1967	400	1991	0
1944	0	1968	-100	1992	840
1945	0	1969	400	1993	-600
1946	0	1970	-250	1994	920
1947	250	1971	250	1995	-75
1948	250	1972	650	1996	0
1949	-600	1973	0	1997	0
1950	0	1974	0	1998	0
1951	0	1975	250	1999	0
1952	-650	1976	50	2000	0
1953	0	1977	250	2001	0
1954	750	1978	1,450	2002	0
1955	600	1979	-400	2003	1,161
1956	500	1980	500	2004	2
1957	250	1981	0	2005	0
1958	0	1982	100	2006	0
1959	-150	1983	0	2007	0
1960	250	1984	0	2008	0
1961	250	1985	0	2009	0
1962	250	1986	0		
1963	250	1987	0		

4. Model Calibration Results

Model calibration provides an evaluation of the long-term performance of the Lake Merced Lake-Level Model to match the observed lake levels. The overall objective of the historical analysis was to develop a rule-based approach for the water balance and to calibrate the model results to measured lake levels. The following discussion characterizes the match of simulated to historical Lake Merced lake levels.

4.1. Comparison of Simulated and Historical Lake Levels

The Lake Merced Lake-Level Model was calibrated to historical lake levels over a 70 year period from October 1939 to June 2009. This period includes a variety of hydrological conditions including wet, normal and dry precipitation years, flood events, and periods of high and low lake levels, thus representing a variety of conditions that may be representative of future conditions.

The comparison of simulated and historical lake levels between October 1939 and June 2009 is presented on Figure 11. Model calibration was conducted primarily as a visual comparison of simulated and historical lake levels. This visual comparison was considered as an appropriate level of calibration to meet the objectives of the historical analysis. Additional statistical analysis could be conducted in the future if necessary.

Overall, the Lake Merced Lake-Level Model closely follows both the long-term and short-term trends, demonstrating a very strong correlation of both the magnitude of annual and seasonal fluctuations. Below is a summary of some of the observations:

- The model results follow the long-term trends in lake levels. The model simulates high and low lake levels as appropriate.
- The model results demonstrate the capability to capture the seasonal variations in lake levels during the year under a wide range of climatic and aquifer conditions. The model results provide approximately the same amplitude of lake level variation per year for each year from 1939 to 2009.
- The model was able to simulate the period of high lake levels near the level of the spillway in the 1940s. This demonstrates that the model provides a realistic evaluation of lake levels and is not overly conservative.
- The model results demonstrate a strong capability of reproducing the period of drought during 1976-77 and the late 1980s and early 1990s. The model produces a similar minimum lake level of approximately -3.3 feet City Datum in 1993.
- The model results show the capability to simulate the recovery of lake levels during the period of above-average precipitation from 1995 to 2006.

Overall, with the improved historical match, the Lake Merced Lake-Level Model builds enough confidence to develop future lake filling scenarios to help evaluate the volumes of water necessary to manage Lake Merced water levels.

4.1.1. Comparison to MODFLOW Model

The Westside Basin Groundwater Model, (HydroFocus, 2007, 2009, and 2011) is a numerical groundwater model that has the capacity to evaluate the effect of changes in groundwater pumping and other stresses on groundwater levels in the Lake Merced area. Understanding the changes in groundwater levels is one key aspect to understanding groundwater-surface water interactions. This model also has the capacity to calculate the flux between Lake Merced and the groundwater aquifer.

The comparison of the calibrated 1958 to 2009 historical simulation using the Westside Basin Groundwater-Flow Model to the measured Lake Merced lake levels and the simulated results from the Lake Merced Lake Level Model is presented in Figure 11. The MODFLOW model shows a divergence from the measured data from 1958 to 1971 with MODFLOW simulated lake levels about 3 to 6 feet higher and have significantly different trends. From 1971 to 1996, the MODFLOW model shows a closer correlation with simulated lake levels within about 1 to 2 feet of the measured data. From 1996 to 2009, the MODFLOW simulated lake levels show similar trends to the measured data but are about 2 to 5 feet higher than the measured data.

Comparing the performance of the MODFLOW model to the Lake-Level model shows that the Lake-Level model has a significantly stronger correlation to the measured Lake Merced lake levels over the same period. Since the general approach between the MODFLOW Lake Package and the Lake-Level Model are similar, and the models use similar data sets, the improved performance by the Lake-Level model is attributed to more site-specific and detailed handling of the hydrologic conditions.

The Lake-Level Model is a spreadsheet-based mass balance model that is used to evaluate changes in water levels of Lake Merced. MODFLOW treats Lake Merced as a boundary condition using the LAK3 package, which relies on a mass balance approach to calculate the lake level. The Lake-Level Model uses a site-specific characterization of Lake Merced that is more complex than that used by the MODFLOW model. Some of the key advantages of the Lake-Level Model include the following:

- Allows changes in the surface area of Lake Merced as a function of lake level, based on measured bathymetry data. This is essential because key water balance components (such as precipitation and evaporation) are dependent upon the lake surface area, as briefly described below.
    - Precipitation accounts for rainfall falling directly onto the lake. As lake levels decline, rain that would have fallen directly onto a fuller lake falls instead on the dry lakebed. In the Lake-Level Model, this is treated as stormwater runoff, only a fraction of which actually reaches the lake.
    - Evaporation is dependent on the surface area of the lake open to the atmosphere; as the surface area declines with lowering lake levels, the overall evaporation losses also decline.

- At lower lake levels, the volume of the lake is smaller; therefore, the volume of water required to change the lake level by a certain amount is less than at higher lake levels.
- The Lake-Level Model includes a more complete evaluation of stormwater runoff that incorporates varied land surface types within the limited lake watershed area, including high runoff coefficients the for paved areas surrounding the lake.
- The Lake-Level Model accounts for flooding events resulting from overflows from the Vista Grande Canal. These are short-tem, high-volume events that can significantly affect lake levels.
- The Lake-Level Model has been more closely calibrated to historical lake levels than was the MODFLOW model, showing that this more site-specific characterization of Lake Merced applies appropriate assumptions that provide the capability to properly evaluate lake conditions.

The primary limitation of the Lake-Level Model is that the GW/SW interactions are based on assumptions of annual average groundwater flux into or out of Lake Merced. To address this limitation, the MODFLOW-calculated groundwater flux for Lake Merced was used, which is calculated on a monthly basis and dynamically incorporates the effects of changing groundwater levels. In this manner, the combined approach provides the best available analysis of the changes in Lake Merced.

A more detailed discussion of the Westside Basin Groundwater-Flow Model and the Lake-Level Model is provided in the TM-10.1.

4.2. Water Balance

The Lake Merced Lake-Level Model tracked the contribution of each of the water balance components from the conceptual model. Reviewing these water balance results is another measure of calibration. The water balance results are provided in Appendix B as an annual summary for each of the water balance components. Figure 12 presents a summary of all water balance components on an annual basis. The Lake Merced water balance over the 70-year historical period is summarized in Table 12.

Table 12 – Water Balance Summary of 70-year Historical Analysis for Lake Merced (in acre-feet)

Statistics	Precipi-tation	Stormwater Runoff	Evapo-ration	Transpi-ration	Ground-water	Singular Events	Lake Storage
Average Inflow	514	221	0	0	69	179	188
Average Outflow	0	0	-647	-133	-171	-45	-193
Overall Average	514	221	-647	-133	-99	135	-5
Maximum	1,069	666	-263	-54	231	1,450	1,257
Minimum	238	55	-725	-146	-418	-650	-956
Total Volume	35,959	15,436	-45,314	-9,320	-6,948	9,438	-380

A summary of the average annual inflow for each of the relevant water balance components is provided in Table 12. A brief summary of the inflow components to Lake Merced is provided below.

- Direct precipitation was the largest inflow source. Year to year variations in precipitation are significant as a function of hydraulic conditions, ranging from 238 AFY (in 1976) to 1,069 AFY (in 1998), with a long-term average of 514 AFY. Direct precipitation accounted for approximately 55 percent of the average inflow to Lake Merced.
- Stormwater runoff, including estimated flooding events from the VGC, contributed an annual average inflow of 221 AFY. Stormwater runoff recharge to the lake ranged from 55 to 666 AFY, accounting for approximately 25 percent of the average inflow to Lake Merced.
- Groundwater inflow was an overall minor source of inflow to Lake Merced over the historical period. The average annual inflow was approximately 69 AFY with a maximum inflow of 231 AFY. Groundwater inflow accounted for approximately 1 percent of average inflow to Lake Merced.
- Singular events accounted for an annual average annual inflow of approximately 179 AFY over the 70-year history with a maximum inflow of 1,450 AFY. Inflow from singular events accounted for approximately 19 percent of average inflow to Lake Merced.

In addition, a summary of the average annual outflow for each of the relevant water balance components is provided in Table 12. A brief summary of the outflow components from Lake Merced is provided below.

- Evaporation was the largest outflow source with an annual average of approximately 650 AFY. The year to year variations in outflow ranged from about 263 to 725 AFY. Evaporation accounted for approximately 67 percent of the average outflow.
- Transpiration had an annual average outflow of approximately 133 AFY. The year to year variations ranged from about 54 to 146 AFY. Transpiration accounted for approximately 14 percent of the average outflow.
- Groundwater outflow accounted for an average annual outflow of approximately 171 AFY with a maximum outflow of 418 AFY. Groundwater outflow accounted for approximately 14 percent of average outflow from Lake Merced.
- Singular events were an overall minor source of outflow to Lake Merced accounting for an annual average annual outflow of approximately 45 AFY over the 70-year history with a maximum outflow of 650 AFY. Outflow from singular events accounted for approximately 5 percent of average outflow from Lake Merced.

The annual change in lake storage varied significantly over years from an increase of 1,257 af to a decrease of 956 af. Total decrease in lake storage over the entire 70 years was estimated to be 380 af, which is equivalent to about 5 AFY of loss on an annual basis (Table 12). This relatively small long-term loss represents the fact that while the lake levels experienced significant declines in the past, lake level increases during the last 15 years have reversed the declining trend.

The annual contribution from each of the water balance components is presented in graphical form in Figure 12, which demonstrates year-to-year variations. The primary recharge components of direct precipitation and stormwater runoff are significantly affected by variations in rainfall. However, the primary outflow components of evaporation and transpiration are much less variable. This shows why the lake is subject to variations in lake levels over time. The change in lake storage is the difference between the total inflow and the total outflow. Figure 13 provides a graphical summary of the annual change in lake storage. For nearly 50 percent of the years analyzed (32 years out of 70 years), the model results showed increasing lake storage (positive change in storage).

5. GSR and SFGW Project Model Setup

For the Project Analysis, the Lake Merced Lake-Level Model was modified to account for the hydrology and incorporate the changes resulting from the Daly City Vista Grande Drainage Area Improvements Project. Otherwise, the GSR and SFGW project scenarios rely on the conceptual hydrology used for the historical calibration analysis (Section 4). Below is a discussion of the setup for the Project Model.

5.1. GSR and SFGW Project Scenarios

Five different scenarios were developed for analysis. The initial model scenario simulated groundwater conditions within the Westside Basin influenced by recent (as of June 2009) municipal and irrigation pumping within the Basin; this is referred to as the "Existing Conditions" scenario. Additional modeled scenarios included the simulated operation of the GSR Project and the SFGW Project separately, and a cumulative scenario that includes the operation of the two Projects together with other reasonably foreseeable future water resources projects within the Basin. The following is a summary of the five scenarios used for the groundwater model analysis:

- Scenario 1 - Existing Conditions: The existing conditions scenario uses recent (as of June 2009) pumping conditions and provides a basis for comparison for the other project scenarios.
- Scenario 2 - GSR Project: Includes the GSR Project operations (i.e., in-lieu recharge in the South Westside Basin). Other conditions are the same as Scenario 1.
- Scenario 3a - SFGW Project (3 mgd): This scenario assumes that groundwater pumping for irrigation is still conducted in Golden Gate Park. The SFGW project includes pumping from 4 wells at an annual average rate of 3 million gallons per day (mgd). Other conditions are the same as Scenario 1.
- Scenario 3b - SFGW Project (4 mgd): This scenario assumes that irrigation pumping in Golden Gate Park is replaced with recycled water, so that the equivalent groundwater production may be used for the project. The SFGW project includes pumping from 6 wells at an annual average rate of 4 mgd. Other conditions are the same as Scenario 1.
- Scenario 4 - Cumulative Scenario: This scenario combines the conditions of the GSR Project (Scenario 2) and the SFGW Project (Scenario 3b). Other reasonably foreseeable future projects that are included primarily consist of the Vista Grande Drainage Area Improvements Project Lake Merced Alternative. Other conditions are the same as Scenario 1.

5.2. Modifications to the Lake Hydrology

For the Project Analysis, the Lake Merced Lake-Level Model was developed for a 47.25-year period based on the background hydrology developed in the historical calibration analysis. The lake-level model for the Project Analysis uses the same rearranged hydrologic sequence as was used for the MODFLOW scenarios. This sequence is based on historical hydrological conditions and includes an 8.5-year Design Drought period used in the PEIR (SFPUC, 2007; SFPUC, 2009a). The rationale for the rearranged hydrology is presented in the main body of the Task 10.1 Technical Memorandum.

The rearranged hydrologic sequence used for the five model scenarios presented in this analysis consists of the following:

- July 1996 to September 2003.
- October 1958 to November 1992.
- December 1975 to June 1978.
- July 2003 to September 2006.

For the Project Analysis, the following modifications were made to the Lake Merced Lake-Level Model used for the historical calibration analysis to represent anticipated future conditions. These modifications include:

- Initial Lake Level was set at 5.7 feet City Datum based on measured lake levels in South Lake during June 2009.
- Groundwater Inflow and Outflow in the historical calibration analysis was based on an empirical analysis developed during the model calibration. For the GSR and SFGW Project scenarios, the groundwater inflow to and outflow from Lake Merced were based on the equivalent MODFLOW scenario. The MODFLOW calculated groundwater-surface water exchange between Lake Merced and the groundwater was input directly into the Lake Merced Lake-Level Model. By so doing, the groundwater inflows and outflows were based on the groundwater model rather than an assumption relative change in groundwater levels in the Lake Merced area. The MODFLOW results are discussed in the main body of the Task 10.1 Technical Memorandum.
- Stormwater Runoff in the Historical Analysis included an area called the pre-1955 drainage area that represented expansion of the City's combined sewer and stormwater system in the Lake Merced watershed. This represents a historical event that is no longer relevant for future project operations. Therefore, this component was not included in the Project Analysis.
- Singular Events from the historical analysis were defined as historical lake additions and extractions; therefore, these are no longer relevant for future project operations. Since these represent historical events, the singular events from the Historical Analysis were not included in the Project Analysis.

All five of the model scenarios performed for the Project Analysis that are reported in this Technical Memorandum use identical lake hydrology to insure consistency in reviewing the results. The precipitation, lake evaporation, transpiration, and stormwater runoff components use the same data, apply the same assumptions, and incorporate the modifications listed above.

5.3. Modifications for the Vista Grande Drainage Area Improvements Project

For the cumulative scenario (Scenario 4), the use of Lake Merced as part of the Vista Grande Drainage Basin Alternatives Analysis project for Daly City is considered one of the other reasonably foreseeable future projects. Daly City's Vista Grande Drainage Basin Alternatives Analysis recommended the Lake Merced Alternative, in which stormwater flow from the Vista Grande Canal would be diverted to Lake Merced (Jacobs Associates, 2011a, 2011b; City of Daly City, 2012).

5.3.1. Changes in Lake Merced Spillway

The Lake Merced Lake-Level Model has a provision for the spillway or overflow from Lake Merced. The existing spillway elevation is approximately 13 feet City Datum; therefore, the maximum lake level is set to 13 feet City Datum in the Project Analysis for Scenarios 1, 2, 3a and 3b. Lake levels in excess of 13 feet City Datum are removed from the lake via a spillway near the VGC, and not accounted for in the water balance.

For the Vista Grande Drainage Area Improvements Project, the assumption is that the spillway will be lowered to 9.5 feet City Datum. This lower spillway elevation is used for Scenario 4.

5.3.2. Engineered Wetland

The Lake Merced Alternative scenarios of Daly City's Vista Grande Drainage Basin Alternatives Analysis also include provisions for an engineered wetland and modification of the Lake Merced spillway (Brown and Caldwell, 2010). In the 75-cfs scenario, the average base flow in the Vista Grande Canal is assumed to be diverted into an engineered wetland for treatment and then discharged to Lake Merced on an ongoing basis. Typical flows in the Vista Grande Canal, or baseflow, would be continuously diverted through an engineered wetland for treatment prior to discharge into Lake Merced. Baseflows have been estimated to range from 18 to 26 af per month (Kennedy/Jenks, 2009).

For the Project Analysis, two different operating scenarios listed below were evaluated for the engineered wetland:

- Baseflow Option is based on the consistent monthly flow rate in the VGC or the minimum anticipated flow without significant input from storms.
- Stormwater Option has a variable monthly flow that includes stormwater flow from the VGC. The maximum stormwater option for the Project Analysis is constrained by the design flow rates for the engineered wetland rather than the maximum stormwater flow rates in the VGC.

An option was included in the Project Analysis to account for the engineering design that includes a diversion of water from the engineered wetland back to the VGC rather than to Lake Merced. For the GSR and SFGW project scenarios, this option was set to the spillway level. When lake levels reached the level of the spillway, the wetland contribution was not included in the annual total. The input for the engineered wetland component is listed in Table 13.

Table 13 – Calculated Stormwater Inflows from the Vista Grande Drainage Area Improvements Project

Scenario Year	Wetland Contribution	VGC Stormwater Diversions (acre-feet)	Scenario Year	Wetland Contribution	VGC Stormwater Diversions (acre-feet)
0	78	0	24	232	126
1	277	283	25	277	37
2	135	681	26	277	162
3	105	126	27	277	216
4	187	200	28	277	126
5	232	97	29	277	353
6	232	144	30	277	123
7	194	268	31	277	204
8	277	141	32	224	291
9	277	55	33	176	130
10	277	122	34	213	214
11	277	353	35	232	338
12	277	436	36	232	97
13	277	104	37	277	57
14	277	163	38	277	151
15	277	145	39	277	42
16	277	384	40	277	42
17	277	170	41	277	292
18	277	165	42	277	37
19	277	364	43	277	162
20	232	236	44	277	216
21	277	19	45	277	234
22	213	433	46	277	321
23	149	251	47	277	395

Note: Scenario Year represents a water year from October until the following September
Scenario Year 0 represents a 3-month period for July, August and September at the beginning of the model

5.3.3. VGC Stormwater Diversions

Scenario 4 incorporates the 75-cubic-feet-per-second (cfs) scenario of the Lake Merced Alternative of the Vista Grande Drainage Basin Alternatives Analysis (Jacobs Associates, 2011a, 2011b; City of Daly City, 2012). The 75-cfs scenario assumes that stormwater discharge rates in the Vista Grande Canal exceeding 75 cfs would be diverted to Lake Merced (Brown and Caldwell, 2010). These flows would occur periodically in response to large storms, and have been calculated as part of the Vista Grande Drainage Basin Alternatives Analysis based on historical precipitation data. Stormwater diversions are calculated to occur in every year and range from 19 to 681 AFY, with an average of 207 AFY (Brown and Caldwell, 2010). The calculated stormwater diversion values are listed in Table 13. These calculated values are input into the Lake-Level model to account for the VGC stormwater diversion component.

5.4. Project Model Scenario Results

The results of the Project Analysis for the Lake Merced Lake-Level Model are documented in the main body and Attachment G of the Task 10.1 Technical Memorandum.

6. Summary and Conclusions

The Lake Merced Lake-Level Model has been developed as a spreadsheet-based model that simulates the hydrological conceptual model of Lake Merced. The conceptual model is composed of hydrologic and hydraulic components with inflows and outflows that simulate the Lake Merced water storage and water levels.

The Lake Merced Lake-Level Model is calibrated to historically measured lake levels over the past 70 years from October 1939 to June 2009. This historical calibration period includes a variety of hydrological conditions including wet, normal and dry precipitation years, flood events, and periods of high and low lake levels, thus representing a variety of conditions that are considered representative of future conditions.

In this study, the historical calibration analysis has been used to develop a rule-based approach that provides a mechanism to estimate the water balance for Lake Merced. The historical calibration analysis using the Lake Merced Lake-Level Model shows a very strong correlation to the historical (observed) lake levels over the entire 70-year period. This model calibration demonstrates a strong conceptual understanding of the key hydrological factors that control lake levels, and increases confidence in the model's ability to forecast future conditions.

The Lake Merced Lake-Level Model has been adapted from the historical calibration analysis to include potential future project conditions, such as the use of an engineered wetland to treat water from the VGC before discharge in Lake Merced, the diversion of stormwater directly from the VGC into Lake Merced, changes in the spillway elevation, and other operational variations. Based on the ability of the Lake-Level Model to simulate historical Lake Merced conditions and the ability to incorporate future project conditions, it is appropriate to use this model as a tool to evaluate the effects of the GSR, SFGW and Cumulative project scenarios on water levels in Lake Merced.

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Filename: Z:\Projects\SFPUC_ConjUseEvents\20090804_LakeMercedFigures\Figure1.mxd

Source: ESRI Online Aerial Imagery, 2007 (2ft resolution)

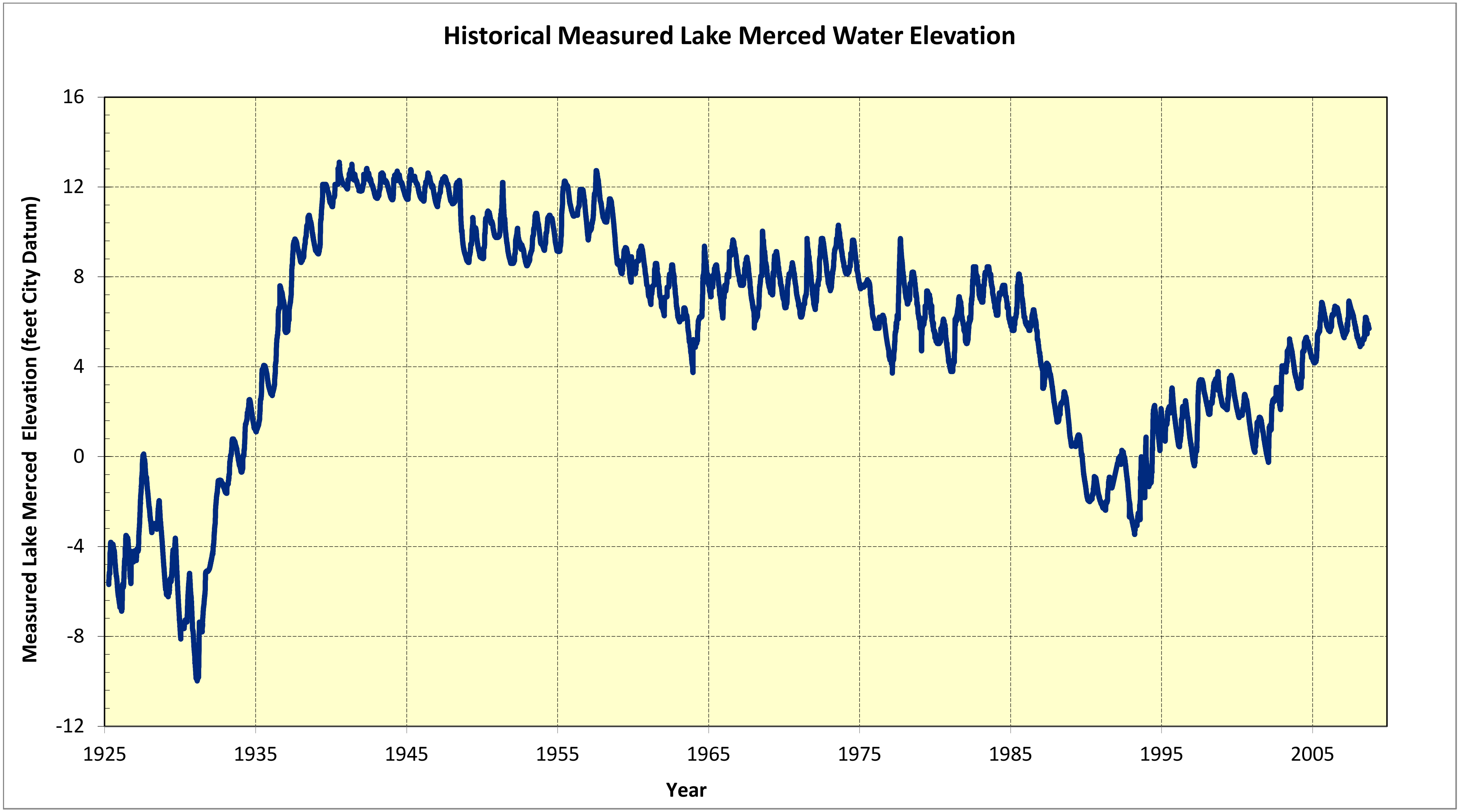
Kennedy/Jenks Consultants

Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Lake Merced Project Area

K/J 0864001
April 2012

Figure 1



Source: Historical Lake Merced water elevation data from the San Francisco Public Utilities Commission
City Datum = NAVD - 11.37 feet

Kennedy/Jenks Consultants

Legend

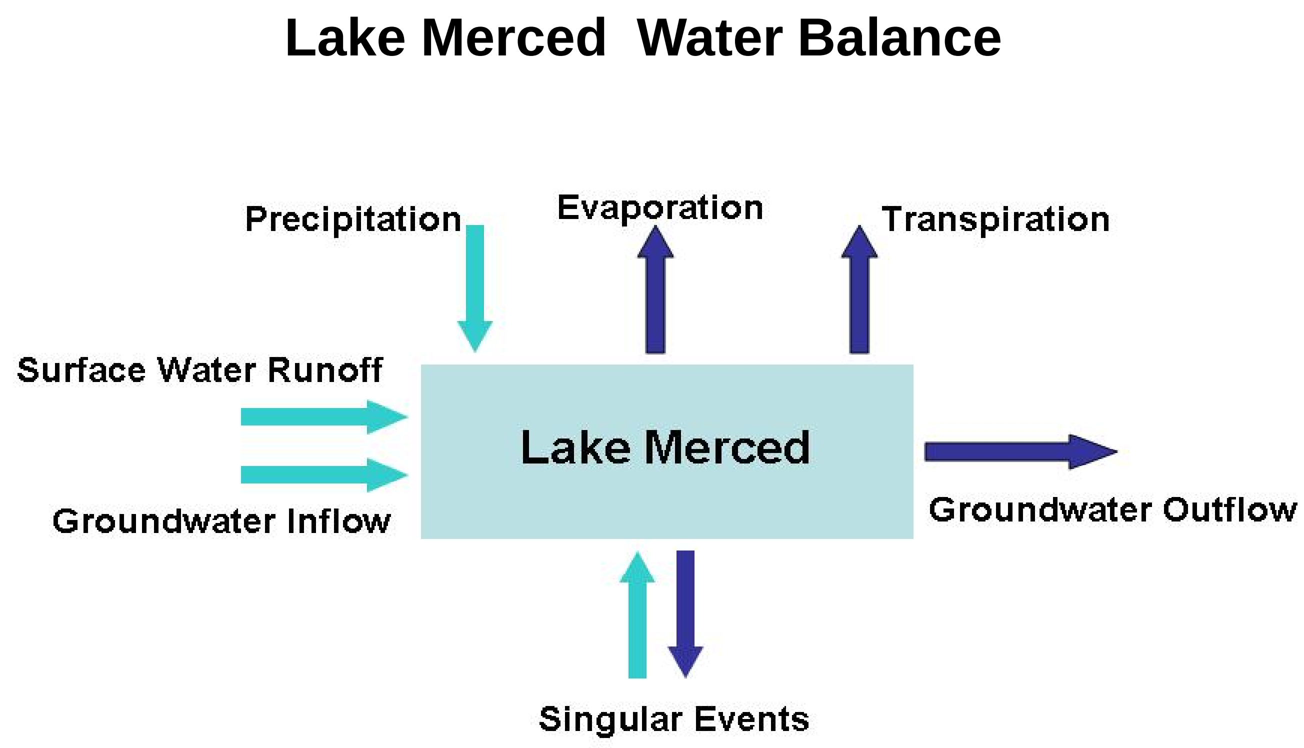
Historical Measured Lake Merced Water Elevation (feet City Datum)

Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Historical Lake Merced Water Elevation

K/J 0864001
April 2012

Figure 2



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San Francisco Public Utilities Commission

Schematic of Conceptual Lake Merced Water Balance Model

K/J 0864001
April 2012

Figure 3

Path: Z:\Projects\SFPUC_ConjUse\Events\20090804_LakeMercedFigures\Figure4.mxd

Source: ESRI Online Aerial Imagery, 2007 (2ft resolution)
Bathymetic, Elevation Contours, and Vista Grande Canal Location from SFPUC, 2008

Kennedy/Jenks Consultants

Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Lake Merced Elevation Contours

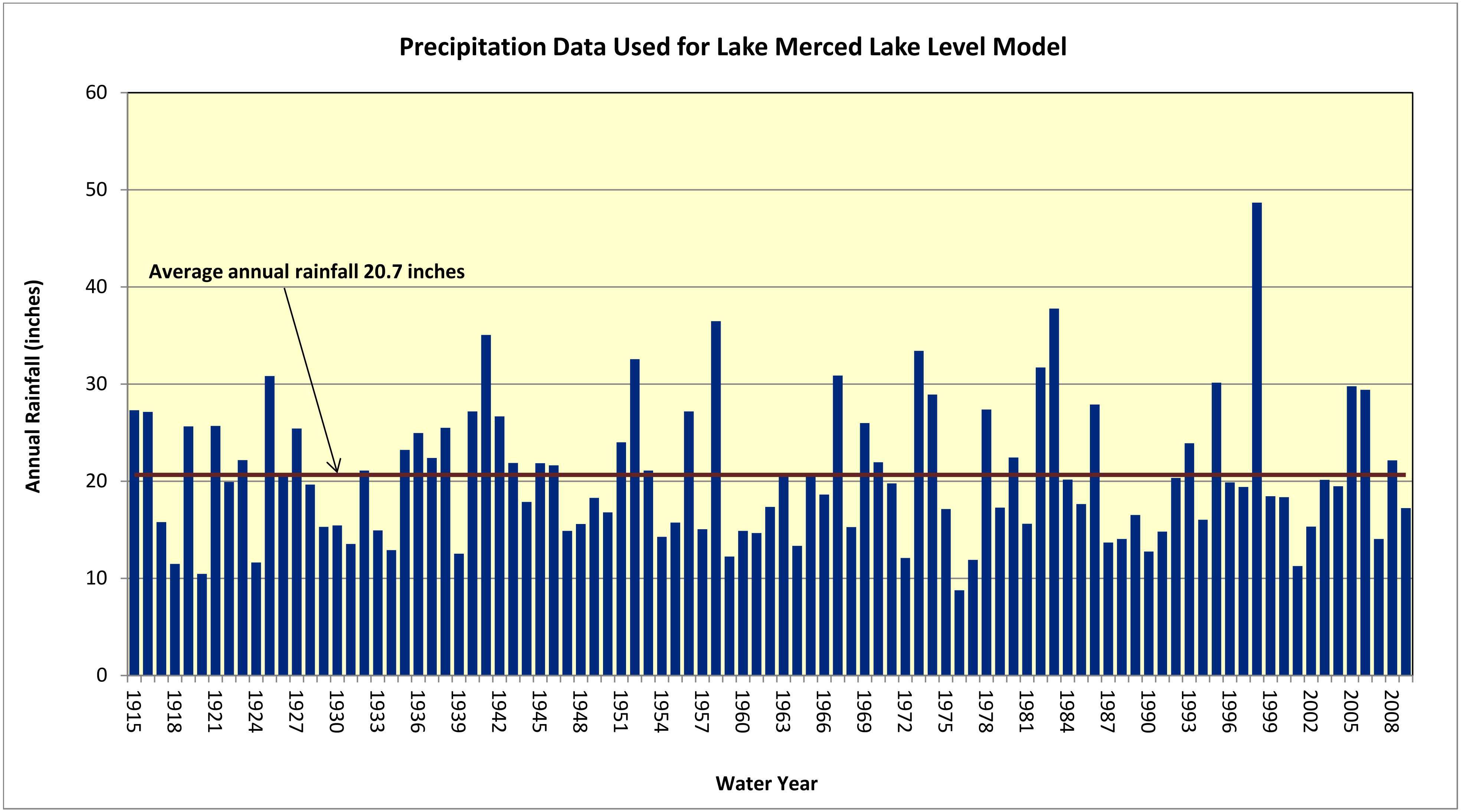
K/J 0864001
April 2012

Figure 4

Legend

Vista Grande Canal

Bathymetric Contour (City Datum, 2 foot contour intervals)



Source: San Francisco Mission Dolores Weather Station, Western Regional Climate Center website (http://www.wrcc.dri.edu/)

Note: Mission Dolores Weather Station Used 1915 to 1958; San Francisco Richmond Sunset station used 1958 to 2009.

Legend

Annual Rainfall (inches)   Average Rainfall (inches)

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Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Lake Merced Annual Rainfall (inches)

K/J 0864001
April 2012

Figure 5

Source: ESRI Online Aerial Imagery, 2007 (2ft resolution)
Stormdrain Data from SFPUC, 2008

Legend

- Stormdrain Catch Basin
- Stormdrain Manhole
- Stormdrain Junction
- Vista Grande Canal
- Stormdrain Line

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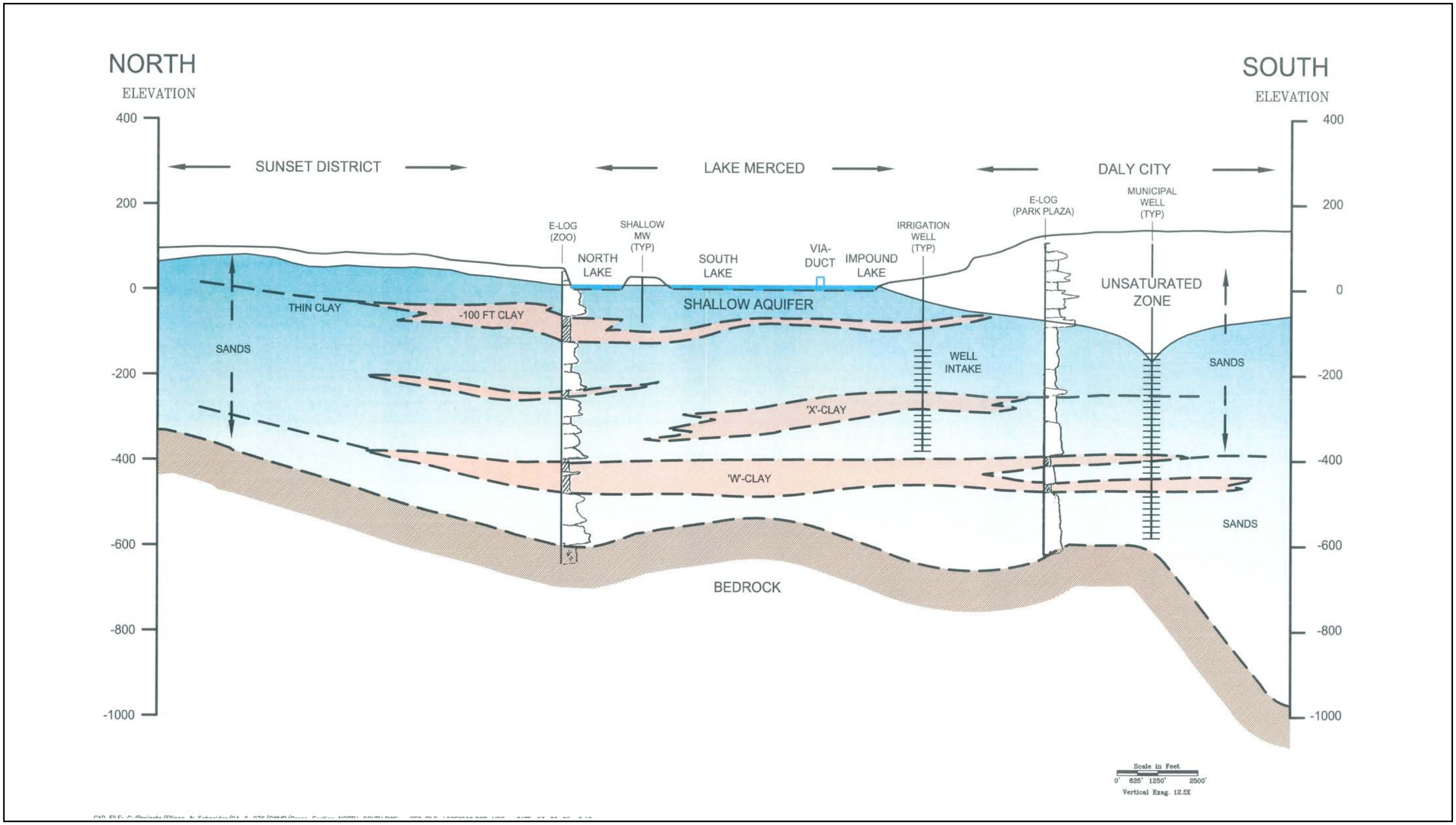
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Locations of Stormdrain Catch Basins

K/J 0864001
April 2012

Figure 6



Source: North Westside Groundwater Management Plan (LSCE, 2005)

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Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Schematic North – South Cross-Section
North Westside Groundwater Basin

K/J 0864001
April 2012

Figure 7

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Source: ESRI Online Aerial Imagery, 2007 (2ft resolution)
Contours from "2007 Annual Groundwater Monitoring Report, Westside Basin, San Francisco and San Mateo Counties, California (SFPUC)

Legend

- Groundwater Elevation Measurement Location
- Approximate Groundwater Elevation Contour (ft NAVD 88)
- Contour dashed where inferred
- General Groundwater Flow Direction

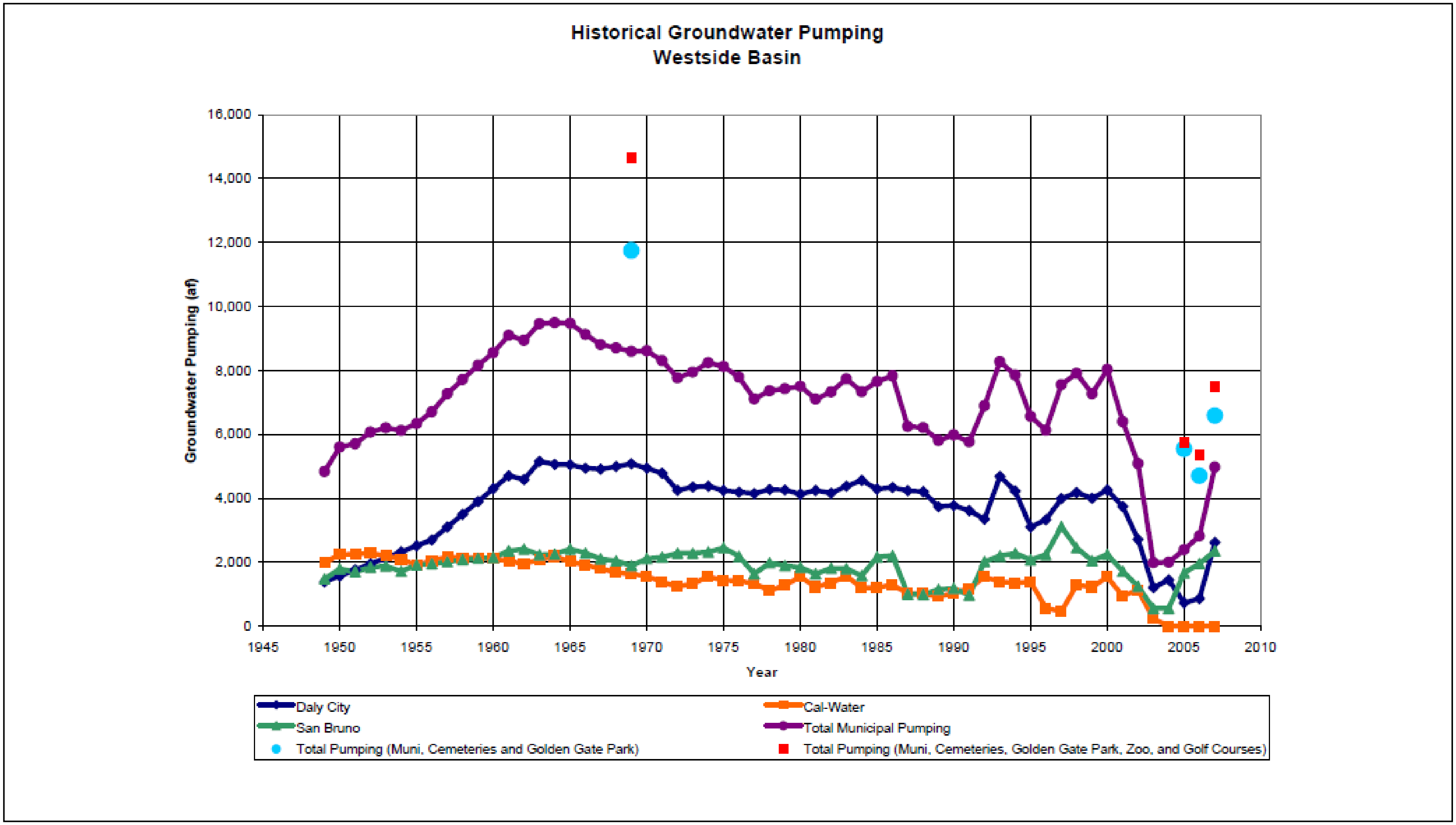
Kennedy/Jenks Consultants

Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Approximate Groundwater Elevation Contours, Shallow Aquifer, Fall 2007

K/J 0864001
April 2012

Figure 8



Source: 2007 Annual Groundwater Monitoring Report Westside Basin San Francisco and San Mateo Counties, California, Prepared by San Francisco Public Utilities Commission

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Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Historical Groundwater Pumping
Westside Basin

K/J 0864001
April 2012

Figure 9

Source: ESRI Online Aerial Imagery, 2007 (2ft resolution)
Stormdrain Data from SFPUC, 2008

Legend

- Stormdrain Catch Basin
- Stormdrain Manhole
- Stormdrain Junction
- Vista Grande Canal
- Stormdrain Line
- Adjacent to Lake (123 Acres)
- Impervious Areas (31 Acres)
- Harding Park Golf Course (183 Acres)

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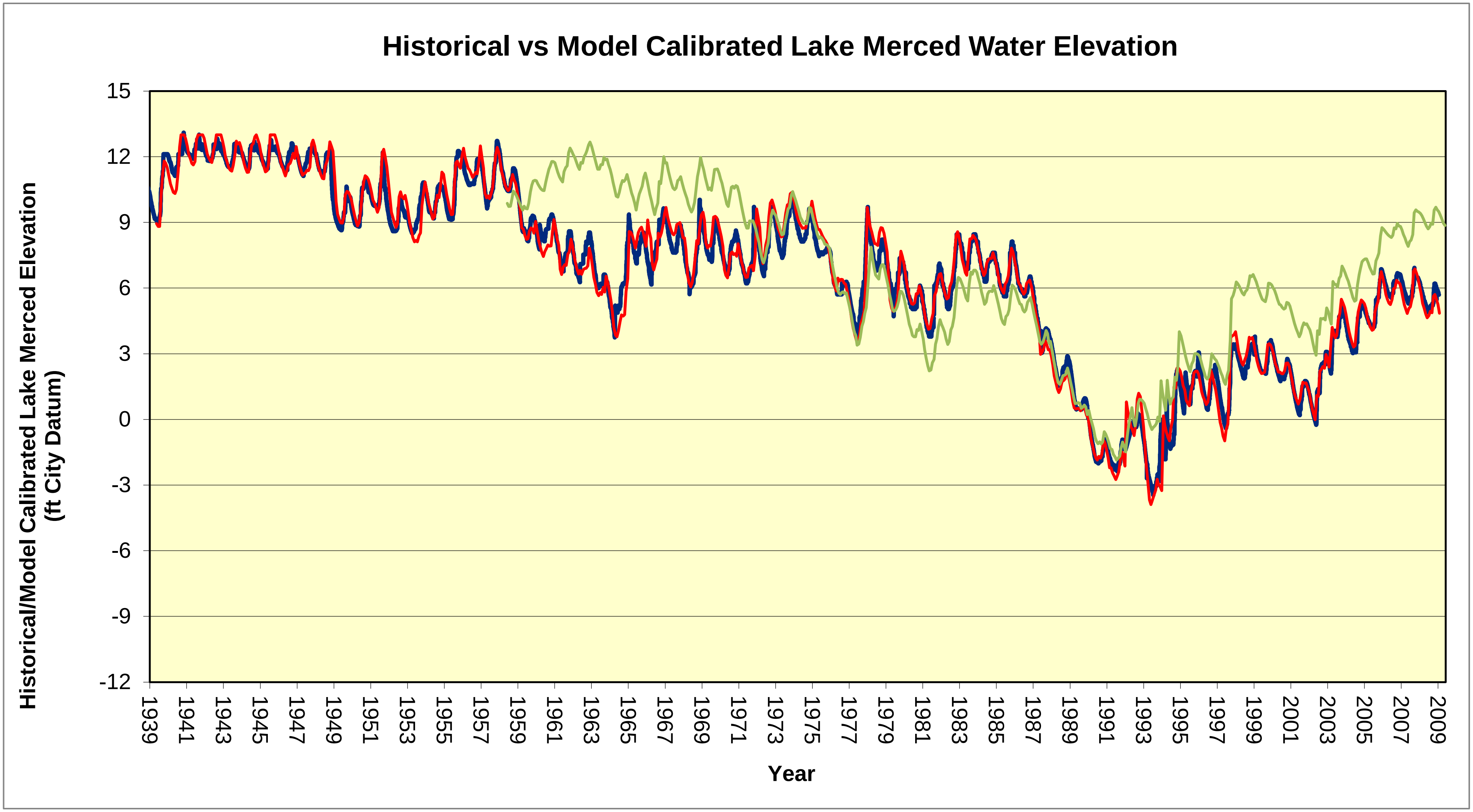
Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Locations of Stormdrain Catch Basins and Approximate Areas of Stormwater Runoff

K/J 0864001
April 2012

Figure 10



Source: Historical Lake Merced water elevation data from the San Francisco Public Utilities Commission
City Datum = NAVD - 11.37 feet

Legend

- Historical Measured Lake Elevation (feet City Datum)
- Lake-Level Model Simulated Lake Elevation (feet City Datum)
- MODFLOW Simulated Lake Elevations (feet City Datum)

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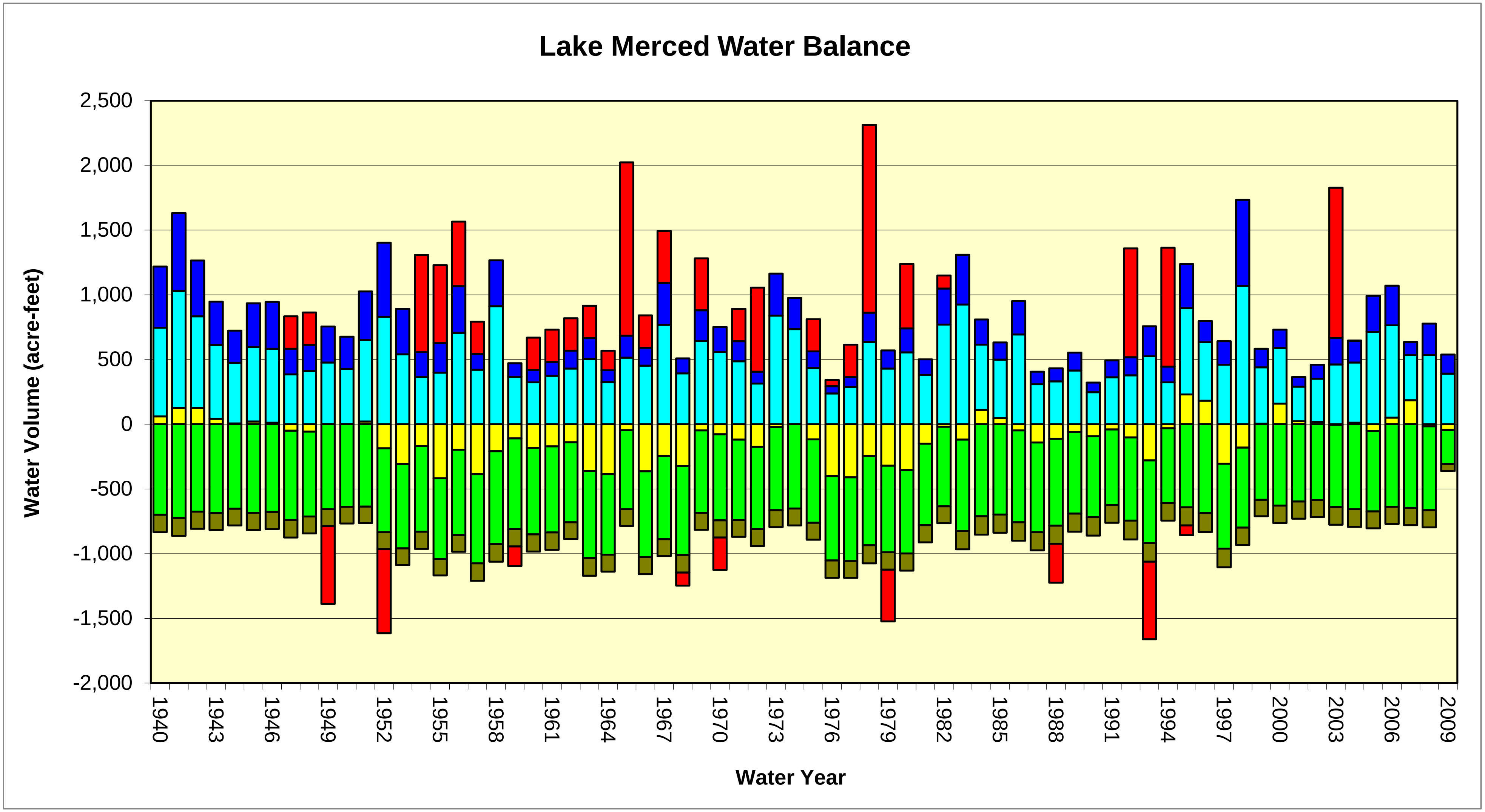
Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Historical vs Simulated Lake Merced Levels

K/J 0864001
April 2012

Figure 11



Legend

Groundwater In/Out (acre-feet) Precipitation (acre-feet) Stormwater Runoff (acre-feet)

Evaporation (acre-feet) Transpiration (acre-feet) Singular Events (acre-feet)

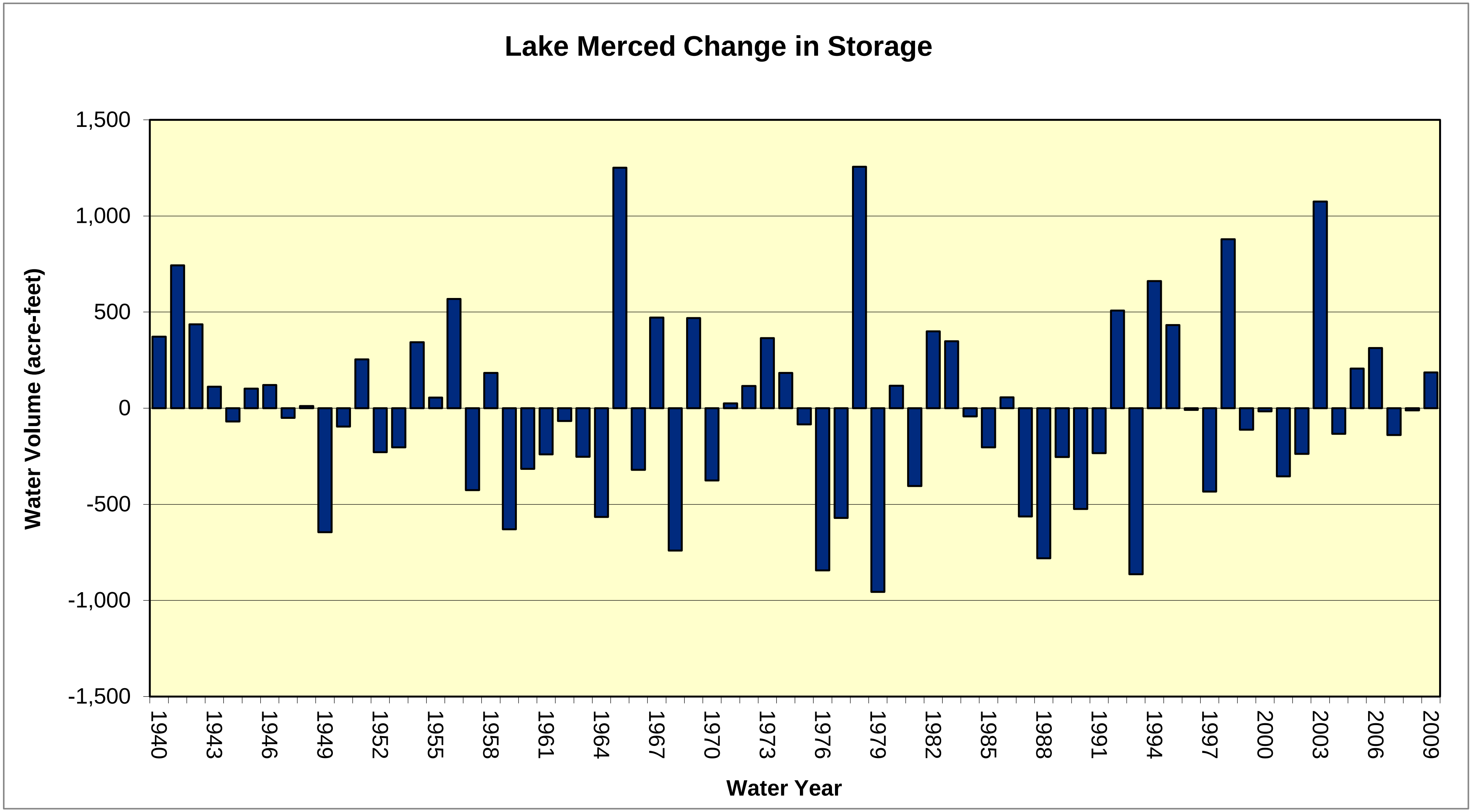
Kennedy/Jenks Consultants

Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Lake Merced Annual Water Balance

K/J 0864001
April 2012

Figure 12



Legend

■ Annual Change in Lake Storage (acre-feet)

Kennedy/Jenks Consultants

Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Lake Merced Change in Storage

K/J 0864001

April 2012

Figure 13

Attachment 10.1-H

Appendix A

San Francisco Lake Merced Pump Station and Mission Dolores
Weather Station Data Summary

Monthly Rainfall Total at Used in Historical Lake Merced Lake-Level Model

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANN
1914	9.76	5.04	1.09	0.99	0.37	0.29	0.02	0.00	0.00	0.29	0.70	5.49	24.04
1915	6.64	7.36	3.02	0.62	3.17	0.00	0.01	0.00	0.00	0.01	0.92	6.42	28.17
1916	14.59	3.77	1.33	0.00	0.07	0.00	0.03	0.29	1.20	0.52	1.50	4.79	28.09
1917	1.83	3.81	1.42	0.33	0.06	0.00	0.00	0.00	0.02	0.00	0.81	0.72	9.00
1918	0.81	5.79	2.73	0.60	0.00	0.00	0.00	0.00	2.53	0.17	5.60	2.62	20.85
1919	2.57	9.31	2.74	0.10	0.00	0.00	0.01	0.00	0.39	0.27	0.44	3.21	19.04
1920	0.26	1.23	3.25	1.36	0.00	0.04	0.00	0.00	0.13	1.83	2.70	7.98	18.78
1921	6.30	1.38	2.28	0.54	2.54	0.00	0.00	0.00	0.35	0.52	1.43	6.39	21.73
1922	2.41	5.15	2.38	0.47	0.55	0.26	0.00	0.00	0.00	2.95	3.77	7.77	25.71
1923	2.84	0.77	0.03	3.92	0.06	0.06	0.00	0.01	0.44	0.46	0.49	1.91	10.99
1924	2.75	3.30	1.96	0.30	0.00	0.00	0.00	0.01	0.00	2.98	1.50	7.37	20.17
1925	1.62	7.90	2.63	2.73	4.02	0.05	0.06	0.00	0.45	0.31	2.32	1.01	23.10
1926	5.48	5.40	0.25	5.26	0.15	0.00	0.00	0.04	0.00	1.90	7.21	1.04	26.73
1927	3.77	6.85	2.19	1.95	0.10	0.38	0.00	0.00	0.00	1.93	3.18	3.94	24.29
1928	2.40	1.97	4.65	1.31	0.26	0.00	0.00	0.00	0.03	0.13	3.35	4.89	18.99
1929	1.32	2.14	1.56	1.01	0.01	0.86	0.00	0.00	0.00	0.01	0.00	3.09	10.00
1930	4.99	2.09	3.53	1.56	0.16	0.00	0.00	0.00	0.10	0.89	1.56	0.98	15.86
1931	5.50	1.10	1.68	0.31	1.10	0.32	0.00	0.00	0.00	0.68	2.93	9.24	22.86
1932	3.23	3.00	0.86	0.47	0.65	0.03	0.00	0.00	0.00	0.01	1.00	2.75	12.00
1933	5.68	1.13	2.93	0.06	1.36	0.01	0.00	0.00	0.14	1.49	0.00	4.19	16.99
1934	1.03	4.68	0.07	0.51	0.12	0.68	0.01	0.00	0.13	0.88	3.76	4.06	15.93
1935	6.23	2.38	2.31	3.45	0.01	0.00	0.00	0.25	0.08	1.44	1.24	3.25	20.64
1936	5.77	10.06	1.01	1.09	0.49	0.28	0.03	0.02	0.00	0.69	0.01	2.94	22.39
1937	5.26	4.88	7.05	0.86	0.06	0.59	0.00	0.00	0.00	0.90	2.46	3.73	25.79
1938	2.65	8.49	5.73	1.52	0.00	0.00	0.01	0.00	0.15	1.33	0.88	1.48	22.24
1939	3.07	1.94	2.62	0.42	0.63	0.00	0.00	0.00	1.06	0.17	0.20	1.05	11.16
1940	9.98	7.81	5.32	0.94	0.63	0.01	0.00	0.00	0.59	1.05	2.22	6.25	34.80
1941	8.24	6.71	4.75	4.05	1.18	0.01	0.01	0.03	0.00	0.93	1.99	7.30	35.20
1942	4.76	4.27	2.62	3.65	1.11	0.00	0.01	0.00	0.18	0.95	4.45	2.87	24.87
1943	6.15	1.95	3.18	1.88	0.13	0.13	0.00	0.00	0.02	0.74	0.80	2.69	17.67
1944	4.31	5.34	0.83	2.07	0.94	0.12	0.01	0.02	0.00	1.73	6.24	3.97	25.58
1945	1.33	3.43	4.15	0.32	0.64	0.01	0.00	0.00	0.04	1.95	3.24	9.84	24.95
1946	1.76	2.03	2.34	0.05	0.37	0.02	0.06	0.00	0.06	0.15	2.73	2.77	12.34
1947	1.35	2.65	3.64	0.17	0.67	0.64	0.00	0.00	0.00	2.09	1.39	1.84	14.44
1948	1.00	2.32	3.36	3.04	0.54	0.01	0.02	0.02	0.09	0.20	1.18	4.76	16.54
1949	2.20	3.04	5.85	0.00	0.93	0.00	0.06	0.04	0.00	0.08	1.18	2.77	16.15
1950	7.40	2.33	1.65	0.87	0.37	0.03	0.00	0.00	0.00	2.72	4.96	6.01	26.34
1951	4.41	3.00	1.32	0.89	0.65	0.04	0.01	0.43	0.08	0.81	3.33	7.92	22.89
1952	10.69	2.62	4.90	1.08	0.30	0.39	0.00	0.01	0.00	0.07	2.42	9.06	31.54
1953	3.26	0.04	1.83	3.42	0.38	0.61	0.00	0.07	0.00	0.34	1.88	0.82	12.65
1954	3.11	2.42	4.56	0.82	0.11	0.14	0.03	0.20	0.00	0.24	2.55	5.67	19.85
1955	4.05	1.18	0.29	1.49	0.04	0.00	0.02	0.00	0.02	0.03	2.38	11.47	20.97
1956	8.72	2.03	0.12	1.68	0.68	0.02	0.00	0.01	0.33	1.14	0.04	0.37	15.14
1957	2.84	3.58	2.39	1.09	3.19	0.06	0.01	0.00	1.46	3.46	1.13	3.60	22.81
1958	4.38	7.78	8.22	5.47	0.88	0.09	0.05	0.00	0.04	0.21	0.28	1.50	28.90
1959	4.17	4.50	0.49	0.91	0.08	0.00	0.00	0.02	2.06	0.09	0.00	1.75	14.07
1960	4.45	2.92	1.91	0.96	0.72	0.00	0.00	0.00	0.00	0.48	3.40	2.33	17.17
1961	2.78	1.30	2.47	0.96	0.91	0.03	0.01	0.04	0.27	0.08	4.72	2.10	15.67
1962	1.05	6.11	2.69	0.23	0.05	0.00	0.00	0.10	0.15	4.11	0.58	3.48	18.55
1963	2.25	2.55	3.71	2.92	0.66	0.03	0.00	0.00	0.16	1.46	3.26	0.82	17.82
1964	4.50	0.24	1.82	0.24	0.38	0.46	0.10	0.04	0.02	1.46	3.46	4.50	17.22
1965	3.68	0.90	2.48	3.92	0.00	0.05	0.00	0.97	0.00	0.02	5.34	4.58	21.94
1966	3.18	2.86	0.75	0.45	0.29	0.17	0.00	0.18	0.12	0.04	4.52	3.72	16.28
1967	10.14	0.64	4.14	5.56	0.13	1.69	0.00	0.00	0.02	0.73	1.00	2.15	26.20
1968	4.88	2.71	3.32	0.28	0.19	0.00	0.04	0.13	0.08	0.74	3.18	4.73	20.28
1969	7.14	6.98	1.00	1.84	0.05	0.08	0.00	0.00	0.13	2.77	0.93	5.79	26.71
1970	7.35	2.02	1.99	0.12	0.05	0.80	0.00	0.28	0.00	0.81	5.82	6.24	25.48
1971	1.98	0.41	2.64	1.14	0.46	0.00	0.00	0.00	0.15	0.15	1.68	4.74	13.35
1972	1.68	2.17	0.28	1.10	0.00	0.13	0.00	0.00	0.80	4.65	6.22	3.67	20.70
1973	8.38	6.64	2.93	0.06	0.06	0.00	0.21	0.00	0.40	2.01	5.90	5.19	31.78
1974	4.25	1.74	6.23	2.76	0.00	0.22	0.49	0.03	0.00	0.78	0.57	1.31	18.38
1975	1.18	5.07	5.99	1.57	0.05	0.10	0.33	0.11	0.02	2.40	0.81	0.35	17.98
1976	0.53	1.49	1.38	1.26	0.05	0.03	0.00	0.98	0.18	0.53	1.31	2.60	10.34
1977	1.84	1.02	2.63	0.13	0.66	0.02	0.00	0.00	1.00	0.24	2.13	3.67	13.34
1978	6.54	3.80	5.89	4.10	0.01	0.00	0.00	0.00	0.26	0.00	1.25	1.09	22.94
1979	6.70	4.14	2.63	0.94	0.23	0.03	0.06	0.00	0.00	1.55	2.63	3.50	22.41
1980	4.83	6.47	2.10	1.04	0.26	0.00	0.05	0.00	0.36	0.10	1.26	1.72	18.19

Monthly Rainfall Total at Used in Historical Lake Merced Lake-Level Model

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANN
1981	4.72	1.69	5.30	0.23	0.19	0.00	0.00	0.09	0.41	2.13	5.07	3.38	23.21
1982	7.10	3.00	5.81	4.53	0.00	0.18	0.04	0.00	0.55	2.62	5.56	2.89	32.28
1983	5.17	7.18	9.29	3.85	0.62	0.00	0.00	0.06	0.11	0.60	8.20	6.35	41.43
1984	0.42	2.31	1.04	0.86	0.07	0.13	0.00	0.23	0.08	2.69	4.82	2.29	14.94
1985	1.32	1.22	4.09	0.34	0.26	0.31	0.21	0.02	0.62	1.00	4.95	2.04	16.38
1986	3.74	7.01	7.18	0.84	0.14	0.13	0.00	0.00	1.07	0.21	0.18	1.94	22.44
1987	4.56	2.52	2.96	0.20	0.05	0.00	0.00	0.00	0.00	1.10	2.07	2.60	16.06
1988	4.24	0.42	0.20	2.67	0.40	0.36	0.00	0.00	0.00	0.64	2.90	3.68	15.51
1989	1.54	1.93	4.75	0.90	0.18	0.00	0.06	0.00	1.70	2.06	1.25	0.00	14.37
1990	1.90	2.25	1.20	0.45	1.78	0.10	0.00	0.00	0.12	0.06	0.61	2.10	10.57
1991	0.51	2.88	6.71	1.13	0.43	0.26	0.04	2.26	0.05	1.11	0.31	2.30	17.99
1992	2.52	5.78	5.09	0.41	0.00	0.46	0.04	0.03	0.00	1.39	0.19	5.77	21.68
1993	8.67	3.67	1.77	1.10	0.90	0.36	0.01	0.04	0.01	0.31	2.79	2.32	21.95
1994	2.75	4.70	0.35	1.23	1.47	0.05	0.00	0.00	0.14	0.12	5.16	3.22	19.19
1995	10.11	0.66	7.85	1.28	0.98	0.62	0.00	0.00	0.00	0.00	0.10	5.40	27.00
1996	3.29	5.28	2.43	1.87	1.49	0.00	0.00	0.02	0.01	1.14	2.95	6.37	24.85
1997	7.45	0.25	0.27	0.29	0.20	0.45	0.00	1.10	0.08	0.86	5.94	3.63	20.52
1998	11.67	15.64	2.77	2.73	4.20	0.05	0.02	0.00	0.05	0.69	2.69	2.04	42.55
1999	3.90	5.27	1.01	2.68	0.09	0.02	0.00	0.03	0.18	0.42	0.86	1.03	15.49
2000	4.74	6.79	1.75	1.20	0.54	0.80	0.00	0.00	0.25	1.40	0.30	0.57	18.34
2001	1.92	4.10	1.96	0.63	0.00	0.12	0.00	0.00	0.50	0.38	2.73	4.28	16.62
2002	3.50	0.84	1.94	0.29	0.86	0.00	0.00	0.00	0.00	0.00	1.18	8.81	17.42
2003	1.96	2.16	1.27	3.65	1.10	0.00	0.00	0.00	0.00	0.00	1.88	6.52	18.54
2004	3.56	6.42	0.94	0.15	0.00	0.00	0.00	0.00	0.00	0.25	2.01	8.13	21.46
2005	6.13	4.32	4.03	1.55	1.78	1.58	0.00	0.00	0.00	0.35	1.64	7.23	28.61
2006	3.03	3.14	8.85	4.82	0.33	0.00	0.00	0.00	0.00	0.51	2.45	4.33	27.46
2007	0.63	3.72	0.66	1.36	0.39	0.00	0.10	0.00	0.15	3.79	1.96	4.01	16.77
2008	9.75	2.14	0.12	0.12	0.00	0.00	0.03	0.04	0.00	0.29	2.08	2.58	17.15
2009	0.74	7.44	2.84	0.30	0.89	0.00	0.08	0.00	0.36				12.65

Period of Record Statistics

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANN
MEAN	**4.31**	**3.72**	**2.88**	**1.45**	**0.57**	**0.17**	**0.02**	**0.09**	**0.24**	**0.98**	**2.39**	**3.89**	**20.62**
S.D.	**2.91**	**2.63**	**2.12**	**1.40**	**0.81**	**0.30**	**0.07**	**0.29**	**0.45**	**1.02**	**1.88**	**2.43**	**6.47**
MAX	**14.59**	**15.64**	**9.29**	**5.56**	**4.20**	**1.69**	**0.49**	**2.26**	**2.53**	**4.65**	**8.20**	**11.47**	**42.55**
MIN	**0.26**	**0.04**	**0.03**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**9.00**
NO YRS	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**96**	**95**	**95**	**95**	**96**

5.85 Precipitation Data from Mission Dolores Station

0.09 Precipitation Data from Lake Merced Pump Station Gauge

SAN FRAN MISSION DOLORE, CALIFORNIA

Monthly Average Temperature (Degrees Fahrenheit)

(047772)

File last updated on Jul 29, 2009
*** Note *** Provisional Data *** After Year/Month 200903
a = 1 day missing, b = 2 days missing, c = 3 days, ..etc..,
z = 26 or more days missing, A = Accumulations present
Long-term means based on columns; thus, the monthly row may not
sum (or average) to the long-term annual value.
MAXIMUM ALLOWABLE NUMBER OF MISSING DAYS : 5
Individual Months not used for annual or monthly statistics if more than 5 days are missing.
Individual Years not used for annual statistics if any month in that year has more than 5 days missing.

YEAR (S)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1914	51.50	53.93	58.40	58.30	56.19	56.60	57.03	58.19	60.77	62.05	58.98	48.69	56.72
1915	50.69	52.82	57.89	57.07	57.60	58.90	60.26	61.16	62.40	61.26	56.13	52.11	57.36
1916	46.98	55.86	56.56	57.58	55.79	57.42	60.00	58.58	62.18	56.94	54.43	48.87	55.93
1917	47.58	52.20	51.68	55.10	53.98	58.60	59.82	57.48	63.98	62.29	58.67	54.58	56.33
1918	52.65	51.88	54.87	57.25	54.68	59.25	58.82	60.82	62.27	64.03	55.60	50.15	56.85
1919	51.21	51.59	52.61	55.98	57.15	57.78	57.06	58.32	61.98	60.71	56.02	48.82	55.77
1920	52.21	52.83	52.48	54.97	55.76	60.20	57.85	60.11	60.42	60.03	55.35	50.98	56.10
1921	49.61	52.91	54.55	54.88	54.31	61.42	59.79	59.55	63.28	61.48	57.78	52.92	56.87
1922	46.74	50.21	52.34	53.55	58.02	60.03	60.16	60.40	63.32	61.31	54.30	50.60	55.91
1923	48.10	52.18	56.74	56.07	57.21	57.18	60.81	61.69	63.95	62.50	60.80	51.06	57.36
1924	50.21	57.05	54.50	57.47	59.11	59.82	59.05	59.13	62.45	59.48	56.70	47.85	56.90
1925	51.42	55.18	55.39	56.95	58.98	60.72	61.21	61.15	62.72	62.19	56.62	52.71	57.94
1926	47.90	56.02	60.65	61.62	61.06	59.15	61.10	60.84	61.28	63.45	60.87	51.50	58.79
1927	51.31	54.02	54.23	55.50	58.19	59.83	58.66	59.79	62.38	62.48	58.12	51.82	57.19
1928	50.44	55.10	58.24	57.73	58.92	60.52	58.68	58.45	61.20	59.52	56.35	49.63	57.06
1929	47.56	51.77	54.24	53.35	56.50	63.00	61.55	61.11	61.42	63.48	59.70	54.24	57.33
1930	49.68	56.64	57.61	59.23	56.08	59.93	58.65	61.52	62.40	63.19	58.08	52.10	57.93
1931	52.27	56.70	59.02	59.02	61.85	62.02	62.31	60.45	62.67	59.73	54.45	49.24	58.31
1932	49.32	51.36	57.10	55.95	58.40	59.17	59.73	60.97	62.97	62.15	60.67	47.45	57.10
1933	47.02	51.21	55.42	55.47	55.15	57.62	59.50	59.77	61.13	62.34	60.03	50.47	56.26
1934	51.84	55.62	60.65	58.97	60.61	60.93	59.94	60.90	63.65	61.76	58.50	52.92	58.86
1935	50.77	54.12	52.63	58.52	58.68	61.32	60.16	59.97	60.53	60.97	54.87	52.85	57.12
1936	53.85	53.41	57.47	58.92	61.53	61.68	59.48	59.31	63.02	62.21	58.03	51.53	58.37
1937	43.58	49.89	54.81	54.52	57.15	61.37	59.29	58.90	61.43	63.37	58.28	54.71	56.44
1938	51.45	53.07	52.82	54.92	56.60	57.45	58.85	60.08	61.18	61.56	56.78	53.61	56.53
1939	51.97	51.23	52.74	55.75	56.97	57.88	58.98	60.69	66.17	62.97	59.15	55.32	57.49
1940	52.61	55.41	57.40	57.77	58.02	59.00	60.16	60.00	65.08	62.29	57.03	55.45	58.35
1941	53.97	55.36	58.39	55.82	61.18	60.03	60.16	61.21	63.48	60.82	58.40	53.45	58.52
1942	51.11	53.36	55.26	55.58	56.85	58.58	59.73	58.47	60.27	60.90	56.02	52.08	56.52

1943	51.89	54.75	55.61	55.58	58.61	57.35	59.05	59.84	63.45	61.32	59.23	53.58	57.52
1944	51.79	51.62	55.77	53.20	56.79	57.77	57.32	58.87	60.65	61.45	55.75	54.19	56.27
1945	50.19	54.34	51.82	55.90	55.39	61.30	59.55	58.65	62.52	61.56	56.38	52.74	56.70
1946	51.37	50.68	53.19	55.22	55.61	58.80	60.48	58.10	62.77	60.31	54.67	51.32	56.04
1947	47.18	53.61	55.98	58.47	57.76	61.82	60.11	61.76	61.40	62.03	55.33	50.97	57.20
1948	54.71	50.78	51.73	53.58	55.55	59.38	59.29	59.66	59.95	60.34	56.58	47.79	55.78
1949	44.68	48.30	53.21	55.55	56.71	58.78	57.53	59.39	62.48	58.50	59.82	50.60	55.46
1950	46.84	51.82	53.19	56.07	54.69	56.78	57.74	59.55	61.90	61.68	61.00	53.63	56.24
1951	50.26	52.18	54.05	52.32	57.29	56.28	56.24	57.29	59.75	61.52	56.22	49.95	55.28
1952	48.03	52.14	51.68	55.33	57.34	56.55	58.68	57.89	61.48	58.76	55.88	51.60	55.45
1953	54.34	54.00	53.18	52.67	56.58	57.78	57.23	59.50	62.52	61.56	56.67	54.98	56.75
1954	51.50	53.93	52.06	57.02	56.15	58.50	59.05	57.85	61.80	61.47	56.63	49.92	56.32
1955	48.11	52.21	54.81	52.25	56.60	57.00	56.85	56.37	59.03	59.63	56.22	53.05	55.18
1956	51.66	51.36	53.65	54.35	57.52	58.87	57.08	58.89	62.53	59.40	59.42	52.71	56.45
1957	48.82	53.96	54.11	57.65	57.89	61.38	59.55	59.52	63.57	62.31	56.80	51.45	57.25
1958	52.76	56.16	53.10	57.13	59.48	62.43	58.94	61.03	66.82	61.76	58.03	57.53	58.76
1959	54.00	53.43	58.16	57.85	56.76	59.37	59.98	61.82	62.92	65.18	60.17	54.84	58.71
1960	51.03	54.24	55.79	56.00	56.90	59.55	58.10	57.71	59.82	60.94	55.48	51.35	56.41
1961	49.05	55.43	54.24	56.90	55.71	60.12	59.98	60.92	63.37	61.19	56.47	50.02	56.95
1962	51.87	51.82	52.63	56.98	55.18	57.52	55.95	59.95	58.30	60.79	58.82	52.85	56.06
1963	50.39	58.38	54.10	54.37	57.19	58.07	59.69	59.76	64.73	62.89	56.62	48.23	57.03
1964	50.94	54.98	53.11	53.78	53.34	57.78	58.84	60.00	62.42	63.03	55.30	53.66	56.43
1965	51.39	53.98	54.39	55.65	54.84	56.17	57.42	61.19	61.18	64.95	58.10	48.32	56.47
1966	52.08	51.79	53.81	57.90	55.08	59.40	58.13	58.81	63.53	62.60	57.22	51.31	56.80
1967	52.61	53.16	52.69	50.73	57.85	57.07	58.85	59.15	63.48	65.48	59.95	51.85	56.91
1968	49.74	56.66	56.66	56.17	55.66	58.98	57.97	62.24	63.08	60.50	56.20	49.81	56.97
1969	48.55	50.04	54.21	54.17	56.98	58.65	57.61	59.32	60.85	61.87	59.32	55.76	56.44
1970	54.00	57.34	57.77	53.28	57.69	56.73	57.82	57.19	64.38	58.58	57.83	50.55	56.93
1971	50.82	51.91	53.29	53.10	54.55	57.30	57.44	61.05	64.68	57.79	55.58	49.00	55.54
1972	48.50	53.97	55.82	55.48	55.52	57.43	60.82	60.19	61.48	61.71	54.90	47.19	56.09
1973	50.15	54.86	52.53	57.20	56.27	60.67	58.56	57.08	61.30	60.95	55.32	51.98	56.41
1974	51.08	52.11	53.31	55.42	54.87	58.15	59.53	59.90	60.28	62.24	56.63	51.10	56.22
1975	51.02	53.30	53.08	51.90	57.16	56.88	58.84	59.45	59.43	59.65	55.55	53.39	55.80
1976	53.34	52.83	52.55	54.10	56.77	61.47	59.18	62.50	62.15	62.73	60.33	54.55	57.71
1977	49.87	56.09	53.18	56.07	55.31	57.05	59.02	61.52	61.93	60.53	58.55	54.92	57.00
1978	54.97	55.18	58.95	56.30	60.73	58.85	58.40	60.56	65.48	61.89	55.92	49.58	58.07
1979	50.94	52.89	55.68	56.42	59.15	58.58	60.21	60.79	66.32	63.16	57.65	55.34	58.09
1980	52.95	57.17	55.92	56.92	55.37	57.93	59.48	57.95	61.30	61.97	58.22	53.42	57.38
1981	52.39	56.02	54.94	55.77	56.76	62.18	57.79	59.21	60.37	59.29	58.32	53.97	57.25
1982	48.44	55.00	52.77	55.60	55.76	56.28	57.92	60.13	62.58	62.77	54.40	52.19	56.15
1983	49.37	54.62	55.29	56.80	59.66	61.78	63.42	65.90	67.07	63.97	56.12	52.82	58.90
1984	51.58	52.57	56.66	54.20	59.90	59.65	63.89	62.73	69.35	61.48	55.93	50.84	58.23
1985	49.95	55.98	53.16	59.80	58.05	63.83	64.05	64.08	64.08	63.15	54.95	51.24	58.53
1986	56.56	58.91	60.44	58.55	60.00	63.22	62.76	61.87	62.75	63.58	60.18	52.47	60.11
1987	51.79	56.41	57.11	60.43	61.06	60.47	61.48	63.45	63.78	65.03	58.73	52.24	59.33
1988	52.82	57.66	59.06	58.73	59.11	61.02	64.19	64.00	63.03	61.44	57.25	53.23	59.30
1989	51.26	49.98	55.35	60.87	59.26	61.55	62.42	63.00	61.80	62.00	58.80	52.60	58.24
1990	52.74	51.95	54.84	59.22	59.00	62.33	62.89	65.24	65.95	64.21	57.98	49.10	58.79

1991	53.37	57.88	53.19	57.03	56.77	58.58	61.29	63.00	63.12	64.35	60.05	53.39	58.50
1992	51.42	58.38	59.23	62.62	62.73	62.53	65.10	63.76	65.78	66.73	59.72	51.69	60.81
1993	51.08	53.77	59.00	59.42	62.45	65.92	63.39	66.56	63.38	64.27	58.17	51.52	59.91
1994	53.66	52.68	58.10	57.58	58.71	61.03	59.61	63.42	63.67	62.19	51.93	49.52	57.68
1995	54.03	56.91	56.15	56.92	57.39	61.67	65.98	64.05	64.68	64.58	60.85	55.50	59.89
1996	54.02	57.09	58.74	61.40	61.71	62.83	63.65	63.73	63.55	62.84	58.02	55.82	60.28
1997	52.65	56.09	58.21	58.10	62.60	61.62	62.27	65.74	67.75	62.45	59.30	53.82	60.05
1998	53.63	52.66	55.66	55.43	56.55	59.30	60.10	61.08	61.72	60.55	55.18	49.95	56.82
1999	50.50	51.45	51.18	54.88	53.74	56.37	58.66	60.87	61.48	62.42	57.78	54.23	56.13
2000	52.63	53.83	54.94	57.10	58.24	59.50	58.32	60.66	64.70	59.52	53.80	53.95	57.27
2001	51.37	52.05	55.85	52.50	61.52	61.30	60.47	61.50	61.00	62.65	58.63	52.76	57.63
2002	50.68	55.45	53.85	54.83	55.02	58.02	59.16	60.39	61.52	60.77	59.38	54.23	56.94
2003	56.27	54.59	56.45	53.92	58.03	60.50	59.32	63.48	64.83	62.97	55.33	52.85	58.21
2004	51.77	53.69	60.24	58.48	58.13	58.93	60.68	62.81	64.88	60.03	56.50	53.48	58.30
2005	50.32	55.84	57.52	55.92	59.10	59.33	60.92 a	59.77	59.67	60.52	60.25	55.48	57.89
2006	52.61	54.70	50.89	54.87	57.35	60.20	61.73	59.52	59.57	60.69	56.25	52.35	56.73
2007	49.97	53.02	57.17 a	55.40	57.29	59.12	61.44	61.95	63.40	60.35	57.28	50.77	57.26
2008	49.85 a	53.14	54.48	54.88	57.60	59.53	60.47	61.94	63.33	63.40	59.08	50.42	57.34
2009	54.11	52.78 a	54.11	55.85	58.02	60.39 b	59.48 h	-----z	-----z	-----z	-----z	-----z	55.88

Period of Record Statistics

MEAN	51.04	53.87	55.21	56.25	57.53	59.49	59.78	60.59	62.67	61.79	57.39	52.05	57.30
S.D.	2.32	2.19	2.40	2.23	2.12	1.98	1.98	2.06	1.98	1.72	1.93	2.19	1.22
SKEW	-0.46	0.11	0.42	0.29	0.54	0.47	0.79	0.62	0.60	0.01	-0.07	-0.10	0.72
MAX	56.56	58.91	60.65	62.62	62.73	65.92	65.98	66.56	69.35	66.73	61.00	57.53	60.81
MIN	43.58	48.30	50.89	50.73	53.34	56.17	55.95	56.37	58.30	56.94	51.93	47.19	55.18
NO YRS	96	96	96	96	96	96	95	95	95	95	95	95	95

Attachment 10.1-H

Appendix B

Lake Merced Lake-Level Model – Historical Analysis Annual Water Balance Data Summary

Lake Merced Lake-Level Model - Historical Analysis Annual Water Balance Data Summary

Water Year	Precipitation (AF)	Stormwater Runoff (AF)	Evaporation (AF)	Transpiration (AF)	Groundwater In/Out (AF)	Singular Events (AF)	Change in Lake Storage (AF)
1940	686	473	-699	-135	60	0	373
1941	905	601	-725	-137	126	0	743
1942	707	431	-676	-132	126	0	436
1943	572	334	-686	-132	41	0	112
1944	469	249	-653	-129	6	0	-70
1945	574	339	-685	-133	22	0	102
1946	570	363	-678	-132	13	0	120
1947	386	197	-689	-135	-50	250	-50
1948	411	203	-656	-130	-57	250	12
1949	477	277	-658	-131	0	-600	-645
1950	427	250	-638	-128	0	0	-95
1951	630	375	-635	-128	22	0	254
1952	829	573	-649	-130	-186	-650	-229
1953	540	352	-651	-130	-307	0	-203
1954	366	192	-662	-132	-168	750	343
1955	399	230	-624	-126	-418	600	55
1956	707	359	-659	-130	-196	500	568
1957	422	120	-689	-134	-387	250	-426
1958	912	355	-717	-138	-208	0	183
1959	366	105	-700	-136	-109	-150	-630
1960	324	96	-668	-134	-182	250	-316
1961	375	106	-666	-134	-171	250	-240
1962	430	138	-618	-128	-139	250	-67
1963	506	159	-673	-136	-362	250	-252
1964	325	93	-622	-131	-385	150	-566
1965	514	170	-611	-128	-46	1,340	1,251
1966	452	138	-663	-133	-364	250	-321
1967	768	324	-642	-130	-246	400	472
1968	392	116	-688	-136	-323	-100	-741
1969	642	239	-637	-131	-47	400	469
1970	557	194	-666	-133	-77	-250	-377
1971	487	154	-621	-128	-120	250	25
1972	315	91	-636	-130	-175	650	116
1973	839	325	-642	-131	-21	0	365
1974	734	239	-652	-131	1	0	184
1975	434	127	-646	-130	-116	250	-84
1976	238	55	-652	-134	-401	50	-844
1977	289	77	-645	-132	-411	250	-570
1978	635	227	-690	-138	-245	1,450	1,257
1979	430	140	-668	-135	-321	-400	-956
1980	556	184	-644	-132	-354	500	117
1981	382	119	-629	-133	-151	0	-405
1982	770	279	-615	-130	-20	100	399
1983	925	384	-706	-141	-119	0	348
1984	506	193	-712	-141	110	0	-43
1985	452	133	-697	-140	48	0	-203
1986	694	257	-710	-142	-47	0	57
1987	309	97	-693	-140	-141	0	-563
1988	332	101	-670	-141	-112	-300	-781
1989	415	138	-632	-140	-58	0	-254
1990	247	75	-627	-141	-92	0	-524

Lake Merced Lake-Level Model - Historical Analysis Annual Water Balance Data Summary

Water Year	Precipitation (AF)	Stormwater Runoff (AF)	Evaporation (AF)	Transpiration (AF)	Groundwater In/Out (AF)	Singular Events (AF)	Change in Lake Storage (AF)
1991	362	131	-583	-137	-41	0	-234
1992	378	140	-642	-146	-102	840	508
1993	525	232	-639	-144	-279	-600	-863
1994	324	120	-577	-138	-30	920	662
1995	665	340	-641	-140	231	-75	432
1996	452	163	-687	-146	182	0	-9
1997	461	181	-656	-144	-305	0	-434
1998	1,069	666	-620	-134	-180	0	878
1999	436	144	-583	-129	4	0	-112
2000	429	143	-628	-135	159	0	-16
2001	267	76	-597	-133	22	0	-355
2002	333	110	-586	-132	18	0	-238
2003	463	204	-635	-136	-5	1,161	1,075
2004	465	168	-656	-137	12	2	-134
2005	714	278	-621	-132	-52	0	206
2006	713	306	-638	-133	52	0	313
2007	349	101	-646	-134	185	0	-140
2008	534	243	-647	-134	-17	0	-11
2009	392	147	-263	-54	-44	0	186
Total	**35,959**	**15,436**	**-45,314**	**-9,320**	**-6,948**	**9,438**	**-380**
Average	**514**	**221**	**-647**	**-133**	**-99**	**135**	**-5**
Max	**1,069**	**666**	**-263**	**-54**	**231**	**1,450**	**1,257**
Min	**238**	**55**	**-725**	**-146**	**-418**	**-650**	**-956**
Std Dev	**182**	**129**	**57**	**11**	**159**	**379**	**476**
Years	**68**	**68**	**68**	**68**	**68**	**27**	**68**

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Technical Memorandum 10.2

Assessment of Groundwater-Surface Water Interactions

for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

1 May 2012

Prepared for

San Francisco Public Utilities Commission
525 Golden Gate Avenue, 10th Floor
San Francisco, CA 94102

K/J Project No. 0864001

Supplemental Explanation for Hydrographs - TM10.2

This supplemental explanation is prepared to address discrepancies on several graphs presented in TM 10.2.

First, the x-axis on several graphs showing model results was shifted. The x-axis is named Scenario Year which should correspond to a water year[1]. However, the graph template was plotted using a calendar year, so the intervals on the x-axis represent the period from January to December. The result is that the graph is shifted 3-months later relative to Scenario Year.

Second, the shaded area representing the Design Drought was added manually and because of this process, it was not presented consistently on the graphs. By definition per the PEIR, the 8.5-year Design Drought includes one Hold year before the 7.5-year Take period. In addition, the Design Drought needs to be shifted 3-months later for the x-axis issue to be consistent with the model output. The Design Drought should be shown as Scenario Years 35.5 to 44.0 on the shifted x-axis.

The following is a list of figures in TM 10.2 where the Design Drought shaded area is shown slightly different and does not match the correct display of the Design Drought. The figures should be viewed based on the correct representation of the Design Drought as explained above.

- Figures 10.2-8 through 10.2-15 (a total of 13 figures) have the shifted x-axis. The Design Drought should be shown as Scenario Years 35.5 to 44.0 on the shifted x-axis.

[1] A water year is October 1 of the previous year to September 30 of the current (named) year.

1 May 2012

Task 10.2 Technical Memorandum

San Francisco Public Utilities Commission

Assessment of Groundwater-Surface Water Interactions for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Prepared For: Greg Bartow and Jeff Gilman, SFPUC

Prepared by: Michael Maley, Dennis Orlowski, Sevim Onsoy and Matt Baillie, Kennedy/Jenks Consultants

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1. Introduction

This Technical Memorandum (TM) was prepared to document work performed by Kennedy/Jenks Consultants (Kennedy/Jenks) for the San Francisco Public Utilities Commission (SFPUC) pursuant to the amended Task Order (TO) authorizations CUW30103-TO-1.12 of the Regional Groundwater Storage and Recovery (GSR) Project and CUW30102-TO-2.7 of the San Francisco Groundwater Supply (SFGW) Project. These projects are funded by the SFPUC's Water System Improvement Program (WSIP).

1.1. Objective

Implementation of the proposed GSR and SFGW Projects may influence groundwater levels within portions of the Westside Groundwater Basin (Basin). Depending on the magnitude of the potential changes in groundwater levels, existing and planned beneficial uses of major surface water features (lakes, streams, and wetlands) located within the Basin and connected to groundwater could be affected. Evaluation of the potential effects of groundwater / surface water (GW/SW) interaction is a key management issue for the long-term sustainability of the groundwater resources and the overall management of the Basin.

This TM was prepared to evaluate the potential interaction between groundwater and surface water for various surface water bodies overlying the Basin as a result of implementing the individual GSR and SFGW Projects, as well as combining both projects with other reasonably foreseeable future projects. For this evaluation, potential changes in future groundwater levels due to the operation of the GSR and SFGW Projects are assessed with respect to the potential to affect GW/SW interactions. Included as part of the evaluation is information related to past, current, and future conditions in the subsurface related to GW/SW interaction, along with a conceptual discussion of the mechanisms that control GW/SW interactions. The TM also includes an evaluation of the possible future groundwater conditions resulting from the implementation of the GSR and SFGW Projects as well as other reasonably foreseeable future projects. This evaluation is based upon the groundwater model scenarios developed based on the existing Westside Basin Groundwater Model (HydroFocus, 2007, 2009, and 2011) as described in TM-10.1.

1.2. General Approach

The general approach used to evaluate GW/SW interaction is first to identify the surface water features of interest in the Basin and to evaluate the existing GW/SW interactions for these features. Then in light of the degree of GW/SW interactions, the potential for the identified surface water features to be affected by the GSR and SFGW Projects is assessed based on an analysis of the changes in groundwater conditions in the Basin. Since each surface water feature may react differently depending upon the local conditions, each of the identified surface water features is evaluated separately.

This TM is part of a series of technical memoranda that address various aspects of the GSR and SFGW Projects. Two of these with significant data and analysis that are pertinent to this TM include the following:

- Task 8B Technical Memorandum No.1 Hydrologic Setting of the Westside Basin (referred to as TM#1) (LSCE, 2010).
- Task 10.1 Groundwater Modeling Analysis for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project (referred to as TM-10.1).

For each of the surface water features under consideration, the available documentation related to surface water hydrology, local hydrogeology, studies related to GW/SW interactions, and past or present management activities was reviewed. From this information, the following aspects of each surface water feature were addressed:

- Lake / Stream Characteristics: General descriptions of each surface water body, including physical characteristics, any anthropogenic modifications performed to the natural features and the historical use of the water body.
- Local Hydrogeology: An evaluation of the hydrogeologic conditions existing in the area of each surface water feature, with a focus on the conditions that are most likely to affect the GW/SW interaction process at a particular location (e.g., relative water levels for groundwater and surface water bodies and the presence or absence of major clay layers).
- Groundwater / Surface Water Interactions: A summary of available documented evidence for GW/SW interactions at a particular surface water body location.
- Managed Lake / Stream Levels: Where applicable, a summary of reported management activities intended to control water levels at a particular surface water feature.

The primary quantitative tools for evaluating potential future groundwater conditions are model scenarios developed using the existing Westside Basin Groundwater-Flow Model (Westside

Basin Groundwater Model) developed by HydroFocus (2007, 2009, and 2011). The development of the model scenarios is documented in TM-10.1. The Westside Basin Groundwater Model is considered a reasonable tool for regional, basin-wide assessment, but it has limited ability to evaluate GW/SW interactions on a local scale. Therefore, analysis of the potential effects with respect to GW/SW interactions is based on an empirical evaluation of the surface water hydrology and GW/SW interactions.

The Lake Merced Lake-Level Model is an empirical / conceptual quantitative tool, (referred to as the Lake-Level Model in this TM), used to evaluate changes in Lake Merced with respect to the GW/SW interactions. The Lake-Level Model is a spreadsheet-based water balance model that incorporates the key surface water components as well as groundwater-surface water interactions. The development of the Lake-Level Model is discussed in TM-10.1, Attachment 10.1-H.

1.3. GSR and SFGW Project Descriptions

The GSR Project is a conjunctive use project that would allow for increased groundwater supplies in the southern portion of the Westside Basin (South Westside Basin) during periods of drought when SFPUC surface water supplies become limited (MWH, 2008). The GSR Project will be designed to provide up to 60,500 acre-feet (af) of stored groundwater to help meet the SFPUC's system demands during the last 7.5 years of SFPUC's Design Drought. The SFPUC plans to install 16 new production wells for the GSR Project to recover the stored groundwater. Under the Draft GSR Operating Agreement, the SFPUC would "store" water in the South Westside Basin through the mechanism of in-lieu recharge by providing surface water as a substitute for groundwater pumping by the City of Daly City (Daly City), the City of San Bruno (San Bruno), and California Water Service Company (Cal Water). Daly City, San Bruno, and Cal Water are collectively referred to as the Partner Agencies (PAs). During shortages of SFPUC system water due to drought, emergencies, or scheduled maintenance, the PAs would return to pumping from their existing wells. During drought periods the SFPUC would extract groundwater from their new wells as long as a positive balance exists in the SFPUC Storage Account.

The SFGW Project would provide a reliable, local source of high-quality groundwater in the northern portion of the Westside Basin (North Westside Basin). The SFGW Project would construct up to six wells and associated facilities in the western part of San Francisco and extract an annual average of up to 4.0 million gallons per day (mgd) of groundwater from the North Westside Basin (SFPUC, 2009b). The extracted groundwater, which would be used both for regular and emergency water supply purposes, would be blended in small quantities with imported surface water before entering the municipal drinking water system for distribution. The SFGW Project includes two phases. In Phase One, SFPUC would build four new municipal supply groundwater wells at the Lake Merced Pump Station, West Sunset Playground, South Sunset Playground, and the Golden Gate Park Central Pump Station. In Phase Two, SFPUC would modify two existing irrigation wells (South Windmill Replacement and North Lake) in Golden Gate Park, converting them into municipal water supply wells.

The locations of the proposed GSR and SFGW Project wells and the existing and proposed PA municipal wells are shown on Figure 10.2-1. Additional detailed discussion of the GSR and SFGW Projects and pumping conditions under each project is provided in TM-10.1.

1.4. Daly City Vista Grande Drainage Basin Improvements Project

Daly City prepared the Vista Grande Drainage Basin Alternatives Analysis in 2011 based on the recommendations of the Vista Grande Watershed Plan. The purpose of the alternatives analysis is to develop and evaluate alternatives that will reduce or eliminate flooding of the canal, reduce erosion along Lake Merced, and provide other potential benefits such as habitat enhancement and lake level augmentation. The recommended program outlined in the plan includes:

- Partial replacement of the existing Vista Grande Canal to incorporate a gross solid screening device;
- Construction of a treatment wetland, and diversion and discharge structure to route some stormwater (and authorized non-stormwater) flows from the Vista Grande Canal to South Lake Merced;
- Replacement of the existing Vista Grande Tunnel to expand the capacity and
- Replacement of the existing outfall structure at Fort Funston. (Jacobs Associates, 2011a, 2011b; City of Daly City, 2012).

Daly City's Vista Grande Drainage Basin Alternatives Analysis recommended the South Lake Merced Alternative in which stormwater flow from the Vista Grande Canal would be diverted to Lake Merced (Jacobs Associates, 2011a, 2011b; City of Daly City, 2012). In the assessment of GW/SW interactions, the use of Lake Merced as part of the Vista Grande Drainage Basin Improvements Project for Daly City is considered a reasonably foreseeable future projects.

2. Conceptual Understanding

This section presents a basic framework for understanding the natural hydrogeologic processes and anthropogenic factors that can affect GW/SW interactions in the Westside Basin.

2.1. Surface Water Hydrology

Located within the Westside Basin are several prominent surface water features that could potentially be influenced by implementation of the GSR, SFGW Projects and other reasonably foreseeable future projects. These surface water features include the following:

- Lake Merced is a 300-acre freshwater lake located in the southwestern corner of San Francisco just north of the San Francisco County-San Mateo County line (Figure 10.2-2). Lake Merced is a major natural habitat for many species of birds and waterfowl, and is a popular recreational venue offering fishing, boating, bicycling, and wildlife viewing opportunities.
- Pine Lake is a 3-acre freshwater lake located north-northeast of Lake Merced in the westernmost portion of Pine Lake Park, which is adjacent to Stern Grove (Figure 10.2-2). Pine Lake (also known as Laguna Puerca) is one of the few natural lakes that still exist in San Francisco.
- The Golden Gate Park Lakes consist of twelve lakes or ponds located within Golden Gate Park (GGP) in the northernmost extent of the Westside Basin (Figure 10.2-3). The lakes provide a multitude of benefits in GGP, including wildlife habitat, recreation, and ornamental purposes.
- Three principal streams, along with their tributaries, exist in the South Westside Basin area: Colma Creek, San Bruno Creek, and Millbrae Creek in San Mateo County (Figure 10.2-1).

These surface water features are identified as the primary focus of this TM. Specific characteristics, local hydrogeology, and the potential for GW/SW interactions for each of the surface water features are discussed in more detail later in this TM.

2.2. Westside Groundwater Basin

This section provides an brief overview of the physical setting and hydrogeology of the Westside Basin to provide relevant context for the analysis presented in this TM. More detailed descriptions of the evaluations of the hydrogeology of the Westside Basin are presented in TM#1 (LSCE, 2010) and TM-10.1. In the Westside Basin, there are three regional aquifer systems, commonly referred to as the Shallow Aquifer, Primary Production Aquifer, and Deep Aquifer, as briefly described below and shown on Figure 10.2-4:

- The Shallow Aquifer is present in the northern part of the Basin, in the vicinity of Lake Merced and the southern portion of the Sunset district of San Francisco. The base of the Shallow Aquifer is defined as the top of the “-100 foot clay.”

- The Primary Production Aquifer is present throughout the Basin, overlying the “W-clay” where present. Where the W-clay is not present in locations to the south (in the South San Francisco area), the Primary Production Aquifer is divided into shallow and deep units separated by a clay unit at an elevation of approximately -300 feet mean sea level (msl).
- The Deep Aquifer underlies the W-clay, and thus its extent is limited to the generally-known extent of that clay unit.

The three aquifer systems are separated by thick, extensive clay units (e.g., the -100 foot clay and W-clay). Because of the discontinuous nature of these clay layers, the Basin is considered to be a semi-confined aquifer system where limited flow occurs between the different aquifer systems.

2.3. Conceptual Understanding of Groundwater-Surface Water Interactions

The phrase “groundwater-surface water interaction” refers to the movement of water between areas beneath the land surface (groundwater) and areas above the ground surface, such as streams, lakes, and wetlands (surface water). The conceptual understanding of this process provides the basic framework for understanding the natural processes that affect GW/SW interactions.

Several general conditions are required for the GW/SW interactions to occur. First, the depth to groundwater (or water table) has to be sufficiently shallow in relation to the bottom of surface water bodies such as streams, lakes, and wetlands. While there does not have to be an actual connection between surface water and the groundwater table to result in some degree of GW/SW interaction, there cannot be significant distance between the two. For instance, if the water table is tens or hundreds of feet below the level of the surface water, then GW/SW interactions are likely negligible.

In addition to the presence of a relatively shallow water table, there also has to be a relatively permeable pathway in the subsurface between the surface water body and groundwater. In other words, the presence of a low permeability clay deposit composing a lakebed might block, or at least greatly limit, the transfer of water flow between the lake and underlying groundwater. A higher permeability lakebed of sand would, on the other hand, allow the transfer of water for a more dynamic GW/SW interaction system. However, even with a natural sand lakebed, settling of silt and organic-rich sediments from the water column to the lake bottom over time would reduce the permeability of the lake bottom. Because of the presence of low permeability sediments on the lake bottom, groundwater interactions can often occur primarily through sediments along the edges of the lake.

Surface water bodies (e.g., lakes and streams) can interact with groundwater in three basic ways (Figure 10.2-5): 1) they can gain water from inflow of groundwater through the streambed or lakebed (gaining system); 2) they can lose water to groundwater by outflow through the streambed or lakebed (losing system); or 3) they can do both, gaining water in some reaches and losing water in others. The relative difference between the elevations of the surface water and the water table determines the relative direction of water flow. For groundwater to discharge into a surface water body, the groundwater level has to be higher than the water level in the surface water body. In this case the stream is considered to “gain” flow through the contribution of groundwater. Conversely, for surface water to be able to seep to groundwater, the level of the groundwater table near the stream has to be lower than the level of the stream surface. Under this condition the stream is considered to “lose” water to the groundwater system. A stream can be both gaining and losing at various reaches along its course, depending on the relative water levels at a specific location.

The seepage rate between the lakebed or streambed and the groundwater system is controlled by the permeability of the subsurface geology and the thickness and character of the streambed or lakebed. If the sediments at the bottom of the lake or stream are composed of clayey materials, then the rate of seepage may be low and the levels in the surface water body may not be in equilibrium with groundwater. Conversely, if the lake or stream has a sandy bottom, then the rate of seepage may be high and the groundwater levels may closely mimic the surface water.

Lakes and streams can be connected to the groundwater system by a continuous saturated zone, such as that depicted on Figure 10.2-5, or they can be disconnected from groundwater by an intervening unsaturated zone. In the latter case, as shown on Figure 10.2-6, the water table might exhibit a discernible mound beneath the stream, if the recharge rate through the streambed and unsaturated zone is greater than the rate of lateral flow of groundwater away from the mound. An important feature of streams that are disconnected from groundwater is that pumping of shallow groundwater near the stream does not affect the flow of the stream near the pumped wells. On the other hand, streams in connection with groundwater could be affected by such pumping (Winter, et al., 1998).

Another type of GW/SW interaction occurs when water from a surface water body moves into adjacent shallow sediments along the margin of the stream or lake. This process, termed “bank storage”, is a dynamic process in which an increase in water level in the surface water body creates a corresponding rise of the water table in these shallow sediments. The difference between bank storage and seepage to an aquifer is that the water in bank storage is not lost to the surface water body; rather the bank storage process provides a temporary storage for surface water during high water periods and a source of water during low water periods. The water can remain in this temporary storage if the water in the shallow sediments is not hydraulically connected to an underlying aquifer system. This can occur if a geologic feature, such as a laterally continuous clay layer, separates the shallow sediments from the underlying aquifer.

3. Groundwater-Surface Water Analysis

To evaluate groundwater conditions resulting from the operations of the GSR and SFGW Projects, a series of model scenarios was developed using the Westside Basin Groundwater-Flow Model. The development of the model scenarios is documented in TM-10.1. This section provides an evaluation of model-predicted changes in groundwater conditions with respect to the GW/SW interactions resulting from the implementation of the GSR and SFGW Projects.

3.1. Modeling Scenarios

Five model scenarios were constructed and simulated to evaluate the potential groundwater and related hydrological effects from the GSR and SFGW Projects and other reasonably foreseeable future projects. The following is a summary of the five scenarios used for the groundwater model analysis:

- Scenario 1 - Existing Conditions: Scenario 1 represents Existing Conditions and does not include the SFPUC Projects (either the GSR or SFGW Project). Groundwater pumping by the PAs and irrigation pumping are representative of the existing pumping conditions (as of June 2009). The PA pumping was established based on historical pumping rates, using the median of the 1959-2009 pumping data for individual agencies.
- Scenario 2 - GSR Project: Scenario 2 represents implementation of the GSR Project operations including: "put" periods when groundwater pumping by SFPUC and the PAs does not occur, except for exercising of the wells, and groundwater is placed into storage in the SFPUC Storage Account through in-lieu recharge; "hold" periods when the PAs are pumping and no in-lieu recharge is occurring because the SFPUC Storage Account is full; and "take" periods when both SFPUC and the PAs are pumping from the South Westside Basin.
- Scenario 3a - SFGW Project (3 mgd): For Scenario 3a, the four new wells constructed for the SFGW Project would pump at an annual average rate of 3.0 mgd; however, the two existing irrigation wells would remain irrigation wells, and their pumping rates would be the same as in Scenario 1.
- Scenario 3b - SFGW Project (4 mgd): For Scenario 3b, the four new wells constructed for the SFGW Project and the two modified irrigation wells in Golden Gate Park would pump at an annual average rate of 4.0 mgd. Irrigation in Golden Gate Park is assumed to be replaced by the Westside Recycled Water Project. Total combined pumping in the Westside Basin for Scenario 3b is slightly less than Scenario 3a, because the total SFGW Project pumping in Scenario 3b would increase by 1.0 mgd, whereas the irrigation pumping that is replaced would be slightly more than 1.0 mgd.
- Scenario 4 - Cumulative Scenario: Scenario 4 represents the implementation of both the GSR and SFGW Projects (Scenarios 2 and 3b) along with other reasonably foreseeable future projects. The other foreseeable projects are discussed in more detail in TM-10.1, but primarily include the Daly City Vista Grande Drainage Basin Improvements Project

(which increases stormwater diversions into Lake Merced) and minor variations in irrigation pumping based upon the planned build-out of the Holy Cross cemetery.

Table 10.2-1 presents a summary of the estimated Basin-wide average pumping rates corresponding to each of the model scenarios. Note that in addition to the pumping by the proposed GSR and SFGW Project wells, average pumping rates are also provided for the PA wells and for irrigation and other non-potable uses in the Basin.

As discussed in TM-10.1, the strongest predictive capability of the Westside Basin Groundwater-Flow Model is its ability to forecast relative changes in water levels over time, rather than to estimate the absolute water levels. Therefore, it is more appropriate to analyze the results of the groundwater model using differences in water levels relative to a base case rather than absolute groundwater elevations. Scenario 1 represents the Existing Conditions and forms the base case against which the results for the GSR and SFGW Projects, and the Cumulative Scenario, are compared.

To allow for the model scenarios to be directly comparable, all five model scenarios are set up using similar initial conditions and background hydrology. All of the modeled scenarios have the same projected simulation period of 47.25 years and use initial groundwater conditions that represent June 2009 conditions. All five model scenarios use the same hydrologic sequence and include the 8.5-year Design Drought period used in the Program Environmental Impact Report (PEIR; SFPUC, 2007; SFPUC, 2009a). The Design Drought repeats the December 1975 to March 1978 drought period following the dry conditions of July 1987 to November 1992. To incorporate the Design Drought, the historical hydrological sequence was rearranged. A more detailed discussion of the development of the background hydrology is presented in TM-10.1.

The GSR-Only Scenario and the Cumulative Scenario (Scenarios 2 and 4) involve the SFPUC Storage Account, which is a book account tracking of the volume of groundwater stored in the Basin from in-lieu recharge during put periods minus the amount of groundwater pumped from the SFPUC Storage Account during take periods. As part of the initial conditions, the accrued volume in the SFPUC Storage Account at the start of the model scenarios is approximately 20,000 acre-feet (af) based on records of in-lieu exchange with the Partner Agencies prior to July 2009. During the Design Drought, the SFPUC Storage Account is taken from a full condition of 60,500 af to an empty condition of no in-lieu storage available at the end of the Design Drought. During the Recovery Period following the Design Drought, the scenarios include a 3-year put period that adds 20,000 af to the SFPUC Storage Account. Using this condition, the SFPUC Storage Account begins and ends with 20,000 af for both Scenarios 2 and 4. This allows for a more direct comparison while evaluating the long-term changes in groundwater levels and storage without having to factor in differences in the amount of in-lieu storage.

3.2. MODFLOW Model

The existing Westside Basin Groundwater-Flow Model (HydroFocus, 2007, 2009 and 2011) was used as one of the quantitative tools to evaluate the groundwater component of GW/SW interactions as a result of the GSR and SFGW Projects. The setup and results of the MODFLOW model scenarios are documented in TM-10.1.

A limitation of this MODFLOW model is that the groundwater model has difficulty in accurately simulating the absolute Lake Merced levels, although it is capable of reproducing the trends and relative changes seen in the available historical data. The model generally reproduces the lake levels and trends during the period from 1972 to 1995. During the first 14 years (1958 to 1972) and the last 13 years of the simulation (1996 - 2009), simulated lake levels were consistently 2 to 3 feet higher than measured lake levels, with differences as high as 7 feet (HydroFocus, 2011). Since the simulation of absolute lake levels was necessary for the analysis presented in this TM, the Lake Merced Lake-Level Model was used. The Lake-Level Model is described in the next section.

3.3. Lake Merced Lake Level Model

Because of the limitations of the MODFLOW model in simulating absolute Lake Merced levels, the assessment of the GW/SW interactions for Lake Merced utilizes the Lake Model. A more complete discussion of the development of the Lake Model is included in TM-10.1, Attachment 10.1-H. Below is a summary of the application of the model to the evaluation of Lake Merced for the GSR and SFGW Projects, and the Cumulative Scenario.

The Lake Merced Lake-Level Model is a spreadsheet-based water-balance that applies a rule-based approach for the water balance. Each water balance component is calculated independently. The model sums up the inflows and outflows from Lake Merced on a monthly time scale, and that sum represents the net change in water volume in the lake for that month. Based on this net change in water volume, a new lake level is calculated.

The Lake Merced Lake-Level Model was calibrated to historical lake levels over a 70-year period from October 1939 to June 2009 (Figure 10.2-7). This period includes a representative sample of hydrological conditions including wet, normal and dry precipitation years. Overall, the Lake Merced Lake-Level Model closely follows both long-term and short-term historical trends. Further details of the model and its development and adaption for use with the GSR and SFGW projects are discussed in TM-10.1, Attachment 10.1-H.

4. Lake Merced

This section provides a summary of the climatic, hydrological, and hydrogeological data representative of the physical setting of Lake Merced. Elevations for Lake Merced are typically reported using San Francisco City Datum (City Datum), which is 11.37 feet higher than NAVD88, and 8.62 feet higher than NGVD 1929 (LSCE, 2002). In other words 0.0 feet City Datum is equal to 11.37 feet NAVD88 and 8.62 feet NGVD 1929. Lake Merced lake levels are reported in City Datum for this TM.

4.1. Lake Merced Conditions

Lake Merced is a freshwater lake located in the southwestern corner of San Francisco approximately 0.25 mile east of the Pacific Ocean, and bounded by Skyline Boulevard, Lake Merced Boulevard, and John Muir Boulevard. Lake Merced is within the North Westside Groundwater Basin, just north of the San Francisco County-San Mateo County line (Figures 10.2-1 and 10.2-2).

4.1.1. Physical Setting

Lake Merced consists of four inter-connected lakes - North Lake, South Lake, East Lake and Impound Lake (Figure 10.2-2). North and East lakes are joined through a narrow channel and these lakes are separated from South Lake by natural or man-made barriers. A conduit between North and South lakes allows water to flow between the two lakes when the lake elevation in either lake is approximately 3.35 feet (City Datum) or higher. When lake levels drop below that elevation, the North and South lakes are separated and typically exhibit different elevations. When the lake elevation in the North and South lake is above 5.0 feet (City Datum), then water can flows between the two lakes. The South and Impound lakes are also partially separated by a low berm. Flow between the South and Impound Lakes is restricted below an elevation of approximately 4.3 feet (City Datum).

The only physical outlet from Lake Merced is an overflow structure, also known as spillway, near the midpoint of the southwestern side of South Lake at an elevation of 13 feet (City Datum). The spillway is a 30-inch-diameter pipe that connects to the existing Daly City Tunnel immediately downstream of the tunnel connection to the Vista Grande Canal. The estimated capacity for the overflow is approximately 400 cubic feet per second (cfs) in its current configuration (Kennedy/Jenks, 2009, Jacobs, 2011b).

Lake Merced is a major natural habitat for many species of waterfowl and other birds, and is a popular recreational venue offering fishing, boating, bicycling, and wildlife viewing opportunities. However, prior to the mid-1930s, Lake Merced was used as a potable water supply source for the City of San Francisco (City). After the City began receiving water from the Hetch-Hetchy Aqueduct system in 1935, Lake Merced became an emergency and irrigation water supply source only. In 1950, San Francisco Recreation and Parks District was given the authority to manage the lake for recreational and ecological purposes. In addition to these types of uses, Lake Merced continues to serve as an emergency non-potable water supply for the City and County of San Francisco (SFPUC, 2010).

4.1.2. Lake Merced Hydrology

Currently, Lake Merced is replenished primarily by direct precipitation on the lake surface, local runoff from the immediately surrounding land area, and shallow groundwater inflow. Because the portion of subsurface inflow has been reduced from historical rates, short-term lake levels are quite sensitive to annual changes in precipitation, and the lake is also slower to recover from drought conditions (LSCE, 2004).

Urbanization of the Basin has resulted in substantial reductions in the amount of surface water that previously flowed into Lake Merced. The original watershed that drained into Lake Merced is estimated at approximately 6,320 acres; however, the current watershed is estimated to be approximately 650 acres (SFSU, 2005; Pezzetti and Bellows, 1998). The current watershed is defined by the adjacent roadways, which include Lake Merced Boulevard, Skyline Boulevard, and John Muir Boulevard. Urbanization has obstructed natural springs and diverted stormwater runoff that historically was a major source inflow into Lake Merced. Most of these flows are now diverted away from the lake into the City’s combined wastewater system. The increase in impervious surfaces within the Basin (e.g., roads, parking lots, buildings) also has reduced the amount of recharge to the local shallow groundwater system, further reducing the amount of subsurface water contributions to Lake Merced (LSCE 2004, 2005a, 2005b; SFPUC 2009).

Historically, water additions and pumping have occurred in Lake Merced. Lake additions were water inflows to the lake typically from surface supplies, periodically done by SFPUC at the Lake Merced Pump Station to maintain or raise lake levels. Recorded additions were identified based on SFPUC records and previously reported data (LSCE, 2002). Other lake additions were known to have occurred in the past; however, the records for these events were not available. Similarly, pumping of water from the lake for golf course irrigation and other uses was known to occur; however, no records are available of the duration and extent of this pumping.

A more detailed discussion of Lake Merced conditions including a detailed water balance study of historical conditions is provided in TM-10.1, Attachment 10.1-H.

4.1.3. History of Lake Levels

Lake levels have generally been measured daily in South Lake since 1926. Figure 10.2-7 shows Lake Merced surface water levels, as measured at South Lake, over the historical period from 1939 to 2009. Prior to the beginning of Hetch-Hetchy aqueduct water delivery to San Francisco in 1935, lake levels typically ranged from elevations of 0 to -10 feet City Datum. In the late 1930s to early 1940s, lake levels increased to over 13 feet City Datum, which is the approximate elevation of the spillway, and thus the maximum controlled lake level.

Water levels in Lake Merced started to decline in the 1940s. During the 1940s to late 1950s, lake level elevations varied between 8 and 13 feet City Datum. Between the late 1950s and early 1980s, the lake experienced a long-term declining trend when levels ranged between

4 and 10 feet City Datum (Figure 10.2-7). Previous reports indicate that the reasons for the overall decline in lake levels during this period were drought, increased municipal groundwater pumping in the Basin, and increased urbanization that diverted stormwater into the City's combined sewer and stormwater system (Pezzetti and Bellows, 1998).

During the late 1980s and early 1990s, Lake Merced water levels declined well below the historical averages measured in the 1950s through early 1980s. A lake level of about -3.2 feet (City Datum) measured in 1993 was the lowest observed since the 1930s (Figure 10.2-7). It is understood that this decline was due to a combination of factors including reductions in the watershed area, the 1987-1992 drought, and regional and local groundwater pumping (Metcalf & Eddy, Inc. 2008).

Water levels in Lake Merced have been recovering steadily since 1993, with substantial rise during the wet winters of 1997 and 1998. As of June 2009, the lake level was approximately 5.7 feet City Datum (Figure 10.2-7). Water level increases over the last 15 years are attributed to a combination of factors, including several years with above average precipitation, SFPUC water additions to the lake between 2002 and 2005, reduced pumping by Lake Merced area golf courses as a result of recycled water deliveries, and reduced municipal pumping as part of the Pilot Conjunctive Use Study.

4.2. Groundwater-Surface Water Interactions

Lake Merced overlies the North Westside Basin, which is the northern portion of the greater Westside Groundwater Basin (Westside Basin). From north to south, the North Westside Basin underlies a portion of the Sunset District in San Francisco from Golden Gate Park to the San Francisco/San Mateo County line. From west to east, the North Westside Basin extends from the Pacific Ocean to inland bedrock exposures generally associated with Mount Sutro and Mount Davidson (LSCE, 2002, 2004).

Lake Merced is hydraulically connected to the unconfined Shallow Aquifer (LSCE, 2002, 2004). Previous hydrogeological investigation also provided some evidence that the surface of the lake is essentially an exposed part of the water table that defines the upper boundary of the Shallow Aquifer (Yates et al., 1990). Groundwater monitoring during the SFPUC's 2002 and 2003 water additions to Lake Merced further demonstrated that the shallow aquifer is in full hydraulic connection with Lake Merced (LSCE, 2004). During these events, 70 to 80 percent of the volume of water additions contributed to lake storage and the remaining 20 to 30 percent contributed to net outflow and evaporative losses during the water addition periods.

Currently, the direction of groundwater flow in the unconfined Shallow Aquifer is predominantly to the southwest; however, north of Lake Merced groundwater flow appears to be more westward toward the ocean (SFPUC, 2009b). Groundwater pumping in the South Westside Basin has resulted in a shift in the groundwater flow direction from northwesterly to southerly in the Lake Merced-northern San Mateo County area of the Westside Basin. The general groundwater flow direction in the deeper portion of the aquifer system (Primary Production Aquifer and Deep Aquifer) exhibits a more pronounced north to south flow direction than in the

Shallow Aquifer, likely due to greater pumping stresses in the deeper aquifer to the south. In addition, interpretation of deeper groundwater levels shows that the groundwater has a steeper gradient toward the pumping depression than the Shallow Aquifer (LSCE, 2002).

In 2009, an aquifer test was performed at the Lake Merced Pump Station (LMPS) Test Well located along the east shore of South Lake (note that this well is labeled as "Lake Merced Pump Station Well" on Figure 10.2-1). The LMPS Test Well is completed in the Primary Production Aquifer. The purpose of conducting the test was to characterize the yield of the LMPS Test Well and aquifer properties within the well's area of influence. Important conclusions derived from the aquifer test were that: 1) pumping and recovery responses in the LMPS Test Well and a nearby deep monitoring well (LMPS MW-440) (both completed in the Primary Production Aquifer) were consistent with a completely confined aquifer system; and 2), the Lake Merced / Shallow Aquifer system is unconfined and hydraulically separated from the pumped interval (within the Primary Production Aquifer) by multiple confining layers (LSCE, 2011). The results from the 2009 LMPS Test Well aquifer test substantiate the results of previous investigations which indicate that the Lake Merced / Shallow Aquifer system is, in the vicinity of Lake Merced, hydraulically isolated from the underlying Primary Production Aquifer system.

4.3. Daly City Vista Grande Drainage Basin Improvements Project

The City of Daly City prepared the Vista Grande Drainage Basin Alternatives Analysis to evaluate alternatives that would reduce or eliminate flooding, reduce erosion along Lake Merced, and provide other potential benefits such as habitat enhancement and lake level augmentation. The recommended program, known as the South Lake Merced Alternative, includes:

- Partial replacement of the existing Vista Grande Canal to incorporate a gross solid screening device;
- Construction of a treatment wetland, and diversion and discharge structure to route some stormwater (and authorized non-stormwater) flows from the Vista Grande Canal to South Lake Merced;
- Replacement of the existing Vista Grande Tunnel to expand the capacity and
- Replacement of the existing outfall structure at Fort Funston. (Jacobs Associates, 2011a, 2011b; City of Daly City, 2012).

For this analysis, the 75 cubic-feet-per-second (cfs) scenario of the Lake Merced Alternative of the Vista Grande Drainage Basin Alternatives Analysis (Jacobs Associates, 2011a, 2011b; City of Daly City, 2012) has been selected. The 75-cfs flow represents a minimum flow threshold (or cutoff volume) for diversions to Lake Merced. In other words, all flows in the Vista Grande Canal that are greater than or equal to 75 cfs would be diverted to Lake Merced (Brown and Caldwell, 2010). Flows of this magnitude are generally associated with stormwater discharges. Stormwater flows are calculated to occur in every year, and range from 19 to 681 afy with an average of 207 afy (Brown and Caldwell, 2010).

The Lake Merced Alternative scenarios also include provisions for an engineered wetland and modification of the Lake Merced spillway (Brown and Caldwell, 2010). In the 75-cfs scenario, the average baseflow in the Vista Grande Canal is assumed to be diverted into an engineered wetland for treatment and then discharge to Lake Merced on an ongoing basis. Baseflows have been estimated to range from 18 to 26 af per month (Kennedy/Jenks, 2009).With respect to the spillway modification, it is assumed that the spillway would be lowered from its existing elevation of 13 feet City Datum to 9.5 feet City Datum. This lower spillway elevation is used in the Cumulative Scenario (Scenario 4).

4.4. Lake Merced Model Results

For the analysis of GW/SW interactions, the Westside Basin Groundwater-Flow Model was used to evaluate groundwater conditions and derive the magnitude and direction of flux of groundwater-surface water interactions. This output from the Westside Basin Groundwater-Flow Model was used as an input to the Lake-Level Model. The Lake Level model was then used to evaluate absolute lake levels. This approach therefore takes advantage of the strengths of both models.

4.4.1. Model Descriptions

The Westside Basin Groundwater-Flow Model is a numerical (MODFLOW) groundwater model that has the capability to evaluate the effect of changes in groundwater pumping and other stresses on groundwater levels in the Lake Merced area. This model also has the capacity to calculate fluxes such as the flux between Lake Merced and groundwater. As described previously, because the model is regional and calibrated only to historical conditions, its strength lies in the assessment of relative (rather than absolute) changes.

The Lake-Level Model is a spreadsheet-based mass balance model that is used to evaluate changes in water levels of Lake Merced. MODFLOW treats Lake Merced as a boundary condition using the LAK3 package, which relies upon a mass balance approach to calculate lake levels. The Lake-Level Model uses a site-specific characterization of Lake Merced that is more complex and accurate than that used by the MODFLOW model. Some of the key advantages of the Lake-Level Model include the following:

- The model allows changes in the surface area of Lake Merced as a function of lake level (as based on measured bathymetry data). This is essential for an accurate simulation of absolute lake levels, because key water balance components (such as precipitation and evaporation) are dependent upon the lake surface area. These components are described as follows:
    - The precipitation input accounts for rainfall falling directly onto the lake. For example, during dry periods, when lake levels decline and portions of the lakebed may be exposed, the model simulates this precipitation as stormwater runoff, only a fraction of which actually reaches the lake.

- Evaporation is dependent on the surface area of the lake open to the atmosphere. For example, if lake levels decline, then the surface area also declines, and the overall evaporation losses also decline.

- The model dynamically simulates changes in lake volume. For example, at lower lake levels, the volume of the lake is smaller; therefore, the volume of water required to change the lake level by a certain amount is less than at higher lake levels.
- The Lake-Level Model includes a more complete evaluation of stormwater runoff than the Westside Basin Groundwater-Flow Model. The Lake-Level Model incorporates varied land surface types within the limited lake watershed area, including high runoff coefficients for the paved areas surrounding the lake.
- The Lake-Level Model accounts for flooding events resulting from overflows of the Vista Grande Canal. These are short-term, high-volume events that can substantially affect lake levels. There is a method for estimating overflows from flood events under existing conditions for the Vista Grande Canal used for Scenarios 1, 2, 3a and 3b, and a separate method for estimating stormwater inflows from the Vista Grande Drainage Basin Improvements Project for Scenario 4.
- The Lake-Level Model is superior to the Westside Basin Groundwater-Flow Model in simulating absolute historical lake levels (see TM-10.1).

The primary limitation of the Lake-Level Model is that the GW/SW interactions are based on assumptions of annual average groundwater flux into or out of Lake Merced. To address this limitation, the MODFLOW-calculated groundwater flux for Lake Merced was used. This flux is calculated on a monthly basis and dynamically incorporates the effects of changing groundwater levels. An earlier version of the Lake-Level Model used a generalized assumption for groundwater-surface water interactions, because the model was developed to support projects in which groundwater conditions were assumed to remain stable. For the GSR and SFGW Project scenarios, the groundwater levels are changing; therefore, a different approach was required. The use of the MODFLOW model results was considered a more reliable method than developing a new approach within the spreadsheet model. The combined approach therefore provides the best available analysis of the possible changes to Lake Merced water levels that could be attributed to the GSR and SFGW Projects.

A more detailed discussion of the Westside Basin Groundwater-Flow Model and the Lake-Level Model is provided in TM-10.1.

4.4.2. Model Analysis Approach

The results of the Lake-Level Model for each of the five model scenarios are shown on Figure 10.2-8 (absolute lake levels) and 10.2-9 (changes in lake level relative to Scenario 1). These figures show the changes in the elevation of Lake Merced over time. Each scenario is based upon a resequenced hydrology and includes the Design Drought (see TM-10.1).

Summary statistics for the simulated lake levels from the Lake-Level Model are provided in Table 10.2-2. These summary statistics provide another basis of comparison to evaluate the relative change from the Existing Conditions (Scenario 1) to the simulation results for Scenarios 2, 3a, 3b and 4. Additional statistical data are provided in Attachment 10.2-A. The summary statistics are:

- Lake Levels Assessment denotes the percentage of time that the simulated lake levels occur in the specified elevation bands. The percentage of time that the lake levels occur between 1 and 13 feet (City Datum) are calculated in 2-foot bands. The percentage for lake levels less than 1 foot (City Datum) is grouped into a single band.
- Monthly Lake Levels are presented for the entire simulation for the mean, 95 percentile and 5 percentile. These statistics provide a means to evaluate the average, upper and lower lake levels experienced during the simulation. Using the 95 and 5 percentile eliminates any short-term extremes and provides a more consistent method for comparison.
- Annual Range of Lake Levels is the difference between the maximum and minimum lake level for each water year (October to September) for the 47 full water years included in the simulation. The range provides a method to evaluate whether the lake level fluctuations during a water year vary due to the effects of the project.

The groundwater flux to Lake Merced as simulated by the MODFLOW model and incorporated into the Lake-Level Model is presented in Figures 10.2-10a and 10.2-10b. The Figure 10.2-10a shows the simulated flux values. Positive values represent groundwater flow into Lake Merced and negative values represent flow from Lake Merced to groundwater. These flux values show considerable seasonal and annual fluctuations. To facilitate the evaluation, the Figure 10.2-10b presents the groundwater flow relative to Scenario 1.

The evaluation of groundwater levels uses simulated groundwater levels from the Westside Basin Groundwater-Flow Model Layers 1 and 4 at selected monitoring well locations. The following four monitoring well clusters, representing different parts of Lake Merced (Figure 10.2-2), were selected to evaluate model-predicted changes in groundwater levels:

- LMMW-1 (Figure 10.2-11), located along the west shore of the South Lake
- LMMW-2 (Figure 10.2-12), located between the North and South Lakes
- LMMW-3 (Figure 10.2-13), located adjacent to the west shore of Impound Lake
- LMMW-4 (Figure 10.2-14), located north of North Lake

On each figure, the upper hydrograph shows model-simulated groundwater elevations in feet (NGVD 29), while the lower pane shows the difference between the groundwater levels of each scenario and those of Scenario 1. Positive differences indicate that a given project scenario has a higher groundwater elevation relative to Scenario 1, while negative results indicate that a given project scenario has a lower groundwater elevation relative to Scenario 1.

The following is a discussion of the results of the model analysis for the GSR and SFGW Project Scenarios and the Cumulative Scenario.

4.4.3. Scenario 1 – Existing Conditions

Scenario 1 represents a continuation of Existing Conditions without either the GSR or SFGW Projects, and defines the background conditions including wet, normal and dry precipitation years. As discussed in TM-10.1, the hydrologic sequence used for all scenarios includes the Design Drought from Scenario Years 36 to 44. Water levels in Lake Merced clearly respond to these climatic variations (Figure 10.2-8). Initially, the lake levels show a sharp increase representing a period of above-average precipitation during Scenario Years 1 to 4. The period from Scenario Years 4 through 16 shows a steady decline in lake levels to about 1.5 feet during a dry period (City Datum). From Scenario Years 16 to 36, lake levels fluctuate in response to climatic conditions but show an overall increasing trend and rise to over 11 feet (City Datum). During the Design Drought period from Scenario Years 36 to 44, lake levels decline sharply to a minimum value of -0.8 feet (City Datum). Following the Design Drought, the lake levels recover to about 5 feet (City Datum).

Summary statistics for simulated lake levels for Scenario 1 are presented in Table 10.2-2 to provide another basis of comparison to evaluate the simulation for Scenarios 2, 3a, 3b and 4. The mean monthly lake level for Scenario 1 is 6.3 feet (City Datum) with an upper and lower lake level represented by the 95 and 5 percentile as 11.3 feet and 1.1 feet (City Datum). Lake levels occur below 3 feet (City Datum) about 13 percent of the simulation period for Scenario 1. The mean annual range of lake levels is 1.6 feet.

In the Lake Merced area, these climatic variations are seen more clearly in simulated groundwater levels in Model Layer 1 for all four locations (Figures 10.2-11 to 10.2-14), whereas groundwater levels in Model Layer 4 show less variability. Groundwater levels are generally higher for locations to the north and lower for locations to the south, which is characteristic of the Westside Basin. This pattern reflects the influence of groundwater pumping in the South Westside Basin. For Lake Merced, this means that there is a higher net outflow of lake water to groundwater in the South and Impound Lakes and more inflow of groundwater to Lake Merced in the North and East Lakes.

Figure 10.2-10a shows the flux of groundwater to Lake Merced based on the MODFLOW model. The overall pattern indicates that the GW/SW interaction is strongly influenced by the climatic conditions used for the simulation. The climatic conditions result in positive net flux for higher precipitation periods showing a net inflow of groundwater to Lake Merced. During the lower precipitation periods, the flux has negative values for a net loss of lake water to groundwater in response to groundwater level declines.

4.4.4. Scenario 2 – GSR Project

Scenario 2 represents the operation of the GSR Project, which is located in the South Westside Basin. The GSR Project contains put periods when in-lieu groundwater storage occurs with minimal pumping by SFPUC or the PAs, hold periods with no in-lieu recharge and normal pumping by the PAs and a full SFPUC Storage Account, and take periods when there is combined pumping by SPFUC and the PAs and no in-lieu recharge. The pumping assumptions used for the GSR Project are presented in Table 10.2-1, with further details provided in TM-10.1.

The level of Lake Merced under Scenario 2 shows a similar pattern of response to climatic variations as Scenario 1 (Figure 10.2-8). Lake levels increase by about 5 feet as compared to Scenario 1 during Scenario Years 1 through 10 (Figure 10.2-9). Under Scenario 2, the relative difference remains at about 5 feet higher than Scenario 1 until the start of the Design Drought in Scenario Year 36. There are two take periods from Scenario Years 10 through 36. Relative to Scenario 1, there is little change in Lake Merced lake levels in response to those take periods. During the Design Drought with 7.5 years of pumping by both SFPUC and the PAs, lake levels drop to their lowest level of -2.5 feet (City Datum), which is less than 1 feet lower than the lowest lake level for Scenario 1 at the end of the Design Drought period (Figure 10.2-8).

During the put period following the Design Drought, the lake levels rise to about 1 foot (City Datum), but the rise in lake levels for Scenario 2 is less than for Scenario 1. At the end of the simulation, the Scenario 2 lake-levels are about 4 feet lower compared to Scenario 1. The interpretation of this response is that the aquifer is taking time to recover from the combined (SFPUC and PA) pumping, which results in lower groundwater levels and slows down the recovery of Lake Merced as well. Additional discussion on the effects of Scenario 2 on regional groundwater levels is provided in TM10.4.

Table 10.2-2 provides summary statistics for lake levels for Scenario 2, and additional statistical data are provided in Attachment 10.2-A. The monthly mean lake level over the simulation period is 9.1 feet (City Datum), which is 2.8 feet higher than the mean level for Scenario 1. Lake levels occur below 3 feet (City Datum) about 2 percent of the simulation period for Scenario 2. This is a lower percentage than in Scenario 1 (where low lake levels occur for 13 percent of the simulation period).

In the Lake Merced area, the effects of GSR Project pumping are clearly seen in groundwater levels in the Primary Production Aquifer (Model Layer 4), whereas groundwater levels in the Shallow Aquifer (Model Layer 1) show more fluctuation related to climatic conditions (Figures 10.2-11 to 10.2-14). There are also variations from north to south across Lake Merced. In the Shallow Aquifer (Model Layer 1), groundwater levels following the Design Drought at the LMMW-3 location (Figure 10.2-13a) are about 10 feet lower than those at LMMW-4 (Figure 10.2-14a) to the north. In the Primary Production Aquifer (Model Layer 4), groundwater levels following the Design Drought at the LMMW-3 location (Figure 10.2-13b) are about 35 feet lower than those at LMMW-4 (Figure 10.2-14b) to the north. The effects of GSR Project pumping are more clearly evident in the southern locations. These include effects in both the Shallow and Primary Production Aquifers. The northern locations show little effect of GSR Project pumping upon the Shallow Aquifer and only a minor response in the Primary Production Aquifer.

Figure 10.2-10b shows the simulated net flux of groundwater to Lake Merced. In comparison to Scenario 1, a higher net inflow of groundwater into Lake Merced is estimated under Scenario 2 for Scenario Years 1 through 38 (Figure 10.2-10b). However, early through the Design Drought period, the response switches to a higher net outflow of groundwater from Lake Merced into the aquifer. This is interpreted as the lake responding to the lower groundwater conditions caused by the operation of the GSR Project with both the GSR and PA wells operating throughout the Design Drought.

4.4.5. Scenarios 3a and 3b – SFGW Project

Scenarios 3a and 3b simulate the operation of the SFGW Project, which is located in the North Westside Basin. The pumping assumptions used for Scenarios 3a and 3b are presented in Table 10.2-1. Scenario 3a assumes 1.142 mgd of irrigation pumping in Golden Gate Park and 3.0 mgd of pumping for municipal water supply throughout the North Westside Basin. Scenario 3b assumes 4.0 mgd of pumping for municipal water supply, and replacing irrigation pumping in Golden Gate Park with recycled water. In comparison to Scenario 3a, Scenario 3b assumes 0.142 mgd less pumping overall. Because of this minor change in pumping, the regional response of groundwater levels to these scenarios is very similar; therefore, the results for Scenarios 3a and 3b are discussed together.

During Scenario Years 1 and 2, Lake Merced levels tend to track those of Scenario 1. Afterwards, however, the level of Lake Merced clearly shows the effects of increased pumping in the North Westside Basin from the SFGW Project (Figure 10.2-8). The change in Lake Merced levels relative to Scenario 1 shows a steady decrease during Scenario Years 3 through 15 for both Scenarios 3a and 3b (Figure 10.2-9). However, during Scenario Years 15 through 44 (when the lake levels in Lake Merced vary in response to climatic conditions), there is an approximately stable difference (of about 9 to 10 feet) between the lake levels simulated in Scenarios 3a and 3b and those simulated in Scenario 1. During Scenario Years 44 to the end of the simulation, the lake levels for Scenarios 3a and 3b recover faster than Scenario 1, but the lake levels are still about 7 feet lower than in Scenario 1 (Figure 10.2-9). However, this faster recovery is due Lake Merced having a substantially smaller surface area at lower lake levels. This is incorporated into the Lake-Level Model so that an equal volume of water added to Lake Merced would result in a greater lake level rise because the volume of the lake is substantially smaller when the lake level is low. Additional information is included in TM10.1-Attachment 10.2-H, which provides more detail on the construction of the model.

Table 10.2-2 provides summary statistics for lake levels for Scenarios 3a and 3b, and additional statistical data are provided in Attachment 10.2-A. For Scenario 3a, the mean lake level over the simulation period is -1.3 feet (City Datum), which is 7.6 feet lower than the mean level for Scenario 1. Lake levels occur below 3 feet (City Datum) about 83 percent of the simulation period for Scenario 3a, as compared to only 13 percent for Scenario 1. For Scenario 3b, the monthly mean lake level over the simulation period was -1.9 feet (City Datum), which is 8.2 feet lower than the mean level for Scenario 1. Lake levels below 3 feet (City Datum) occur for about 85 percent of the simulation period for Scenario 3b.

In the Lake Merced area, the effects of the SFGW Project pumping are observed in groundwater levels in both the Shallow and Primary Production Aquifers (Model Layers 1 and 4) (Figures 10.2-11 to 10.2-14). There are also variations from north to south across Lake Merced.

In the Shallow Aquifer (Model Layer 1), groundwater elevations following the Design Drought at the LMMW-3 location (Figure 10.2-13a) are about 10 feet lower than those at LMMW-4 (Figure 10.2-14a) to the north. In the Primary Production Aquifer (Model Layer 4), groundwater elevations following the Design Drought at the LMMW-3 location (Figure 10.2-13b) are about 40 feet lower than those at LMMW-4 (Figure 10.2-14b) to the north. The groundwater levels at the LMMW-3 location (Figures 10.2-13b) in Model Layer 4 are substantially lower than those at the LMMW-4 location (Figures 10.2-14b) to the north. This reflects the proximity of the LMMW-3 location to the SFGW Project well at the Lake Merced Pump Station.

Figure 10.2-10b shows the net flux of groundwater to Lake Merced. Comparing Scenarios 3a and 3b to Scenario 1 with respect to groundwater flux (Figure 10.2-10b), it can be seen that there is a higher net outflow from Lake Merced to groundwater under Scenarios 3a and 3b relative to Scenario 1. This relative difference is greatest near the beginning of the simulation; however, as the simulation continues, this difference gradually diminishes during the remainder of the simulation. During the Design Drought, the groundwater flux in Scenarios 3a and 3b is similar to that of Scenario 1. As the relative difference in net outflow diminishes, the relative difference between simulated lake levels for Scenarios 3a and 3b and Scenario 1 becomes consistent as well (Figure 10.2-9).

4.4.6. Scenario 4 – Cumulative Scenario

Scenario 4 represents the combined operations of the GSR and SFGW Projects along with other reasonably foreseeable future projects. Scenario 4 uses the same pumping assumptions as Scenario 2 for the GSR Project and Scenario 3b for the SFGW Project. The most pertinent foreseeable future project for Lake Merced is the Daly City Vista Grande Drainage Basin Improvements Project, which is described in Section 4.3. For reference, the key features of this project are repeated as follows:

- Lowering of the existing spillway elevation from 13 feet City Datum to 9.5 feet City Datum.
- Diversion of all Vista Grande Canal stormwater flows in excess of 75 cfs directly into Lake Merced. These flows generally range from 19 to 681 afy with an average of 207 afy (Brown and Caldwell, 2010).
- Diversion of Vista Grande Canal baseflow through an engineered wetland (for treatment prior to discharge) and into Lake Merced. Baseflows were estimated to range from 18 to 26 af per month.

The water levels of Lake Merced for Scenario 4 show a similar pattern to Scenario 2 (GSR Project) but are consistently 2 to 4 feet lower due to the effects of SFGW Project pumping (Figure 10.2-8). Relative to Scenario 1 (Figure 10.2-9), the lake levels are generally within 3 feet higher or lower than Scenario 1 until Scenario Year 44 (the end of the Design Drought). For Scenario Years 44 to the end of the simulation, the lake levels are about 4 to 5 feet lower than Scenario 1. This is a similar pattern to that observed for Scenario 2. During the Design Drought, the lake levels under Scenario 4 drop to -4.9 feet (City Datum); this value is 4.1 feet lower than the lowest lake level under Scenario 1.

The lowering of the spillway level to 9.5 feet (City Datum) has an effect on the long-term lake levels for Scenario 4, resulting in a loss of storage in the lake such that there is less water available in the lake at the beginning of drought periods. However, this is somewhat counteracted by the inflow of stormwater from the Vista Grande Canal, which augments the volume of water in the lake.

Table 10.2-2 provides summary statistics for lake levels for Scenario 4, and additional statistical data are provided in Attachment 10.2-A. The monthly mean lake level over the simulation period is 6.1 feet (City Datum), which is 0.2 feet lower than the mean level for Scenario 1. Lake levels occur below 3 feet (City Datum) about 16 percent of the simulation period for Scenario 4, as compared to 13 percent for Scenario 1.

In the Lake Merced area, the groundwater levels tend to parallel those of Scenario 2 but at an elevation that is about 2 to 4 feet lower (Figures 10.2-11 to 10.2-14). The difference in groundwater levels varies from north to south across Lake Merced. Groundwater levels in the LMMW-3 location (Figures 10.2-13ab) are lower than those for LMMW-4 (Figures 10.2-14ab) to the north. However, the difference relative to Scenario 2 is greater in the northern locations. This is because of SFGW Project pumping.

Figure 10.2-10b shows the net flux of groundwater to Lake Merced. A higher portion of the net outflow from Lake Merced to the groundwater is estimated under Scenario 4 than in Scenario 1 throughout the simulation period. This is due to the continuous augmentation of stormwater and baseflow from the Vista Grande Canal to Lake Merced. With the increase in lake levels, the net outflow is a natural process that equilibrates the shallow groundwater levels with Lake Merced. Scenario 4 therefore has a distinctly different pattern of groundwater flux than that observed in the other scenarios.

4.5. Summary

This section summarizes the results of the evaluation of groundwater-surface water interaction based on the modeling analysis using the Lake-Level Model and the Westside Basin Groundwater-Flow model.

Scenario 2 (GSR Project) generally results in higher lake levels than Scenario 1 for most of the simulation period. During the Design Drought (in which the extended period of pumping from SFPUC and PA wells occurs over a 7.5-year take period), the simulated lake levels for Scenario 2 are below those of Scenario 1 toward the end of the Design Drought period. The lowest lake level estimated under Scenario 2 is -2.5 feet (City Datum) toward the end of the Design Drought period, which is similar to the lowest historical lake level of -3.2 (City Datum) experienced in 1993.

Scenarios 3a and 3b (SFGW Project) result in lake levels that are substantially lower than Scenario 1 for the entire simulation period. Lake levels decline during the first approximately 15 years of operation of the SFGW Project. During the final approximately 30 years of the simulation, lake levels are consistently about 10 feet lower than the Existing Conditions Scenario. The lowest lake levels for Scenario 3a and 3b are about 7 feet lower than the lowest historical lake level experienced in 1993 of -3.2 feet (City Datum).

Scenario 4 (Cumulative Scenario) includes operation of the GSR and SFGW Projects using the assumptions of Scenario 2 and 3b. In addition, other reasonably foreseeable future projects such as the Daly City Vista Grande Drainage Basin Improvements Project, are included. This Project would augment Lake Merced with stormwater and baseflow from the Vista Grande Canal. The result of the Cumulative Scenario is that the simulated lake levels are similar to Scenario 1. They also tend to mimic the pattern from Scenario 2 (GSR Project) but at a lower elevation (by about 3 to 4 feet) as a result of SFGW Project pumping. The lowest lake level under Scenario 4 is -4.9 feet (City Datum), which is about 1.5 feet lower than the lowest historical lake level experienced in 1993.

5. Pine Lake

Pine Lake, also known as Laguna Puerca, is located about 0.5 mile north-northeast of Lake Merced in the westernmost portion of the Stern Grove and Pine Lake Park (Figures 10.2-1 and 10.2-2).

5.1. Physical Setting and Lake Conditions

Pine Lake is a relatively shallow lake that is approximately 3.4 acres in area. It has been used only for recreational purposes and has never served as a water supply source. Records related to historic conditions and lake levels in Pine Lake are sparse until the past 10 to 15 years. In November 2004, the lake level was reported to be very low, at an elevation of 33.5 feet (NGVD 29; 24.9 feet City Datum). The design water level elevation for Pine Lake was established at 40.1 feet (NGVD 29, or 31.5 feet City Datum; SFDPW, 2005b), which is about 4 feet higher than average historic lake levels and about 7 feet higher than the lake level in 2004.

Pine Lake has changed physically over time. It is reported that in the 1930s, about one third of the total lake area at its eastern end was filled in to accommodate additional park development. Pine Lake has also become shallower over time. In the early 1900s the depth of the lake was reportedly around 20 feet; during the period of low lake levels in the early 2000s, maximum lake depths were only 7 to 8 feet (SFDPW, 2001; Bennett Consulting Group, 2005). The historic shallowing of Pine Lake was attributed to a combination of long-term sedimentation and local declines in groundwater levels (Pilat, 2002). It is also likely that intense urbanization in the area surrounding Pine Lake reduced the amount of natural inflow to the lake.

To address declining water level and ecological issues in Pine Lake, during the past decade SFRPD conducted studies and capital improvement projects. As part of a capital improvement project completed in 2007 (Pine Lake and Pine Lake Meadow Improvement Project), SFRPD performed substantial water quality and habitat upgrades at Pine Lake. The improvements included the eradication of invasive plants, which were replaced with native vegetation, installation of a new pump in the Stern Grove well, and construction of a 6-inch diameter pipe from the well to an outlet channel that drains to Pine Lake.

Lake levels in Pine Lake currently are maintained by adding groundwater from the nearby 270-foot-deep Stern Grove well. Based on discussions with the well's operator, the Stern Grove Well is operated for 24 hours at a time with a pumping rate of about 270 gpm. The well is operated about 3 to 4 times each year to maintain the Pine Lake design water level. At that pumping rate and operational period, the total volume of groundwater added annually to Pine Lake to maintain the water level is approximately 4.8 acre-feet. At the design lake level, Pine Lake would be about 10 to 12 feet deep under the current lakebed configuration. The San Francisco Recreation and Park Department (SFRPD) will continue groundwater pumping from the rehabilitated Stern Grove well as part of a long-term program to augment water levels in Pine Lake (SFRPD, 2010, LSCE, 2010).

5.2. Groundwater Conditions near Pine Lake

Pine Lake overlies the Shallow Aquifer, which in this area comprises the upper portion of the Colma Formation. Groundwater levels measured in monitoring well LMMW-5S, which is located near the western end of Pine Lake, have consistently been about 6 to 7 feet bgs over the past ten years or so. Generally, lake levels are slightly higher than nearby groundwater levels due to the ongoing additions to the lake from the Stern Grove well. The 270-foot-deep Stern Grove well pumps groundwater from below the clay aquitard that forms the base of the Shallow Aquifer (LSCE, 2010); therefore, pumping from the well is not considered to directly affect groundwater levels near the lake.

Groundwater levels around Pine Lake are monitored in wells LMMW-5SS and LMMW-5S. LMMW-5SS is a shallow well completed between 38 and 48 ft bgs, designed to evaluate the shallow sediments near the lake. LMMW-5S is completed between 65 and 85 ft bgs, and was designed to evaluate groundwater levels in the Shallow Aquifer. Groundwater level data are available from both of these wells since 2002 (SFPUC, 2009a, 2011). Reviewing these data indicates that:

- Groundwater elevations in LMMW-5SS typically range between 37 to 40 feet (NGVD 29); however, during a period of low levels in Pine Lake, groundwater levels declined to about 33 feet. Since 2008, groundwater levels have varied between 38 and 40 feet (NGVD 29). Variations in groundwater elevations measured in LMMW-5SS appear to closely approximate changes in lake levels in Pine Lake.
- Groundwater elevations in LMMW-5S have ranged from 31 to 36 feet (NGVD 29), but show a trend over time. From 2002 to 2006, groundwater levels in LMMW-5S varied within a narrow range of 31 to 33 feet (NGVD 29). Groundwater levels steadily rose by about 2 feet from 2006 to 2008. From 2008 to 2010, groundwater levels varied within a narrow range of 35 to 36 feet (NGVD 29).
- Groundwater elevations in LMMW-5SS have typically been about 1 to 4 feet higher than elevations observed in LMMW-5S.

In November 2004, SFRPD performed a test filling of the lake using groundwater from the Stern Grove well (SFDPW, 2005a, Bennett Consulting, 2005). The purpose of the test filling was to raise the lake level from 33.5 feet (NGVD 29; 24.9 feet City Datum) to 40.1 feet (NGVD 29; 31.5 feet City Datum). It was anticipated that it would take up to 15 days of pumping at 400 gpm to fill the lake to the desired level to compensate for losses to groundwater. Instead, lake levels rose to 1.15 feet over the desired level with only 8 days of pumping from the Stern Grove well. The total volume of groundwater added to the lake was about 14 acre-feet. During the test period, there were additional unquantified inflows into Pine Lake from precipitation and runoff.

Based on the results of this test filling project, there was less groundwater loss resulting from lake additions than was anticipated, and it was determined that levels in Pine Lake could be maintained at 40.1 feet (NGVD 29, or 31.5 feet City Datum) by periodic additions from the Stern Grove well.

During the lake-filling test, groundwater levels in well LMMW-5SS rapidly rose about 5 to 6 feet and leveled out at 40.2 feet (NGVD 29; 31.6 feet City Datum), near the level in Pine Lake. In well LMMW-5S, groundwater levels rose less than 1 foot during the test, and were about 8 feet lower than the lake level in Pine Lake at the end of the test.

The groundwater response to the lake-filling operations indicates that Pine Lake is well-connected to the shallowest groundwater near the lake (LMMW-5SS). Based on the groundwater responses and the ability to sustain levels in Pine Lake during the test filling, it appears that the shallowest groundwater, which is monitored by LMMW-5SS, seems to be in good hydraulic communication with Pine Lake. Lower groundwater elevations measured in LMMW-5S suggest that direct hydraulic communication of deeper parts of the Shallow Aquifer with Pine Lake may be limited. This limitation may be due to a geologic restriction such as the presence of shallow clay layers that are sufficiently extensive (laterally and vertically); however, insufficient data are available to confirm this interpretation. Limited hydraulic communication with the Shallow Aquifer is consistent with observations that water from the Stern Grove well is only required a few times per year to maintain levels in Pine Lake. If good hydraulic communication were established with the portion of the Shallow Aquifer represented by the groundwater elevations monitored in LMMW-5S, it would be difficult to maintain lake levels in Pine Lake without substantially more water from the Stern Grove well than has been used historically (SFRPD, 1994, 2010). Groundwater levels in the Shallow Aquifer suggest possible groundwater mounding beneath the lake due to leakage from the overlying sediments, but this leakage appears to be rate limited, likely due to the presence of a low-permeability layer.

5.3. Pine Lake Water Balance

To help evaluate the potential effects on Pine Lake water levels resulting from SFGW Project implementation, a water balance assessment of Pine Lake was performed. The purpose of the assessment was to evaluate whether the amount of additional pumping assumed for the Stern Grove well to maintain the water level in Pine Lake at elevation 40.2 feet (NGVD 29, or 31.5 feet City Datum) during operation of the SFGW Project was adequate based on the changes in groundwater elevations from the results of the MODFLOW model.

Under the conceptual model for Pine Lake, inflows are primarily precipitation, stormwater runoff and lake additions from the Stern Grove well, while outflows are primarily evapotranspiration and groundwater outflow. Because of the sparse availability of historical data, the water balance incorporated the results of the test filling operations (SFDPW, 2005a; Bennett Consulting, 2005).

During the operation of the SFGW Project, groundwater pumping in the North Westside Groundwater Basin is expected to lower groundwater levels in the Shallow Aquifer in the Pine Lake area. The water balance provides a means for estimating the additional volume of groundwater necessary to maintain Pine Lake under these conditions. The difference between the total inflow to and total outflow from Pine Lake was considered to represent the volume of groundwater needed from the Stern Grove well to maintain lake levels. Assumptions for the volume of pumping from the Stern Grove well used for the model scenarios are based on the water balance discussed above, and are shown on Table 10.2-1. In summary, these include:

- Under the Existing Conditions and GSR-Only Scenarios (1 and 2, respectively), pumping from the Stern Grove well needed to maintain lake levels in Pine Lake is estimated at 0.0043 mgd (4.8 afy). At the given operational rate and duration of approximately 270 gpm for 24 hours to fill the lake, lake filling is expected to occur about 4 times per year on average.
- For Scenario 3a, the amount of Stern Grove well pumping needed was 0.012 mgd (13.6 afy), which represents an increase of 0.008 mgd (8.8 afy) over the results for Scenario 1.
- For Scenarios 3b and 4, Stern Grove well pumping increased to 0.013 mgd (14.8 afy), which represents 0.009 mgd (10 afy) more pumping than under Scenario 1.

For the water balance assessment, some simplifying assumptions were applied. Since all the scenarios use the same background hydrology, the water balance components for precipitation, stormwater runoff, and evapotranspiration are unchanged between scenarios. Therefore, the differences between scenarios are related solely to changes in groundwater-surface water interactions.

Under the Existing Conditions Scenario (Scenario 1), we assumed that the pumping from the Stern Grove well needed to maintain lake levels in Pine Lake would be about 0.0043 mgd (4.8 afy) based on current operations (SFRPD, 2010). From the MODFLOW model, the average groundwater elevation for LMMW-5S is 33.24 feet (NGVD 29), which is 7.0 feet below the maintained Pine Lake lake-level of 40.2 feet (NGVD 29).

To determine the groundwater outflow from Pine Lake, a Darcy's Law approximation was applied. For this approximation, it is assumed that the hydraulic conductivity and cross sectional area of the lake are the same for all scenarios. Therefore, the change in groundwater discharge from Pine Lake is directly proportional to the change in groundwater gradient in the aquifer underneath the lake. The results of this assessment include:

- For Scenario 2, LMMW-5S had an average groundwater elevation of 35.6 feet (NGVD 29), which is 4.6 feet below the maintained Pine Lake level. Scenario 2 has higher groundwater levels in LMMW-5S than Scenario 1. Proportional to Scenario 1, Scenario 2 requires about 66% of the pumping from the Stern Grove well to maintain lake levels in Pine Lake as was required for Scenario 1. Estimated water needed to maintain lake levels is 0.0028 mgd (3.2 afy) for Scenario 2.
- For Scenario 3a, LMMW-5S had an average groundwater elevation of 20.7 feet (NGVD 29), which is 19.5 feet below the maintained Pine Lake level. Scenario 3a has lower groundwater levels in LMMW-5S than Scenario 1. Proportional to Scenario 1, Scenario 3a requires about 280% of the pumping from the Stern Grove well to maintain lake levels in Pine Lake as was required for Scenario 1. Estimated water needed to maintain lake levels is 0.0120 mgd (13.5 afy) for Scenario 3a.

- For Scenario 3b, LMMW-5S had an average groundwater elevation of 21.2 feet (NGVD 29), which is 19.0 feet below the maintained Pine Lake level. Scenario 3b has lower groundwater levels in LMMW-5S than Scenario 1. Proportional to Scenario 1, Scenario 3b requires about 270% of the pumping from the Stern Grove well to maintain lake levels in Pine Lake as was required for Scenario 1. Estimated water needed to maintain lake levels is 0.0117 mgd (13.1 afy) for Scenario 3b.
- For Scenario 4, LMMW-5S had an average groundwater elevation of 26.5 feet (NGVD 29) which is 13.7 feet below the maintained Pine Lake level. Scenario 4 has higher groundwater levels in LMMW-5S than Scenario 1. Proportional to Scenario 1, Scenario 4 requires about 200% of the pumping from the Stern Grove well to maintain lake levels in Pine Lake as was required for Scenario 1. Estimated water needed to maintain lake levels is 0.0085 mgd (9.5 afy) for Scenario 4.

Based on this analysis, the pumping assumptions used for the MODFLOW model for the Stern Grove Well are appropriate and conservative with respect to the volume of water needed to maintain lake levels at Pine Lake. The Stern Grove well is currently, and will continue to be, dedicated to maintaining the design water level in Pine Lake using groundwater pumped from the Primary Production Aquifer.

5.4. Groundwater Model Results

The Westside Basin Groundwater-Flow Model does not simulate Pine Lake as a discrete lake feature, nor does it explicitly account for the addition of groundwater pumped from the Stern Grove well to Pine Lake (HydroFocus, 2007, 2009, 2011). As discussed in Section 5.3, additional pumping from the Stern Grove well to maintain the Pine Lake water level is incorporated into the model assumptions. The Groundwater Model does simulate changes in the groundwater levels in the Shallow Aquifer beneath Pine Lake based on the effects of the GSR and SFGW Projects; however, it does not have the ability to simulate groundwater levels in the shallowest sediments (monitored by LMMW-5SS) which have been shown to be in good hydraulic communication with Pine Lake (Section 5.2). Consequently, the model cannot be used to evaluate specific changes in water levels in Pine Lake, or in seepage of lake water to the Shallow Aquifer, that might result from SFGW Project implementation.

However, it was possible to use the simulated groundwater levels for LMMW-5S to evaluate the general changes in groundwater conditions in the Shallow Aquifer during the simulation. Figure 10.2-15 shows hydrographs for the LMMW-5S location in Model Layer 1 for all five modeled scenarios. The upper figure pane shows absolute simulated groundwater levels (absolute hydrographs), whereas the lower pane depicts groundwater levels relative to Scenario 1 (relative hydrographs).

The relative hydrograph for Scenario 2 shows a general increase in groundwater levels of up to several feet at the LMMW-5S location over those of Scenario 1, until near the very end of the simulation period, when there is a very slight reduction below Scenario 1 levels after the Design Drought period. The absence of any extended periods of reduced groundwater levels illustrates that there is anticipated to be little to no effect of GSR Project pumping on groundwater levels in the Shallow Aquifer (Model Layer 1) in the portion of the Westside Basin near Pine Lake.

Implementation of the SFGW Project (Scenarios 3a and 3b) is expected to result in a relative decline in Shallow Aquifer groundwater levels near Pine Lake of about 15 to 16 feet by the end of the simulation period. For Scenario 4, the Shallow Aquifer relative decline is about 10 feet by the end of the simulation period. The higher groundwater levels under Scenario 4 than in Scenarios 3a and 3b represent the effects of the GSR Project in-lieu recharge operations in addition to increased groundwater recharge resulting from additions to Lake Merced from the Daly City Vista Grande Drainage Basin Improvements Project.

The lower groundwater levels simulated in the Shallow Aquifer during Scenarios 3a, 3b, and 4 are expected to increase the leakage rate from the shallowest sediments surrounding Pine Lake, but this would potentially be offset by the possible geologic control that limits the connection between the lake and the Shallow Aquifer (Section 5.2). Therefore, addition of groundwater from the Stern Grove well to Pine Lake is anticipated to successfully maintain water levels in Pine Lake at the desired lake level during operation of the SFGW Project and under the Cumulative Scenario.

5.5. Summary

Under the conceptual model for Pine Lake, inflows are primarily precipitation, stormwater runoff, and additions to the lake from the Stern Grove well. Outflows are primarily evapotranspiration and groundwater outflow. The nature of the interactions between the lake and the connected aquifer is principally outflow from the lake to the aquifer, as maintained lake levels are typically higher than groundwater levels. As discussed above, Pine Lake shows strong hydraulic communication with the shallowest sediments (monitored by LMMW-5SS), but does not appear to be in direct hydraulic communication with the Shallow Aquifer (monitored by LMMW-5S). However, there is evidence of groundwater mounding in the Shallow Aquifer, indicating a steady, but rate-controlled, leakage of groundwater from Pine Lake to the Shallow Aquifer via the shallowest sediments.

For the SFGW-Only and Cumulative Scenarios (3a, 3b, and 4), groundwater levels in the Shallow Aquifer beneath Pine Lake are projected to decline by approximately 10 to 16 feet relative to Scenario 1 (see Figure 10.2-15). Based on the conceptual model, these projected declines in shallow groundwater levels are anticipated to have the potential to increase groundwater leakage from Pine Lake. However, levels in Pine Lake are already maintained by additions of groundwater from the Stern Grove well, and this well is expected to continue to be dedicated to maintaining the design water level in Pine Lake in the future.

Groundwater levels in the Shallow Aquifer for the GSR-Only Scenario (2) are projected to be similar to or slightly higher than under Existing Conditions (Scenario 1). Therefore, operation of the GSR Project is not expected to affect levels in Pine Lake, or to lead to any change in lake additions operations from the Stern Grove Well.

6. Golden Gate Park Lakes

Golden Gate Park (GGP) is located along the northernmost extent of the North Westside Basin (Figure 10.2-1). Located within GGP are twelve lakes or ponds: Stow Lake, Spreckels Lake, North Lake, Lily Pond, Lloyd Lake, Elk Glen Lake, Metson Lake, Mallard Lake, South Lake, Middle Lake, Alvord Lake and Rainbow Falls Bowl. The locations of these lakes are shown on Figure 10.2-3.

6.1. Physical Setting and Lake Conditions

The GGP lakes provide a multitude of benefits, including wildlife habitat, recreation, and ornamental purposes. The largest GGP lakes are Stow, Spreckels, and North lakes, with approximate surface areas of 13, 6, and 4 acres, respectively. The other lakes range from about 0.5 to 2 acres in area (SFRPD, 1994). Alvord Lake and Rainbow Falls Bowl are both very small, with paved bottoms and containing fountains or falls, and are more properly water features than lakes.

The GGP lakes are mostly manmade or, in some cases, were drastically altered from pre-existing natural conditions. Approximately 100 years ago the man-made GGP lakes were excavated into the existing shallow soils. Elk Glen, Middle, and North lakes are believed to have originally been natural groundwater-fed ponds that were deepened, whereas the other lake locations may or may not have coincided with pre-existing natural surface water features.

The GGP lakes, with the exception of Elk Glen Lake, were constructed to be very shallow, with original depths generally less than 5 feet. As sediment has accumulated on their bottoms, the GGP lakes have become even shallower, on average by about 1 foot by 1994 (although the north portion of North Lake was deepened in 1990 to about 9 to 10 feet). The shallow GGP lakes are very susceptible to excessive algal growths that have substantial negative impacts on lake water quality (SFRPD, 1994).

It was recognized prior to construction that, with groundwater levels below the bottoms of the lakes, the lakes would likely go dry due to leakage to the aquifer. To minimize this potential leakage, most of the lakes were constructed with bottoms of gravelly clay. Lily Pond did not require this addition of material because it was an old shale quarry, and therefore possessed a natural gravelly clay bottom that already minimized leakage. The three lakes that were originally natural groundwater-fed ponds (Elk Glen, Middle, and North lakes) have been confirmed to be unlined.

A 1994 study determined that most of the GGP lakes, even those lined with clay material, do leak appreciable amounts of water. In 1994 it was estimated that the combined leakage from all of the GGP lakes was about 0.5 million gallons per day, with about 77% of the leakage occurring from the 3 unlined lakes. Some of the water lost from the GGP lakes is periodically made up by additions of groundwater pumped from wells located in GGP (SFRPD, 1994), while the rest is replenished by surface water flows (precipitation-derived runoff).

6.2. Groundwater Conditions in Golden Gate Park

Golden Gate Park is located in the northernmost part of the North Westside Basin, approximately 3 miles north of the Lake Merced area. The geology and hydrogeology of this area are somewhat different than near Lake Merced and Pine Lake. In this area, the bedrock surface slopes downward to the southwest from surface exposures in the east, and geophysical data indicate the presence of a buried bedrock valley beneath GGP. Additional discussion on the geology is presented in TM#1 (LSCE, 2010). The total thickness of sedimentary deposits on top of the bedrock thins from south to north in the North Westside Basin, from about 600 feet beneath Lake Merced to 400 feet beneath GGP (Figure 10.2-4). The “W-clay”, which forms the bottom of the Primary Production Aquifer throughout most of the basin, pinches out near the Ortega monitoring well cluster, and does not appear to exist north of this point (Figure 10.2-4). Similarly, the prominent shallower clay units present in the Lake Merced area, such as the -100-foot clay and the X-clay units, also appear to thin and pinch out near the Kirkham monitoring well cluster, just south of GGP (LSCE, 2010).

Because the -100-foot clay is not present in the GGP area, the Shallow Aquifer (as defined to the south) is not present in the GGP area. However, groundwater elevations measured in shallow wells located in GGP are typically several feet above the elevations recorded in wells screened deeper. This relationship indicates a downward vertical gradient, which implies downward vertical groundwater flow, similar to conditions seen in the Lake Merced area, where the Shallow Aquifer is prominently defined. In the GGP area, the horizontal component of groundwater flow in both the shallower and deeper portions of the Primary Production Aquifer is mostly due west, with a slight northwesterly component in some areas (SFPUC, 2009b).

Historic groundwater levels measured in wells located in GGP indicate that the groundwater surface (water table) throughout most of the park ranges from approximately 40 to 60 feet bgs, except in the western quarter of GGP, where the ground surface elevation drops fairly rapidly towards the Pacific Coast (HydroFocus 2009). At the Alvord-PW well location in the southeast corner of GGP, groundwater depths are typically about 40 to 60 feet bgs. To the west, at the Arboretum-4 well location, groundwater depths usually range from 40 to 50 feet bgs. In the central portion of GGP, near Elk Glen Lake, groundwater depths measured in the shallow USGS Elk Glen monitoring well range from about 40 to 45 feet bgs. Only at the far western edge of the GGP, right along the coast, do groundwater depths become shallower; the depth to groundwater is typically about 14 to 15 feet bgs. Additional information on groundwater levels is provided in TM-10.1, TM-10.4 and TM#1.

The average depths to groundwater within GGP noted above imply that the GGP lakes do not intersect the water table (unlike Lake Merced and Pine Lake to the south), and thus GW/SW interaction does not affect conditions in the GGP lakes. With few exceptions, the GGP lakes are very shallow, with present average depths on the order of only about 2 to 4 feet; even Elk Glen Lake, which is the deepest, is on average only about 6 feet deep. With average depths to groundwater in GGP of about 40 to 60 feet bgs, the GGP lakes are hydraulically separated from the water table.

Note that aquifer recharge provided by leakage from the GGP lakes is not considered a GW/SW interaction. The effect is only in one direction, because the water table is too far below the lake bottoms for changes in groundwater levels to affect lake levels. The water table beneath a particular lake might show evidence of mounding if the volume of seepage from the overlying lake is sufficiently high, but even then the water table remains well below the lake bottom. With implementation of the SFGW and GSR Projects, the GGP lakes are expected to continue to recharge the aquifer at the same rate because they would continue to be filled as before.

6.3. Managed Lake Levels

Some of the water lost to leakage from the GGP lakes is made up by additions from groundwater supply wells located within GGP. These wells, which are operated and maintained by SFRPD, are located east of Elk Glen Lake, at North Lake, and at the South Windmill location. Stow Lake, Elk Glen Lake, and South Lake receive water from these wells on a regular basis. The other lakes periodically receive make-up water from groundwater sources when operating engineers redirect discharges to them (SFRPD, 1994).

Historically, groundwater pumping information for the GGP wells was not maintained. However, in 2005 meters were installed in all three GGP production wells to quantify the amount of groundwater pumping in the park. In 2007, approximately 830 acre-feet of groundwater were pumped from the wells. In 2008 this amount increased to approximately 1,300 acre-feet of water (LSCE, 2010). A portion of this groundwater pumping is diverted into the Golden Gate Park lakes.

It has been recognized that water leakage from the GGP lakes recharges the underlying aquifer system. Because the water used to supplement the GGP lakes is obtained from this same aquifer system, most of the leakage from the GGP lakes is viewed as not being lost, but is instead largely considered to be circulated between the surface water and groundwater systems. The Westside Basin Groundwater-Flow Model assumes approximately 627 afy of groundwater recharge resulting from seepage from the lakes to the underlying aquifer; this rate is based on the results of a seepage investigation of the GGP lakes conducted by the San Francisco Department of Public Works (SFRPD, 1994).

6.4. Summary

The average depths to groundwater within GGP indicate that, unlike Lake Merced and Pine Lake to the south, the shallow GGP lakes do not intersect the water table and thus GW/SW interaction does not affect surface water conditions in the GGP lakes. As shown previously for other locations in the North Westside Basin, long-term operation of the GSR and SFGW Projects is expected to result in net decreases in groundwater levels in this area. This is particularly the case for the SFGW Project because the Project wells are to be installed within the North Westside Basin. Declining groundwater levels caused by operation of the SFGW wells would further reduce the likelihood of GW/SW interaction between the aquifer and the GGP lakes. Consequently, it is not expected that operation of either the SFGW Project, GSR Project, or the Cumulative Scenario would affect existing water level conditions within the GGP lakes.

7. Colma, San Bruno, and Millbrae Creeks

Three principal streams, along with their tributaries, exist in the South Westside Basin: Colma Creek, San Bruno Creek, and Millbrae Creek. Colma Creek is located in the central and southern portions of the South Westside Basin, originating near San Bruno Mountain and extending southwest and then southeast through South San Francisco before discharging into the Bay just north of the San Francisco International Airport. San Bruno Creek flows from the uplands along the west side of the Basin, and also discharges to the Bay at a location just south of the Colma Creek discharge. Millbrae Creek is in the southernmost part of the Basin, with its headwaters also located in the western uplands and with a discharge to the Bay south of the San Francisco International Airport (Figure 10.2-1).

7.1. Physical Setting and Stream Conditions

As is typical of surface water features located in heavily urbanized areas, much of the stream reaches of Colma Creek, San Bruno Creek, and Millbrae Creek have been channelized, buried, and/or lined with impervious materials. Almost the entire Colma Creek watershed is located within the Colma Creek Flood Control Zone, which was created in 1964 to construct flood control facilities in the creek to alleviate flooding in South San Francisco. Except for its upper reaches on San Bruno Mountain, all of historic Colma Creek and its tributaries have been diverted into engineered channels or underground storm drains. Similar alterations have also been made to San Bruno Creek and Millbrae Creek (Oakland Museum, 2010). These modifications have resulted in major changes to the natural hydrologic and ecologic processes that previously existed.

Colma Creek sometimes runs dry, believed to result at least in part from excessive groundwater use by non-native vegetation (e.g., eucalyptus trees) present in the headwaters of the Creek. In the upper reaches of Colma Creek, a headwaters restoration project is underway in which the non-native vegetation is being eradicated to both restore natural habitat and improve groundwater conditions (Cannon and Heath, 2005). In the lower Colma Creek watershed, along the mouth of the creek where it enters the San Francisco Bay, a habitat mitigation project is ongoing in which wetlands and native upland habitat are being constructed to restore features that were lost during construction of flood control facilities in the area.

7.2. Groundwater Conditions

In the portion of the South Westside Basin where Colma Creek is located (except for the eastern area closer to the Bay), the depth to groundwater ranges from many tens to hundreds of feet bgs, due to drawdown of the water table caused by intensive historic municipal pumping in the Daly City, South San Francisco, and San Bruno areas. Large production wells in these areas pump from the Primary Production and Deep Aquifers (the Shallow Aquifer is not present from the Daly City area southward).

Where the lower reaches of Colma Creek are located, in South San Francisco, the depth to groundwater is highly variable, depending largely on proximity to pumping wells and the depth of the aquifer being measured.

Where San Bruno and Millbrae Creeks are located, in South San Francisco and San Bruno, the groundwater in the Primary Production Aquifer is typically at elevations ranging from -100 to -200 feet (NGVD 29). However, in areas closer to the Bay, groundwater elevations are in the range of approximately 10 to -30 feet (NGVD 29), with the deeper levels corresponding to deeper monitoring wells.

7.3. Groundwater-Surface Water Interactions

Extensive modifications to Colma Creek, San Bruno Creek, and Millbrae Creek have effectively isolated almost all of the creek reaches from the underlying groundwater, precluding any substantial degree of GW/SW interaction with the creeks. Furthermore, groundwater beneath much of Colma Creek is far below ground surface, further reducing the likelihood of GW/SW interaction.

Even where groundwater levels are relatively shallow in the southernmost portion of the South Westside Basin, the heavy alteration of all three creeks (i.e., concrete lining) precludes exchanges between surface water and shallow groundwater.

Colma Creek is apparently in some degree of communication with shallow groundwater in its upper, least-altered reaches near San Bruno Mountain, because water use by stands of eucalyptus trees there is believed to deprive the Creek of some baseflow (Cannon and Heath, 2005). However, any shallow groundwater in this area exists in a highly localized system, far removed from the deeper groundwater of the Primary Production Aquifer, which exists at lower elevations in the Basin. Similar conditions are likely present for the unaltered upland portions of San Bruno Creek and Millbrae Creek.

7.4. Groundwater Model Results

The existence of thick deposits of low-permeability Bay Mud in San Bruno and portions of South San Francisco (Bay Plain area) also lessen the likelihood of GW/SW interaction in these areas (LSCE, 2010). The 2011 update to the Westside Basin Groundwater-Flow Model incorporated drain boundaries in Layer 1 of the Bay Plain area to simulate seepage to San Francisco Bay. Implementation of the drain boundaries reduced the occurrence of simulated water levels above land surface (i.e., flooding) in the Bay Plain area, but had minimal effect on simulated water levels further inland where the bulk of the major creek systems are located (HydroFocus, 2011).The simulated drainage averaged less than 120 afy, which is less than 1 percent of the volumetric budget. This equates to about 0.17 cubic feet per second (cfs) distributed among Colma, San Bruno, and Millbrae Creeks. The flow in these creeks is primarily stormwater runoff and other discharges. The total groundwater discharge is considered to be a very low percentage of the overall streamflow.

To evaluate the effects of the GSR and SFGW Projects on groundwater discharge to the creeks, the water balance for each scenario was evaluated using the data in TM10.1 Attachment TM 10.1-C. The discharge to the drains was limited to the South Westside Basin representing Colma, San Bruno and Millbrae Creeks. The average annual groundwater discharge to the creeks for Scenario 1 was 94 afy, or 0.13 cfs. For Scenarios 2 and 4, the average annual groundwater discharge to the creeks increased to 122 afy, or 0.17 cfs. This is similar to the results for the historical model (HydroFocus, 2011). For Scenarios 3a and 3b, the average annual groundwater discharge to the creeks was 93 afy, or 0.13 cfs. This is essentially the same as for Scenario 1. Based on the groundwater model results, there would be little to no change to groundwater discharge to Colma, San Bruno and Millbrae Creeks as a result of project operations.

7.5. Summary

Given the hydrogeologic conditions and substantial engineered modifications, it is unlikely that GW/SW interaction processes are present to any measureable extent for Colma, San Bruno, or Millbrae Creeks. Consequently, implementation of the SFGW Project, GSR Project, or the Cumulative Scenario is not expected to affect existing surface water conditions for Colma Creek, San Bruno Creek, or Millbrae Creek, or their respective tributaries.

8. Summary

The following discussion summarizes the results of the GW/SW interaction analysis for the principal surface water features identified in the Westside Groundwater Basin.

8.1. Lake Merced

Lake Merced is a freshwater lake located in the southwestern corner of San Francisco and is located within the North Westside Groundwater Basin, just north of the San Francisco County-San Mateo County line (Figures 10.2-1 and 10.2-2). Lake Merced consists of four inter-connected lakes - North Lake, South Lake, East Lake and Impound Lake (Figure 10.2-2).

This section summarizes the results of the evaluation based on the modeling analysis using the Lake-Level Model and the Westside Basin Groundwater-Flow Model.

Scenario 2 (GSR Project) generally results in higher lake levels than Scenario 1 for most of the simulation period. During the Design Drought (in which the extended period of pumping from SFPUC and PA wells occurs over the 7.5-year take period), the simulated Lake Merced levels are below those of Scenario 1 toward the end of the Design Drought period. The lowest lake level estimated under Scenario 2 is -2.5 feet (City Datum), which is similar to the lowest historical lake level of -3.2 (City Datum) experienced in 1993.

Scenarios 3a and 3b (SFGW Project) result in substantially lower lake levels for the entire simulation period relative to Scenario 1. Lake levels decline during the first approximately 15 years of operation of the SFGW Project. During the final approximately 30 years of the simulation, the lake levels are generally stable, remaining about 10 feet lower than the Existing Conditions Scenario. The simulated lake levels rise several feet compared to the Existing Conditions Scenario after the Design Drought period. The lowest lake levels for Scenarios 3a and 3b are about 7 feet lower than the lowest historical lake level experienced in 1993 of -3.2 feet (City Datum).

Scenario 4 (Cumulative Scenario) includes operation of the GSR and SFGW Projects using the assumptions for Scenario 2 and 3b. In addition, other reasonably foreseeable future projects such as the Daly City Vista Grande Drainage Area Improvements Project are included. This Project would augment Lake Merced with stormwater and baseflow from the Vista Grande Canal. The result of the Cumulative Scenario is that the simulated lake levels are similar to Scenario 1. They also tend to mimic the pattern from Scenario 2 (GSR Project) but at a lower elevation (by about 3 to 4 feet) as a result of SFGW Project pumping. The lowest lake level under Scenario 4 is -4.9 feet (City Datum), which is about 1.5 feet lower than the lowest historical lake level experienced in 1993.

8.2. Pine Lake

Pine Lake is a relatively shallow lake that is approximately 3 acres in area and located about 0.5 mile north-northeast of Lake Merced (Figures 10.2-1 and 10.2-2). The design water level elevation for Pine Lake is established at 40.2 feet (NGVD 1929, or 31.5 feet City Datum). Pine

Lake is already maintained by additions of groundwater from the Stern Grove well, and water additions from this well would continue to be necessary to maintain water levels in Pine Lake.

Pine Lake does not appear to be in direct hydraulic communication with the Shallow Aquifer. Rather, there is evidence of groundwater mounding in the Shallow Aquifer indicating a steady, but rate-controlled, leakage of groundwater from the shallowest sediments to the Shallow Aquifer.

For the SFGW Project and Cumulative Scenarios (Scenarios 3a, 3b and 4) groundwater levels in the Shallow Aquifer beneath Pine Lake are projected to decline by approximately 10 to 16 feet relative to the Existing Conditions (Scenario 1). However, based on the conceptual model, these projected declines in shallow groundwater levels are not considered to cause a substantial increase in groundwater leakage from Pine Lake. Therefore, proposed operations of the Stern Grove well are anticipated to maintain the design water level in Pine Lake.

Groundwater levels in the Shallow Aquifer for the GSR Project (Scenario 2) are projected to be similar to or slightly higher than the Existing Conditions. Therefore, operation of the GSR Project is not considered to affect water levels in Pine Lake or cause a change in lake additions from the Stern Grove Well during GSR Project operations.

8.3. Golden Gate Park Lakes

Golden Gate Park is located at the northernmost extent of the North Westside Basin (Figure 10.2-1). Twelve lakes or ponds -- Stow Lake, Spreckels Lake, North Lake, Lily Pond, Lloyd Lake, Elk Glen Lake, Metson Lake, Mallard Lake, South Lake, and Middle Lake, Alvord Lake and Rainbow Falls Bowl -- are located within Golden Gate Park (Figure 10.2-3).

The average depths to groundwater indicate that these shallow lakes do not intersect the water table and thus GW/SW interaction does not affect surface water conditions in the Golden Gate Park lakes. The operation of the GSR Project is not anticipated to affect this area; thus, no changes are anticipated for the Golden Gate Park lakes. The operation of the SFGW Project wells is expected to result in net groundwater decreases in this area. Declining groundwater levels caused by operation of the SFGW wells would further reduce the likelihood of GW/SW interaction processes occurring in the Golden Gate Park lakes. Consequently, it is not expected that operation of the SFGW Project, GSR Project, or the Cumulative Scenario will affect existing water level conditions within the Golden Gate Park lakes.

8.4. Colma, San Bruno, and Millbrae Creeks

Colma, San Bruno and Millbrae Creeks are located in the central and southern portions of the South Westside Basin (Figure 10.2-1). Given the hydrogeologic conditions and substantial engineered modifications made to Colma, San Bruno and Millbrae Creeks, it is unlikely that GW/SW interaction processes are present to any measureable extent for any of these creeks. The Westside Basin Groundwater-Flow Model showed no substantial effects of the operations of the GSR or SFGW Projects on the groundwater discharges to these creeks. Consequently, implementation of the SFGW Project, GSR Project, or the Cumulative Scenario is not anticipated to affect existing surface water conditions for Colma Creek, San Bruno Creek, or Millbrae Creek, or any of their respective tributaries.

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Figure List

Table List

Attachment List

Figures

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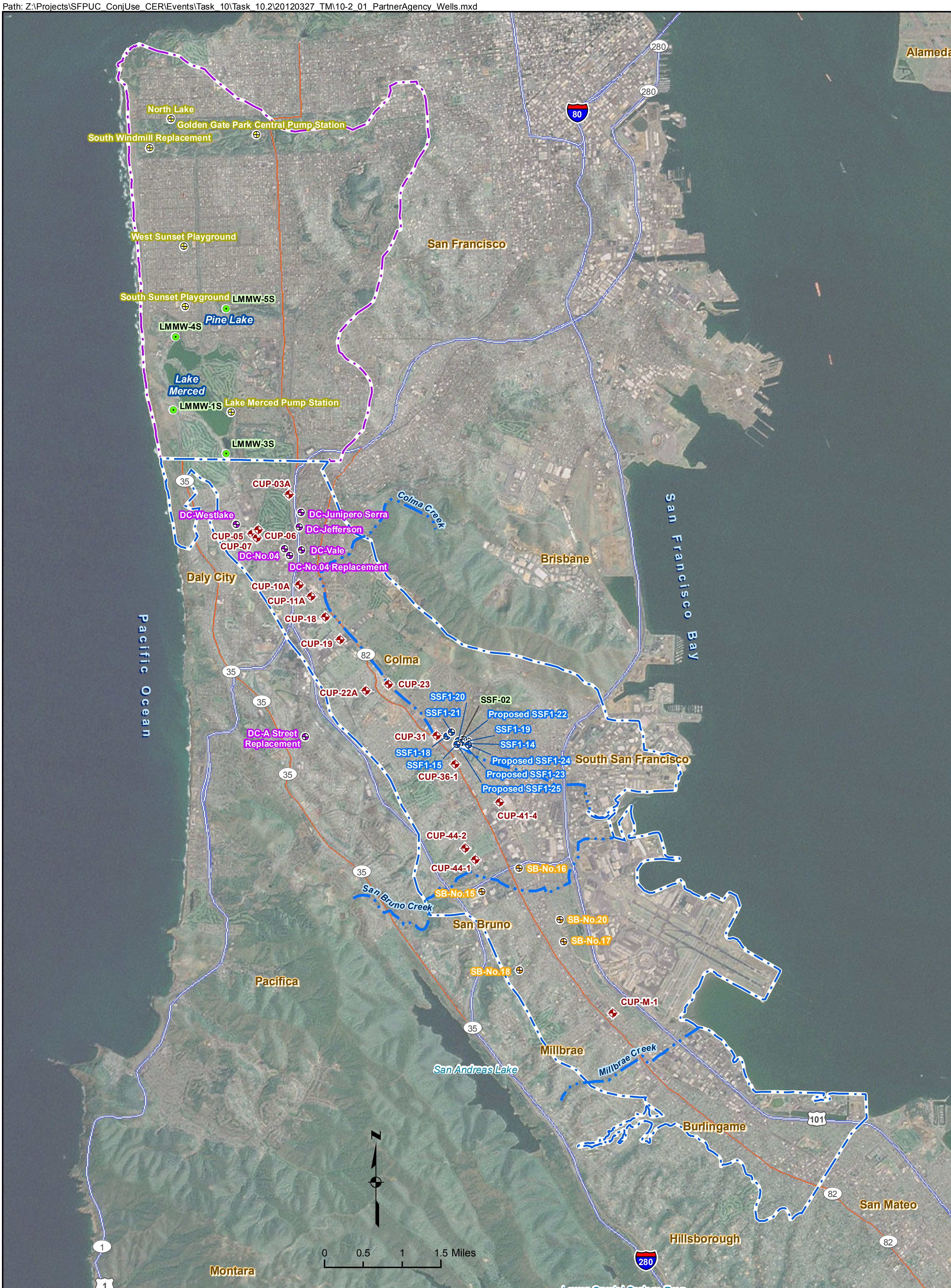

Aerial Photo Source: World Imagery from ESRI. Copyright:© 2009 ESRI, AND, TANA, UNEP-WCMC

Legend

- GSR Proposed Municipal Wells
- SFGW Proposed Municipal Wells
- Selected Representative Monitoring Wells
- Cal Water Municipal Wells
- Daly City Municipal Wells
- San Bruno Municipal Wells
- South Westside Groundwater Basin
- North Westside Groundwater Basin

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
ENGINEERING MANAGEMENT BUREAU

LOCATIONS OF SURFACE WATER FEATURES, PROPOSED GSR AND SFGW PROJECT WELLS, AND MONITORING WELLS IN THE WESTSIDE GROUNDWATER BASIN

Kennedy/Jenks Consultants
303 Second Street, Suite 300 South
San Francisco, CA 94107

Figure **10.2-1**

Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Date May 2012

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Legend

● Monitoring Wells in Lake Merced Area

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LAKE MERCED AND PINE LAKE

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Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Figure **10.2-2**

Date May 2012

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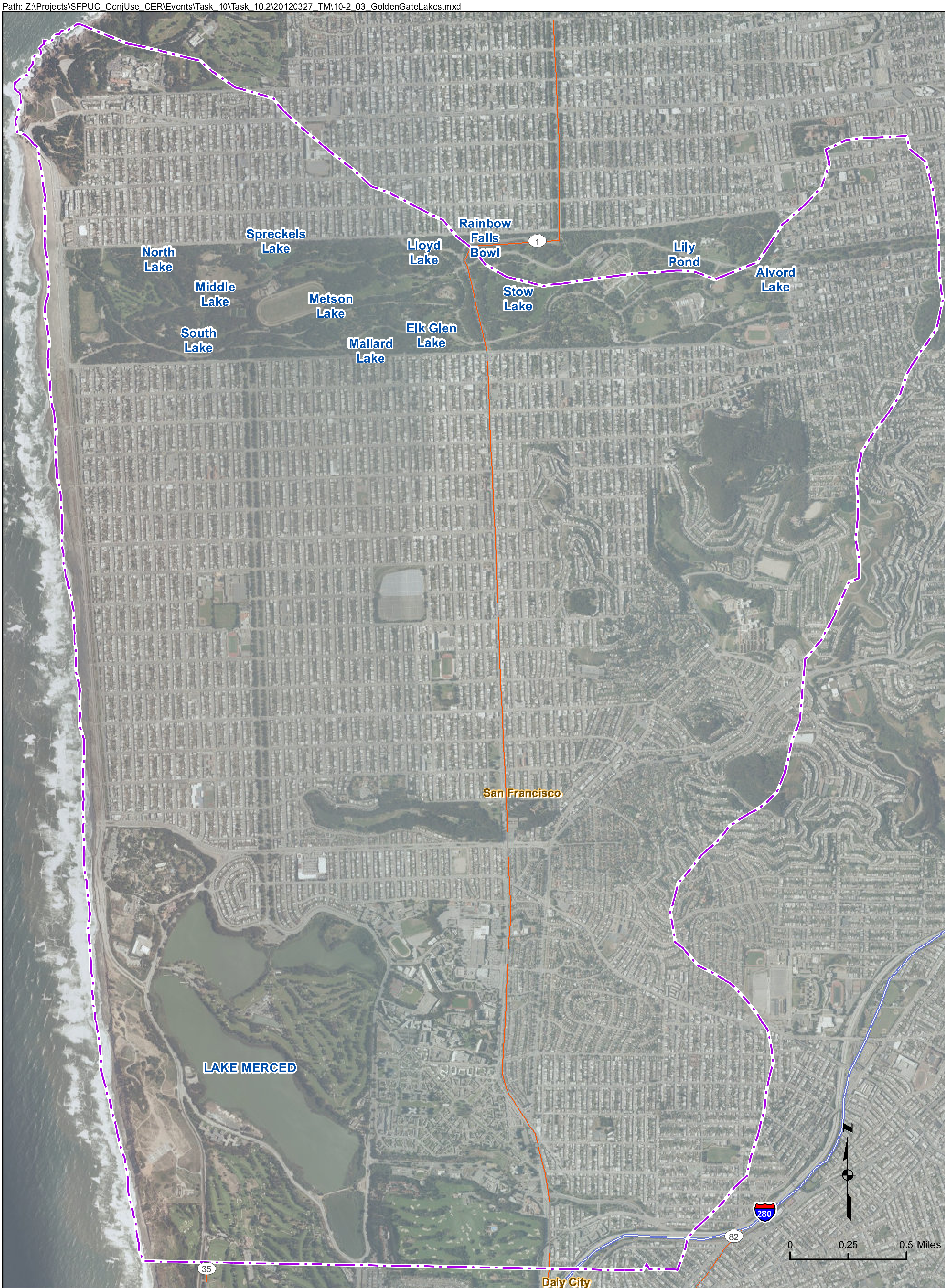

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Legend

North Westside Groundwater Basin

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PUBLIC UTILITIES COMMISSION
ENGINEERING MANAGEMENT BUREAU

GOLDEN GATE PARK LAKES

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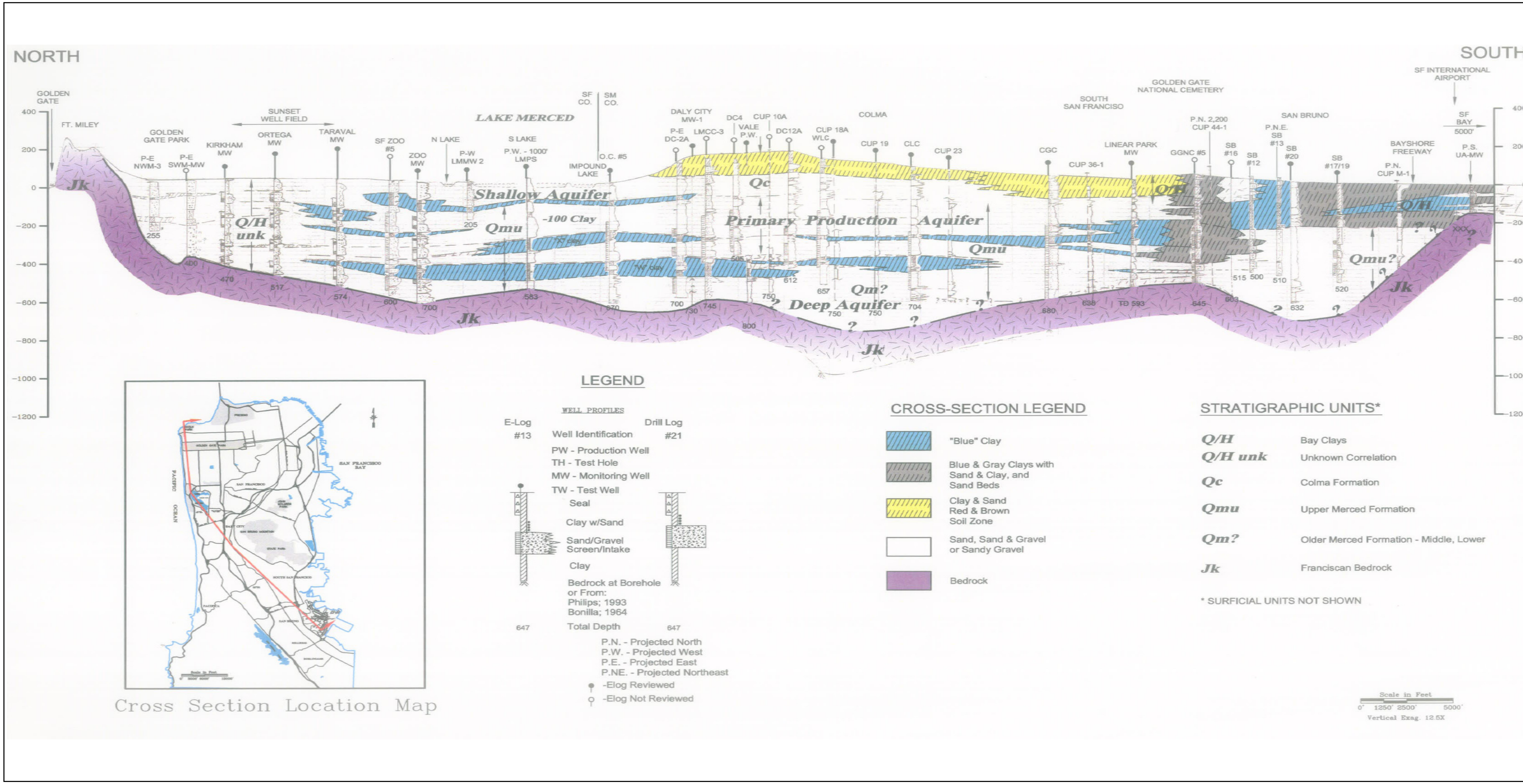
Figure **10.2-3**

Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Date May 2012



Source: Final Task 8B Technical Memorandum No.1, Hydrologic Setting of the Westside Basin, LSCE, May 2010.

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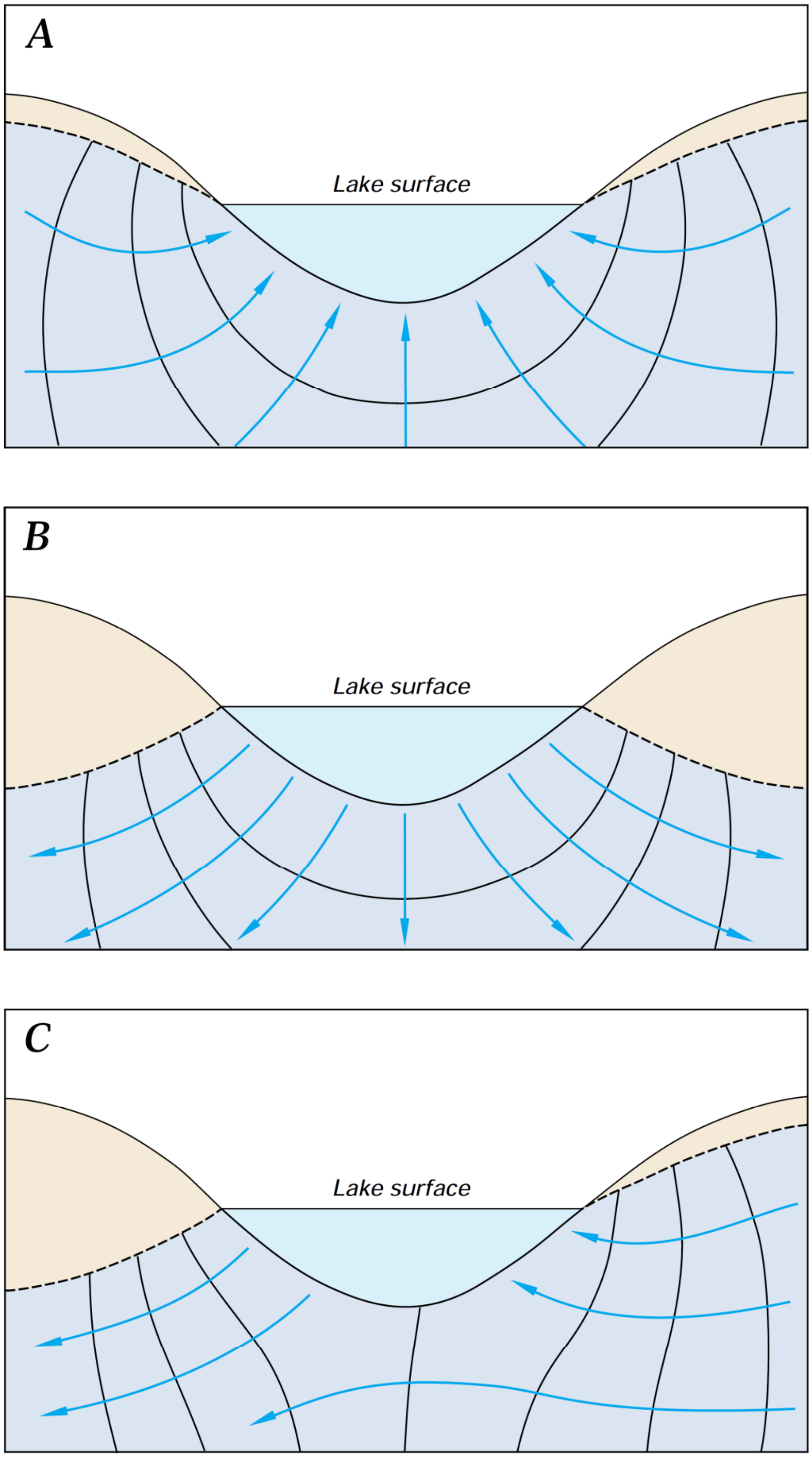
Regional Groundwater Storage and Recovery Project
And San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Westside Basin Regional Subsurface Hydrogeology

K/J 0864001
May 2012

Figure 10.2-4



Lakes can receive groundwater inflow (A), lose water as seepage to groundwater (B), or both (C). From Winter et al. (1998).

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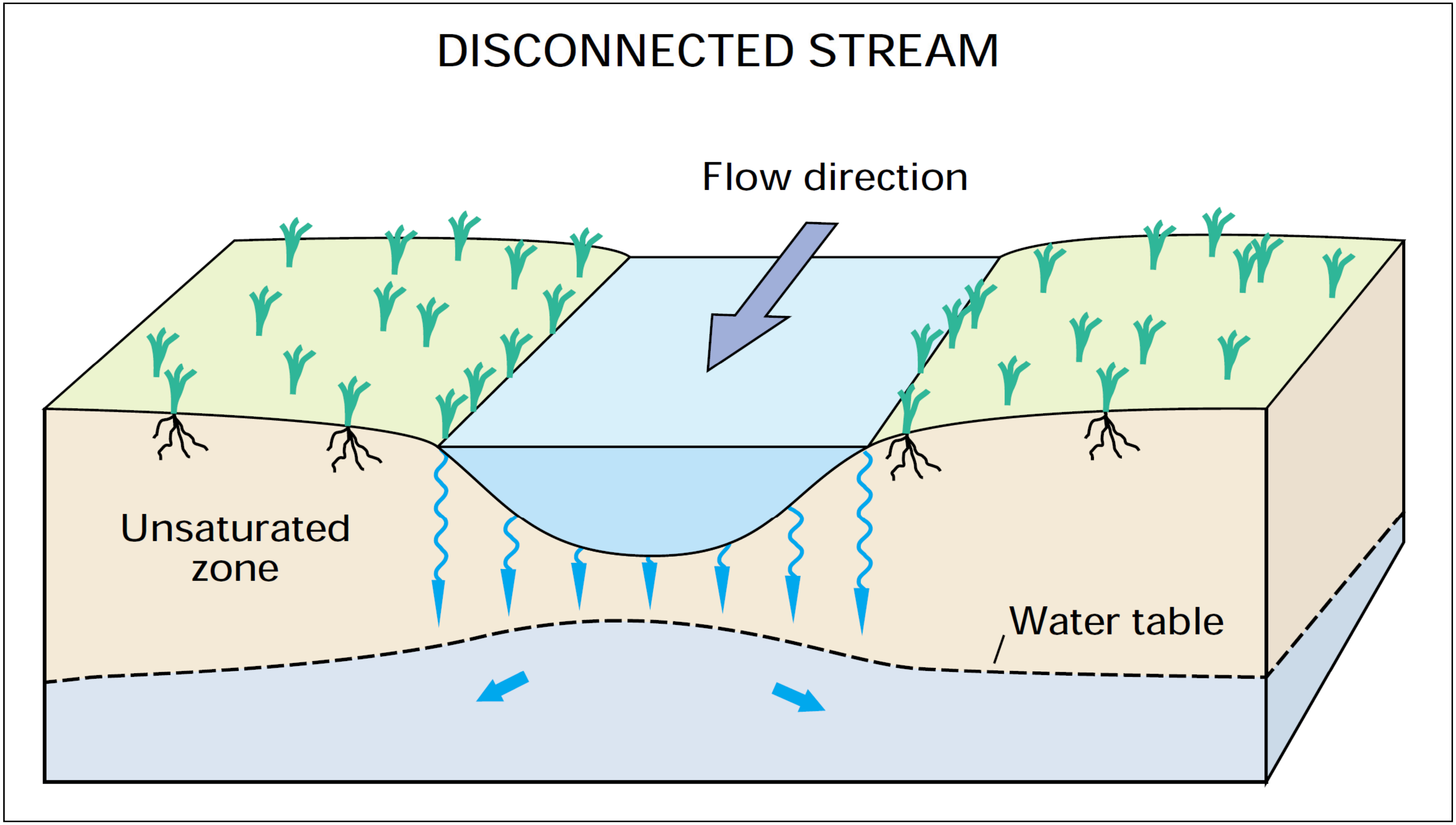
San Francisco Public Utilities Commission

Interaction of Groundwater and Lakes

K/J 0864001
May 2012
Figure 10.2-5



Disconnected streams are separated from the groundwater system by an unsaturated zone. From Winter et al. (1998).

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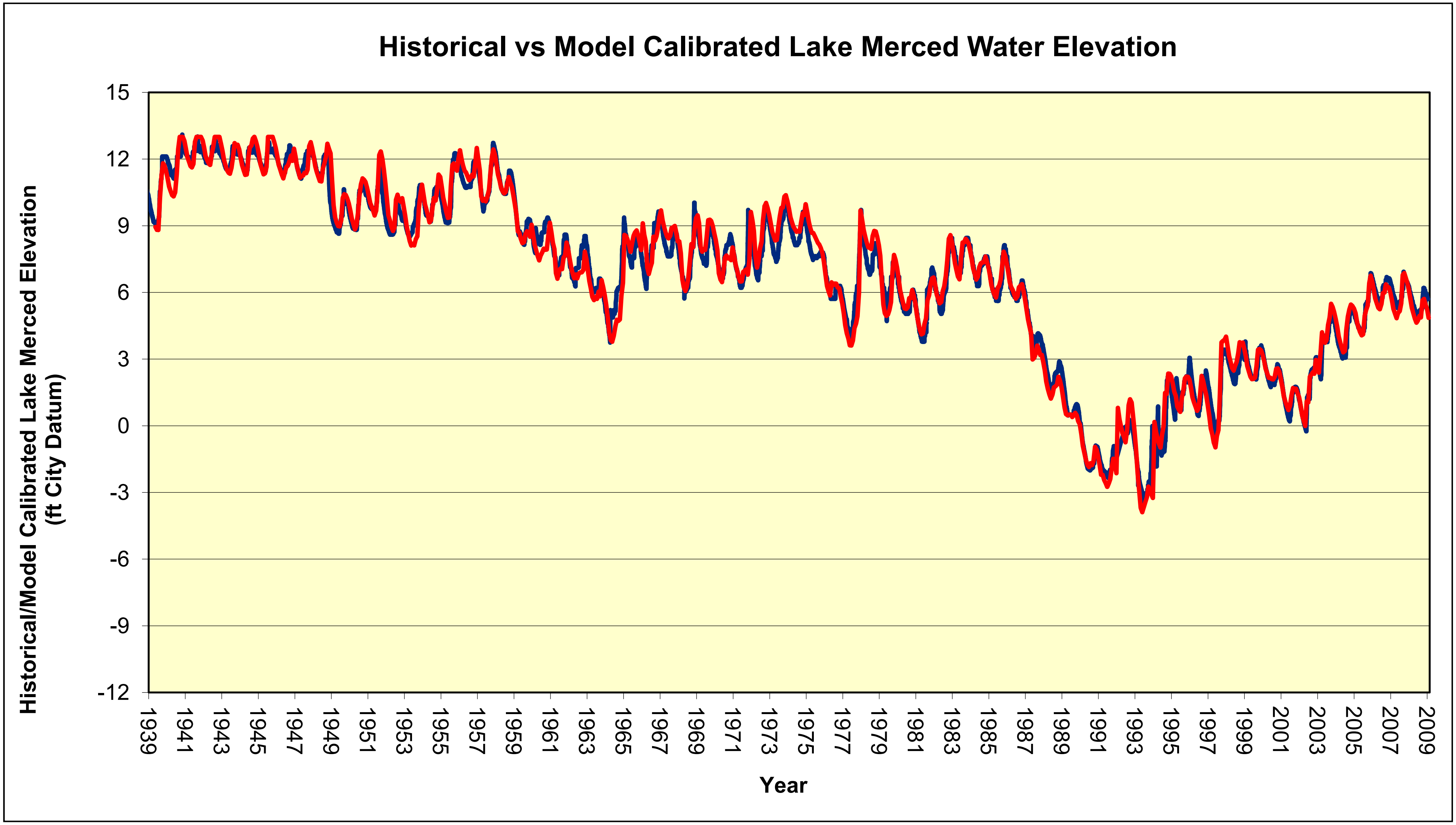
Disconnected Streams

K/J 0864001
May 2012
Figure 10.2-6



Source: Historical Lake Merced water elevation data from the San Francisco Public Utilities Commission
City Datum = NGVD - 8.62 feet

Legend

Historical Measured Lake Elevation (feet City Datum)

Model Calibrated Lake Elevation (feet City Datum)

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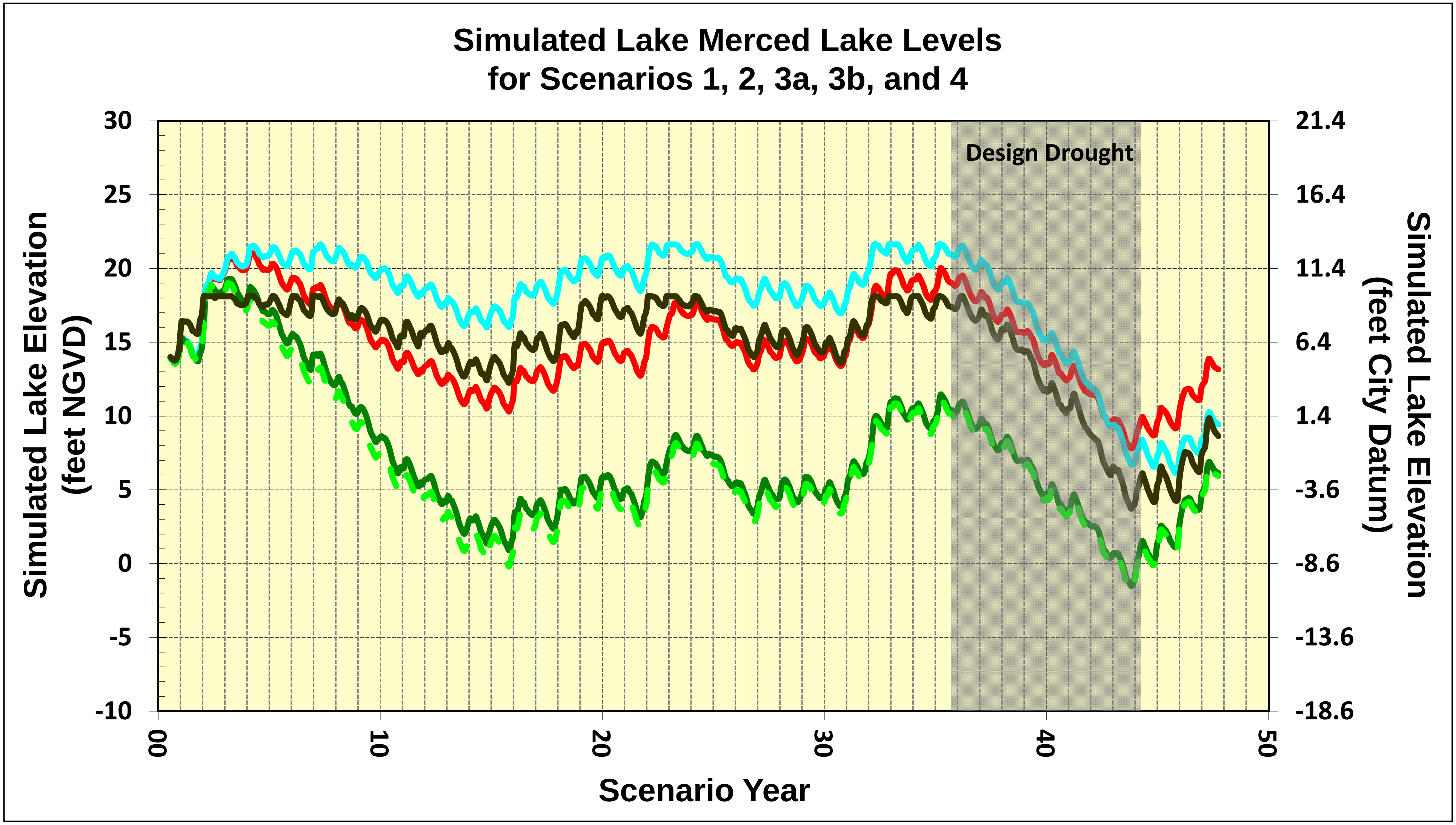
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Historical Measured and Simulated Lake Merced Levels

K/J 0864001
May 2012
Figure 10.2-7



Note: Zero elevation NGVD is equivalent to mean sea level NGVD. City Datum = NGVD - 8.62 feet.

Lake Levels:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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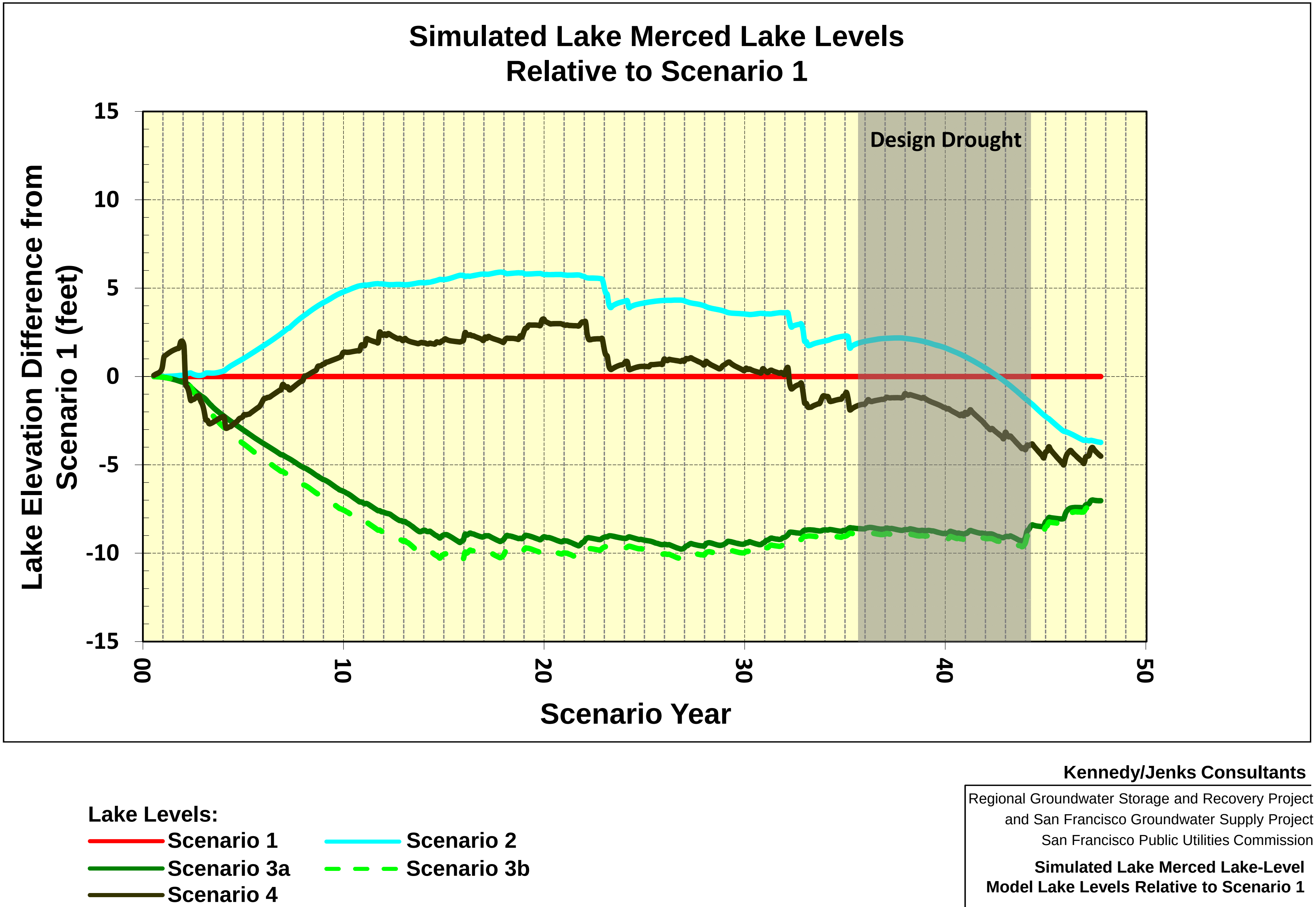
Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Simulated Lake Merced Lake-Level
Model Lake Levels

K/J 0864001
May 2012
Figure 10.2-8



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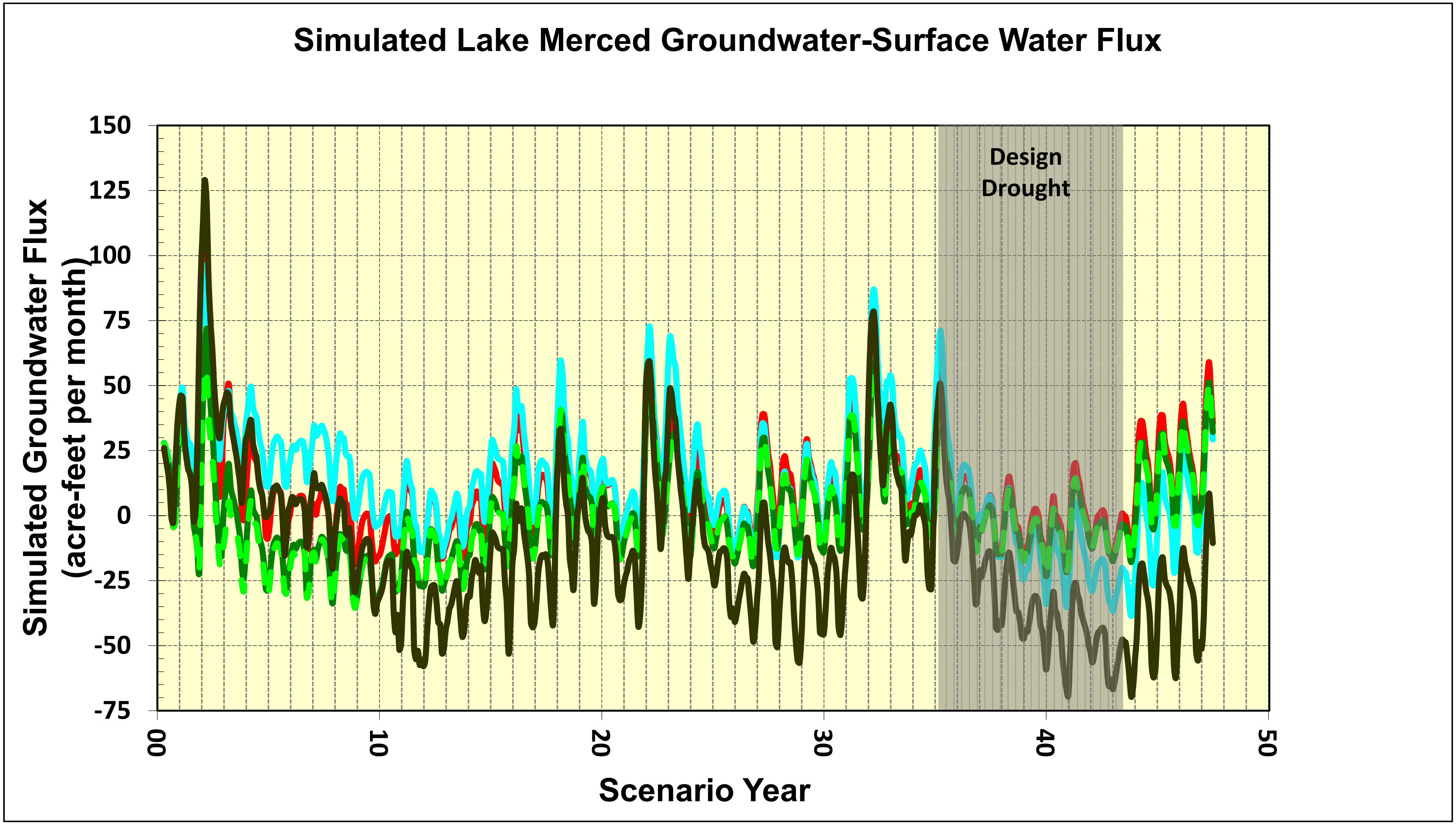
San Francisco Public Utilities Commission

Simulated Lake Merced Lake-Level
Model Lake Levels Relative to Scenario 1

K/J 0864001
May 2012
Figure 10.2-9



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Regional Groundwater Storage and Recovery Project
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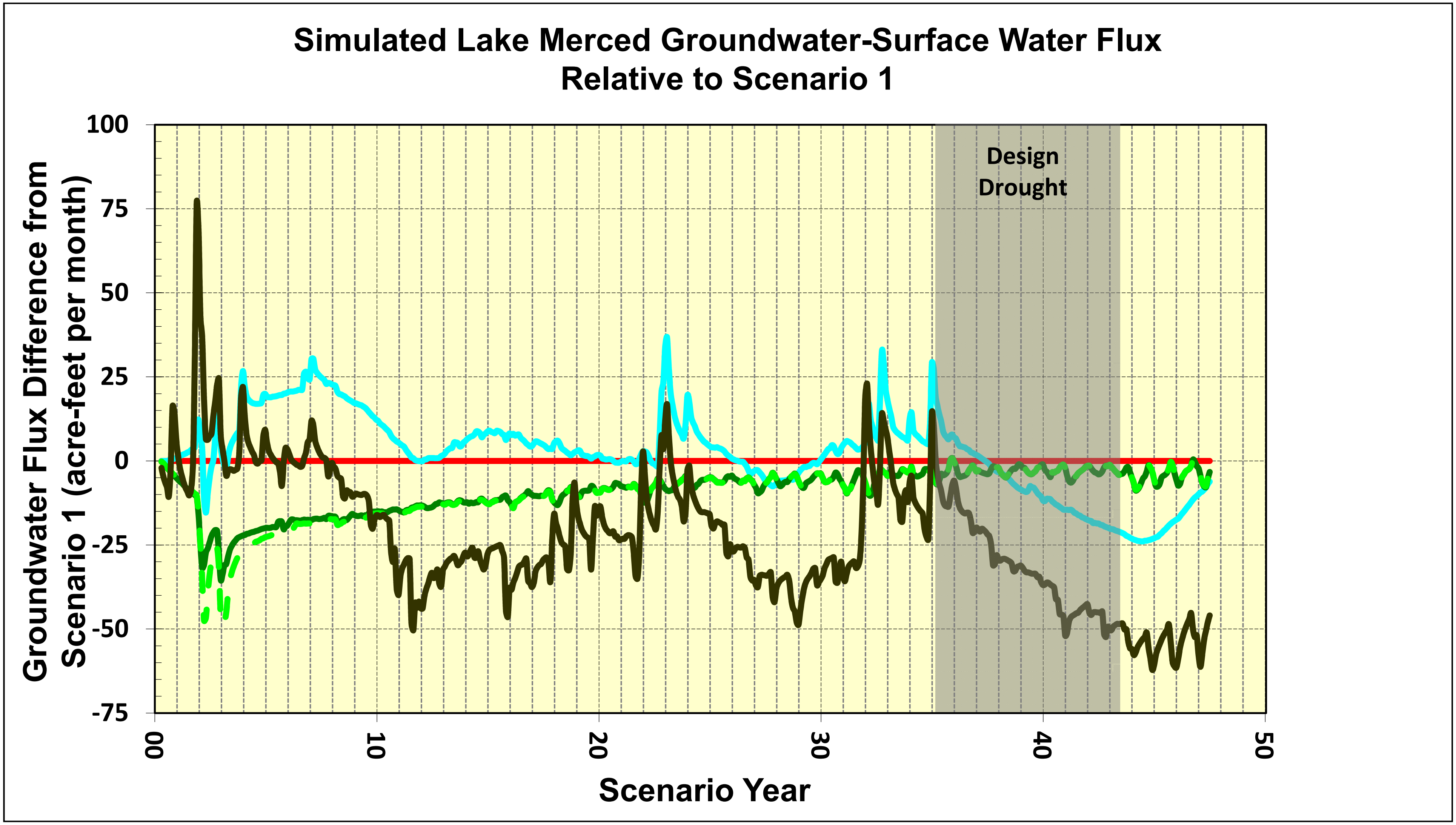
San Francisco Public Utilities Commission

Simulated Lake Merced Groundwater-Surface Water Flux

K/J 0864001
May 2012
Figure 10.2-10a



Model Flux:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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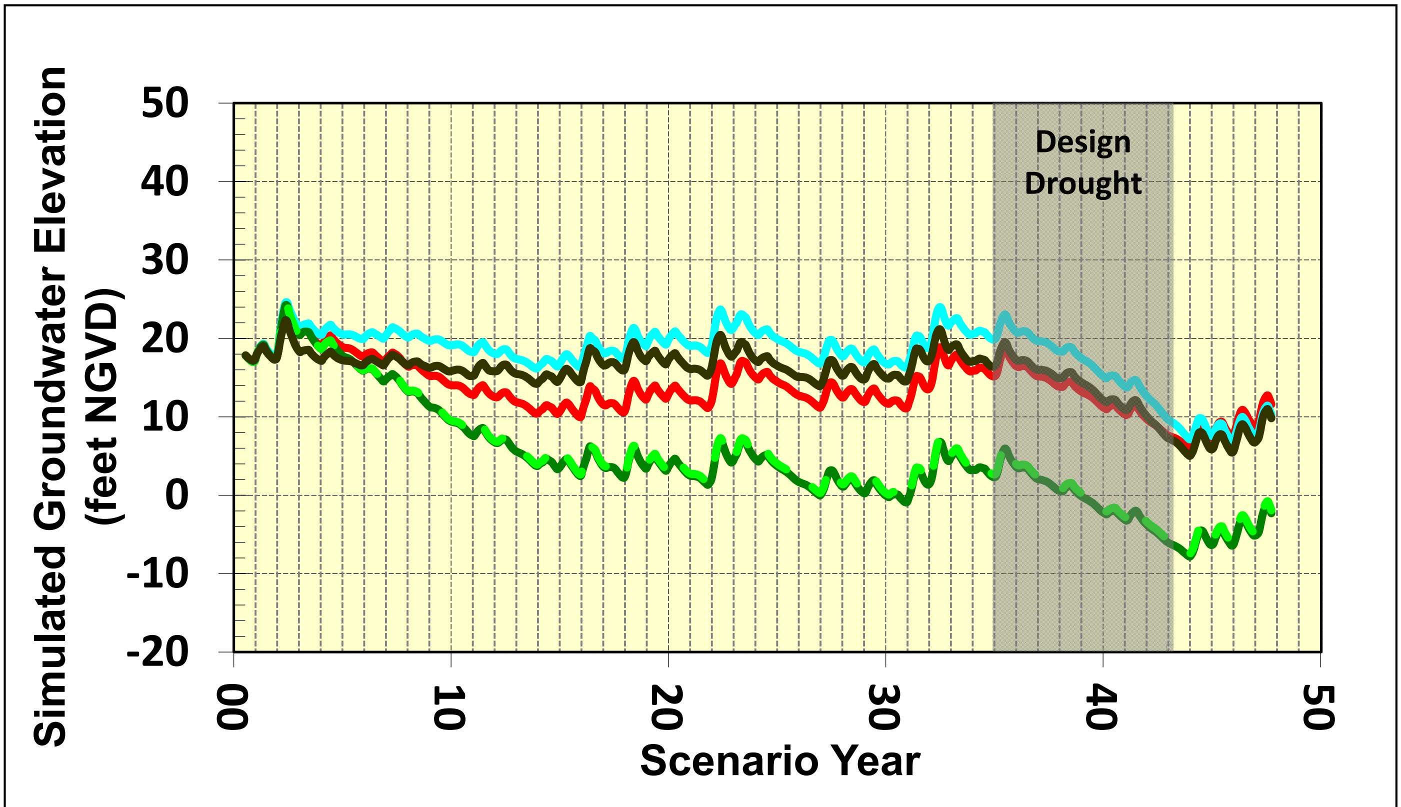
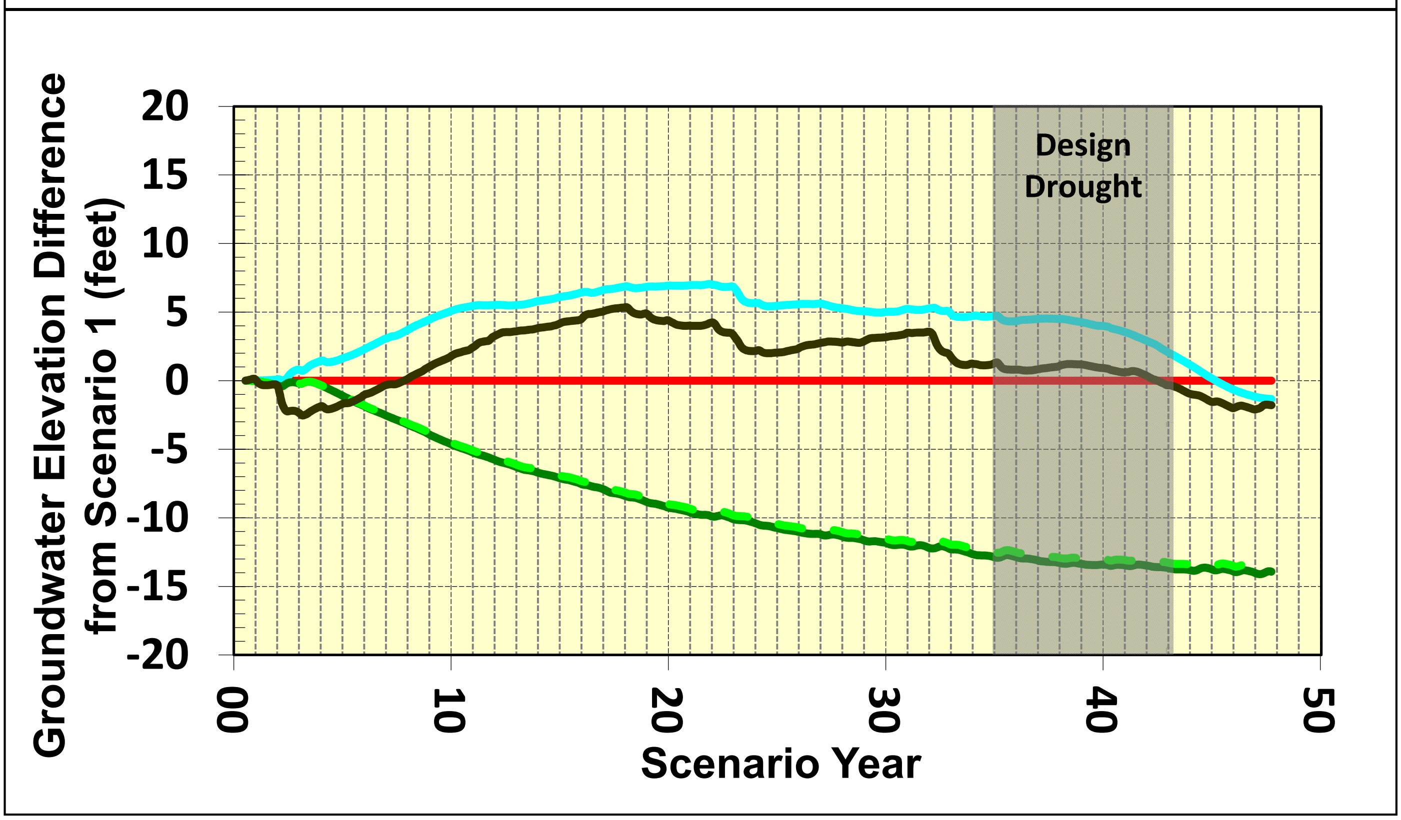
Simulated Lake Merced Groundwater-Surface Water Flux Relative to Scenario 1

K/J 0864001
May 2012
Figure 10.2-10b





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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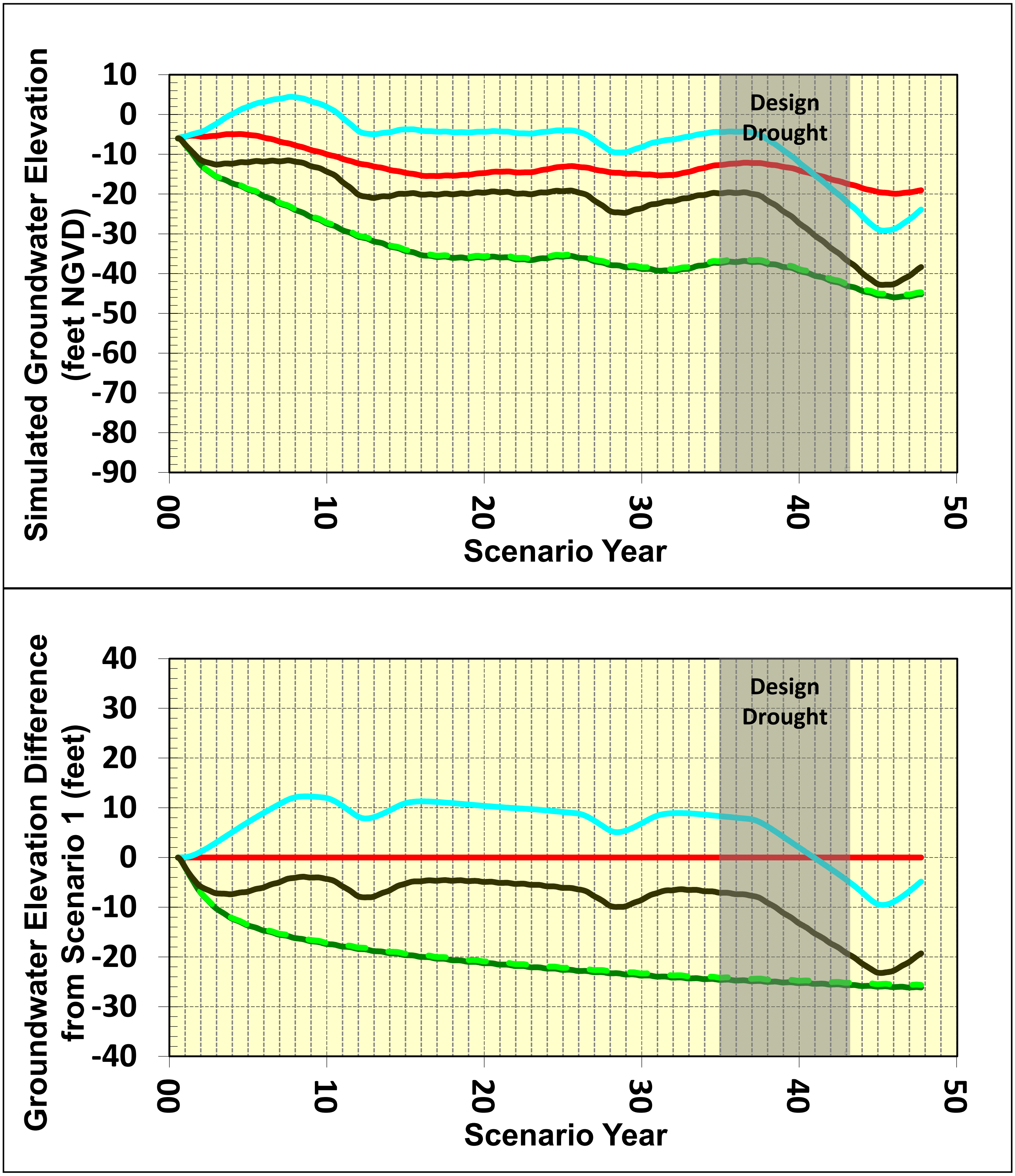
Model Layer 1 Hydrographs for LMMW-1

K/J 0864001
May 2012
Figure 10.2-11a



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- **Scenario 1**
- **Scenario 2**
- **Scenario 3a**
- **Scenario 3b**
- **Scenario 4**

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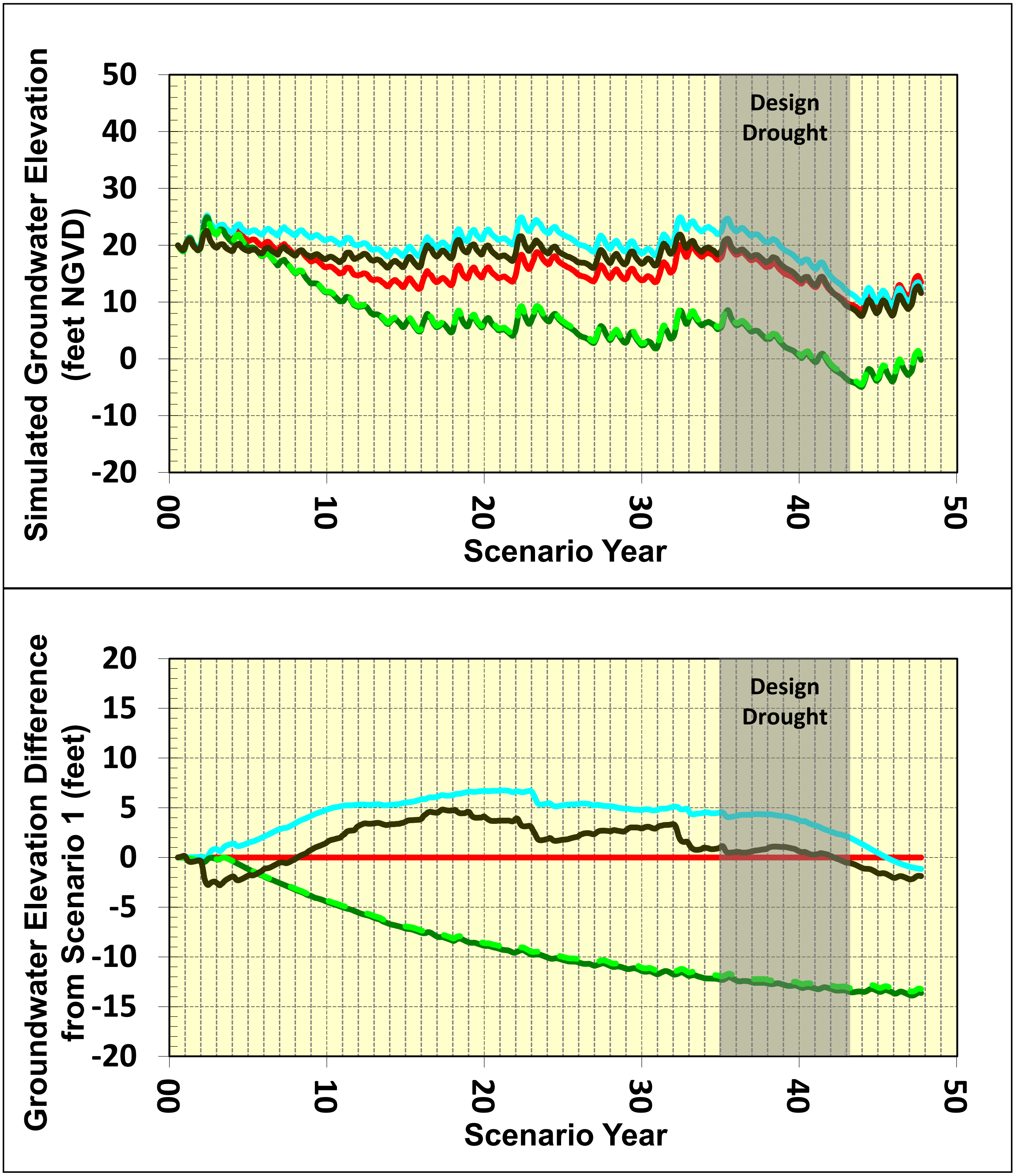
Model Layer 4 Hydrographs for LMMW-1

K/J 0864001
May 2012
Figure 10.2-11b



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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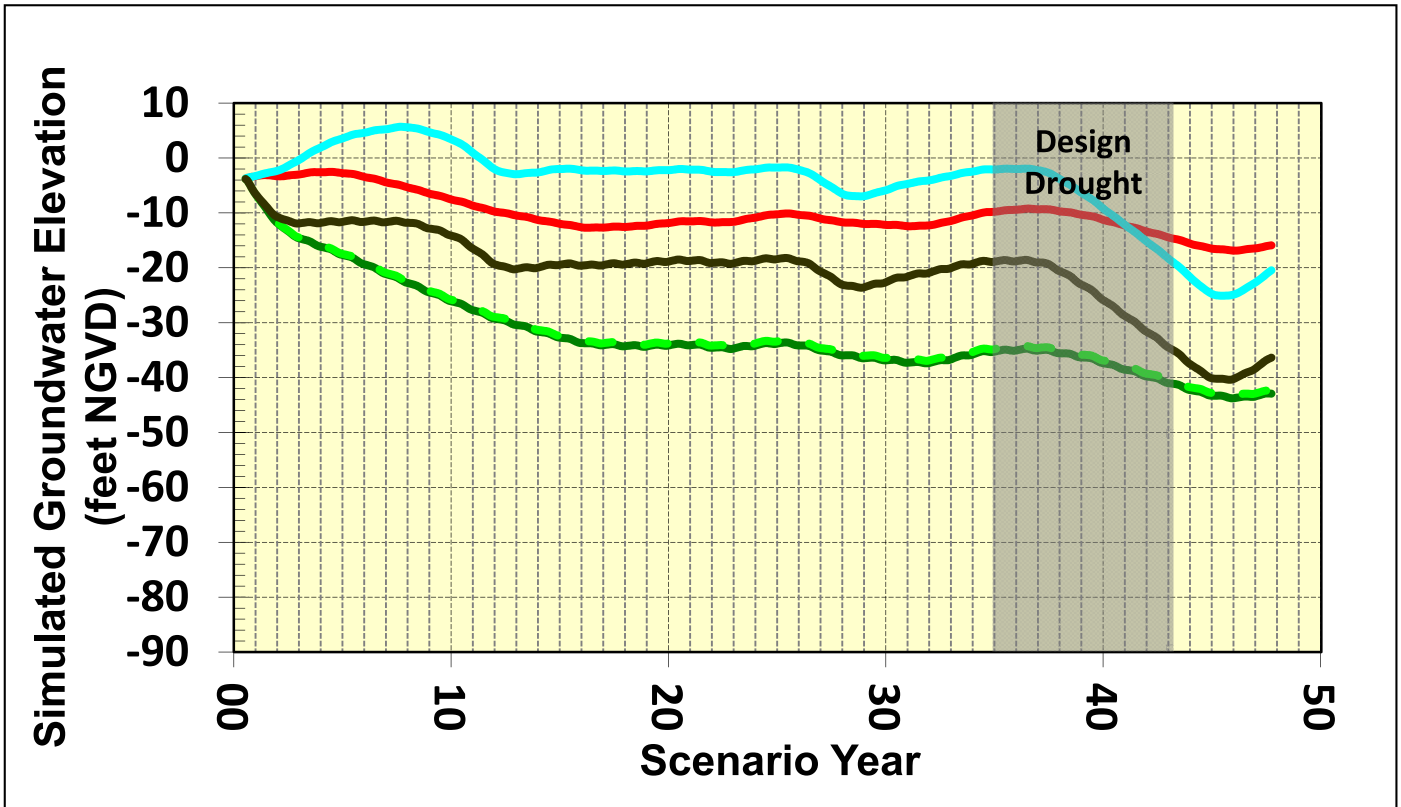
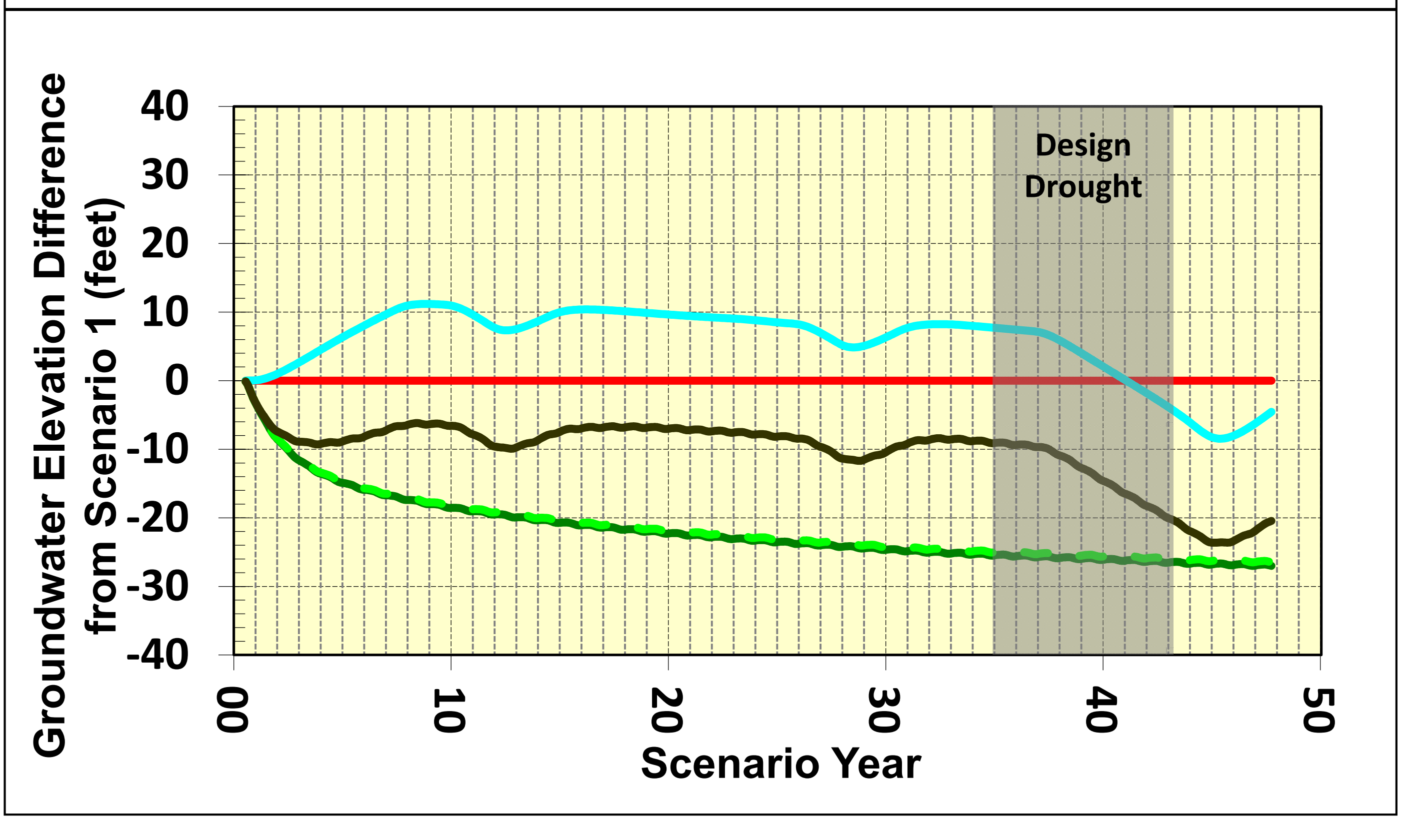
Model Layer 1 Hydrographs for LMMW-2

K/J 0864001
May 2012
Figure 10.2-12a





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- **Scenario 1**
- **Scenario 2**
- **Scenario 3a**
- **Scenario 3b**
- **Scenario 4**

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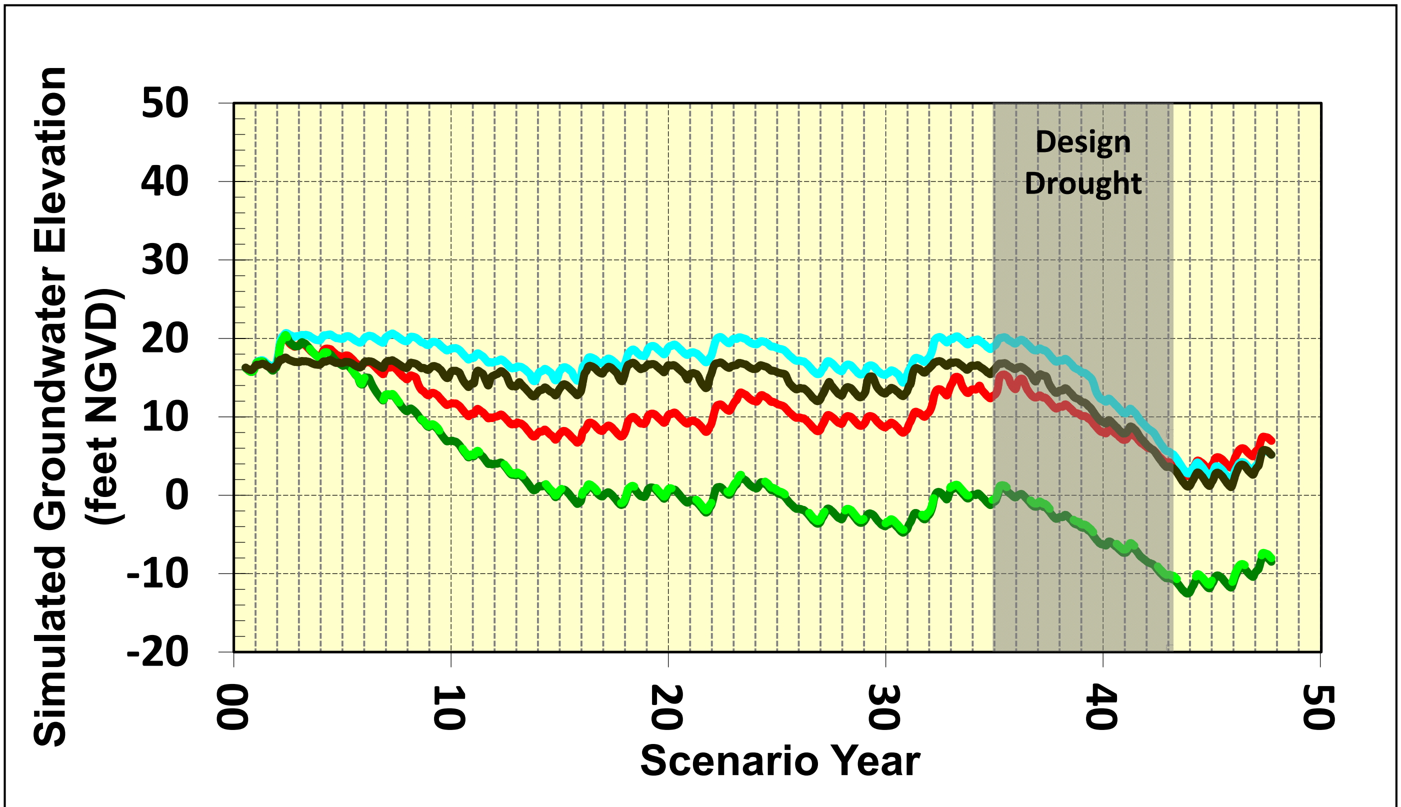
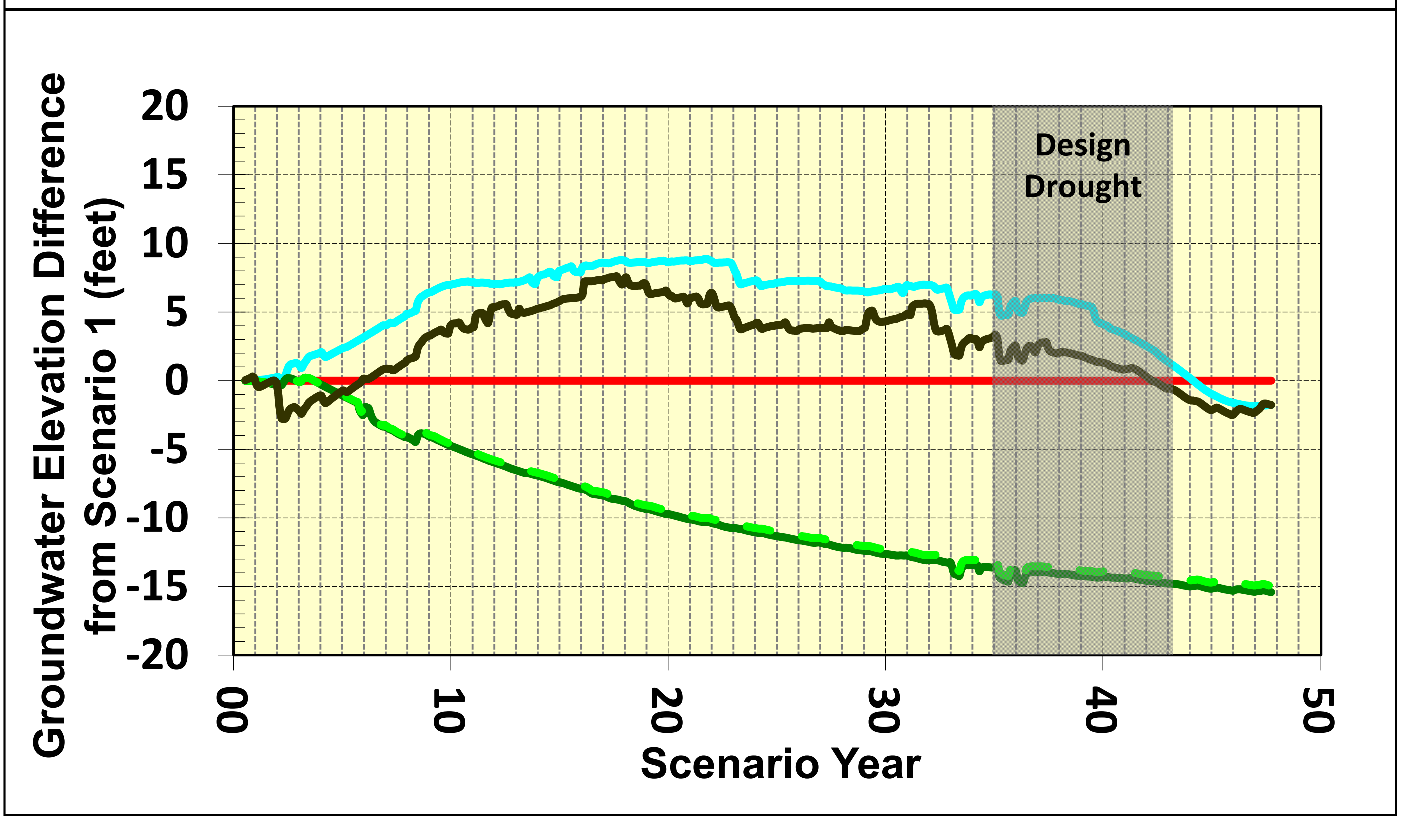
San Francisco Public Utilities Commission

Model Layer 4 Hydrographs for LMMW-2

K/J 0864001
May 2012
Figure 10.2-12b





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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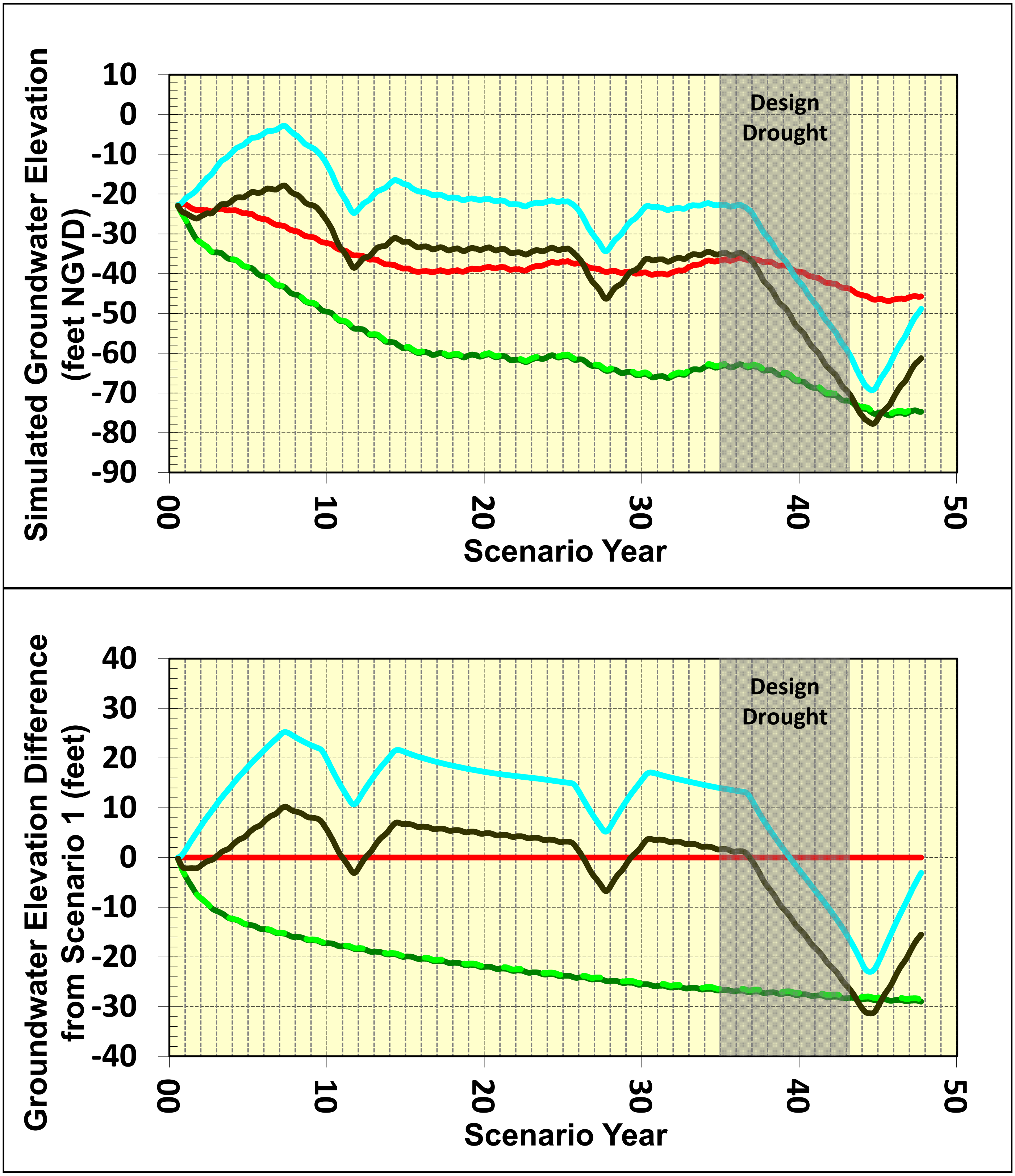
San Francisco Public Utilities Commission

Model Layer 1 Hydrographs for LMMW-3

K/J 0864001
May 2012
Figure 10.2-13a



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

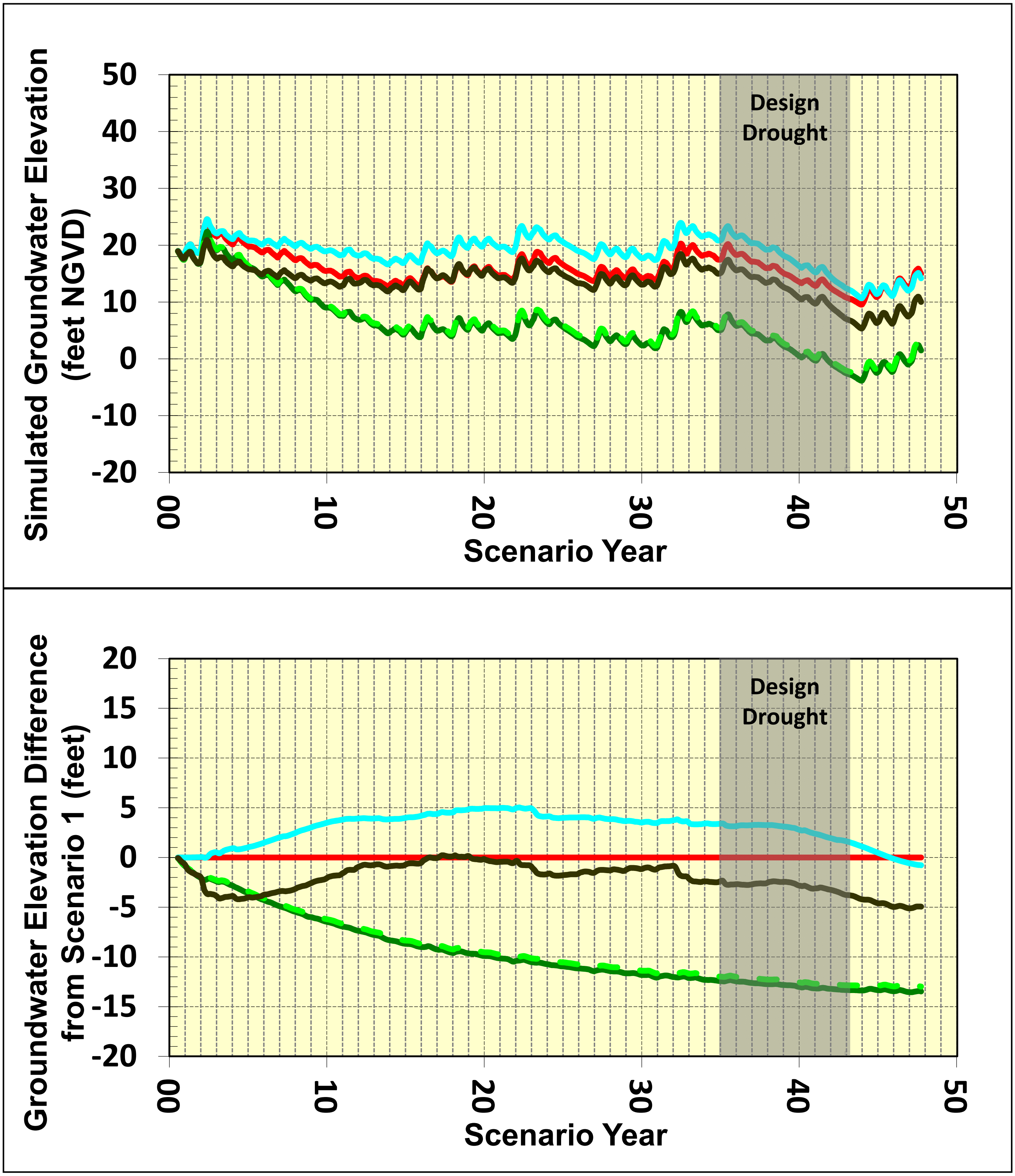
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Kennedy/Jenks Consultants

Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Model Layer 4 Hydrographs for LMMW-3

K/J 0864001
May 2012
Figure 10.2-13b



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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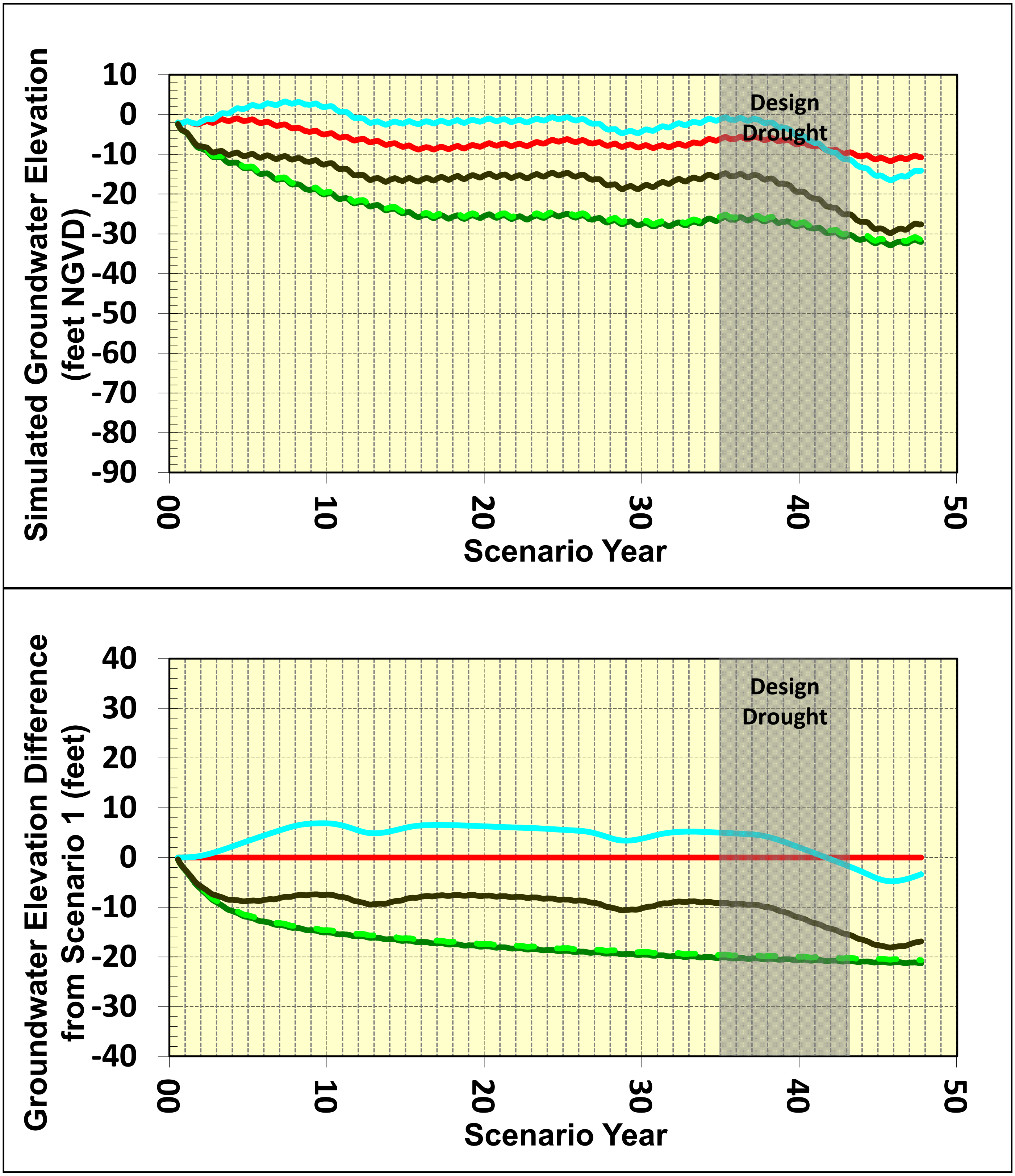
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Model Layer 1 Hydrographs for LMMW-4

K/J 0864001
May 2012
Figure 10.2-14a



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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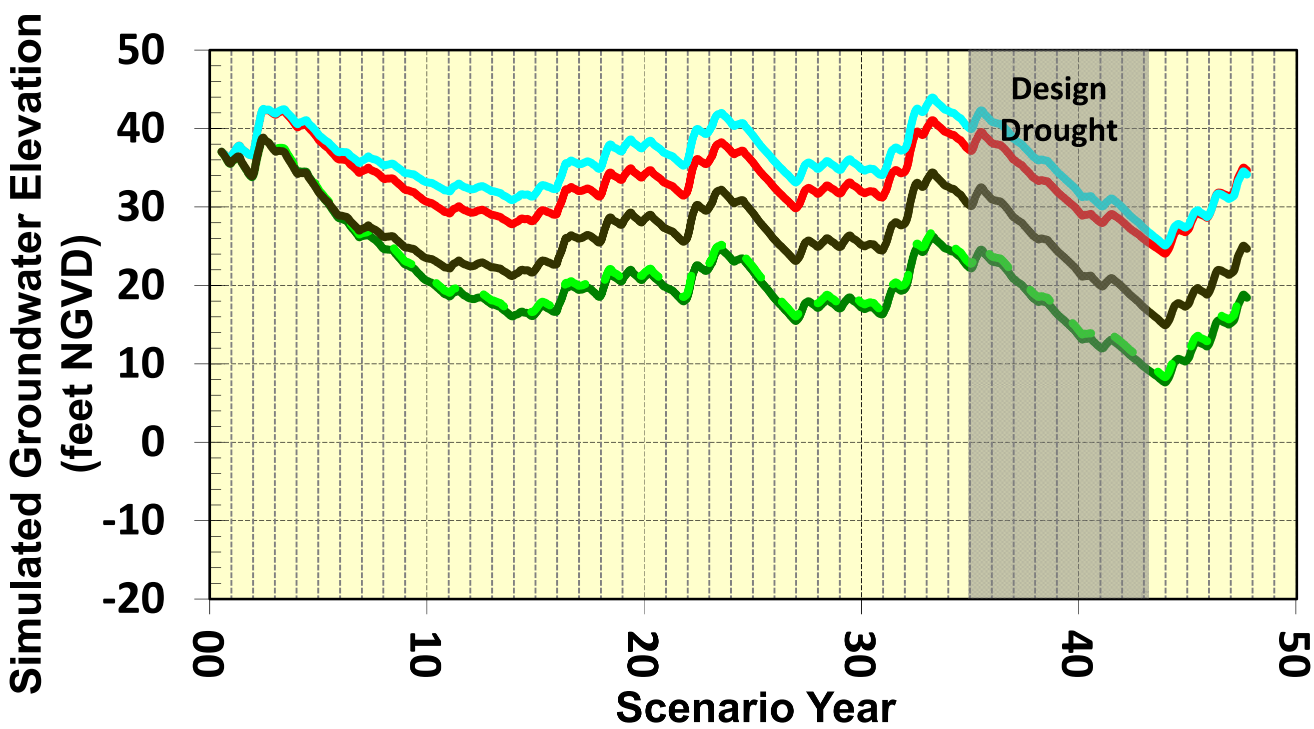
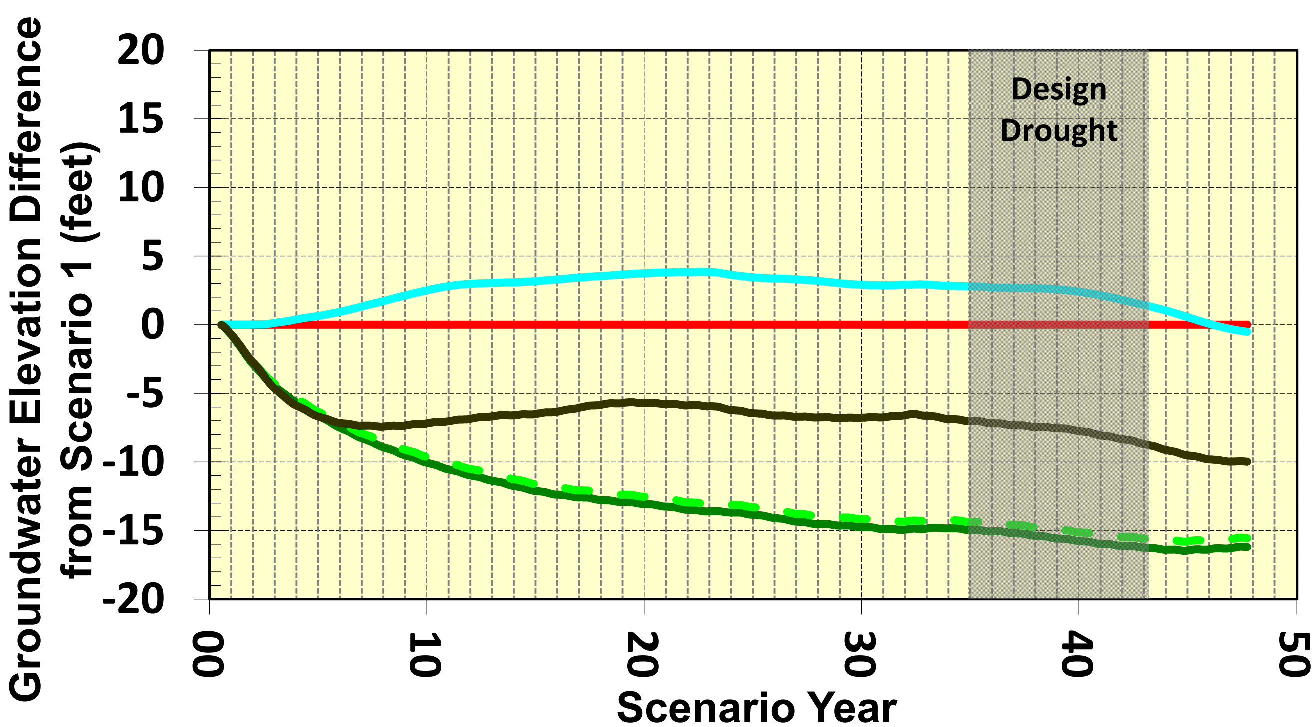
Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Model Layer 4 Hydrographs for LMMW-4

K/J 0864001
May 2012
Figure 10.2-14b





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Model Layer 1 Hydrographs for LMMW-5

K/J 0864001
May 2012
Figure 10.2-15

Tables

Table 10.2-1: Summary of Model Scenario Pumping Assumptions

		Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4
Model Scenarios		**Existing Conditions**	**GSR**	**SFGW**	**SFGW**	**Cumulative**
Establish Initial Conditions		Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence
	June 2009 Condition	√	√	√	√	√
Model Scenario Simulation Period						
	47.25 years (including Design Drought) Hydrologic Sequence: July 1996 to September 2003 -> October 1958 to November 1992 -> December 1975 to June 1978 -> July 2003 - September 2006		√	√	√	√
Pumping Assumptions for Municipal Use						
PA Municipal Wells (mgd)						
	"Take" Periods	6.84	6.90	6.84	6.84	6.90
	"Put" Periods	6.84	1.38	6.84	6.84	1.38
	"Hold" Periods	6.84	6.90	6.84	6.84	6.90
GSR Project Proposed Municipal Wells (mgd)						
	"Take" Periods	0.0	7.23	0.0	0.0	7.23
	"Put" Periods	0.0	0.04	0.0	0.0	0.04
	"Hold" Periods	0.0	0.04	0.0	0.0	0.04
SFGW Project Proposed Municipal Wells (mgd)						
	Year-Round Pumping	0.0	0.0	3.0	4.0	4.0
Total Municipal Pumping (PA + GSR + SFGW)						
	"Take" Periods	***6.84***	***14.13***	***9.84***	***10.84***	***18.13***
	"Put" Periods	***6.84***	***1.42***	***9.84***	***10.84***	***5.42***
	"Hold" Periods	***6.84***	***6.94***	***9.84***	***10.84***	***10.94***
Irrigation and Other Non-Potable Pumping Assumptions (mgd)[1]						
Golden Gate Park	Elk Glen (GGP)	0.081	0.081	0.081	0.000	0.000
	South Windmill (GGP)	0.498	0.498	0.498	0.000	0.000
	North Lake (GGP)	0.563	0.563	0.563	0.000	0.000
	Sub-Total	***1.142***	***1.142***	***1.142***	***0.000***	***0.000***
Golf Courses	Burlingame Golf Club	0.150	0.150	0.150	0.150	0.150
	California Golf No. 02	0.192	0.192	0.192	0.192	0.192
	Green Hills No. 05	0.099	0.099	0.099	0.099	0.099
	Lake Merced Golf No. 01	0.004	0.004	0.004	0.004	0.004
	Lake Merced Golf No. 02	0.004	0.004	0.004	0.004	0.004
	Lake Merced Golf No. 03	0.010	0.010	0.010	0.010	0.010
	Olympic Club No. 09[2]	0.002	0.002	0.002	0.002	0.002
	SF Golf West	0.035	0.035	0.035	0.035	0.035
	Sub-Total	***0.495***	***0.495***	***0.495***	***0.495***	***0.495***
Cemeteries	Cypress Lawn No. 02	0.020	0.020	0.020	0.020	0.020
	Cypress Lawn No. 03	0.144	0.144	0.144	0.144	0.144
	Eternal Home	0.013	0.013	0.013	0.013	0.013
	Hills of Eternity No. 02	0.020	0.020	0.020	0.020	0.020
	Holy Cross No. 03[3]	0.190	0.190	0.190	0.190	0.230
	Home of Peace No. 02	0.039	0.039	0.039	0.039	0.039
	Italian Cemetery	0.033	0.033	0.033	0.033	0.033
	Olivet	0.098	0.098	0.098	0.098	0.098
	Woodlawn No. 02	0.085	0.085	0.085	0.085	0.085
	Sub-Total	***0.641***	***0.641***	***0.641***	***0.641***	***0.681***
Other	Hillsborough Residents No. 1-12	0.291	0.291	0.291	0.291	0.291
	Edgewood Development Ctr.	0.009	0.009	0.009	0.009	0.009
	Zoo No.05	0.321	0.321	0.321	0.321	0.321
	Stern Grove	0.004	0.004	0.012	0.013	0.013
	Sub-Total	***0.626***	***0.626***	***0.634***	***0.635***	***0.635***
Total Irrigation and Other Non-Potable Pumping		***2.90***	***2.90***	***2.91***	***1.77***	***1.81***

Key:
afy - acre-feet per year
mgd - million gallons per day
PA - Partner Agencies
GGP - Golden Gate Park
GSR - Regional Groundwater Storage and Recovery
SFGW - San Francisco Groundwater Supply
SFPUC - San Francisco Public Utilities Commission

Notes:
(1) Pumping wells that are listed identify the wells in the model scenarios whose pumping assumptions were modified compared to the 2008 No-Project Scenario by HydroFocus (May, 2011, ver. 3.1), as a result of revised Soil Moisture Budget (SMB). Pumping rates for the three wells in GGP and the California Golf No. 02, Edgewood Development Center, Zoo No. 05, and Stern Grove wells were further modified compared to the results of revised SMB.
(2) Olympic Club No. 09 values include pumping for both Olympic Golf Club wells.
(3) Holy Cross No. 3 well irrigation pumping for Scenarios 1, 2, 3a, and 3b is based on the results of revised SMB. Based on the projected future build-out at the Holy Cross cemetery, an additional pumping of 0.04 mgd (45 afy) was estimated to occur under Scenario 4 (Cumulative).

Table 10.2-2: Lake Merced Lake-Level Model Summary Statistics for Scenarios 1, 2, 3a, 3b, and 4

	Model Scenarios	Scenario 1 Existing Conditions	Scenario 2 GSR	Scenario 3a SFGW	Scenario 3b SFGW	Scenario 4 Cumulative
Lake Level\ Assessment (*percentage of simulation duration with lake levels within specified ranges*)[1]						
Lake Level (feet City Datum)	> 11	7%	40%	0%	0%	N/A[4]
	9 – 11	17%	30%	5%	4%	19%
	7 – 9	15%	10%	2%	3%	35%
	5 – 7	28%	6%	7%	5%	24%
	3 – 5	20%	2%	3%	3%	7%
	1 – 3	9%	2%	10%	9%	3%
	< 1	4%	10%	73%	76%	13%
Monthly Lake Level Statistics (*feet City Datum*)[2]						
	95th Percentile	11.3	12.9	9.1	8.5	9.5
	Mean	6.3	9.1	-1.3	-1.9	6.1
	5th Percentile	1.1	-0.8	-7.5	-8.1	-2.7
Annual Lake Level Range Statistics (*feet*)[3]						
	95th Percentile	3.2	2.8	3.6	3.8	3.1
	Mean	1.6	1.5	1.8	1.8	1.6
	5th Percentile	0.8	0.6	0.9	0.9	0.5

Key:
GSR - Regional Groundwater Storage and Recovery Project
SFGW - San Francisco Groundwater Supply Project

Notes:
Summary Statistics are from TM10.2-Attachment 10.2-A.
(1) Lake Level Assessment indicates the percentage of months in the simulation period for which lake levels in Lake Merced were within the specified range. Ranges are given in feet City Datum, which is equal to feet NGVD minus 8.62 feet.
(2) Monthly Lake Level Statistics provide the mean, 95th and 5th percentile of lake levels over the entire simulation period. The 95th Percentile value represents the level below which the Lake Merced lake level was simulated for 95% of the simulation period months. The 5th Percentile value represents the level below which the Lake Merced lake level was simulated for 5% of the simulation period months.
(3) Annual Lake Level Range is the difference between the highest and lowest lake level for a water year (October to September) and averaged over the 47 complete water years in the simulation. The 95th Percentile value represents the range below which 95% of the annual ranges in lake levels (maximum minus minimum levels over an October to September water year) fell. The 5th Percentile value represents the range below which 5% of the annual ranges in lake levels fell.
(4) Category is not applicable, because lake spillway elevation in Scenario 4 is 9.5 feet City Datum.

Attachment 10.2-A

Lake Merced Lake-Level Model Simulation Results for Lake Merced with Summary Statistics

Explanation for TM10.2 - Attachment 10.2-A

The following sheets provide a summary of the Lake Merced Lake Model for Scenarios 1, 2, 3a, 3b and 4. These scenarios are described in more detail in TM 10.1 and the Lake Model is described in more detail in TM10.1 Attachment 10.1-H.

Summary of Lake Conditions

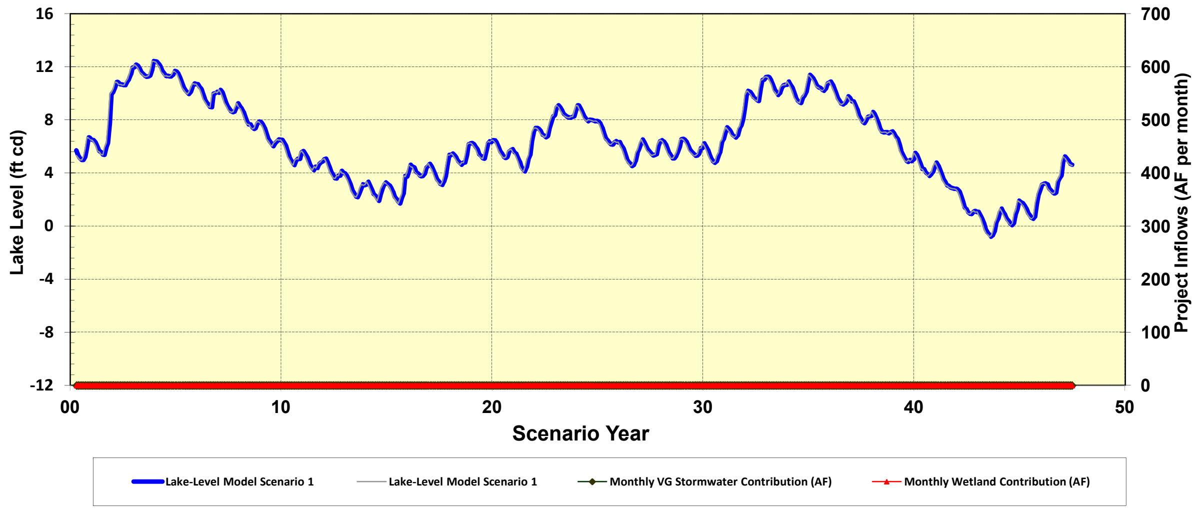
- Project Performance Summary denotes the percentage of time that the simulated lake levels occur in the specified elevation bands. The percentage of time that the lake levels occur between 1 and 13 feet (City Datum) are calculated in 2-foot bands. The percentage for lake levels less than 1 foot (City Datum) is grouped into a single band.
- Monthly Lake Level Summary provides the maximum, minimum and mean lake level for the entire simulation period. In addition, the 95th, 90th, 10th and 5th percentile lake levels are also provided to provide a basis of comparison of the lake level extremes.
- Monthly Lake Level Change Summary provides the range of month-to-month changes that occur over the entire simulation period.
- Lake Level Continuity provides the maximum length of time that lake levels remain within the specified range over the entire simulation period.
- The Average Annual Lake Elevation Summary provides the maximum, minimum and mean lake level for the 47 full water years (October to September) contained within the simulation. In addition, the 95th, 90th, 10th and 5th percentile lake levels are also provided to provide a basis of comparison of the lake level extremes.
- Annual Range of Lake Levels is the difference between the maximum and minimum lake level for each water year (October to September) for the 47 full water years included in the simulation. The range provides a method to evaluate whether the lake level fluctuations during a water year vary due to the effects of the project.

Summary of Project Flows

- Spillway flows provides the number of water years (October to September) for the 47 full water years within specific flow rate bands for lake water flow over the Lake Merced spillway.
- Wetland contribution provides the number of water years (October to September) for the 47 full water years within specific flow rate bands for inflow into Lake Merced through an engineered wetland from water diverted from the Vista Grande Canal. This only occurs in Scenario 4 as part of the Vista Grande Drainage Basin Improvements Project.
- Vista Grande (VG) Stormwater Contribution provides the number of water years (October to September) for the 47 full water years within specific flow rate bands for inflow into Lake Merced from direct diversions of stormwater from the Vista Grande Canal. This only occurs in Scenario 4 as part of the Vista Grande Drainage Basin Improvements Project.
- Project Contribution provides the number of water years (October to September) for the 47 full water years within specific flow rate bands for inflow to or outflow from Lake Merced for the sum of all spillway flows, wetland contributions and Vista Grande stormwater contributions.

Scenario 1 - SFPUC GSR and SFGW Project Technical Analysis

Assumptions:	Initial Lake Level	Wetland Source	VG Stormwater	Diversion Elevation	Spillway
	5.7	none	none	13.0	13



Lake Conditions

Project Performance Summary

Monthly Lake Elevation (ft, City Datum)	*Percent Time*
Above 11 feet	7%
between 9 and 11 feet	17%
between 7 and 9 feet	15%
between 5 and 7 feet	28%
between 3 and 5 feet	20%
between 1 and 3 feet	9%
Below 1 feet	4%
TOTAL	**100%**

Monthly Lake Level Summary

Percentile	*Lake Elevation (ft, City Datum)*
Maximum Lake Level	12.4
95th percentile	11.3
90th percentile	10.6
Mean Lake Level	6.3
10th percentile	2.4
5th percentile	1.1
Minimum Lake Level	-0.8

Monthly Lake Level Change Summary

Percentile	*Lake Elevation (ft, City Datum)*
Maximum Lake Level	2.14
95th percentile	0.61
90th percentile	0.42
Mean Lake Level	0.00
10th percentile	-0.32
5th percentile	-0.37
Minimum Lake Level	-0.48

Lake Level Continuity

Monthly Lake Elevation (ft, City Datum)	Consecutive months
Above 11 feet	30
between 9 and 11 feet	24
between 7 and 9 feet	18
between 5 and 7 feet	43
between 3 and 5 feet	25
between 1 and 3 feet	11
Below 1 feet	11

Average Annual Lake Elevation Summary

Percentile	*Annual Average Lake Elevation (ft, City Datum)*
Maximum Lake Level	11.8
95th percentile	11.0
90th percentile	10.4
Mean Lake Level	6.3
10th percentile	2.7
5th percentile	1.3
Minimum Lake Level	0.1

Annual Range in Lake Levels

Percentile	*Lake Level Change (ft)*
Maximum Lake Level	5.5
95th percentile	3.2
90th percentile	2.7
Mean Lake Level	1.6
10th percentile	0.9
5th percentile	0.8
Minimum Lake Level	0.2

Project Flows

Spillway Flows

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

Wetland Contribution

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

VG Stormwater Contribution

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

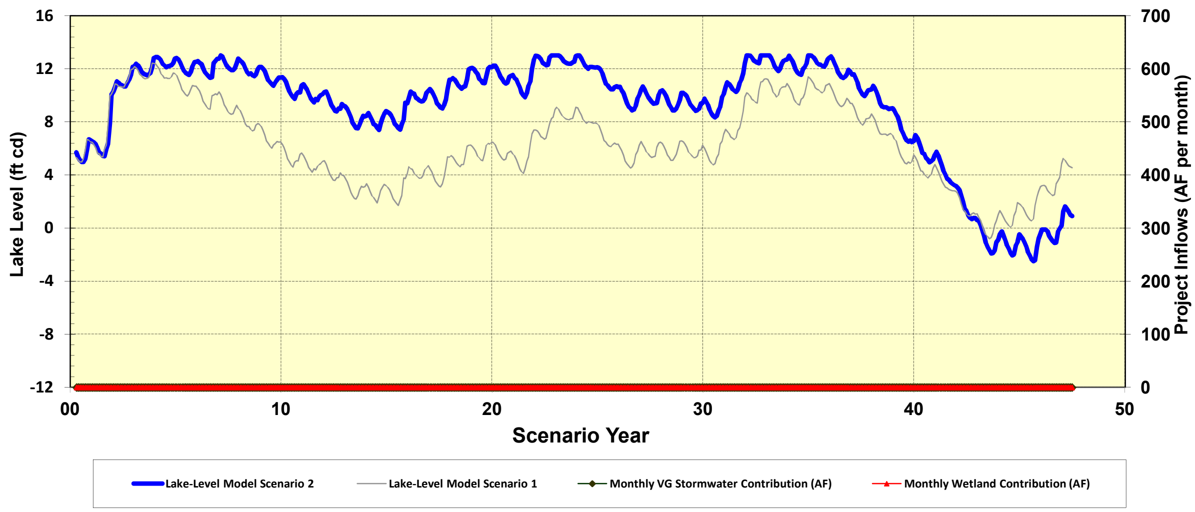
Project Contribution

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Total Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

Scenario 2 - SFPUC GSR and SFGW Project Technical Analysis

Assumptions:	Initial Lake Level	Wetland Source	VG Stormwater	Diversion Elevation	Spillway
Units - Feet City Datum	5.7	none	none	13.0	13



Lake Conditions

Project Performance Summary

Monthly Lake Elevation (ft, City Datum)	*Percent Time*
Above 11 feet	40%
between 9 and 11 feet	30%
between 7 and 9 feet	10%
between 5 and 7 feet	6%
between 3 and 5 feet	2%
between 1 and 3 feet	2%
Below 1 feet	10%
TOTAL	**100%**

Monthly Lake Level Summary

Percentile	*Lake Elevation (ft, City Datum)*
Maximum Lake Level	13.0
95th percentile	12.9
90th percentile	12.6
Mean Lake Level	9.1
10th percentile	1.1
5th percentile	-0.8
Minimum Lake Level	-2.5

Monthly Lake Level Change Summary

Percentile	*Lake Elevation (ft, City Datum)*
Maximum Lake Level	2.18
95th percentile	0.59
90th percentile	0.42
Mean Lake Level	0.00
10th percentile	-0.32
5th percentile	-0.36
Minimum Lake Level	-0.52

Lake Level Continuity

Monthly Lake Elevation (ft, City Datum)	Consecutive months
Above 11 feet	80
between 9 and 11 feet	27
between 7 and 9 feet	33
between 5 and 7 feet	14
between 3 and 5 feet	10
between 1 and 3 feet	5
Below 1 feet	54

Average Annual Lake Elevation Summary

Percentile	*Annual Average Lake Elevation (ft, City Datum)*
Maximum Lake Level	12.8
95th percentile	12.6
90th percentile	12.4
Mean Lake Level	9.0
10th percentile	0.8
5th percentile	-0.7
Minimum Lake Level	-1.3

Annual Range in Lake Levels

Percentile	*Lake Level Change (ft)*
Maximum Lake Level	5.6
95th percentile	2.8
90th percentile	2.7
Mean Lake Level	1.5
10th percentile	0.7
5th percentile	0.6
Minimum Lake Level	0.2

Project Flows

Spillway Flows

During operation	Volume (AFY)
Average	37
Maximum	604
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	41
0 to 100	1
100 to 200	1
200 to 300	2
300 to 500	1
>500	1
TOTAL	**47**

Wetland Contribution

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

VG Stormwater Contribution

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

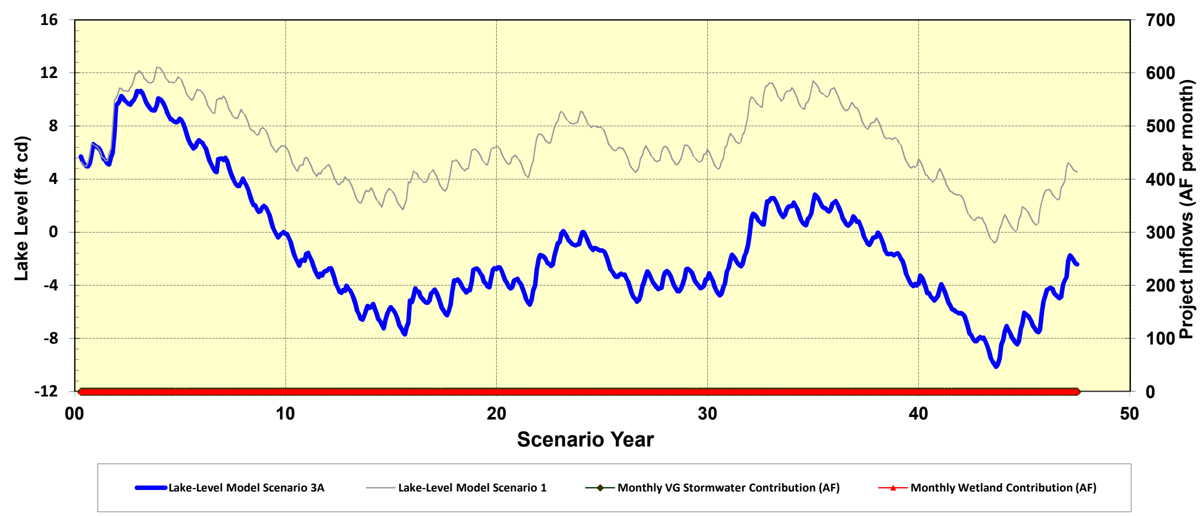
Project Contribution

During operation	Volume (AFY)
Average	37
Maximum	604
Minimum	0

Total Flow (AFY)	*Frequency (# of years)*
0	41
0 to 100	1
100 to 200	1
200 to 300	2
300 to 500	1
>500	1
TOTAL	**47**

Scenario 3A - SFPUC GSR and SFGW Project Technical Analysis

Assumptions:	Initial Lake	Wetland Source	VG Stormwater	Diversion Elevation	Spillway
Units - Feet City Datum	5.7	none	none	13.0	13



Lake Conditions

Project Performance Summary

Monthly Lake Elevation (ft, City Datum)	*Percent Time*
Above 11 feet	0%
between 9 and 11 feet	5%
between 7 and 9 feet	2%
between 5 and 7 feet	7%
between 3 and 5 feet	3%
between 1 and 3 feet	10%
Below 1 feet	73%
TOTAL	**100%**

Monthly Lake Level Summary

Percentile	*Lake Elevation (ft, City Datum)*
Maximum Lake Level	10.7
95th percentile	9.1
90th percentile	6.2
Mean Lake Level	-1.3
10th percentile	-6.3
5th percentile	-7.5
Minimum Lake Level	-10.1

Monthly Lake Level Change Summary

Percentile	*Lake Elevation (ft, City Datum)*
Maximum Lake Level	2.11
95th percentile	0.65
90th percentile	0.48
Mean Lake Level	-0.01
10th percentile	-0.36
5th percentile	-0.42
Minimum Lake Level	-0.51

Lake Level Continuity

Monthly Lake Elevation (ft, City Datum)	Consecutive months
Above 11 feet	0
between 9 and 11 feet	29
between 7 and 9 feet	12
between 5 and 7 feet	14
between 3 and 5 feet	12
between 1 and 3 feet	21
Below 1 feet	273

Average Annual Lake Elevation Summary

Percentile	*Annual Average Lake Elevation (ft, City Datum)*
Maximum Lake Level	10.1
95th percentile	8.0
90th percentile	6.0
Mean Lake Level	-1.3
10th percentile	-6.0
5th percentile	-6.9
Minimum Lake Level	-8.7

Annual Range in Lake Levels

Percentile	*Lake Level Change (ft)*
Maximum Lake Level	5.2
95th percentile	3.6
90th percentile	3.3
Mean Lake Level	1.8
10th percentile	0.9
5th percentile	0.9
Minimum Lake Level	0.2

Project Flows

Spillway Flows

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

Wetland Contribution

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

VG Stormwater Contribution

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

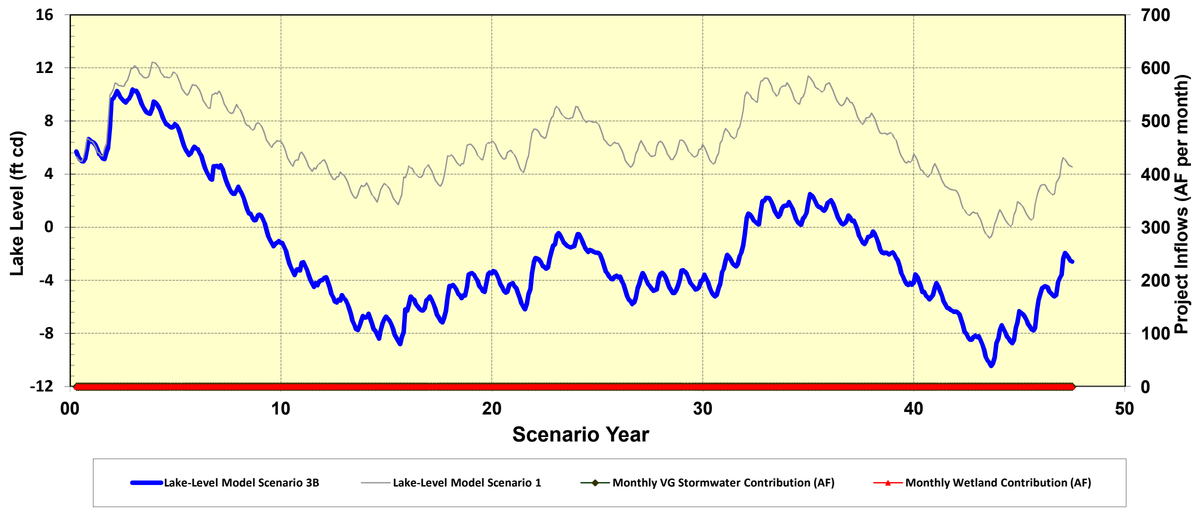
Project Contribution

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Total Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

Scenario 3B - SFPUC GSR and SFGW Project Technical Analysis

Assumptions:	Initial Lake	Wetland Source	VG Stormwater	Diversion Elevation	Spillway
Units - Feet City Datum	5.7	none	none	13.0	13



Lake Conditions

Project Performance Summary

Monthly Lake Elevation (ft, City Datum)	*Percent Time*
Above 11 feet	0%
between 9 and 11 feet	4%
between 7 and 9 feet	3%
between 5 and 7 feet	5%
between 3 and 5 feet	3%
between 1 and 3 feet	9%
Below 1 feet	76%
TOTAL	**100%**

Monthly Lake Level Summary

Percentile	*Lake Elevation (ft, City Datum)*
Maximum Lake Level	10.4
95th percentile	8.5
90th percentile	5.7
Mean Lake Level	-1.9
10th percentile	-7.1
5th percentile	-8.1
Minimum Lake Level	-10.4

Monthly Lake Level Change Summary

Percentile	*Lake Elevation (ft, City Datum)*
Maximum Lake Level	2.11
95th percentile	0.67
90th percentile	0.48
Mean Lake Level	-0.01
10th percentile	-0.36
5th percentile	-0.42
Minimum Lake Level	-0.52

Lake Level Continuity

Monthly Lake Elevation (ft, City Datum)	Consecutive months
Above 11 feet	0
between 9 and 11 feet	19
between 7 and 9 feet	13
between 5 and 7 feet	14
between 3 and 5 feet	15
between 1 and 3 feet	18
Below 1 feet	282

Average Annual Lake Elevation Summary

Percentile	*Annual Average Lake Elevation (ft, City Datum)*
Maximum Lake Level	9.8
95th percentile	7.5
90th percentile	5.7
Mean Lake Level	-1.9
10th percentile	-7.1
5th percentile	-7.5
Minimum Lake Level	-9.0

Annual Range in Lake Levels

Percentile	*Lake Level Change (ft)*
Maximum Lake Level	5.1
95th percentile	3.8
90th percentile	3.3
Mean Lake Level	1.8
10th percentile	1.0
5th percentile	0.9
Minimum Lake Level	0.2

Project Flows

Spillway Flows

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

Wetland Contribution

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

VG Stormwater Contribution

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

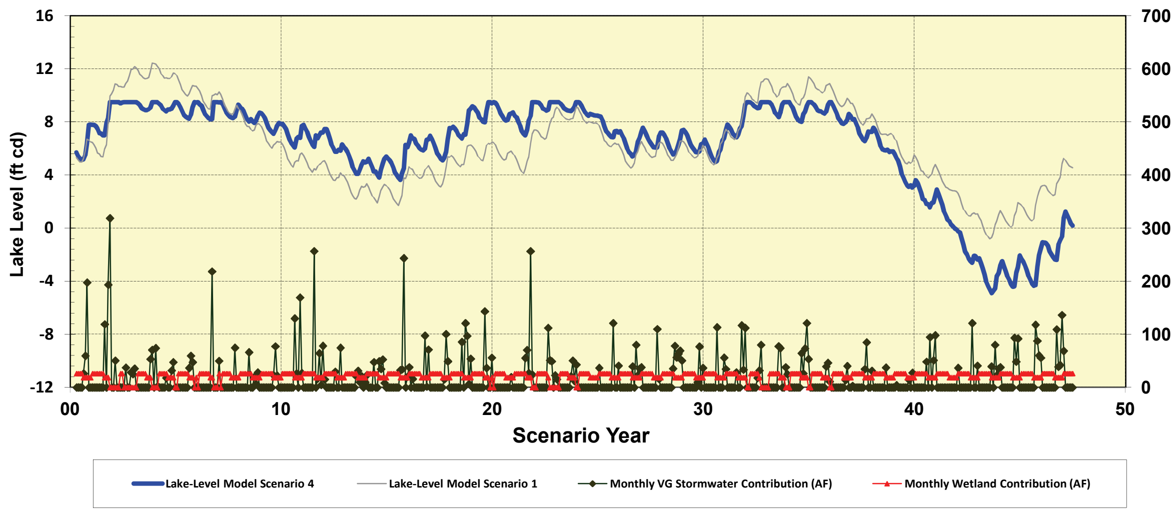
Project Contribution

During operation	Volume (AFY)
Average	0
Maximum	0
Minimum	0

Total Flow (AFY)	*Frequency (# of years)*
0	47
0 to 100	0
100 to 200	0
200 to 300	0
300 to 500	0
>500	0
TOTAL	**47**

Scenario 4 - SFPUC GSR and SFGW Project Technical Analysis

Assumptions:	Initial Lake Level	Wetland Source	VG Stormwater	Diversion Elevation	Spillway
Units - Feet City Datum	5.7	baseflow	baseflow	9.5	9.5



Lake Conditions

Project Performance Summary

Monthly Lake Elevation (ft, City Datum)	*Percent Time*
Above 11 feet	0%
between 9 and 11 feet	19%
between 7 and 9 feet	35%
between 5 and 7 feet	24%
between 3 and 5 feet	7%
between 1 and 3 feet	3%
Below 1 feet	13%
TOTAL	**100%**

Monthly Lake Level Summary

Percentile	*Lake Elevation (ft, City Datum)*
Maximum Lake Level	9.5
95th percentile	9.5
90th percentile	9.5
Mean Lake Level	6.1
10th percentile	-0.7
5th percentile	-2.7
Minimum Lake Level	-4.9

Monthly Lake Level Change Summary

Percentile	*Lake Elevation (ft, City Datum)*
Maximum Lake Level	2.78
95th percentile	0.83
90th percentile	0.52
Mean Lake Level	0.02
10th percentile	-0.34
5th percentile	-0.39
Minimum Lake Level	-0.54

Lake Level Continuity

Monthly Lake Elevation (ft, City Datum)	Consecutive months
Above 11 feet	0
between 9 and 11 feet	19
between 7 and 9 feet	26
between 5 and 7 feet	25
between 3 and 5 feet	12
between 1 and 3 feet	14
Below 1 feet	68

Average Annual Lake Elevation Summary

Percentile	*Annual Average Lake Elevation (ft, City Datum)*
Maximum Lake Level	9.5
95th percentile	9.2
90th percentile	9.1
Mean Lake Level	6.0
10th percentile	-0.2
5th percentile	-2.6
Minimum Lake Level	-3.8

Annual Range in Lake Levels

Percentile	*Lake Level Change (ft)*
Maximum Lake Level	3.6
95th percentile	3.1
90th percentile	2.7
Mean Lake Level	1.6
10th percentile	0.7
5th percentile	0.5
Minimum Lake Level	0.2

Project Flows

Spillway Flows

During operation	Volume (AFY)
Average	128
Maximum	1547
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	32
0 to 100	4
100 to 200	2
200 to 300	1
300 to 500	4
>500	4
TOTAL	**47**

Wetland Contribution

During operation	Volume (AFY)
Average	248
Maximum	277
Minimum	78

Flow (AFY)	*Frequency (# of years)*
0	0
0 to 100	0
100 to 200	6
200 to 300	41
300 to 500	0
>500	0
TOTAL	**47**

VG Stormwater Contribution

During operation	Volume (AFY)
Average	198
Maximum	681
Minimum	0

Flow (AFY)	*Frequency (# of years)*
0	0
0 to 100	9
100 to 200	16
200 to 300	12
300 to 500	9
>500	1
TOTAL	**47**

Project Contribution

During operation	Volume (AFY)
Average	574
Maximum	2362
Minimum	78

Total Flow (AFY)	*Frequency (# of years)*
0	0
0 to 100	0
100 to 200	0
200 to 300	1
300 to 500	24
>500	22
TOTAL	**47**

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Technical Memorandum 10.3

Assessment of Potential Seawater Intrusion

for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

24 April 2012

Prepared for

San Francisco Public Utilities Commission
525 Golden Gate Avenue, 10th Floor
San Francisco, CA 94102

K/J Project No. 0864001

Supplemental Explanation for Hydrographs - TM10.3

This supplemental explanation is prepared to address discrepancies on several graphs presented in TM 10.3.

First, the x-axis on several graphs showing model results was shifted. The x-axis is named Scenario Year which should correspond to a water year[1]. However, the graph template was plotted using a calendar year, so the intervals on the x-axis represent the period from January to December. The result is that the graph is shifted 3-months later relative to Scenario Year.

Second, the shaded area representing the Design Drought was added manually and because of this process, it was not presented consistently on the graphs. By definition per the PEIR, the 8.5-year Design Drought includes one Hold year before the 7.5-year Take period. In addition, the Design Drought needs to be shifted 3-months later for the x-axis issue to be consistent with the model output. The Design Drought should be shown as Scenario Years 35.5 to 44.0 on the shifted x-axis.

The following is a list of figures in TM 10.3 where the Design Drought shaded area is shown slightly different and does not match the correct display of the Design Drought. The figures should be viewed based on the correct representation of the Design Drought as explained above.

- Figures 10.3-4 through 10.3-17 (a total of 30 figures) have the shifted x-axis. The Design Drought should be shown as Scenario Years 35.5 to 44.0 on the shifted x-axis.

[1] A water year is October 1 of the previous year to September 30 of the current (named) year.

24 April 2012

Task 10.3 Technical Memorandum

San Francisco Public Utilities Commission

Assessment of Potential Seawater Intrusion for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Prepared For: Greg Bartow and Jeff Gilman, SFPUC

Prepared by: Matthew Baillie, Michael Maley and Sevim Onsoy, Kennedy/Jenks Consultants

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1. Introduction

This Technical Memorandum (TM) was prepared to document work performed by Kennedy/Jenks Consultants (Kennedy/Jenks) for the San Francisco Public Utilities Commission (SFPUC) pursuant to the amended Task Order (TO) authorizations CUW30103-TO-1.12 of the Regional Groundwater Storage and Recovery (GSR) Project and CUW30102-TO-2.7 of the San Francisco Groundwater Supply (SFGW) Project. These projects are funded by the SFPUC's Water System Improvement Program (WSIP).

1.1. GSR and SFGW Project Description

The GSR Project is a conjunctive use project that would allow for increased groundwater supplies in the southern portion of the Westside Groundwater Basin (South Westside Basin) during periods of drought when SFPUC surface water supplies might become limited (MWH, 2008). The project would be designed to provide up to 60,500 acre-feet (af) of stored water to meet SFPUC system demands during the last 7.5 years of SFPUC's Design Drought. The SFPUC plans to install 16 new production wells for the GSR Project to recover the stored groundwater. Under the Draft GSR Operating Agreement, the SFPUC would "store" water in the South Westside Basin through the mechanism of in-lieu recharge by providing supplemental surface water as a substitute for groundwater pumping by the Partner Agencies (PAs). As a result of the in-lieu deliveries, up to 60,500 af of groundwater storage or put credits could accrue to the SFPUC Storage Account. During shortages of SFPUC Regional Water System water due to drought, emergencies, or scheduled maintenance, the PAs would return to pumping from their existing wells, and SFPUC would extract groundwater from GSR Project wells as long as a positive balance exists in the SFPUC Storage Account.

The SFGW Project would provide a reliable, local source of high-quality groundwater in the northern portion of the Westside Groundwater Basin (North Westside Basin) to supplement the

San Francisco municipal water system. The SFGW Project would construct up to four wells (and convert two existing irrigation wells in Golden Gate Park for municipal supply) and associated facilities in the western part of San Francisco and extract an annual average of up to 4.0 million gallons per day (mgd) of water from the North Westside Basin (SFPUC, 2009a). The extracted groundwater, which would be used both for regular and emergency water supply purposes, would be blended in small quantities with imported surface water before entering the municipal drinking water system for distribution. The SFGW Project includes two phases. In phase one, SFPUC would build four new groundwater wells at the Lake Merced Pump Station, West Sunset Playground, South Sunset Playground, and the Golden Gate Park Central Pump Station. In phase two, SFPUC would modify two existing irrigation wells (South Windmill Replacement and North Lake) in Golden Gate Park, converting them into municipal water supply wells.

The locations of existing and proposed GSR and SFGW wells, existing PA wells, and monitoring wells are shown on Figure 10.3-1. Additional detailed discussion of the GSR and SFGW Projects is provided in Task 10.1 Technical Memorandum - Groundwater Modeling Analysis for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project (TM-10.1).

1.2. Objective

Implementation of the proposed GSR and SFGW Projects would influence groundwater heads in the Westside Groundwater Basin (Westside Basin, or Basin). Because the Westside Basin underlies both the Pacific Ocean west of San Francisco and San Francisco Bay near San Bruno, there is the potential for seawater intrusion to occur as a result of implementation of the GSR and SFGW Projects.

The purpose of this TM is to present the results of an evaluation of potential changes in groundwater head resulting from operation of each of the GSR and SFGW Projects, as well as the cumulative effects of both the GSR and SFGW Projects (along with other reasonably foreseeable future groundwater projects in the Basin), in order to assess the potential for seawater intrusion in areas that may be susceptible. The potential changes in groundwater head resulting from implementation of the GSR and SFGW Projects and other reasonably foreseeable future projects were evaluated based on groundwater model scenarios developed using the existing Westside Basin Groundwater-Flow Model (HydroFocus, 2007, 2009, and 2011). These model results were evaluated with respect to the potential to induce seawater intrusion. This TM presents information on the past, current, and future subsurface conditions that are relevant to the issue of seawater intrusion along with a conceptual discussion of the mechanisms that control seawater intrusion.

2. Approach and Conceptual Understanding of Seawater Intrusion

Before analyzing seawater intrusion in the context of the Westside Basin, a conceptual understanding of the process of seawater intrusion is presented. This section includes a description of the process, including the variables involved, the time-frame over which intrusion typically occurs, and hydrogeological factors that control intrusion.

2.1. General Approach

The general approach used to evaluate potential seawater intrusion for this TM is based on an analysis of the changes in groundwater conditions in the Basin, including groundwater heads[1] and flux, resulting from the operation of the GSR and SFGW Projects. This TM is part of a series of technical memoranda that address various aspects of the GSR and SFGW Projects. Two of these include significant data and analysis that are used for this TM. These include the following:

- Task 8B Technical Memorandum No.1 Hydrologic Setting of the Westside Basin (referred to in the text as TM#1; LSCE, 2010)
- Task 10.1 Groundwater Modeling Analysis for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project (referred to in the text as TM-10.1; Kennedy/Jenks, 2012)

The primary quantitative tools for evaluating potential future conditions are model scenarios generated using the existing Westside Basin Groundwater-Flow Model developed by HydroFocus (2007, 2009, and 2011). For this analysis, the potential for seawater intrusion is evaluated using scenarios that evaluate the proposed GSR and SFGW Projects in isolation. A Cumulative Scenario is evaluated that includes both the GSR and SFGW Projects along with other reasonably foreseeable future groundwater projects in the Basin. The development of the model scenarios is documented in TM-10.1.

This TM includes a brief conceptual understanding of the hydrogeologic processes and factors that influence seawater intrusion and a hydrogeological evaluation summarizing the current conditions with respect to seawater intrusion in the Westside Basin. Much of the information used for this analysis is discussed in detail in TM#1.

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[1] As used in this TM, head is the elevation at which groundwater would rest in a piezometer completed in the referenced aquifer. In an unconfined aquifer, this is equivalent to the water table elevation; in a confined aquifer, this is equivalent to the piezometric head.

2.2. Westside Groundwater Basin

This section provides a brief overview of the physical setting and Basin hydrogeology. More detailed evaluations of the hydrogeology of the Westside Basin are presented in TM#1 and TM10.1.

Figure 10.3-2 provides a representative cross-section from north to south across the Westside Basin. There are three aquifer systems that are commonly referred to within the Westside Basin. These include:

- Shallow Aquifer: this aquifer is present in the northern part of the Basin, in the vicinity of Lake Merced and the southern portion of the Sunset district of San Francisco. The base of the Shallow Aquifer is defined as the top of the “-100 foot clay.”
- Primary Production Aquifer: this aquifer is present throughout the Basin, overlying the “W-clay” where present. Where the W-clay is not present in locations to the south (in the South San Francisco area), the Primary Production Aquifer is divided into shallow and deep units separated by a clay unit at an elevation of approximately -300 feet mean sea level (msl).
- Deep Aquifer: this aquifer underlies the W-clay, and thus its extent is limited to the generally-known extent of that clay unit (TM#1).

The three aquifer systems are separated by thick, extensive clay units (e.g., the -100 ft clay and W-clay). Because of the discontinuous nature of these clay layers, the basin is considered to be a semi-confined aquifer system with limited flow between the different aquifer systems where local geologic conditions permit (TM#1).

2.2.1. Areas Susceptible to Seawater Intrusion

The Westside Basin is bounded by bedrock highs in Golden Gate Park to the north and at Coyote Point to the south (Rogge, 2003; San Bruno, 2007; DWR, 2003). San Bruno Mountain and the San Francisco Bay form the eastern boundary of the Basin (Cal Water, 2006). The San Andreas Fault and Pacific Ocean form the Basin’s western boundary, and its southern limit is defined by a bedrock high that separates it from the San Mateo Plain Groundwater Basin (Rogge, 2003, DWR, 2003, and San Bruno, 2007). The Westside Basin opens to the Pacific Ocean on the northwest and San Francisco Bay on the southeast. Major structural features include the San Andreas Fault system and the Serra Fault.

Areas that are considered potentially susceptible must be investigated for the occurrence of seawater intrusion. Two areas of the Basin are likely to be susceptible to seawater intrusion given certain conditions (Figure 10.3-1). The first is along the Pacific Ocean, between Lincoln Park in the north and Lake Merced in the South. The second is along San Francisco Bay, from the Basin border with the Visitacion Valley Basin in the north to the border with the San Mateo

Plain Basin to the south. The susceptibility of the Westside Basin to seawater intrusion is discussed in more detail in Section 7.

2.2.2. Current Seawater-Intrusion Monitoring System

The two areas monitored for seawater intrusion (the Pacific Coast and the Bay Coast) contain a number of monitoring wells completed in the various aquifers present in the Westside Basin. The two sets of wells are known as the coastal and Bay side monitoring networks. Groundwater head in the Westside Basin is monitored in a network of production and monitoring wells as part of the semi-annual monitoring program that was initiated throughout the Basin in 2000. Results of the most recent groundwater level monitoring were reported in the 2010 Westside Basin Annual Groundwater Monitoring Report (SFPUC, 2011), prepared by SFPUC in coordination with the City of Daly City (Daly City), the City of San Bruno (San Bruno), and the California Water Service Company (Cal Water). Annual monitoring reports have been published by the SFPUC since 2006 (LSCE, 2006 and SFPUC, 2007, 2008a, 2009b, 2010, and 2011); these reports are summarized in TM#1 and TM10.1.

The coastal monitoring network consists of a series of wells stretching along the Pacific Coast from the west end of Golden Gate Park south to Thornton Beach in Daly City (SFPUC, 2009b). The three well clusters (nested wells) along the Old Great Highway (near Kirkham, Ortega, and Taraval Streets) and the well cluster at the San Francisco Zoo were installed specifically for the purpose of monitoring seawater intrusion, and were completed by 2004. Head in some of these wells is monitored continuously using pressure transducers, while in others it is measured quarterly by hand. The results of these monitoring activities are presented as hydrographs in Appendix B of TM#1.

Nested wells or well clusters are present at the South Windmill (57 and 140 feet below land surface; ft bls), Kirkham (130, 255, 385, and 435 ft bls), Ortega (125, 265, 400, and 475 ft bls), Taraval (145, 240, 400, and 530 ft bls), Zoo (275, 450, and 565 ft bls), and Thornton Beach (225, 360, and 670 ft bls) locations. Additional monitoring wells in the coastal monitoring network are present at Lake Merced (LMMW-9SS, LMMW-1D, LMMW-1S) and Fort Funston (S and M).

The Bay side monitoring network is less extensive. Head data were provided to SFPUC for two monitoring wells by the San Francisco Airport (UAL MW13C, constructed to a depth of 146 ft bls, and MW13D, constructed to a depth of 41.5 ft bls) from late 2003 to 2006, and since then SFPUC has been collecting data. Two additional clusters of wells were installed in the Bay side area by San Bruno in 2006 (WRIME, 2007) at the San Francisco Airport (SFO-S, 74 ft bls, and SFO-D, 146 ft bls) and in Burlingame (Burlingame-S, 98 ft bls, Burlingame-M, 166 ft bls, and Burlingame-D, 280 ft bls). These wells have been monitored for groundwater elevation and various chemical constituents since November 2006.

The groundwater elevation and water quality data collected to date from these monitoring wells are provided in TM#1, and the monitoring results are discussed in Sections 7.2 and 7.3.

2.3. Conceptual Understanding of Seawater Intrusion

Seawater intrusion is the movement of saline water from an ocean or bay into freshwater aquifers. Some degree of seawater intrusion occurs in virtually all coastal aquifers, as long as they are hydraulically connected with seawater. Seawater intrusion usually occurs when coastal freshwater aquifers begin to be developed as sources of water supply. Pumping of freshwater from an aquifer reduces the groundwater head and gradient towards the seawater-freshwater interface, drawing seawater into the freshwater aquifer. The increase in chloride and other constituents that accompanies seawater intrusion can cause the freshwater aquifer to become unfit for beneficial uses such as drinking or irrigation.

The intrusion of seawater into a freshwater aquifer is an effect of the respective heads in the ocean and the freshwater aquifer and the difference in densities of the two fluids (the standard value of density for freshwater is 1.0 grams per cubic centimeter, g/cm^3, and a typical value of seawater density is 1.026 g/cm^3). Because freshwater is less dense than seawater, it actually floats on top of the saline water when both are present in an aquifer. The depth of the interface between the saline and freshwater depends on the freshwater head in the aquifer, with a higher head leading to a greater depth to the salt water. Under a simplified aquifer system with groundwater flowing toward the ocean, the freshwater head declines closer to the ocean, so the seawater-freshwater interface gets progressively closer to the ground surface moving from inland toward the ocean; this has led to the seawater intrusion into the aquifer being termed a "wedge" (Figure 10.3-3).

As discussed above, due to its high salt content seawater has a density about 2.6% higher than does freshwater. Based on this difference in densities, the Ghyben-Herzberg principle states that, for every foot of freshwater head in an unconfined aquifer above sea level, there will be 38 feet of fresh water in the aquifer below sea level at equilibrium (Badon-Ghyben, 1888; Herzberg, 1901).

When freshwater heads drop, the seawater-freshwater interface can migrate inland, and over time the interface may eventually reach coastal wells. If the groundwater head were to rise again, the seawater-freshwater interface would migrate back seaward. Movement of the seawater-freshwater interface is a slow process. Seawater intrusion may not reach a production well for a number of years, and only when the conditions leading to seawater intrusion are sustained for an extended period of time.

It is important to note that the freshwater head does not need to be lowered below sea level for seawater intrusion to occur, although a groundwater head below sea level certainly increases the potential rate and extent of seawater intrusion. Instead, the groundwater head must simply be dropped to a level lower than 1/38 the depth below sea level of the bottom of the aquifer. If this occurs, the thickness of freshwater is no longer great enough to exclude seawater from intruding along the base of the aquifer. The presence of freshwater head above this level represents what in this TM is termed a hydrologic control.

In addition, seawater intrusion does not necessarily need to follow the typical conceptual route of intruding from the location of freshwater discharge to the seawater body, as shown in Figure 10.3-3; instead, an aquifer can be intruded via another, bounding aquifer. To illustrate this, we can consider an unconfined aquifer in direct contact with the ocean overlying a semi-confined aquifer that is not in direct contact with the ocean, and is separated from the unconfined aquifer by a discontinuous low-permeability confining layer. If head in the unconfined aquifer is lowered far enough to allow it, seawater would intrude along the base of the aquifer. If the intruding wedge encounters a gap in the low-permeability base of the unconfined aquifer, its density, higher than that of freshwater, dictates that it would sink and intrude into the lower semi-confined aquifer.

The seawater-freshwater interface is not actually a sharp interface because of the action of dispersion and diffusion, instead it forms a transition zone where chloride concentrations range from values typical of freshwater to those of seawater (Bear and Cheng, 1999). The movement of the transition zone within the aquifer is due to changing of the groundwater conditions on the freshwater side of the interface. As the seaward flow of freshwater and/or the groundwater elevations near the interface decline, the interface can move landward. If freshwater flow and groundwater head later increase, the interface would move back toward the ocean; however, some of the salt can remain in the freshwater aquifer even after the interface moves away. Once salt water enters a part of the freshwater aquifer, it is very difficult to expunge, demonstrating that it is important to prevent the movement of the interface into the freshwater aquifer to the extent possible (Bear and Cheng, 1999).

Geologic features can limit communication between the freshwater aquifer and ocean water. In order for seawater to intrude into a freshwater aquifer, that aquifer must be in contact with the ocean in some way, usually by being exposed on the ocean floor. Other geologic configurations can limit or prevent seawater intrusion. These can include tilted beds, impermeable bedrock, gradational changes in aquifer permeability (i.e., the freshwater aquifer grading from sand inland into mud offshore), or fault zones. If one or more of these physical controls exists between the freshwater aquifer and the ocean, and is sufficiently low in permeability, it can serve as an effective barrier to the intrusion of seawater into the aquifer. If this is the case, less care would be required to prevent seawater intrusion, as long as the barrier (or barriers) is known to be sound and continuous. Of course, no natural barrier is truly impervious to flow, but its hydraulic conductivity may be so low that the flux of seawater through it would not have a substantial effect on the quality of water in bounding freshwater aquifers. These structural controls, referred to herein as physical controls, are, for all intents and purposes, permanent.

The two types of controls noted above (hydrologic and physical) are discussed further throughout this TM, and can be used to consider the vulnerability of a given freshwater aquifer to seawater intrusion. As is implied by the above discussion, either a hydrologic control or a physical control can prevent seawater intrusion; therefore, both must be absent for seawater intrusion to occur. In locations where physical controls on seawater intrusion (such as a low-permeability clay layer or fault zone) are absent, hydrologic controls are necessary to limit intrusion. For locations where physical controls do exist, freshwater head below the level dictated by the Ghyben-Herzberg relationship may be possible without leading to any intrusion, depending on the nature of the physical control.

3. Groundwater Model Analysis

Groundwater models are useful tools that can help quantify the changes in groundwater conditions due to future activities. This section summarizes previous modeling studies of seawater intrusion along the Pacific Coast of the Westside Basin and documents the results of the current modeling conducted for this study using the existing Westside Basin Groundwater-Flow Model (HydroFocus, 2007, 2009 and 2011).

3.1. Previous Seawater Intrusion Model

CH2M HILL (1995) performed a numerical modeling exercise to determine the effect that proposed increases in groundwater extraction would have on the intrusion of seawater into the freshwater aquifers of the North Westside Basin. Although focused in the same area, their model does not deal with the same changes in pumping as would be entailed in the SFGW Project.

There are important differences between the CH2M HILL seawater intrusion model (SIM) and the numerical model for the Westside Basin discussed here. The most important difference is that the SIM was constructed as a steady-state model, unlike the transient Westside Basin model; this means that the results of the model indicate the seawater intrusion that would eventually happen if a given pumping rate was maintained indefinitely, and cannot deal with changes in pumping rate or climatic conditions (e.g., an extended drought). The SIM does not simulate the connection between Lake Merced and the North Westside Basin, instead assuming a general head boundary to be present just north of Lake Merced that imposes head values that are constant in time and assumed to be uniform vertically throughout the aquifer. This rigid assumption does not allow head in the aquifer in the Lake Merced area to vary, meaning that the North Westside Basin cannot be dynamically linked to the South Westside Basin using this model, and therefore does not have the capacity to simulate changes to the groundwater system in the North Westside Basin due to changes in hydrologic conditions in the South Westside Basin, a key component of this analysis. In particular, the head in the Deep Aquifer along this boundary is assumed to be the same as the head in the Shallow Aquifer, which does not conform to measurements (see TM#1). Finally, the model assumes that the gradient across the entire model domain is the same as in Golden Gate Park, while the gradient across the southern Sunset District has been shown to be lower than in Golden Gate Park (see, for example, HydroFocus, 2009). Unlike the Westside Basin model, the SIM is explicitly designed to handle the problems of dual-density fluids and the movement of seawater onshore. The SIM used a combination of the finite-element code MicroFem and a seawater migration routine developed by CH2M HILL.

The SIM simulated the intrusion of seawater into the North Westside Basin under various pumping conditions (total of 9 scenarios). These scenarios dealt with the installation of three wells, and increased pumping in one previously-existing well. The new wells, located between Golden Gate Park and Lake Merced: one at the location of the currently proposed West Sunset Playground well, one at the Francis Scott Key Elementary School, and one at Noriega Early

Education School. The previously existing well was the Elk Glen well in Golden Gate Park. All other pumping in the study area was set equal to values estimated for water year 1988. The total pumping under their calibration scenario was 1.02 mgd.

Total additional pumping in the four wells mentioned varied from 0.54 to 0.94 mgd in the nine model scenarios. For all of these scenarios, the greatest pumping occurred at the Elk Glen well, due to the fact that the freshwater flux through Golden Gate Park is assumed to be greater than it is to the south of the Park. The pumping was generally assumed to be equal in the three proposed Sunset wells.

The results of this modeling exercise indicate that the North Westside Basin can handle an additional pumping load of about 0.9 mgd above the rates of water year 1988, as long as the pumping is properly configured. Rates between 0.91 and 0.94 mgd did induce seawater intrusion into the proposed Sunset wells, which are well inland (some 2,000 feet or more) from the coast. This implies that smaller amounts of pumping in the Sunset area would induce substantial seawater intrusion some way inland of the coast. The baseline scenario of the CH2M HILL model (which involved no changes from existing pumping) calculated the top of the freshwater-seawater interface (i.e., the point where the freshwater discharges from the seafloor) as being about 1,400 feet offshore. Figure 10 in CH2M HILL (1995) shows the calculated location of the interface along a cross-section perpendicular to the coast that runs through their proposed well at the Francis Scott Key School; at this location, the toe of the interface wedge stretches inland from the shore by about 2,200 feet, while the well is about 2,600 feet inland. Under one pumping scenario shown, the toe of the wedge stretches inland for more than 4,600 feet, although the interface does not actually intersect the well since it is not screened across the entire model thickness. The results of the CH2M HILL model indicate that, at least in the North Westside Basin, pumping of about 2 mgd may result in the landward shift of the seawater-freshwater interface.

As stated above, the CH2M HILL model has certain limitations that make it less than ideal for analyzing seawater intrusion into the North Westside Basin along the Pacific Coast. The first is that the model is a steady-state model, meaning that it simulates seawater intrusion at equilibrium. Thus, it does not have the capacity to model seawater intrusion in the context of changing conditions, whether these changes are in the amount and location of pumping, or in the climatic conditions that act as inputs to the model (such as wet years and droughts). Second, the SIM does not have the capacity to allow conditions from Lake Merced south to change dynamically, meaning that it cannot simulate how the North Westside Basin would respond to changes in the South Westside Basin. Therefore, the HydroFocus Westside Basin model is considered a better tool to assess the dynamic vulnerability of the North Westside Basin to seawater intrusion.

3.2. MODFLOW Model

The existing Westside Basin Groundwater-Flow Model (HydroFocus, 2007, 2009, and 2011) was used as a tool to provide the level of analysis necessary to evaluate the potential for seawater intrusion as a result of the GSR and SFGW Projects. The setup and results of the model are documented in TM-10.1. A limitation of this model is the handling of the boundary conditions representing the Pacific Ocean and San Francisco Bay. These boundary conditions are set to a constant head of zero elevation. This usage is overly rigid, limiting the ability of the near-Ocean head in the aquifer to behave dynamically. HydroFocus (2007) states that “model results should be interpreted with caution near constant head boundaries like the Pacific Ocean or San Francisco Bay.”

The model does not simulate dual-density flow. Therefore, the application of the model results to the problem of seawater intrusion is accomplished in this TM chiefly by analyzing how hydrologic controls are affected by the conditions simulated by the various scenarios, rather than by any direct simulation of seawater flow and transport. The two important hydrologic controls that will be examined here are the flux toward the Ocean or Bay and the groundwater (freshwater) head elevation. The more the oceanward flux is reduced, or the lower the groundwater head drops, the less effective would be the hydrologic controls preventing seawater intrusion (as discussed above, a lack of hydrologic control on seawater intrusion does not automatically imply actual intrusion, as physical controls may still exist that effectively prevent intrusion).

3.3. Model Scenario Summary

Five model scenarios were constructed and simulated to evaluate potential groundwater and related hydrological effects from the GSR and SFGW Projects and from the Cumulative Scenario that includes the GSR and SFGW Projects and other reasonably foreseeable future projects. The following is a summary of the five scenarios used for the groundwater model analysis:

- Scenario 1, Existing Conditions: Scenario 1 represents the continuation of the Existing Conditions into the future and does not include the SFPUC Projects (either GSR or SFGW Project). Groundwater pumping by the PAs and irrigation pumping are representative of the existing pumping conditions (as of June 2009). The PA pumping was established based on the historical pumping rates, using the median of the 1959-2009 pumping data for individual agencies.
- Scenario 2, GSR Project Only: Scenario 2 represents implementation of the GSR Project operations including put periods when groundwater pumping by SFPUC and the PAs does not occur and groundwater is placed into storage using in-lieu recharge; hold periods when the PAs are pumping and no in-lieu recharge is occurring because the SFPUC Storage Account is full, and take periods which represent periods when both SFPUC and the PAs are pumping from the South Westside Basin.

- Scenario 3a, SFGW Project Only (3 mgd): For Scenario 3a, the four new wells constructed for the SFGW Project would pump an annual average of 3.0 mgd; however, the two existing irrigation wells in Golden Gate Park would remain irrigation wells, and their pumping rates would be the same as in Scenario 1.
- Scenario 3b, SFGW Project Only (4 mgd): For Scenario 3b, the four news wells constructed for the SFGW Project and the two modified irrigation wells in Golden Gate Park would pump an annual average of 4.0 mgd. Irrigation in Golden Gate Park is assumed to be replaced by the WestsideRecycled Water Project. Total combined pumping in the Westside Basin for Scenario 3b is slightly less than Scenario 3a, because the total SFGW Project pumping in Scenario 3b would increase by 1.0 mgd, whereas the irrigation pumping that is replaced would be slightly more than 1.0 mgd.
- Scenario 4, Cumulative Scenario: Scenario 4 represents implementation of both the GSR and SFGW Projects (Scenarios 2 and 3b) along with other reasonably foreseeable future projects. The other foreseeable projects are discussed in more detail in TM-10.1 but primarily include the Daly City Vista Grande Drainage Area Improvements Project, which increases stormwater diversions into Lake Merced, and a minor increase in irrigation pumping based on the planned build-out of the Holy Cross cemetery.

As discussed in TM-10.1, the strongest predictive capability of the existing model is to forecast relative changes over time, rather than absolute predictions of head. Therefore, analyzing differences in head relative to a base case rather than the actual groundwater elevation output by the model is the more appropriate method to evaluate the results of the groundwater model. However, in the case of seawater intrusion, the important relationship is between groundwater head in the model and sea level, so absolute head must be considered in this analysis as well. Scenario 1 (the Existing Conditions scenario) forms a basis of comparison for evaluating the results of the GSR-only, SFGW-only, and Cumulative Project scenarios.

To allow for the model scenarios to be directly comparable, all five model scenarios are set up using similar sets of assumptions regarding initial conditions and background hydrology. All of the modeled scenarios have the same projected simulation period of 47.25 years and use initial groundwater conditions representing June 2009 conditions.

All five model scenarios use the same hydrologic sequence and include the 8.5-year Design Drought period included in the Water System Improvement Program Environmental Impact Report PEIR (SFPUC, 2008b and 2009c). The 8.5-year Design Drought repeats the December 1975 to March 1978 drought period following the dry hydrologic conditions of July 1987 to November 1992. To incorporate the Design Drought, the historical hydrological sequence was rearranged. A more detailed discussion of the development of the background hydrology is presented in TM-10.1.

Table 10.3-1 presents a summary of the estimated Basin-wide average pumping rates corresponding to each of the model scenarios. Note that, in addition to the anticipated GSR and

SFGW Project wells, average pumping rates are also provided for the PA wells and for irrigation wells in Golden Gate Park.

3.4. Use of Model Results

As stated above, HydroFocus (2007) suggests that the strongest predictive capability of the MODFLOW model is to forecast relative changes over time, rather than absolute predictions of head. Therefore, the model analysis for the different scenarios will consider differences in head and flux relative to the Existing Conditions Scenario (Scenario 1). However, because seawater intrusion is dependent on the relationship between elevations of the seawater and the freshwater aquifers, it is necessary to evaluate the simulated groundwater elevations as well as the relative changes, to evaluate the potential for seawater intrusion.

For the evaluation of the model scenarios, the results of the MODFLOW model are applied to seawater intrusion by considering the flux of water across the coastal boundary conditions and the head just landward of the coastal boundaries. These quantities will be analyzed for each of the five model scenarios listed at the beginning of this section.

3.4.1. Head Results

The numerical model includes the capability of monitoring head at 87 different monitoring points, included to track head in the aquifer. Of these, this section examines the results for 9 monitoring points along the Pacific Coast and 3 monitoring points along the Bay Coast. Hydrograph representations for each of the monitoring points are presented as Figures 10.3-4 through 10.3-15. In each of these figures, the upper panel includes the absolute simulated head for each of the five scenarios; the lower panel is the difference between the results of each scenario and those of Scenario 1. Each figure presents results for Model Layer 1, 4, or 5 as representative of conditions in the Shallow, Primary Production, or Deep Aquifer, respectively. The exclusion heads plotted on these figures represent a theoretical freshwater head that must be maintained at the well location to prevent seawater intrusion to reach that location; see Section 3.5. Selected statistics (average, maximum and minimum as calculated from the 47.25 years of model simulation) were compiled for the difference between the head results of the four Project scenarios and Scenario 1 (Table 10.3-2).

Along the Pacific coast, 9 monitoring locations were set in the numerical model. All of these except for North Windmill correspond to locations of an actual monitoring well or well cluster, which correspond to the seawater intrusion monitoring network already existing along the Pacific Coast (Figure 10.3-1). The North Windmill location corresponds to a historical well location, but not an active monitoring well. These locations include:

- North Windmill
- South Windmill
- Kirkham
- Ortega
- West Sunset Playground

- Taraval
- Zoo
- Fort Funston
- Thornton Beach

Along the Bay Coast, monitoring locations were set in the numerical model at the locations of actual monitoring well clusters (UAL, SFO, and Burlingame). These locations correspond to the seawater intrusion monitoring network already existing in the South Westside Basin (Figure 10.3-1). The UAL cluster consists of pre-existing monitoring wells, but the SFO and Burlingame clusters were installed as part of work conducted under Assembly Bill 303[2] specifically to track the occurrence of seawater intrusion (WRIME, 2007).

In addition to the absolute and relative heads depicted in the hydrographs (Figures 10.3-4 through 10.3-15), seasonal fluctuations in absolute head were computed for each of the model scenarios. These values were determined by calculating the average annual difference in head values under each scenario for May (generally representing the highest annual heads) and November (generally representing the lowest annual heads). These values were analyzed to determine whether the aquifer experiences annual head declines sufficient to leave it substantially more susceptible to seawater intrusion during the dry parts of the year.

3.4.2. Flux Results

The flux of groundwater out to the Ocean or Bay from the coast is a convenient variable for tracking the occurrence of seawater intrusion in the model domain because it tracks the amount of water passing through the boundary conditions placed along the coastlines. The fluxes are presented as total fluxes for the entire North Westside Basin (Pacific Coast) (Figure 10.3-16) and South Westside Basin (Bay Coast) (Figure 10.3-17). This means that these flux values indicate whether or not each of the coasts is, as a whole, experiencing seawater intrusion on average. Seawater intrusion is expected to occur locally during its initial stages, and this would not be captured in this analysis. However, in the context of the strengths and limitations of the numerical model discussed above, this approach is considered a sufficiently comprehensive, conservative, and scientifically-sound evaluation that properly addresses seawater intrusion.

A positive freshwater flux toward the Ocean or Bay does not necessarily preclude seawater intrusion, because the seawater wedge would enter into the lowest part of the freshwater aquifer. Therefore, the use of modeled freshwater flux as a proxy for seawater intrusion is a way to indicate when intrusion is predicted to be a major problem, rather than when it might begin to occur.

As with the head analysis, this analysis of the flux calculated by the numerical model is not able to give accurate quantification of the intrusion of seawater into the freshwater aquifer. This is

[2] Passed by the California Legislature in 2000, Assembly Bill 303 created the Local Groundwater Assistance Grant Program, providing funding to local public agencies for the performance of groundwater studies or to carry out groundwater monitoring and management activities.

due to several factors: the flux numbers are totals of flux along the entire coastline; the boundary condition along the coastline does not accurately reflect the dynamic conditions at the land-Ocean interface; and the real occurrence of seawater intrusion is a complex process involving aquifer heterogeneity, tidal fluctuations, diffusive transport, and dual-density fluid flow, which are not captured in the existing model.

3.4.3. Groundwater Contour Map Analysis

Under Scenario 1, the model-simulated groundwater elevations for the Shallow Aquifer (Model Layer 1) are above sea level throughout the North Westside Basin (Figure 10.3-18). The water table gradient was highest through Golden Gate Park and along the fronts of the elevated bedrock areas, and lowest just north of Lake Merced. Water table elevations were predicted to be between five and ten feet above sea level in the direct vicinity of the Coast, with higher elevations along the northern part of the Coast. This indicates that the existing conditions are not anticipated to induce seawater intrusion along the Pacific Coast.

3.5. Application of Analytical Method Along the Pacific Coast

As mentioned, the Westside Basin model does not have the capability to evaluate seawater intrusion using the density differences between freshwater and saline water. Therefore, an analytical evaluation is included with the groundwater model results to incorporate the density driven components of seawater intrusion while evaluating the MODFLOW output.

3.5.1. Methodology

The movement of the seawater-freshwater interface is a dynamic process that is dependent upon the relative difference in the freshwater and seawater groundwater head, flux and density. The analytical method discussed in Attachment A was used to evaluate the freshwater head, based on the Ghyben-Herzberg relationship, necessary to maintain hydrologic control, keeping seawater from intruding into freshwater aquifers (a function of the depth below sea level of the bottom of the aquifer). This value is termed the “exclusion head” and it represents a conservative analysis for maintaining freshwater aquifer conditions (see Section A.5).

The freshwater head results from the numerical model were compared to the exclusion head at the various monitoring points; it is assumed that groundwater head at a location equal to or greater than its exclusion head indicates that the location would not experience seawater intrusion.

For locations where the groundwater head stays above the exclusion head, the pressure of the freshwater aquifer is sufficient that seawater would not intrude to this location based on the Ghyben-Herzberg relationship for the aquifer thickness at a given location.

For locations where groundwater head falls below the exclusion head, there is the potential that seawater could intrude to this location. However, there are other factors that control seawater intrusion, so groundwater head below the exclusion head does not necessarily imply that seawater intrusion may reach this location, but rather that the hydrologic potential exists for the landward migration of the seawater-freshwater interface. Therefore, this is a conservative analysis of the potential for seawater intrusion.

If groundwater head moves back above the exclusion head, the interface could be expected to slow or reverse its movement toward land. It should be noted that sustained, repeated fluctuations in head, even when they remain above the exclusion head, would result in a widening of the transition zone between seawater and freshwater.

Movement of the seawater-freshwater interface is a slow process. Seawater intrusion may not manifest in a production well for a number of years, and only when the conditions leading to seawater intrusion are continuously sustained for an extended period of time, depending on aquifer conditions. Additionally, physical controls, where present, can prevent seawater intrusion even if head conditions are maintained below the exclusion head long-term.

Uncertainty in these results is due mostly to uncertainties in the prediction of the input parameter, b (aquifer thickness below sea level). However, uncertainties in the estimate of b must be very large to create substantial errors in the estimate of the exclusion head, due to the fact that the exclusion head is only a fraction of the aquifer thickness. Additionally, the analytical method assumes that the individual aquifers are single bodies; if aquifers are divided up into several discrete sections separated by continuous low-permeability layers, seawater intrusion would be less extensive than indicated by this method because the exclusion head is higher in the thicker, composite aquifer than in the thinner, separate aquifers.

It is important to note that the analytical analysis presented here assumes that the aquifer is near horizontal. As the analytical method shows (Attachment A), this has some effect on the length of intrusion. The aquifers present in the North Westside Basin are actually sloped toward the Ocean, and so the intrusion length could be expected to be somewhat smaller than shown by the analytical method, thus making the analysis more conservative with relation to the potential for seawater intrusion.

3.5.2. Definition of Parameters

For this analysis, the elevation of the base of the aquifer is the only variable that must be known. Because the offshore structure of the coastal aquifers (e.g., the continuity of low-permeability layers between aquifers, which is key to the movement of intruding seawater) is not precisely known, two approaches were taken to compute the exclusion head. The thicknesses were then input into the Ghyben-Herzberg equation to determine the exclusion head. These levels are indicated on Figures10.3-4 through 10.3-15, and given in Table 10.3-3.

Along the Pacific Coast, the sediment thickness is considered to include several aquifers (multiple-aquifer case). The thicknesses of the individual aquifers were determined using the cross-sections of LSCE (2010) by estimating (to the nearest 10 feet) the elevations of the bottom of each aquifer below sea level. It should be noted that extensive clay layers present within an aquifer (e.g., the Y clay within the Primary Production Aquifer at the Taraval and Zoo clusters) are not removed from the aquifer thickness, so that these clay layers are counted as part of the aquifer. This is a conservative assumption, as excluding them would reduce the thickness of the aquifer, thereby reducing the exclusion head. Because the Primary Production Aquifer is thicker than the other two aquifers, the values of exclusion head in this aquifer are higher than in the others.

3.5.3. Use of the Analytical Evaluation

As discussed, the results are a conservative estimate of the potential for seawater intrusion along the Coast, but do provide a point of reference for evaluating the MODFLOW results with respect to the density aspects of seawater intrusion. The analysis can identify areas where seawater intrusion would not occur, or where there is the potential that seawater intrusion may occur. Other factors have to be considered. A major limitation to evaluation of seawater intrusion is that the seawater-freshwater interface has not been located along the Pacific Coast.

The results of this analysis for the Pacific Coast are discussed for the SFGW-Only and Cumulative Scenarios. The GSR-Only Scenarios are not presented, because the MODFLOW model analysis showed little variation from Scenario 1.

4. GSR Only Scenario Analysis

The GSR-Only Scenario analysis evaluates the potential for seawater intrusion from the operation of the GSR Project. The GSR Project is a conjunctive use project that would allow for increased groundwater supplies in the Westside Basin during periods of drought (MWH, 2008). The GSR Project is sponsored by the SFPUC in coordination with its PAs: Cal Water, Daly City, and San Bruno. The GSR Project is located within San Mateo County in the South Westside Basin. This Project is discussed in more detail in Section 1.1 of this TM, and in TM-10.1. In summary, the PAs would reduce pumping during normal and wetter than normal times (put periods) to naturally replenish groundwater in the South Westside Basin, and both SFPUC and the PAs would extract groundwater during drier than normal times (take periods). The total pumping capacity to be developed by the Project would be about 7.2 mgd, and the maximum amount of groundwater that would be placed in a storage account via this in-lieu recharge would be 60,500 af (MWH, 2008). If surface water is available, but the storage account is full (hold periods), the PAs would pump as during a take period, but SFPUC would not extract groundwater, aside from a small amount to exercise the Project wells[3].

4.1. Conceptual Analysis

The GSR Project consists primarily of using excess surface water instead (or "in-lieu") of pumping groundwater from the Westside Basin. The Project is planned to have up to 60,500 af of in-lieu recharge capacity. During the take cycle, both SFPUC and the PAs would be pumping groundwater; however, SFPUC would not take more than the amount of in-lieu recharge available in the SFPUC Storage Account.

In addition, the GSR Project would be operated in the South Westside Basin, where groundwater head has been substantially below sea level for decades. This portion of the Basin appears to be isolated from sources of saline water from the Pacific Ocean and San Francisco Bay.

Because of this mode of operation, the GSR Project would typically produce groundwater head similar to or higher than Scenario 1 in the South Westside Basin. Higher groundwater head would typically have the effect of reducing the potential for seawater intrusion due to the higher freshwater head and flux towards the Ocean and the Bay. Therefore, in general, the likelihood of seawater intrusion resulting from the GSR Project is considered to be low.

4.2. Model Results along the Pacific Coast

The GSR-only Scenario (2) does not include any additional pumping in the North Westside Basin, so large changes in head are not anticipated in this area. Hydrographs (Figures 10.3-4 through 10.3-12) present the model-derived head for this scenario, as well as the differences in

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[3] Exercising the production wells would entail pumping for a few hours approximately monthly, with an anticipated average monthly total production rate for all of the wells of 0.04 mgd.

head between this scenario and Scenario 1. Table 10.3-2 presents the maximum, average, and minimum differences between the results for this scenario and those of Scenario 1.

4.2.1. Head

In Model Layer 1, head at the various monitoring locations is generally slightly higher than under Scenario 1 throughout most of the simulation duration, dropping slightly below Scenario 1 levels at the end of the simulation. The maximum increase over Scenario 1 (Table 10.3-2a) is less than a foot at all of the monitoring locations except the West Sunset Playground well (1.3 ft; Figure 10.3-8) and the Zoo cluster (2.7 ft; Figure 10.3-10). The maximum decrease compared to Scenario 1 at the end of the simulation reaches a maximum of 0.4 ft at the Zoo cluster, and is 0.2 ft or less at all other locations.

In Model Layer 4, the difference in head from Scenario 1 follows a similar pattern to that of Model Layer 1, but the changes tend to be more pronounced, especially in the southern part of the North Westside Basin. The maximum increase over Scenario 1 (Table 10.3-2b) varies from 0.1 ft at the South Windmill cluster (Figure 10.3-5) to 6.1 ft at the Zoo cluster. In almost all monitoring locations, the head results from Scenario 2 are above those of Scenario 1 except during and after the Design Drought, except at the Thornton Beach cluster (Figure 10.3-12), where head drops below the Scenario 1 results around Scenario Year 28. The maximum decrease compared to Scenario 1 near the end of the simulation varies from 0.1 ft at the South Windmill cluster to 4.3 ft at the Zoo cluster. This Model Layer is not present at the North Windmill location.

In Model Layer 5, the difference in head from Scenario 1 follows a similar pattern to that of the other Model Layers, with still more pronounced changes. The Scenario 2 heads are below those of Scenario 1 during the take periods (as shown by large downward deflections in relative head difference) at many locations. The maximum increase over Scenario 1 (Table 10.3-2c) varies from 0.3 ft at the Kirkham cluster (Figure 10.3-6) to 12.2 ft at the Zoo cluster. The greatest relative decrease at all locations occurs just after the Design Drought, and varies from 0.2 ft at the Kirkham cluster to 14.4 ft at the Zoo cluster. Head values recover to levels similar to or above those of Scenario 1 throughout the North Westside Basin by the end of the simulation period. This Model Layer is not present at the North Windmill location or the South Windmill cluster.

The average differences presented here indicate that the GSR Project would not have a substantial effect on the occurrence of seawater intrusion in the North Westside Basin within the Shallow Aquifer. There would also not be much of an effect north of the Zoo cluster in the Primary Production Aquifer. In the southern part of the North Westside Basin, head dips during take periods, particularly the Design Drought. The effect is smallest in Model Layer 1, greater in Model Layer 4, and largest in Model Layer 5 (Figures 10.3-4 through 10.3-12). The magnitude of the dips in head is indicated by the maximum relative decrease compared to the results of Scenario 1 ("minimum difference" in Table 10.3-2). Although the declines in head during the take periods are locally substantial (greatest during the Design Drought in the southern part of the North Westside Basin in the Deep Aquifer; see results for the Zoo cluster above), the aquifer returns to conditions similar to Scenario 1 by the end of the simulation period, indicating that the situation of lowered head is fairly short-lived.

Simulated seasonal fluctuations in head (defined in Section 3.5.1; Table 10.3-4) varied in Model Layer 1 from 0.5 ft at the Taraval cluster to 1.7 ft at the North Windmill location, from -0.7 ft (South Windmill cluster) to 0.3 ft (Kirkham, Ortega, and Taraval clusters and West Sunset Playground well) in Model Layer 4, and from -0.5 ft (Zoo cluster) to 0.3 ft (Kirkham and Ortega clusters) in Model Layer 5; it should be noted that negative values of seasonal fluctuation indicate that head is generally higher in the summer than in the winter. The greatest fluctuations are in Model Layer 1 at every location, as the Shallow Aquifer (represented by Model Layer 1) directly receives recharge from precipitation, the root cause of the seasonal fluctuations. These results indicate that seasonal changes in head are not very large, and would not substantially affect the occurrence of seawater intrusion in the North Westside Basin.

4.2.2. Groundwater Flux

Freshwater flux leaving the model domain through the Pacific Coast is the result of recharge in the upper reaches of the North Westside Basin that flows through the aquifers in this Basin toward the Ocean. A reduction in this freshwater flux indicates an increasing chance of seawater intrusion occurring along this coast. Figure 10.3-16 shows the fluxes predicted for the North Westside Basin by the numerical model, as well as the difference between the results of each scenario and Scenario 1. Table 10.3-5 gives the maximum, minimum, and average monthly freshwater fluxes and fluxes relative to Scenario 1 for each scenario.

As discussed above, the GSR Project pumping conditions included in Scenario 2 are not expected to have a large effect on head in the North Westside Basin. Therefore, the freshwater flux into the Pacific Ocean is not expected to change very much. Indeed, Figure 10.3-16 indicates very minor differences between Scenario 1 and this scenario. For most of the duration of the model simulation, the freshwater flux out of the Pacific Coast remains above the Scenario 1 conditions, up to 30 acre-feet per month (afm). Toward the end of the simulation, during the Design Drought, the freshwater flux dips slightly below the Scenario 1 conditions, by up to about 10 afm. The minimum freshwater flux for this scenario was about 150 afm, the same as for Scenario 1. Compared to the absolute flux values (an average of about 270 afm for Scenario 2 versus an average of about 260 afm for Scenario 1), the differences in flux values indicate, as do the head results, that the GSR Project pumping conditions are not expected to have a substantial effect on the occurrence of seawater intrusion in this part of the Basin.

4.2.3. Groundwater Contour Map Analysis

Under Scenario 2, the model-simulated groundwater elevation map for the Shallow Aquifer at the end of the simulation period (Figure 10.3-19) is almost identical to that simulated under Scenario 1 (Figure 10.3-18), with slightly lower groundwater elevations (by approximately 5 feet or less) in the southern part of the North Westside Basin; almost no difference is visible north of

Lake Merced. This confirms that the operation of the GSR Project by itself would have little effect on the water table in the North Westside Basin. This indicates that the GSR Project is not anticipated to induce seawater intrusion along the Pacific Coast.

4.2.4. Evaluation

Pumping in the South Westside Basin for the GSR-only Scenario (2) would have only a minor effect on groundwater head in the North Westside Basin. These conditions are anticipated to lead to minimal landward movement of the seawater-freshwater interface due to operation of the GSR Project.

None of the monitoring points in Model Layer 1 show head falling below sea level, although some of the heads do approach sea level. In Model Layer 4, the head drops below sea level at the Zoo and Taraval clusters and the West Sunset Playground well. In Model Layer 5, the head drops below sea level at the Ortega, Taraval, Zoo, and Fort Funston clusters and the West Sunset Playground well. In fact, head is largely below sea level throughout the simulation period in the southern half of the North Westside Basin in Model Layers 4 and 5, indicating that the hydrologic conditions would be conducive to seawater intrusion; however, as noted above, these layers are likely to have physical controls that would prevent intrusion from happening. In addition, at no location does head drop below sea level in the Scenario 2 results without also dropping below sea level in the Scenario 1 results. The differences between this scenario and Scenario 1 are not great, with generally higher head through most of the simulation except the take periods (Section 4.2.1), indicating that the changes in the pumping regime included in the GSR Project would not substantially alter the likelihood of seawater intrusion along the Coast. The drops in head seen during the take periods may lead to conditions more favorable for seawater intrusion along the Pacific Coast, but the drops do not persist for more than a few years after the end of each take period, indicating that any such increase in the possibility of seawater intrusion due to the operation of the GSR Project would be temporary. Similarly, seasonal declines in freshwater head throughout the North Westside Basin are unlikely to substantially alter the likelihood of seawater intrusion along the Pacific Coast, as the declines are temporary and compensated for by seasonal increases. In much of the North Westside Basin, the differences between Scenarios 2 and 1 are not great, indicating that the GSR Project is not responsible for any substantial decreases in head.

4.3. Model Results along the San Francisco Bay Coast

The GSR-only scenario (Scenario 2) focuses on changes in the pumping regime in the South Westside Basin, so substantial changes in head may occur in this area. Figures 10.3-13 through 10.3-15 show heads for this scenario, as well as the differences in head versus Scenario 1 (note that the results for this Scenario are nearly identical to those of Scenario 4, so their lines overlap on the hydrograph figures). Table 10.3-2 presents the maximum, average, and minimum differences between the results for this scenario and those of Scenario 1.

4.3.1. Head

Under GSR-only conditions, the heads in the Bay monitoring system react similarly to the Scenario 1 conditions. Compared to Scenario 1, the head results of Scenario 2 at the Burlingame cluster are mostly higher than under Scenario 1 (up to maximums of 1.3 ft in Model Layer 1 and 2.3 ft in Model Layer 4), although at the end of the simulation period the head in Model Layer 4 is lower, by up to 0.6 ft (Figure 10.3-13, Table 10.3-2b). At both the SFO (Figure 10.3-14) and UAL (Figure 10.3-15) clusters, the Scenario 2 results are higher (up to 3.1 ft at the SFO cluster and 2.4 ft at the UAL cluster) in Model Layer 1 than in Scenario 1. Model Layer 4 is not present at the SFO and UAL clusters, and Model Layer 5 is not present at any of the three well clusters along the Bay coast.

To understand the implications of the Scenario 2 results, it is helpful to note how groundwater head behaves in this area under Scenario 1. The Burlingame cluster is projected to see a substantial decline in head during Scenario 1, approaching sea level in Model Layer 1 (Figure 10.3-13), while in Model Layer 4, head at the Burlingame cluster begins just above sea level, and declines throughout the scenario. These results indicate that, if there is a route for seawater intrusion, intrusion would become more rapid over the simulation period in both Model Layers. Because Scenario 2 head results are mostly higher than under Scenario 1 throughout the simulation, the potential rate of seawater intrusion over time would actually be lower than in Scenario 1. At the SFO (Figure 10.3-14) and UAL (Figure 10.3-15) clusters, head under Scenario 2 rises throughout most of the simulation period, indicating that, if seawater intrusion were occurring in this area, its pace may decline or even reverse.

Whether heads are higher or lower under Scenario 2, the results are not very different from those of Scenario 1. This indicates that the GSR Project pumping rates would not have a substantial effect on the occurrence of seawater intrusion in this part of the Basin because groundwater head is mostly higher than under Scenario 1.

Seasonal fluctuations along the Bay Coast are very small, and all between +0.1 ft and -0.1 ft for this scenario (Table 10.3-4). These results indicate that seasonal fluctuations in head would not have a substantial effect on seawater intrusion in this area.

4.3.2. Groundwater Flux

Freshwater flux into the San Francisco Bay is expected to be substantially lower than flux into the Pacific Ocean. The exposed coastline is somewhat shorter, the Bay Mud presents a low-permeability barrier between the freshwater aquifer and the saline water, the aquifer is thinner, and heads on land are lower. As discussed in Section 7.3, this area may or may not be physically susceptible to seawater intrusion. Table 10.3-5 gives the maximum, minimum, and average monthly freshwater fluxes and fluxes relative to Scenario 1 for these scenarios.

Scenario 2 adds the pumping entailed in the GSR Project. The maximum freshwater flux is about 110 afm, while the minimum is about 70 afm (Figure 10.3-17); these maximum and minimum numbers are similar to those of Scenario 1. The freshwater flux is slightly higher than in Scenario 1 through most of the simulation before dropping below Scenario 1 conditions around Scenario Year 40, during the Design Drought. Because the freshwater flux is generally higher than under Scenario 1 conditions, GSR Project pumping is not anticipated to have a substantial effect on seawater intrusion along the Bay Coast.

4.3.3. Evaluation

In general, the changes to groundwater pumping for the GSR-only Scenario (2) would not have a substantial effect on the potential for seawater intrusion compared to Scenario 1 conditions. The freshwater flux out of the aquifer into the San Francisco Bay is quite low, and is not modified to any great degree by the pumping configurations simulated in the numerical model.

The modeling results suggest that the Bay Coast is not especially vulnerable to seawater intrusion, at least under the conditions simulated by the model (Figure 10.3-17). The presence of the Bay Mud is considered to represent a physical barrier that limits the potential for seawater intrusion along the San Francisco Bay Coast, even when groundwater head is lowered.

5. SFGW Only Scenario Analysis

The SFGW Project would provide a local source of high-quality groundwater within the North Westside Basin. The SFGW Project is discussed further in Section 1.1 and TM-10.1.

The SFGW Project Scenarios (3a and 3b) simulate increased pumping in the North Westside Basin, and so the model predicts a much greater change in head in this area under these scenarios than under the GSR Project Scenario (2). Scenario 3a assumes that irrigation in Golden Gate Park would continue as in the past. Scenario 3b assumes that irrigation would be provided largely by a recycled water project, so that two of the existing irrigation wells can be converted for use as a municipal supply. These two scenarios begin with June 2009 initial head conditions.

5.1. Conceptual Analysis

Because operation of the SFGW Project includes substantial pumping of groundwater, and the wells to be utilized are located relatively close to the Pacific Coast, there is the potential for seawater intrusion in this area. Therefore, additional analysis is necessary to characterize the potential for seawater intrusion in the North Westside Basin. However, because of the distance from the pumping wells to the San Francisco Bay Coast, the potential of seawater intrusion induced by the SFGW Project in the South Westside Basin is low.

5.2. Pacific Coast

The SFGW-only Scenarios (3a and 3b) include substantial additional pumping in the North Westside Basin (3.0 mgd and 2.9 mgd, respectively; see Table 10.3-1), so changes in head would be expected to occur in this area. Figures 10.3-4 through 10.3-12 show head results for these scenarios, as well as the differences in head between these scenarios and Scenario 1. Table 10.3-2 presents the maximum, average, and minimum differences between the results for these scenarios and those of Scenario 1.

5.2.1. Head

Scenario 3a: In general, heads in the North Westside Basin under Scenario 3a decline quickly over the first approximately 10 years of the simulation period, eventually leveling out at a fairly constant offset from Scenario 1 results (Figures 10.3-4 through 10.3-12). This fairly constant offset (as represented by the average difference between the scenario results and those of Scenario 1 from Scenario Years 37 to 47) varies from well to well. In Model Layer 1 (Table 10.3-2a), the average offset varies from 0.1 ft at the Fort Funston cluster to 23.0 ft at the West Sunset Playground well. In Model Layer 4 (Table 10.3-2b), the average offsets varied from 0.3 ft at the Thornton Beach cluster to 18.5 ft at the Zoo cluster. In Model Layer 5 (Table 10.3-2c), the average offsets varied from 0.3 ft at the Thornton Beach cluster to 6.9 ft at the West Sunset well cluster. Note that head decreases more at the West Sunset Playground well because its location is close to a proposed SFGW Project production well. Additionally, it is important to note that this well is about 3,000 feet inland, so results at this location should not be considered typical of head along the coast.

At the North Windmill location and the Fort Funston and Thornton Beach clusters (Figures 10.3-4, 10.3-11, and 10.3-12), the head in all present Model Layers remains at least a bit above sea level at all times during the model simulations. Elsewhere, head drops to sea level and below, up to -11.4 ft msl at the West Sunset Playground well (Figure 10.3-8a) in Model Layer 1, -31.3 ft msl at the Zoo cluster (Figure 10.3-10b) in Model Layer 4, and -32.1 ft msl at the Zoo cluster in Model Layer 5 (Figure 10.3-10c). After head declines slow between Scenario Years 10 and 15, heads are mainly above sea level at all Model Layer 1 locations aside from the West Sunset Playground well, only dropping below sea level at isolated times (particularly during the Design Drought). In Model Layer 4, head hovers around sea level at the South Windmill and Kirkham clusters, and remain below sea level through most of the simulation period at the Ortega, Taraval, and Zoo clusters and the West Sunset Playground well. In Model Layer 5, head is around sea level at the Kirkham cluster, and below sea level at the Ortega, Taraval, and Zoo clusters and the West Sunset Playground well.

Scenario 3b: Scenario 3b is similar to Scenario 3a, except that it includes the assumed recycled water delivered to Golden Gate Park; this means that total groundwater extraction in Golden Gate Park is slightly lower in Scenario 3b than in Scenario 3a, and also slightly lower in the South Sunset Playground and West Sunset Playground wells.

The difference between the results of Scenario 3b and Scenario 3a is generally not large. As might be expected by the scenario construction, head in the Golden Gate Park wells resulting from Scenario 3b is slightly lower at the North Windmill location (Figure 10.3-4a) and the South Windmill cluster (Figure 10.3-5) in Model Layer 1. In Model Layer 4, head at the South Windmill cluster is generally higher than in Scenario 3a, and with much larger seasonal fluctuations. At the Kirkham cluster (Figure 10.3-6b), head is generally slightly higher, with larger seasonal fluctuation, than in Scenario 3a. At the Ortega (Figure 10.3-7b), Taraval (Figure 10.3-9b), and Zoo (Figure 10.3-10b) clusters and the West Sunset Playground well (Figure 10.3-8b), head results for Scenario 3b are slightly higher than those for Scenario 3a. Finally, heads at the Fort Funston (Figure 10.3-11) and Thornton Beach (Figure 10.3-12) clusters are almost equal under Scenarios 3b and 3a.

Seasonal Fluctuations: Seasonal fluctuations are generally somewhat smaller than under Scenario 1 (Table 10.3-4). For Scenario 3a, values range from about 0.5 ft (West Sunset Playground well and Taraval cluster) to 1.6 ft (North Windmill location) in Model Layer 1, from -0.8 ft (South Windmill cluster) to 0.3 ft (Kirkham, Ortega, and Taraval clusters and West Sunset Playground well) in Model Layer 4, and from -0.6 ft (Zoo cluster) to 0.2 ft (Kirkham and Ortega clusters) in Model Layer 5. For Scenario 3b, seasonal fluctuations vary from 0.5 ft (West Sunset Playground well and Taraval cluster) to 1.3 ft (Fort Funston cluster) in Model Layer 1, from 0.0 ft (Fort Funston and Thornton Beach clusters) to 0.3 ft (South Windmill, Kirkham, and Taraval) in Model Layer 4, and from -0.6 ft (Zoo cluster) to 0.2 ft (Kirkham and Ortega clusters) in Model Layer 5. These results indicate that seasonal fluctuations in head would not have a substantial effect on the occurrence of seawater intrusion in this area.

5.2.2. Groundwater Flux

Scenario 3a includes increased pumping in the North Westside Basin envisioned as part of the SFGW Project. As discussed in Section 5.2.1, the general reaction of the aquifers in this part of the Basin is a decline in head, although it is not uniform throughout the area studied. This decline in head indicates that the oceanward freshwater flux could be expected to decrease. Figure 10.3-16 shows the freshwater flux predicted by the numerical model for this scenario. Table 10.3-5 gives the maximum, minimum, and average monthly freshwater fluxes and fluxes relative to Scenario 1 for these scenarios.

Although flux still responds strongly to climatic variation, the fluxes predicted for this scenario are much lower than those of Scenario 1, varying from a maximum of about 370 afm to a minimum of about 10 afm. Additionally, the variance of flux is higher (standard deviation of about 70 afm versus about 50 afm under Scenario 1).

As discussed above, the flux values presented in this analysis represent the total flux for the entire coast, and so can only be used to discuss average conditions along the coast. However, it is probable that, at the extremely low flux totals seen in this scenario, flux is either zero or negative (i.e., inland from the Ocean) at certain locations. Therefore, this analysis indicates that the increased pumping entailed by the SFGW Project would create conditions conducive to the potential inducement of seawater intrusion in localized areas along the coast.

Scenario 3b is identical to Scenario 3a, except as noted above. The results for this scenario are very similar to those of Scenario 3a: a maximum freshwater flux of about 350 afm, and a minimum of about 10 afm. The change in pumping conditions does not have a substantial effect on the flux out of this stretch of coastline compared to Scenario 3a, although the head results (Section 5.2.1) do show some spatial variability in the North Westside Basin. This indicates that the freshwater flux may be decreased in some places and increased in others compared to Scenario 3a, something that this analysis of total flux would not capture. These results indicate that the pumping rates and distribution of pumping under Scenario 3b would not have a substantial effect on seawater intrusion in the North Westside Basin compared to Scenario 3a, although the location and timing of intrusion may be affected.

These results indicate that there is no major difference between Scenarios 3a and 3b in terms of seawater intrusion, except on the coastline directly west of Golden Gate Park, where heads are projected to be slightly higher under Scenario 3b, possibly reducing the rate of intrusion along this part of the coast.

5.2.3. Groundwater Contour Map Analysis

Under Scenario 3a, the model-simulated groundwater head elevations for the Shallow Aquifer at the end of the simulation period (Figure 10.3-19) were lower than under Scenario 1

(Figure 10.3-18). This reflects the effect of the SFGW Project operations in the North Westside Basin. The head was just below sea level in the immediate area around West Sunset Playground and in central Golden Gate Park, representing the drawdown cones around production wells. Head was above sea level through most of the rest of the North Westside Basin, other than the southernmost parts (where head was below sea level in Scenario 1 as well).

Scenario 3b was similar to Scenario 3a, except as noted above. The model-simulated water table elevations in the North Westside Basin under this scenario (Figure 10.3-20) were mostly similar to those of Scenario 3a. The water table was very slightly higher at the western end of Golden Gate Park. The area of the North Westside Basin with groundwater heads below sea level under this scenario was slightly smaller than under Scenario 3a, as the cone of depression in central Golden Gate Park does not reach below sea level.

The map distributions for Scenarios 3a and 3b suggest that the area between the West and South Sunset Playgrounds would have an increased potential for landward migration of the seawater-freshwater interface resulting from groundwater pumping (as noted in Section 2, the groundwater elevation does not have to drop below sea level for seawater intrusion to occur). Areas along the northern part of the Coast are predicted to have higher groundwater head even with the pumping, suggesting a lesser potential for the landward migration of the seawater-freshwater interface in this area compared to the southern part of the Coast.

5.2.4. Evaluation of Analytical Results

Comparing the exclusion heads calculated by the analytical method (see Section 3.5.1) to the head results from the numerical model suggests that conditions near the Pacific Coast of the North Westside Basin under Scenarios 3a and 3b have the potential for seawater intrusion, particularly during periods of drought. Table 10.3-6 provides the percentage of each scenario duration during which head is below the applicable exclusion heads.

- At the North Windmill location (Figure 10.3-4), head in Model Layer 1 is below the single-aquifer exclusion head[4] for much of the simulation after about Scenario Year 10 (57% of the simulation duration for Scenario 3a, 60% for Scenario 3b), and is below the Shallow Aquifer exclusion head during the Design Drought and Scenario Year 27 (5% of the simulation duration for Scenario 3a, 4% for Scenario 3b).

- At the South Windmill cluster (Figure 10.3-5), head in Model Layer 1 is below the single-aquifer exclusion head for the entire simulation duration after about Scenario Year 4 (95% of the Scenario 3a simulation duration, 98% for Scenario 3b), and varies around the Shallow Aquifer exclusion head throughout most of the simulation duration (below the exclusion head for 73% of the simulation duration under Scenario 3a, 85% for

[4] As discussed in Section 3.5.1, this represents the exclusion head for the entire subsurface taken as a single aquifer, rather than discretized into multiple aquifers.

Scenario 3b). In Model Layer 4, head is below the single-aquifer and Primary Production Aquifer exclusion heads for the entire simulation.

- At the Kirkham cluster (Figure 10.3-6), head in Model Layer 1 is below the single-aquifer exclusion head for the entire simulation duration, and is mostly below the Shallow Aquifer exclusion head for most of the simulation after about Scenario Year 8 (77% of the Scenario 3a simulation duration, 75% for Scenario 3b). In Model Layers 4 and 5, head is below both exclusion heads for the entire simulation, although this is also true of Scenario 1.

- At the Ortega cluster (Figure 10.3-7), head in Model Layer 1 is below the single-aquifer exclusion head for the entire simulation duration (as is true of Scenario 1), and below the Shallow Aquifer exclusion head for the bulk of the simulation duration after about Scenario Year 6 (89% of the total simulation duration for both scenarios). In Model Layers 4 and 5, head is below both exclusion heads for the entire simulation, as is true for Scenario 1.

- At the West Sunset Playground Well (Figure 10.3-8), head in Model Layer 1 is below the single-aquifer exclusion head for the entire simulation duration after about Scenario Year 1 (99% of the simulation duration for both scenarios), and below the Shallow Aquifer exclusion head after about Scenario Year 6 (90% of the simulation duration for both scenarios). In Model Layers 4 and 5, head is below both exclusion heads throughout the simulation duration, as is the case for Scenario 1.

- At the Taraval cluster (Figure 10.3-9), head in Model Layer 1 is below the single-aquifer exclusion head throughout the simulation (as is the case for Scenario 1), and below the Shallow Aquifer exclusion head for the entire simulation duration after about Scenario Year 5 (91% of the simulation duration for both scenarios). Head in Model Layers 4 and 5 is below both exclusion heads for the entire simulation period, as is the case for Scenario 1.

- At the Zoo cluster (Figure 10.3-10), head in Model Layer 1 is below the single-aquifer exclusion head throughout the simulation duration (as is the case for Scenario 1), and varies around the Shallow Aquifer exclusion head for the entire simulation duration after about Scenario Year 14 (below for 35% of the simulation duration for Scenario 3a, 30% for Scenario 3b). Head in Model Layers 4 and 5 is below both exclusion heads for the entire simulation, as is the case for Scenario 1.

- At the Fort Funston cluster (Figure 10.3-11), head in Model Layers 1, 4 and 5 is below the single-aquifer exclusion heads for the model simulation, as is the case for Scenario 1. Note that the units at this cluster and at the Thornton Beach cluster do not correlate to the individual aquifers present east of the Serra Fault, so only the single-aquifer exclusion head is considered and presented on the hydrographs.
- At the Thornton Beach cluster (Figure 10.3-12), head in Model Layer 1 varies around the single-aquifer exclusion head throughout the simulation duration (below the exclusion head for 64% of the simulation duration for both scenarios, compared to 63% of the simulation duration for Scenario 1). Head is below the single-aquifer exclusion head for the entire simulation duration for Model Layers 4 and 5, as is true of Scenario 1.

These results indicate that there is the potential for the landward migration of the seawater-freshwater interface under the pumping conditions proposed for the SFGW Project along some parts of the Pacific Coast, but not others. The exclusion head is a way to evaluate the long-term potential for seawater intrusion. It is important to note that groundwater heads below the exclusion head at a location do not necessarily imply that seawater intrusion will reach that location, because there are other hydrogeologic factors that may influence the location of the seawater-freshwater interface. In particular, physical controls may exist, such as low-permeability layers or offshore fault zones, as discussed earlier. Rather, the analytical model indicates that there is an increased potential for the landward migration of the seawater-freshwater interface. Also, seawater intrusion is typically a slow process that may take years to manifest in a production well, and only if the conditions favorable for seawater intrusion are sustained continuously for an extended period of time.

Varying groundwater heads over the year can have a substantial effect on the movement of the seawater-freshwater interface. If groundwater head rises and falls within a similar range from year to year, then the seawater-freshwater interface would move back and forth in a similar fashion. If this were the case, the interface would not continue to advance landward over time, but would establish a new transition zone and remain at that new location over time. If groundwater head declines over a period but become stable at some lower level, then the seawater-freshwater interface would shift to a new equilibrium location, which may still be offshore.

For the most part, seasonal fluctuations in head in Model Layer 1 are not great enough to lower head below exclusion head values during dry parts of the year (Table 10.3-4). In general, seasonal fluctuations, even when they repeatedly cross the exclusion head, are not likely to substantially affect the occurrence of seawater intrusion, because intrusion occurs on a much greater time scale than these annual fluctuations. Therefore, the small inward interface migration that would occur during the low summer heads would be offset by the outward migration that would occur during the higher winter heads. In this conceptual scenario, the seasonal fluctuations would approximately cancel each other out, indicating that the average annual head is the most important factor that relates to the potential for seawater intrusion.

5.2.5. Evaluation

Groundwater head, especially in the southern half of the North Westside Basin, is projected by the model to be below sea level (and the calculated exclusion heads) for some or most of the simulation period. During the operation of the SFGW Project, the model results show lower groundwater heads throughout the northern half of the North Westside Basin. For Scenarios 3a and 3b, the groundwater heads along the Pacific Coast would be depressed and hydrologic conditions may allow for the landward migration of the seawater-freshwater interface in the aquifer in areas where no physical controls exist to prevent intrusion. Based on the groundwater elevation contour maps from the model, these areas would be limited to an area along the Coast. It is unclear how far landward the seawater-freshwater interface may move or at what rate.

Groundwater head responds similarly during drought periods compared to the same drought periods under Scenario 1, except that they are offset by fairly uniform amounts, so the change in head appears to be due almost entirely to the increase in pumping in this area; head also does not rebound to Scenario 1 levels during wet periods, indicating that the extra pumping in the North Westside Basin would have a uniform effect on head in both wet and dry times.

The results of this analysis indicate that the increase in pumping in the North Westside Basin entailed in the SFGW Project would result in the landward migration of the seawater-freshwater interface in the aquifer beyond that which would occur naturally due to climatic fluctuations. Although the flux results quantified by the numerical model are not expected to accurately represent the actual flux everywhere along the coast, the relative changes resulting from the various scenarios are informative for understanding the possible timing of seawater intrusion.

5.3. San Francisco Bay Coast

The SFGW-only Scenarios (3a and 3b) do not include any additional pumping in the South Westside Basin, so large changes in head are not anticipated in this area. Figures 10.3-13 through 10.3-15 show the difference in head for these scenarios versus Scenario 1 (note that the results of these scenarios are nearly identical to those of Scenario 1, so the Scenario 1 results are generally not visible on the hydrographs). Table 10.3-2 presents the maximum, average, and minimum differences between the results for these scenarios and those of Scenario 1.

5.3.1. Head

Scenario 3a: This scenario includes additional pumping in the North Westside Basin, which is far from the Bay monitoring well locations. Therefore, minimal change is expected in these wells. Indeed, the average differences in head in these wells compared to Scenario 1 are all between -0.01 and -0.03 ft (Table 10.3-2). This indicates that the SFGW Project pumping conditions would not have a substantial effect on the occurrence of seawater intrusion in this part of the Basin.

Seasonal fluctuations under this scenario are all between +0.1 ft and -0.1 ft (Table 10.3-4), indicating that seasonal head fluctuations would not have a substantial effect on the occurrence of seawater intrusion in this part of the Basin.

Scenario 3b: As with Scenario 3a, the situation simulated in this scenario is not expected to affect this area greatly. The average differences in head compared to Scenario 1 are all between -0.01 and -0.03 ft (Table 10.3-2). As such, the Scenario 3b conditions are not expected to have a substantial effect on the occurrence of seawater intrusion in this part of the Basin.

Seasonal fluctuations in head under this scenario are all between +0.1 ft and -0.1 ft (Table 10.3-4), indicating that seasonal head fluctuations would not have a substantial effect on the occurrence of seawater intrusion in this part of the Basin.

5.3.2. Groundwater Flux

Scenario 3a: This scenario simulates the pumping entailed in the SFGW Project, which increases groundwater extraction in the North Westside Basin. Even though pumping is not modified in the South Westside Basin, the inclusion of the SFGW Project seems to have a slight effect on the freshwater flux along the Bay coast, decreasing it slightly compared to Scenario 1 throughout the simulation period (Figure 10.3-17 and Table 10.3-5). This decrease is not reflected in the heads. The minimum freshwater flux is about 80 afm, a decline of only 2 afm compared to Scenario 1. These results indicate that this configuration of the SFGW Project would not have a substantial effect on the occurrence of seawater intrusion in the South Westside Basin.

Scenario 3b: This scenario is identical to Scenario 3a, except as noted above. Because of the distance to the North Westside Basin and the relatively small change in pumping involved from Scenario 3a, conditions along the Bay Coast are expected to show only minimal changes. The minimum freshwater flux is still about 80 afm (Table 10.3-5). These results indicate that the changes between Scenarios 3a and 3b do not have a substantial effect on the occurrence of seawater intrusion along the Bay coast.

5.3.3. Evaluation

In general, the modeling results suggest that the Bay Coast would not be vulnerable to seawater intrusion due to the operation of the SFGW Project. The freshwater flux out of the aquifer into San Francisco Bay is quite low, and would not be modified to a great degree by the pumping configurations simulated in the numerical model (Figure 10.3-17). As noted previously, the hydrogeological framework in this part of the Basin is not well-known, so these results are considered to be fairly qualitative.

6. Cumulative Scenario Analysis

The Cumulative Scenario (4) includes the assumed operation of both the GSR and SFGW Projects, projected pumping for the PAs and third party pumpers, and other reasonably foreseeable future projects. Reasonably foreseeable projects that are considered under the cumulative scenario include the Daly City Vista Grande Drainage Basin Improvements Project and the Holy Cross cemetery future build-out with its anticipated increase in irrigation pumping.

6.1. Scenario Conditions

Scenario 4 assumes the operations of the GSR (as per Scenario 2) and SFGW Projects with total SFGW Project pumping of 4 mgd (as per Scenario 3b). The model assumptions used for Scenario 4 are summarized in TM-10.1.

The Daly City Vista Grande Drainage Basin Improvements Project is assumed to be a reasonably foreseeable future project under the cumulative scenario. It is assumed that supplemental water to the Lake would be supplied by Daly City storm water from the Vista Grande canal with baseflows being maintained via a wetland (see TM-10.1 for details).

Based on the future land use development projections in the Holy Cross cemetery, irrigation pumping in this cemetery is anticipated to increase under the cumulative scenario by 0.04 mgd, and the associated recharge to groundwater has also been adjusted (see TM-10.1).

6.2. Conceptual Analysis

The Cumulative Scenario includes both the GSR and SFGW Projects. However, since the GSR Project is located in the South Westside Basin, and the SFGW Project is located in the North Westside Basin, it is not anticipated that there would be much interaction between the two projects with respect to seawater intrusion. Scenario 2 showed that the GSR Project conditions did not have a large effect on conditions in the North Westside Basin, while Scenarios 3a and 3b showed that the SFGW Project conditions did not have a large effect on conditions in the South Westside Basin. Therefore, in terms of the potential for seawater intrusion, it is anticipated that the Cumulative Scenario would produce results in the South Westside Basin similar to those of the GSR-only Scenario (2), and in the North Westside Basin similar to those of the SFGW-only Scenarios (3a and 3b).

As shown in TM-10.1, diversion of water from the Vista Grande Canal into Lake Merced would have the effect of raising groundwater head in the Lake Merced area as a result of leakage from the Lake to the aquifer. This localized increase in head may decrease the potential for seawater intrusion along the coast near Lake Merced, but this effect diminishes with distance from the Lake.

The changes to pumping associated with the Cumulative Scenario (such as the pumping increase at the Holy Cross cemetery) are located in the South Westside Basin and are too far from either coast to have a substantial effect on seawater intrusion.

6.3. Pacific Coast

The results of the Cumulative Scenario (4) are shown on Figures 10.3-4 through 10.3-12. These figures show predicted head at the various Pacific Coast monitoring locations as well as the difference in head between this scenario and Scenario 1. Table 10.3-2 presents the maximum, average, and minimum differences between the results for this scenario and those of Scenario 1.

6.3.1. Head

Scenario 4 combines the GSR Project pumping of Scenario 2 with the SFGW Project pumping of Scenario 3b. Because the GSR Project pumping is concentrated in the South Westside Basin, the results of this scenario in the Pacific Coast area are very similar to those of Scenario 3b (Figures 10.3-4 through 10.3-12). At the North Windmill location, and the South Windmill and Kirkham clusters, the average difference between the results of Scenario 3b and those of this scenario in Model Layer 1 is minimal (Table 10.3-2a).

Further to the south, head is slightly higher in this scenario versus Scenario 3b. This reflects the operation of the GSR Project, which is shown (under Scenario 2; see Section 4.2.1) to increase head slightly in this area compared to Scenario 1. At the Ortega Cluster, head in Model Layer 1 (Table 10.3-2a) is on average less than a foot higher than under Scenario 3b. This average difference increases to the south to about 0.8 ft at the Taraval cluster and 4 ft at the Zoo cluster. At the West Sunset Playground well (Figure 10.3-8), head is about 2 ft higher than under Scenario 3b. Head is nearly unchanged at the Fort Funston (Figure 10.3-11) and Thornton Beach (Figure 10.3-12) clusters.

In Model Layer 4 (Table 10.3-2b), the results are similar. At the West Sunset Playground well, the average difference from Scenario 1 is about 3 fthigher than under Scenario 3b, about 3 ft higher at the Taraval cluster, and 6 ft higher at the Zoo cluster.

In Model Layer 5 (Table 10.3-2c), results are similar to those of Model Layer 1, except that the average difference is about 2 ft higher at the Taraval cluster than under Scenario 3b.

Seasonal fluctuations in this area are mostly smaller than under Scenario 1 for the Cumulative Scenario, and similar to those of Scenario 3b (Table 10.3-4). Values for Scenario 4 range from about 0.5 ft (West Sunset Playground well and Taraval cluster) to 1.3 ft (Zoo and Fort Funston clusters) in Model Layer 1, from about 0 ft (Fort Funston and Thornton Beach clusters) to 0.3 ft (South Windmill, Kirkham, and Taraval clusters and West Sunset Playground well) in Model Layer 4, and from -0.5 ft (Zoo cluster) to 0.2 ft (Kirkham and Ortega clusters) in Model Layer 5. These results indicate that seasonal fluctuations in head would not have a substantial effect on the occurrence of seawater intrusion in this part of the Basin.

6.3.2. Groundwater Flux

Scenario 4 combines the pumping changes of the GSR and SFGW Projects simulated in Scenarios 2 and 3b. The average flux (and head) conditions are higher than under the SFGW Project Scenarios (3a and 3b), although by only a small amount relative to the total flux (Figure 10.3-16 and Table 10.3-5).

The maximum freshwater flux for this simulation is about 350 afm, while the minimum is about 15 afm. The minimum flux is slightly higher than under Scenarios 3a and 3b, but the difference is not large compared to the total range of fluxes from maximum to minimum. Therefore, the results of this scenario indicate that the combination of the SFGW and GSR Project pumping regimes would not have a substantial effect in the North Westside Basin compared to the SFGW Project alone.

6.3.3. Groundwater Contour Map Analysis

Under Scenario 4, the model-simulated groundwater elevations for the Shallow Aquifer at the end of the simulation period (Figure 10.3-20) are very similar to those of Scenario 3b. The lack of difference between the results of Scenarios 3b and 4 indicate again that the GSR Project would have only a minor effect on groundwater head in the North Westside Basin. The cone of depression around the West Sunset Playground well is very slightly smaller, and areas north of this well see very slightly higher groundwater elevations. South of the West Sunset Playground well, areas of below-sea-level groundwater elevations around Lake Merced disappear, and groundwater elevations just north of Lake Merced are generally around five feet higher, a likely result of the modeled additions of the Daly City Vista Grande Drainage Basin Improvement Project under the Cumulative Scenario.

Compared to Scenario 1, the map distribution for Scenario 4 suggests that the area of the West Sunset Playground well would have an increased potential for landward migration of the seawater-freshwater interface resulting from groundwater pumping, similar to the results of Scenarios 3a and 3b. Areas to the south would have a much smaller extent of decreased groundwater head, suggesting a lesser potential for the landward migration of the seawater-freshwater interface.

6.3.4. Evaluation of Analytical Results

From the Ortega cluster (Figure 10.3-7) south, head is actually higher than predicted for Scenario 3b in Model Layers 1 and 4, likely the result of the Vista Grande additions to Lake Merced. However, the differences are generally quite small, and would only slightly change the degree and rate of seawater intrusion, not its occurrence. Therefore, combined operation of the GSR and SFGW Projects is considered to have the same effect on seawater intrusion as does the SFGW Project alone. The exception to this is in Model Layer 1 at the Zoo cluster (Figure 10.3-10a), where heads are about four feet higher under this simulation and above the Shallow Aquifer exclusion head throughout the simulation duration (compared to Scenario 3b, during which head was below the Shallow Aquifer exclusion head for 30% of the simulation duration).

Seasonal head fluctuations in Model Layer 1 (Table 10.3-4) are similar to those of Scenario 3b, and the same conclusions apply (Section 5.2.4). Even in the southern part of the North Westside Basin, where there is some slight difference between the head values for this scenario and those of Scenario 3b, the seasonal fluctuations are not markedly different.

6.3.5. Evaluation

The Scenario 4 results indicate that some of the groundwater heads in the North Westside Basin for the Cumulative Scenario would be higher than those for the SFGW-only Scenarios (3a and 3b), while other groundwater heads would be similar to Scenarios 3a and 3b. Exceptions are seen in Model Layer 5 in the southern part of the North Westside Basin (from the West Sunset Playground well south). Head values under Scenario 4 drop below the results of Scenarios 3a and 3b during take periods, with the largest declines seen during the Design Drought; these declines follow similar patterns as the Scenario 2 results, indicating that they result from the operation of the GSR Project. As noted in Section 4.2.4, the declines in head seen during the take periods are temporary, and would not have a significant effect on the occurrence of seawater intrusion along this Coast. Taken as a whole, the results of Scenario 4 indicate that the combined effects of the Projects would create conditions less favorable for the landward migration of the seawater-freshwater interface than those seen in Scenarios 3a and 3b.

6.4. San Francisco Bay Coast

The results of the Cumulative Scenario (4) for the Bay side monitoring network locations are shown on Figures 10.3-13 through 10.3-15, which depict the head predictions for this scenario as well as the differences in head between this scenario and Scenario 1. Table 10.3-2 presents the maximum, average, and minimum differences between the results for this scenario and those of Scenario 1.

6.4.1. Head

Scenario 4 combines the pumping changes entailed in the GSR and SFGW Projects. Because neither of these projects would have much of an effect on head in this part of the Basin (see Sections 4.3.3 and 5.3.3), the Cumulative Scenario pumping would not have a large effect either. Indeed, the hydrograph results for the three well clusters in the area (Figures 10.3-13 through 10.3-15) show minimal differences compared to the results of Scenario 2. This finding is confirmed by the statistical evaluation of head (Table 10.3-2). This indicates that the operation of the combined Projects would not have a substantial effect on seawater intrusion in this part of the Basin.

Seasonal fluctuations in head under Scenario 4 are between about -0.1 ft and +0.1 ft (Table 10.3-4). This indicates that seasonal fluctuations in head would not have a substantial effect on the occurrence of seawater intrusion in this part of the Basin.

6.4.2. Groundwater Flux

Scenario 4 combines the pumping conditions of the GSR and SFGW Projects. The average freshwater flux results of this scenario fall below those of the other scenarios (Figure 10.3-17 and Table 10.3-5), with a maximum flux of about 110 afm and a minimum flux of about 50 afm. This minimum flux is substantially lower than under Scenario 2 (minimum flux of 70 afm), indicating that the combined operation of the Projects may have an increased effect on freshwater flux, but the flux remains well above zero throughout the simulation period, and the fine-grained nature of the aquifer deposits may represent a physical control preventing seawater intruson.

6.4.3. Evaluation

In general, the changes to groundwater pumping entailed in the GSR and SFGW Projects would not have a substantial effect on seawater intrusion along the San Francisco Bay Coast compared to what may occur under Scenario 1 conditions. The Burlingame cluster is projected to see a decline in head during Scenario 1, approaching sea level in Model Layer 1 (Figure 10.3-13a). In Model Layer 4 (Figure 10.3-13b), head at the Burlingame cluster begin slightly above sea level, and decline throughout the scenario. At the SFO (Figure 10.3-14) and UAL (Figure 10.3-15) clusters, the head rises throughout the simulation period.

7. Assessment of Areas Susceptible to Seawater Intrusion

The occurrence of seawater intrusion into a freshwater aquifer depends greatly on the connection between the ocean and the aquifers. If the aquifer is isolated from seawater, there is no potential for intrusion, while freshwater aquifers in direct communication with seawater may have no physical barrier preventing the intrusion of seawater. To understand the susceptibility of the various aquifers in the study area to seawater intrusion, it is necessary to understand the configuration of the aquifers offshore. In general, studies suggest that the aquifers present in the North Westside Basin do stretch offshore to some distance, but how far, and whether these aquifers are in direct communication with the ocean, are questions that have not to date been fully resolved.

7.1. Potential Rate of Intrusion

The rate of seawater intrusion into an aquifer can be widely variable, depending on the values of the various parameters that control it. Because groundwater head in the coastal areas of the Westside Basin is not as far below sea level as in some of the examples presented in Section 8.2, the rate of seawater intrusion that would be seen in this basin may be on the low end of the rates determined by other studies.

The timing of seawater intrusion depends on a number of variables. A large inland gradient or high horizontal hydraulic conductivity would hasten seawater intrusion. Seawater intrusion would also occur more quickly if the seawater front is already close to land due to lower onshore head or freshwater flux. Although the thickness of the aquifer does not analytically have an effect on the rate at which seawater intrudes into a freshwater aquifer, a seawater wedge would form earlier in a thicker aquifer because the thicker aquifer requires a larger freshwater head to keep seawater out. An analytical equation can be developed that gives a first approximation of the potential rate of seawater intrusion under various conditions; this is described in Attachment A.

A simplified aquifer was constructed to apply this analytical solution, and the various parameters were chosen to reflect approximate actual values at the South Windmill cluster in Golden Gate Park. The parameter values, and the sources from which they were derived, are given in Table 10.3-7. These values were used to calculate the change in seawater intrusion length over various periods of time (0.25, 0.5, 1, 2, 5, 10, 20, and 50 years) at pumping rates varying from zero to equal to the freshwater flux rate determined by Yates et al. (1990) for the Golden Gate Park area. It should be noted that the aquifer at this location was assumed to be continuous from the top of the sediments to the bedrock surface, due to the lack of large aquifer-bounding clay layers here (LSCE, 2010).

The results of this analysis indicate that the rate of intrusion would be quite low (Figure 10.3-21; note that the vertical axis is logarithmic). The dotted line on this figure represents the equilibrium change in intrusion length (i.e., the equilibrium intrusion length, L_{eq}, minus the pre-pumping intrusion length, L_0) based on the new freshwater flux rate (i.e., the original freshwater flux rate,

Q'_0, minus the pumping rate, Q'_w); this is the intrusion length that would eventually be reached at steady state. The blue dashed line indicates the percentage of the original freshwater flux rate that is left after pumping is increased. The three solid lines indicate the change in intrusion length (i.e., the transient intrusion length, L(t), minus the pre-pumping intrusion length, L_0) at three different values of t: 1, 10, and 50 years. The change in intrusion length, read off the left-hand axis, represents how far the toe of the intrusion wedge would have advanced in the period of time corresponding to each line; for example, at a pumping rate of 5,000 cubic feet per year per foot of shoreline (cfy/ft of shoreline), the intruding wedge would have moved 3 feet in 1 year, 13 feet in 10 years, and 39 feet in 50 years. When a solid line intersects with or is above the red dotted curve representing the equilibrium change in intrusion length, the system would be at equilibrium, and the interface would not progress past L_{eq}.

These results indicate that the rate of seawater intrusion is lower than has been seen in other settings (see Section 8.2). Even if pumping in the Basin were equal to the pre-pumping freshwater flux (an extreme scenario that is not expected to occur), the change in the intrusion length would be 7 feet after 1 year, 33 feet after 10 years, and 96 feet after 50 years (note that the method assumes that the freshwater pumping is small compared to the initial freshwater flux, so these results should be considered approximate). An equilibrium change in intrusion length of 12,600 feet for this pumping rate indicates that it would take many decades for this system to reach equilibrium.

This method can be applied to the pumping rates from the various modeling scenarios. Scenario 1 utilizes an average pumping rate of about 4,830 cfy/ft of shoreline. The proposed total pumping in the North Westside Basin is about 13,640 cfy/ft of shoreline in Scenario 3a, which represents an increase of about 8,810 cfy/ft of shoreline. The analytical method indicates that the change in intrusion length would be 4 feet over the first year, 19 feet over 10 years, and 57 feet over 50 years. The proposed total pumping of 14,050 cfy/ft of shoreline in Scenario 3b represents an increase of about 9,220 cfy/ft of shoreline. At this rate, the change in intrusion length would be 4 feet over 1 year, 20 feet over 10 years, and 59 feet over 50 years. It should be noted that the increased pumping entailed by the SFGW Project represents about 45% of the initial freshwater flux under Scenario 3a and 47% under Scenario 3b, which indicates that one of the assumptions of the analytical method (that pumping be small compared to the initial freshwater flux) is not completely valid. Because of this, these results should be considered approximate. However, the results are still instructive of the general magnitude of the potential seawater intrusion rate, and are useful in providing an independent line of evidence that pertains to the seawater intrusion analysis.

As with the analysis of flux predicted by the numerical model, it should be noted that this rate analysis assumes that the fluxes can be applied in average across the entire Pacific coast. The actual rate of intrusion at Golden Gate Park may be greater or less than that implied by this analysis, depending on how flux in the area is actually modified.

7.2. Physical Conditions Along the Pacific Coast

Previous reports (LSCE, 2002; LSCE, 2010; SFPUC, 2005; SFPUC, 2006) discussed the coastal topography and stratigraphy in relation to the problem of seawater intrusion. These reports considered pre-existing information on the onshore geology (e.g., Clifton and Hunter, 1987) coupled with the results of a study of offshore seismic reflection (Bruns et al., 2002). The information in these reports is summarized in this section. Because no control studies have been performed (i.e., coring offshore to confirm stratigraphy), this discussion of offshore stratigraphy is somewhat speculative.

7.2.1. Offshore Geology

The upper surface of sediments continues offshore at a very gentle slope for a large distance. The water depth in the Ocean is only 60 feet about 2 miles offshore, 100 feet 8 miles offshore, and 300 feet 25 miles offshore, at the edge of the continental shelf; the Ocean bottom drops off steeply further offshore. This indicates that the onshore sedimentary units, if they stretch continuously offshore, may not outcrop on the Ocean floor for some distance. The intersection of the top of each aquifer with the Ocean bottom (i.e., its highest outcrop) is important to the problem of seawater intrusion because this is, theoretically, where freshwater exits the aquifer, and is the location where the uppermost part of the seawater wedge exists within the aquifer (Figure 10.3-3).

Because of the structural complications that exist offshore, the slope of the aquifer boundaries that exist onshore and the depth to the Ocean floor cannot be used to predict the depths of the units offshore and where the aquifers are connected to the Ocean. The San Andreas Fault is present offshore from around Mussel Rock north to Bolinas Lagoon. Further to the west, the San Gregorio Fault Zone also sits offshore. Between these faults exists the extensional San Gregorio Basin, a down-dropped area that results from the structure of the two bounding fault zones. This extensional basin has filled with more than 3,000 feet of sediment that is presumed to correlate to the Merced and Colma Formation sediments further inland (Bruns et al., 2002). However, no control points exist to confirm this. The extensional regime that led to the deepening of this basin likely made this a somewhat different depositional environment from the areas east of the San Andreas Fault, so there may be some differences even between units that correlate exactly in time across the San Andreas Fault. West of the San Gregorio Fault Zone, the stratigraphic sequence revealed by the seismic profiling resembles the units seen in the Santa Cruz Mountains to the southeast, indicating that these units have been translated by strike-slip motion along the San Andreas and San Gregorio Fault Zones (Bruns et al., 2002), and the aquifers that exist in the North Westside Basin therefore cannot be correlated to units west of the San Gregorio Basin. As long as the individual onshore aquifer units do not intersect the Ocean floor before reaching the San Andreas Fault, this fault zone may act as a physical barrier preventing seawater intrusion. The Shallow Aquifer, which is not covered by a confining clay layer, is in direct communication with the Ocean all along the coast.

Faults may represent hydrologic barriers in other parts of the Basin. The Serra Fault makes the Daly City area non-susceptible to seawater intrusion from the Ocean (see Section 7.2.3), and the same might be true of the lower aquifers in the North Westside Basin north of Lake Merced due to the presence of the San Andreas Fault, although no direct evidence of this exists.

An additional factor that may aid in reducing the likelihood of seawater intrusion is the presence of freshwater in offshore sediments (LSCE, 2010). During the Pleistocene glaciations, Ocean levels were about 300 to 400 feet lower, exposing the coastal plain to the atmosphere. During that time, the Sacramento-San Joaquin River system flowed across the coastal plain, depositing river sediments. The presence of this river and the exposure to the atmosphere for a relatively long period of time likely allowed fresh water to flush through most or all of the present-day offshore aquifer system. Provided the fine-grained units that exist between the aquifer layers are continuous offshore, these offshore units may still be filled with fresh water. If this is the case, then even head below sea level in the Primary Production and Deep Aquifers may not lead to seawater intrusion on any near-term time frame (SFPUC, 2006); it may take years to decades of continuously below-sea level onshore freshwater head for seawater to intrude through the miles of aquifer potentially occupied by fresh water. Indeed, about 5.5 mgd of groundwater was pumped from the North Westside Basin from 1930 to 1935, immediately prior to the completion of the Hetch Hetchy aqueduct, without inducing any noticeable degradation of water quality in the production wells (Gilman, 2010; SFPUC, 2006). LSCE (2010) also notes that the boreholes at the Fort Funston and Thornton Beach clusters, both located in deformed Merced Formation sediments west of the Serra Fault, did not encounter any saline water to their total depths of 1,500 feet.

7.2.2. Pacific Coast Northeast of the Serra Fault

The western boundary of the North Westside Basin is the Pacific Ocean. This stretch of the Pacific Coast is considered potentially susceptible to seawater intrusion due to its direct connection to the Pacific Ocean; however, it does not seem to be currently affected by seawater intrusion. Chloride levels in the monitoring wells along the coast have remained steady and fairly low. The shallow well at the South Windmill monitoring well cluster shows relatively high chloride concentrations, up to 154 milligrams per liter (mg/L) in the most recent (2011) samples (J. Gilman, personal communication, April 22, 2012). The California secondary maximum contaminant level (MCL) for chloride is 250 mg/L recommended and 500 mg/L upper limit.

As noted above, three aquifers exist in this part of the Basin, the Shallow, Primary Production, and Deep Aquifers, although the Deep Aquifer pinches out between the Kirkham and South Windmill well clusters (LSCE, 2010). The boundaries between these units tend to dip slightly toward the Ocean, especially in the deepest sediments as noted in TM#1.

The onshore hydrogeology presented in Appendix A of LSCE (2010) provides insights into the structure of the aquifers. Cross-sections J-J’, Z-Z’, and Y-Y’ stretch through this area. According to these cross-sections, the Shallow Aquifer is in direct contact with the Ocean, and so there are no physical controls to prevent the intrusion of seawater should currently-existing hydrologic controls change.

The cross-sections do not stretch far enough off the coast to show where the Primary Production and Deep Aquifers may be in direct contact with seawater. SFPUC (2006) notes that the structural and depositional features that exist in the offshore sediments preclude the intrusion of seawater into the Primary Production and Deep Aquifers north of Lake Merced, but the physical barriers implied by this are not yet proven to exist. Rather, they are suggested by offshore seismic studies (Bruns et al., 2002) and the presence of offshore fault zones.

Cross-section J-J' is located along an west-east transect from the Ocean through Golden Gate Park to Strawberry Hill. In this area, the Shallow and Primary Production Aquifers are present. At the coast, the Shallow Aquifer is about 100 feet thick, while the Primary Production Aquifer may be about 350 feet thick. There is no fine-grained layer between the two aquifers at this location, meaning that they are hydraulically connected, and they can effectively be considered to be one thick aquifer. According to the cross-section, no physical barrier exists here that would prevent intrusion of seawater into the Primary Production Aquifer via the Shallow Aquifer above. As noted above, these cross-sections do not stretch far offshore; the absence of an intervening fine-grained layer onshore does not necessarily imply that no such layer separates the different aquifers offshore.

Cross-section Z-Z' runs from the Ortega cluster approximately east through the West Sunset Playground to the Sunset Reservoir. Along this cross-section, all three aquifers are present, and they are divided by at least some thickness of fine-grained units, although these lenses are fairly thin and could be discontinuous between the existing wells. At the coast, the Shallow Aquifer is about 120 feet thick, while the Primary Production Aquifer is about 310 feet thick and the Deep Aquifer is about 60 feet thick. If the clay layers between the aquifers are continuous as indicated on the cross-section, and if they continue offshore to some physical barrier (e.g., the San Andreas Fault), the Primary Production and Deep Aquifers at this location may be physically protected from seawater intrusion.

Cross-section Y-Y' runs from the San Francisco Zoo area east to Pine Lake Park and beyond. This cross-section, like Z-Z', indicates that there are continuous clay layers present between (and, in some cases, within) the aquifers here. The Shallow Aquifer is about 40 feet thick at the coast, while the Primary Production Aquifer is about 300 feet thick and the Deep Aquifer is about 130 feet thick. As with cross-section Z-Z', the Primary Production and Deep Aquifers may be isolated from the Ocean. It should be noted that the thick clay present between the Shallow and Primary Production Aquifers at the coast (the "-100 clay") is indicated to be possibly discontinuous about 2,000 feet inland of the coast.

From the information summarized above, a conceptual model of the potential route of seawater intrusion can be constructed for the North Westside Basin. The Shallow Aquifer is connected directly to the Ocean everywhere along the coast, indicating that seawater intrusion would occur in this aquifer anywhere that the on-shore freshwater head is low enough that seawater is not excluded from the aquifer. From the Kirkham cluster north, there are no continuous confining layers present that separate the aquifers, indicating that all three aquifers are open to intrusion along this stretch of the coast should head levels permit it.

South of the Kirkham cluster, clay layers are present between the three aquifers. To the extent that these layers are laterally continuous, they present a barrier to seawater intruding into the lower two aquifers from the Shallow Aquifer above. Cross-section D-D' in LSCE (2010) indicates that the W clay is continuous from the Kirkham cluster south to the Serra Fault, separating the Primary Production Aquifer from the Deep Aquifer below. This indicates that, should seawater enter the Primary Production Aquifer, it would not intrude into the Deep Aquifer except at the rate allowed by the W clay. The -100 clay, which separates the Shallow from the Primary Production Aquifer, is not fully continuous south of the Ortega cluster, and there is a gap in this layer between the Taraval and Zoo clusters. Should seawater intrusion occur in the Shallow Aquifer along the coast in locations where the -100 clay is not present, the Primary Production Aquifer would also be susceptible to seawater intrusion. The -100 clay is continuous from north of the Zoo cluster to the Serra Fault (to the south).

7.2.3. Pacific Coast Southwest of the Serra Fault

The southwestern boundary of the South Westside Basin is made up of the San Andreas Fault, which juxtaposes Merced Formation sediments against the Franciscan bedrock southwest of the Basin. This barrier likely prevents the part of the Basin bounding it from experiencing any ill effects in terms of seawater intrusion due to groundwater development. As with the bedrock high sections along the eastern edge of the North Westside Basin, it is always somewhat possible that connate water (seawater trapped in a formation when the sediments are deposited) could be mobilized out of marine sediments by changes in the head distribution, but this is considered unlikely. Therefore, the areas of the Basin bounded by the San Andreas Fault, from San Andreas Lake to the Pacific Ocean, are considered non-susceptible to seawater intrusion.

The Serra Fault, which runs sub-parallel to the San Andreas Fault, has unknown hydraulic characteristics. While the San Andreas Fault to the south has placed low-permeability bedrock against the sediments of the Merced Formation, the Serra Fault separates Merced Formation sediments from those of the Colma Formation, implying that, if a physical barrier to groundwater flow exists, it must be the fault zone itself rather than the rocks bounding it. LSCE (2002) suggest that, due to their "presence and configuration," the deformed Merced Formation sediments present along the Serra Fault could act as a barrier to seawater intrusion as far north as Fort Funston, where the fault heads offshore, but no corroborating evidence for this has been found elsewhere. The well cluster at Thornton Beach shows very different groundwater head trends from the other wells in the coastal monitoring network, indicating that this cluster, which is located between the San Andreas and Serra Faults, may be hydraulically disconnected by the Serra Fault from the rest of the Westside Basin. For the purposes of this TM, the portion of the Basin along the Pacific Ocean southwest of the Serra Fault between the San Andreas Fault and Lake Merced is considered to be non-susceptible to seawater intrusion based on the assumption that the Serra Fault represents an effective physical barrier to intrusion.

7.2.4. Pacific Coast Head Monitoring

The coastal monitoring wells are screened in the Shallow, Primary Production, and Deep Aquifers (hydrographs for the wells discussed in this section are presented as Appendix B of TM#1). Within the Shallow Aquifer, head has generally not changed much since monitoring began (2004) at the Ortega (120 ft bls) and Taraval (145 ft bls) well clusters. At the Kirkham cluster, head in the well screened within the Shallow Aquifer (130 ft bls) fluctuates quite a bit on a seasonal basis, and LSCE (2010) suggest that this is due to irrigation cycles in Golden Gate Park. The average head in this well dropped by about 4 feet around the spring of 2006; this drop could be related to a change in the irrigation practices. All available heads in the Shallow Aquifer remain above sea level, currently averaging about +10 ft mean sea level (msl) in the Ortega and Taraval wells and about +8 ft msl in the Kirkham wells.

The recent head trends in the Primary Production Aquifer have shown more spatial variability, although they have generally been fairly steady and above sea level. The South Windmill well (140 ft bls) has seen head dip below sea level repeatedly during the irrigation season, by as much as 20 feet. Of the three wells screened in this aquifer at the Kirkham cluster, head in the upper one (255 ft bls) has fluctuated around an average of about +11 ft msl, that in the middle one (385 ft bls) has fluctuated around an average of +8 ft msl, and has not dropped below sea level, and head in the deeper one (435 ft bls) has generally been about +5 ft msl, and dipped below sea level in September of 2007; at the same time, head in the upper (255 ft bls) and middle (385 ft bls) wells dropped below +3 ft msl for the only time over the period of record. The Ortega cluster also has three wells screened within the Primary Production Aquifer. The upper two (265 and 400 ft bls) show very similar trends in head over time, with little change and values hovering around +12 ft msl for most of the period of record. Head in the lowest well (475 ft bls) has fluctuated quite a bit, with two major excursions below sea level in 2006 and 2007. Two wells screened in the Primary Production Aquifer at the Taraval cluster (240 and 400 ft bls) have had heads averaging around +10 to +13 ft msl, with fairly steady heads and no major trends up or down. At the West Sunset Playground well, head has been fairly steady over the period of record at between +17 and +18 ft msl. At the Zoo cluster, two wells are screened within the Primary Production Aquifer. The upper one (275 ft bls) has shown a generally rising head since 2004, staying consistently above sea level; recent head measurements have ranged between about +6 and +7 ft msl. The lower well (450 ft bls) head has also been highly variable, although it has seen at least three drops slightly below sea level, in 2004, 2006, and 2007. Finally, the Thornton Beach cluster has two wells screened within the Primary Production Aquifer. The upper one (225 ft bls) shows head between +82 and +85 ft msl, with the most recent heads about a foot above the earliest heads. The lower one (360 ft bls) shows head between +13 and +15 feet msl, with no appreciable trend over time.

Head in the Deep Aquifer has generally stayed steady on average, with large seasonal fluctuations. The deepest wells at the Taraval (530 ft bls) and Zoo (565 ft bls) clusters are screened in this aquifer. Head in the Taraval well varies between 4 and -9 ft msl, with the lowest heads recorded during the autumn of 2007. The Zoo well varies between +1 and -14 ft msl, with the timing of the deepest head coincident with that in the Taraval well. Neither of these wells shows an identifiable upward or downward groundwater head elevation trend over the period of record.

7.2.5. Pacific Coast Chemical Monitoring

Within the coastal monitoring network, the clusters at South Windmill, Kirkham, Ortega, and Taraval are sampled for chloride, total dissolved solids (TDS), and specific conductance, while the Zoo cluster and the West Sunset Playground well are measured for nitrate and general minerals (which includes chloride and TDS). Chloride concentrations for selected wells are included on the hydrographs of TM#1, and average concentrations for selected chemical constituents are given in Table 10.3-8.

The wells in the monitoring network are sampled for chloride semi-annually. At the Kirkham, Ortega, and Taraval wells, chloride has varied between about 20 and 40 mg/L, and each well has seen fairly steady concentrations since monitoring began in 2004. The three wells in the Zoo cluster have higher chloride, varying from about 70 mg/L (275 ft bls) to 45 mg/L (450 ft bls) to 50 mg/L (565 ft bls). These wells have shown no appreciable upward or downward trend in concentrations over time. Limited data exist for the cluster at South Windmill, with the shallower well (57 ft bls) concentrations varying from 115 to 193 mg/L, and the deeper well (140 ft bls) concentrations varying between 48 and 70 mg/L. The concentrations in this shallower well increased with every measurement from when monitoring began in 2006 through 2009, but have since decreased to 154 mg/L in November 2011.

The highest chloride concentrations measured in the North Westside basin have been at LMMW-1S, screened in the Shallow Aquifer and located between Lake Merced and the Pacific Ocean along the west side of John Muir Drive (data are available for April and November of 2009 and 2010). The highest chloride concentration measured was 393 mg/L in November 2009, with the lowest concentration being 129 mg/L in April 2010 (SFPUC, 2011). The ultimate cause of these high chloride concentrations is unknown. The co-located well LMMW-1D, screened in the Primary Production Aquifer, yielded samples with chloride concentrations of 104 and 106 mg/L in April and November of 2010. The proximity of these wells to the Pacific Ocean (approximately 1,300 feet to the west) indicates that the Ocean is a potential source for elevated chloride; however, LMMW-1S is separated from the Ocean by the Serra Fault, which is interpreted to be a barrier to groundwater flow and seawater intrusion in this area, as discussed further in TM#1. In addition, some other chemical constituents are not typical of Ocean water; in particular, the pH (average of 6.8) is well below the average pH of seawater (about 7.8 to 8.4; see, for example, Krauskopf and Bird, 1995) and below the values seen in the other wells within the North Westside Basin (averages for wells monitored by SFPUC vary from 7.2 to 8.6), perhaps indicating that some other source is affecting the chemistry of groundwater at LMMW-1S. These observations indicate that the elevated chloride concentrations seen in LMMW-1S likely result from a source other than seawater intrusion.

Other previous studies have also presented chloride data in the North Westside Basin that could potentially provide useful information on the occurrence of seawater intrusion along the Pacific coast. AGS (1994) presented results of production well sampling in November and December of 1993 at various wells around the North Westside Basin. Chloride varied from 21 to 68 mg/L, with the highest value at the Oceanside Water Pollution Control Plant (just south of the Zoo cluster and LMMW-4S on Figure 10.3-1); outside of this sample, the highest chloride concentration was 42 mg/L at Sunset Well #7. Samples were obtained from a few locations studied in detail in this TM: North Windmill, South Windmill, and the San Francisco Zoo. At these production wells, chloride concentrations varied from 37 to 39 mg/L. High capacity, deep production wells have been pumping at the west end of Golden Gate Park since the 1920s and at the San Francisco Zoo since the 1930s.

Yates et al. (1990) and Phillips et al. (1993) provided the results of sampling for various constituents (including chloride) at several wells, mostly in the North Westside Basin. Chloride concentrations in all of the wells sampled varied from 21 to 210 mg/L (this highest value was seen at the Elk Glen-S monitoring well in central Golden Gate Park; the highest value along the coast was 130 mg/L at HLA E). Samples from the North Windmill, South Windmill, and Zoo locations (including both production and monitoring wells) had chloride concentrations of 35 to 54 mg/L, except a sample from the shallowest monitoring well at South Windmill, which had a chloride concentration of 100 mg/L. Yates et al. (1990) offered the following explanation for the chloride concentrations in shallow groundwater: “Most of the chloride in shallow ground water is probably derived from near-surface sources. For example, the average concentration of chloride during 1987 in sewage flowing out of the Richmond-Sunset Water Pollution Control Plant was 145 mg/L.” Phillips et al. (1993) offered the following explanation for the elevated chloride concentrations seen at the Elk Glen-S and the South Windmill-S (now known as MW57) monitoring wells: “The apparent saltwater contamination in shallow wells at Golden Gate Park probably is a result of leakage of seawater used at Steinhart Aquarium, either from the supply pipe or exfiltration of saltwater discharge to the sewer system.”

The data presented in the reports discussed above indicate that there have not been appreciable trends over time in the coastal chloride concentrations in the North Westside Basin. Further, the recent sample results have been in line with historical data. The generally stable chloride concentrations along the Pacific Coast indicate that substantial seawater intrusion has not occurred to date, despite long-operating irrigation wells in the areas of Golden Gate Park and the San Francisco Zoo.

Additional groundwater chemistry monitoring has been performed on a short-term basis as part of construction projects in the North Westside Basin. An important and instructive example occurred during dewatering associated with construction at the Oceanside Water Pollution Control Plan (WPCP) from 1989 to 1994 (dewatering started in May of 1990, and continued until April 1991). Oceanside WPCP is located south of the San Francisco Zoo, between the Pacific Ocean and Lake Merced. ESA (1994) presented monitoring data collected in the Oceanside WPCP area during the construction activities. Observation wells were installed surrounding the site, including along the Great Highway along the Pacific Coast (OB-3, OB-6, and OB-7), along the northern end of the site (OB-1, OB-2, and OB-5), and along the eastern boundary of the site where it borders Lake Merced (OB-4). Well OB-3, screened in the Shallow Aquifer, was directly west of the field of dewatering wells, and saw 19 feet of water table decline during dewatering operations, but rebounded to pre-pumping levels within a month of the cessation of dewatering. Water quality was also monitored during construction activities; chloride in OB-3 rose quickly from background concentrations, eventually reaching a maximum of 10,500 mg/L. Monitoring of chloride continued after the cessation of dewatering, and the groundwater in OB-3 remained brackish throughout the period of post-dewatering monitoring, at least to 1994 when ESA reported these results. The monitoring results indicate several important things relevant to this TM:

- Based on the speed with which seawater reached OB-3 after dewatering began, the freshwater-seawater interface in the Shallow Aquifer must be located just offshore in this aquifer, and the Shallow Aquifer is in direct contact with the Ocean here.
- Seawater intrusion can affect coastal monitoring wells within a span of just a few months.
- Once seawater intrusion does occur, it is difficult to reverse the process and return aquifer water quality to its pre-intrusion state, even when head has rebounded to this pre-intrusion state.
- Intrusion, especially when it is caused by highly localized pumping in the vicinity of the coast, can be localized (none of the other monitoring wells saw any decline in water quality during dewatering operations) and temporary (SFPUC, 2005).

The results of the dewatering operations are not expected to exemplify the reaction of the aquifer system to pumping associated with either the GSR or SFGW Projects, which would involve pumping further away from the Coast, and would derive groundwater from deeper, confined aquifers that are not expected to experience seawater intrusion on the short timescales demonstrated for the Shallow Aquifer by ESA (1994).

7.3. Physical Conditions Along the San Francisco Bay Coast

The portion of the Westside Basin along the San Francisco Bay is the easternmost part of the South Westside Basin. This is another area potentially susceptible to seawater intrusion, and may in fact currently be affected by seawater intrusion. Chloride concentrations in this area vary from 42 to 13,000 mg/L, with the highest values seen in the shallowest wells. The chloride-bromide ratios for the sampling events in November 2006 and April 2007 (WRIME, 2007) are fairly similar to that of water collected from a nearby location in the San Francisco Bay (Cl:Br = 327), also in April 2007.

As noted in WRIME (2007), both the Bay Mud and the artificial fill were emplaced in the environment of the saline Bay, meaning that these deposits likely contain substantial connate water. While the similarity of chloride concentrations and chloride-bromide ratios to those of Bay water may seem indicative of seawater intrusion into this area, similar concentrations could be due to the presence of connate Bay water in the sediments of the area, which may be expected to be fairly similar chemically to today's Bay water and would therefore have a similar effect on aquifer water quality as would intruding seawater. Because the available reservoir of connate water is determined by the porosity of the Bay Mud, this reservoir can be assumed to be much smaller than the effectively infinitely large reservoir of Bay water nearby; therefore, the flux of connate water into the freshwater aquifer would likely be lower than would be the flux of seawater intrusion from the Bay if the aquifer were in direct communication with the Bay.

7.3.1. San Francisco Bay Geology

In the San Bruno area, the deposits closest to the Bay are made up of Bay Mud overlain by artificial fill deposited into the Bay (WRIME, 2007). LSCE (2010) produced two cross-sections that stretch through the South Westside Basin toward the Bay, although neither provides a representation of the sediments at the Bay Coast. These cross-sections (N-N' and O-O' in Appendix A of LSCE, 2010) show Colma Formation deposits on the surface inland, interfingering with Bay deposits closer to the Bay. A subsurface bedrock ridge is also shown that provides some protection to the southern portion of the South Westside Basin from potential seawater intrusion from San Francisco Bay.

Cross-section O-O' runs from San Andreas Lake northeast towards San Francisco Bay. Based on the inferred geologic correlations, the Colma Formation sediments that are present on this cross-section inland are not continuous to the Bay, being separated from it by deposits of low-permeability Bay Mud that likely stretch from the land surface to the bedrock surface below. If true, this would present a physical barrier, likely precluding seawater intrusion in this area. The Bay deposits are very fine-grained, and are considered by some to be a physical control on seawater intrusion into the freshwater aquifers. However, TM#1 notes the presence of some sands within this unit that could be conduits for seawater intrusion. The properties of the artificial fill deposited over the Bay Mud are not noted in WRIME (2007), although it is likely that it contains a wide variety of grain sizes.

7.3.2. San Francisco Bay Head Monitoring

Head in the Bay side monitoring well network is available for the Shallow and Primary Production Aquifers (hydrographs for the wells discussed in this section are presented as Appendix B of TM#1). At the UAL site, one well (MW13D) is screened within the Shallow Aquifer (SFPUC, 2010). Head in this well hovered around +2.5 ft msl from late 2003 to early 2006, after which head dropped to around -0.5 ft msl through at least late 2009. At the SFO and Burlingame sites, the shallowest wells (SFO-S and Burlingame-S) are both screened within the Shallow Aquifer; these two wells show very similar head results (with fairly sparse data). Each well shows a seasonal variation, with high values (around +2.3 ft msl at SFO and +3.5 ft msl at Burlingame) in the winter and low values (around +1.9 ft msl at SFO and +1.8 ft msl at Burlingame) in the summer.

At the UAL site, one well (MW13C) is screened within the Primary Production Aquifer. This well shows head varying between -29 and -33 ft msl from 2004 to 2009. At the SFO and

Burlingame sites, the deepest wells (SFO-D and Burlingame-D) are both screened within the Primary Production Aquifer. These wells show a similar seasonal fluctuation to the co-located wells screened within the Shallow Aquifer. SFO-D head varies from about -30 ft msl in the summer to about -29 ft msl in the winter. Burlingame-D head varies from about -5 ft msl in the summer to about -4 ft msl in the winter.

7.3.3. San Francisco Bay Chemical Monitoring

The wells in the Bay side monitoring network are sampled for general minerals, nitrate, bromide, boron, and orthophosphate (see Table 10.3-8 for average concentrations of selected constituents for each well). The Burlingame cluster contains three wells. Samples from the shallowest (Burlingame-S) well have chloride concentrations varying from 110 to 518 mg/L, with the highest values measured in February, 2009. The middle well (Burlingame-M) has shown concentrations ranging from 63 to 140 mg/L, while the deep well (Burlingame-D) has shown concentrations between 41 and 140 mg/L; these two wells have both shown a decreasing trend in chloride concentration over the sampling period. In the SFO cluster, the shallow well (SFO-S) has shown the most elevated values of chloride, between 8,400 and 12,400 mg/L, with increasing chloride over time. The deep well (SFO-D) has shown chloride values between 240 and 2,210 mg/L, with highly variable concentrations that don't seem to have a specific trend. Chloride results from the UAL cluster indicate that concentrations in the deeper well (MW-13C) are slightly over 500 mg/L, while one sample in the shallower well (MW-13D) shows a chloride concentration of 13,000 mg/L (WRIME, 2007). Bay water near the site was reported to have a chloride concentration of 17,000 mg/L. The high chloride concentrations observed in the Bay side monitoring network wells may result from the mobilization of or mixing with connate water with high salt concentrations (see Section 7.3).

Bromide results are also available for the Burlingame and SFO clusters from two sampling events (WRIME, 2007). At Burlingame, bromide concentrations were 0.22 and 0.36 mg/L in Burlingame-D, 0.24 and 0.38 mg/L in Burlingame-M, and 0.26 and 0.66 mg/L in Burlingame-S. At SFO, bromide concentrations were 0.79 and 1.7 mg/L in SFO-D and 27 and 32 mg/L in SFO-S. Bay water near the site was reported to have a bromide concentration of 52 mg/L.

Chloride:bromide ratios represent a better method for detecting seawater intrusion than simple chloride concentrations. In the Burlingame well cluster, this ratio was 389 and 427 in Burlingame-D, 368 and 458 in Burlingame-M, and 333 and 423 in Burlingame-S. At the SFO cluster, the ratio was 259 and 342 in SFO-D and 291 and 311 in SFO-S (WRIME, 2007). The ratio in Bay water near the site was reported to be 327. Salinity in the southern Bay changes on a seasonal basis due to changes in the inflows, reaching a maximum in October and a minimum in February (Figure 10.3-22). Because this salinity change is the result of the mixing of two very different waters, the chloride:bromide ratio may be expected to change seasonally as well, so a single measurement should not be taken as the definitive representation of Bay water.

8. Seawater Intrusion Monitoring and Management

In addition to evaluating the conceptual model and the results of the analytical and MODFLOW models, other evaluations were conducted to add insight into potential seawater intrusion issues.

8.1. Drinking Water Standards

For the purpose of managing water resources to minimize the occurrence of seawater intrusion, a set of performance measures must be defined. Although this is a complex issue, it is helpful to put the problem in terms that are easily understood. CH2M HILL (1995) defined seawater intrusion as “significant migration (based upon an intermediate composition of fresh water and salt water) of salt water into the potable aquifer and/or extraction of salt water by production wells.” However, this definition is fairly subjective, and represents a definition of seawater intrusion that is reactionary, rather than preventative, in nature.

For effects on the freshwater aquifer, it is useful to define some level of chloride (and other constituents) that represents degradation of the groundwater resource. Although various levels can be defined, management agencies generally use pre-existing maximum contaminant level (MCL) values. The Environmental Protection Agency (EPA) publishes a secondary drinking water standard of 250 milligrams per liter (mg/L) for chloride (EPA, 2009); there is no primary MCL for chloride as high chloride levels are not dangerous to health, but rather cause aesthetic degradation (e.g., taste or odor). This level has been used as a threshold for defining seawater intrusion in other basins, including Soquel Creek in California (Hydrometrics, 2009) and those around the City of Honolulu in Hawaii (Todd, 2004). Performance measures could be defined for other constituents based on EPA MCL values, but chloride is the most commonly utilized one for seawater intrusion.

8.2. Summary of Seawater Intrusion Rate Studies

The rate at which the seawater-freshwater interface enters the aquifer depends on a number of parameters, and is difficult to determine except by direct measurement or numerical simulation. This section summarizes the results of previous studies in other parts of the world, where geophysical, chemical, or modeling techniques were used to estimate a rate of seawater intrusion.

Izbicki (1996) summarized the occurrence of seawater intrusion into the Oxnard and Mugu aquifers of southern California. Seawater intrusion into these aquifers occurred as the result of extended groundwater overdraft in the coastal zone, with head levels dropping to below sea level in large parts of the aquifer system. Seawater began intruding into the coastal freshwater aquifers as early as the mid-1950’s. Using a time-series of chloride measurements, Izbicki (1996) was able to estimate the total extent of seawater intrusion from 1955 to 1992 as being 2.7 miles in the Oxnard aquifer and 1.9 miles in the Mugu aquifer, implying rates of 375 and 264 feet per year (ft/yr), respectively.

Yakirevich et al. (1998) used the SUTRA computer model code to predict the rate of seawater intrusion in the coastal aquifer along the Gaza Strip. Seawater intrusion is currently occurring in this aquifer, where groundwater is heavily over-used. Yakirevich et al. (1998) predicted that seawater intrusion over the ten-year period from 1997 to 2006 would occur at a rate of 66 to 148 ft/yr.

Kennedy/Jenks (2004) studied the intrusion of seawater into the Salinas Valley groundwater basin by constructing a three-dimensional hydrogeologic conceptual model to assess the susceptibility of the different aquifers to seawater intrusion. An analysis of the movement of chloride fronts was based on a time-series of chloride concentration from a system of monitoring wells. It was concluded that the rate of intrusion into the coastal aquifer varied between 202 and 673 ft/yr, depending on location in the aquifer.

8.3. Typical Monitoring Procedures

To monitor whether seawater intrusion is occurring, an extensive monitoring system is typically employed. A network of groundwater monitoring wells is typically employed that monitors groundwater head and water quality at different depth intervals within the aquifer (or aquifers). Monitoring different depth ranges is necessary because, since seawater intrusion occurs as a wedge, the presence of vertical variations in water quality is important to understanding the extent of intrusion. Also, aquifer heterogeneity may cause seawater intrusion to find preferential pathways through the aquifer that a single well screen might miss.

The primary parameter that is monitored is groundwater head, as this represents the driving mechanism for seawater intrusion. Based on the Ghyben-Herzberg ratio, seawater is kept out of the freshwater aquifer if the groundwater elevation above sea level is at least about 1/38th of the thickness of the aquifer. For example, if the aquifer is 380 feet thick, a freshwater head of 10 feet is required to keep the aquifer at that location free of seawater at the bottom of that aquifer. Therefore, at each location an aquifer thickness must be defined, and then divided by 38 to determine the threshold above which freshwater head should be maintained.

Water quality parameters are also monitored, primarily chloride (Cl) and total dissolved solid (TDS) concentrations. Because of the contrast in marine and typical continental anion matrices, the clearest indication of possible seawater intrusion is an increase in Cl concentration as a proxy for salinity (although other processes may lead to a similar phenomenon; see below). In those coastal aquifers where continuous over-exploitation causes a reduction of groundwater head levels, intrusion of seawater would result in an increase in salinity. Thus, a time-series of chloride concentrations can help provide early indications of seawater intrusion.

In addition to the lateral infiltration of seawater through aquifers that communicate directly with the ocean, there are several possible sources of increased salinity of freshwater aquifers (DWR, 1958). The best way to differentiate intruding seawater from degradation through some other cause is to employ an extensive monitoring network to track the spatial and temporal variability in groundwater chemistry. If saline water can be observed progressing steadily inland and upward in the formerly freshwater aquifer, causes other than seawater intrusion can be discounted. In situations where salinity increases are observed in a monitoring network, more intensive monitoring may be initiated, using other ionic constituent concentrations or stable isotope values to identify seawater intrusion and differentiate it from other potential sources of increased salinity. These approaches exploit the differences in geochemistry and transport processes between seawater intrusion and other sources of salinity. In summary, these include (modified from Jones et al., 1999):

- **Chloride-bromide (Cl/Br) ratios:** These ratios can be used as a reliable tracer as both constituents usually behave conservatively (i.e., they are not particularly subject to retardation through reaction or sorption, and therefore are transported almost entirely by advection alone). Seawater is distinguished from anthropogenic sources like sewage effluents (which have higher Cl/Br ratios) or agriculture-return flows (which have lower Cl/Br ratios). This and the other geochemical methods listed here rely on the fact that seawater chemistry is quite uniform in time and space.
- **Sodium-chloride (Na/Cl) ratios:** Na/Cl ratios of intruding seawater are usually lower than the values in ocean water due to the fact that sodium interacts with aquifer sediments more strongly than does chloride. The low Na/Cl ratio of seawater intrusion is distinguishable from the higher Na/Cl ratios typical of anthropogenic sources like domestic wastewaters.
- **Calcium-anion (Ca/X) ratios:** One of the most conspicuous features of seawater intrusion is the enrichment of Ca over its concentration in seawater. High Calcium-Magnesium (Ca/Mg) and Calcium-Bicarbonate-Sulfate ($Ca/(HCO_3 + SO_4)$) ratios are further indicators of seawater intrusion.
- **Oxygen and hydrogen stable isotopes:** Linear correlations are expected from mixing of seawater with ^{18}O-depleted groundwater when comparing $\delta^{18}O$[5] to δ^2H or Cl because all three behave conservatively (so a straightforward mixture of seawater and freshwater would fall along a line between the seawater and freshwater end-members). Salinity introduced to an aquifer by sources enriched by evaporative processes (e.g., agriculture-return flows) would result in mixing lines with different slopes from the seawater-freshwater mixing line, which could generally be expected to follow a meteoric water line.
- **Boron isotopes:** The boron isotopic composition of groundwater can be useful in distinguishing seawater intrusion from anthropogenic salinity sources such as domestic wastewater or non-seawater salinity sources such as hydrothermal fluids (Vengosh and Spivack, 1999). The $\delta^{11}B$ value of seawater is about 39‰, distinctly different from the more depleted values in sewage effluents (0-10‰) and non-marine hydrothermal fluids (-10-5‰). Because of the significant differences between seawater and other potential

[5] Stable isotope measurements are expressed in delta (δ) notation, calculated as the difference between the abundance of a specific isotope to that in a reference standard divided by the abundance in the reference standard. This is a much more accurate measure than the actual abundance. See Clark and Fritz, 1997.

salinity sources, boron isotopes may be one of the most useful constituents to include in a monitoring program.

- **Residence time tracers:** The above constituents are measured to monitor for the intrusion of saline water, and to differentiate intruding seawater from domestic effluents and evaporatively enriched groundwater. Radioactive and other residence time tracers can be used to differentiate between recently-intruded seawater and connate water (seawater trapped in a formation when the sediments are deposited) that may have been present in the sediments for thousands of years. The specific tracer chosen would depend on the expected residence time of the connate water.

8.4. Potential Control Measures for Seawater Intrusion

Various control methods can be utilized to prevent, slow, or reverse seawater intrusion into coastal aquifers. These methods have been developed in areas that have experienced significant intrusion. Control measures have been summarized elsewhere (e.g., DWR, 1975; van Dam, 1999), and will only be briefly discussed here. Two categories of control methods exist, corresponding to two types of controls on seawater intrusion discussed in Section 2.3: physical and hydrological methods.

Physical controls entail the installation of actual physical barriers in the subsurface to block the flow of ocean water. These barriers are only useful when intrusion occurs on a fairly small scale, where the area of intrusion is limited. Barriers can be constructed of grout, slurry, or some kind of membrane, anything that is low enough in permeability to effectively exclude seawater. In thick or complex aquifer systems, physical barriers would have to be very long and extend very deep into the aquifer to prevent seawater intrusion, making them impractical.

Hydrologic controls are more widely employed, and are better suited to large aquifers. As discussed in Section 2.3, the two important factors for preventing seawater intrusion are freshwater flux into the ocean and the freshwater head just landward of the coast. Hydrologic methods of control consist of enhancing one or both of these. The simplest method is conservation, where extraction of groundwater is reduced. This can be considered a “natural” approach to control, as it seeks to prevent intrusion by returning the hydrologic system closer to its “natural” (or pre-development) state. However, this method may not be practical in systems where the groundwater extraction is necessary. Similarly, active management of groundwater extraction, where pumping is shifted around in the basin so that individual locations are not pumped too heavily, is used to allow the aquifer to recover when not pumped; this requires the installation of extra wells, and could greatly increase the cost required to build a groundwater extraction network.

Seawater intrusion can also be controlled hydrologically through artificial means. Attempts to limit or prevent seawater intrusion through engineering often focus on creating a head barrier near the shoreline through injection of freshwater. Commonly, this involves the injection of freshwater into the aquifer landward of the intrusion wedge, and seaward of production wells.

The injected freshwater can be locally-sourced groundwater, imported surface water, or reclaimed wastewater. The goal of this method is to build up a mound of freshwater with sufficient head to prevent seawater from intruding into the base of the aquifer.

A similar effect can be achieved by pumping groundwater on the seaward side of the seawater intrusion wedge, although this is necessarily temporary (since the goal is to get the wedge to move toward, and eventually past, these extraction wells), and the produced water must be disposed of somehow; as the wedge is moved back toward the pumping wells, much of the extracted water would be made up of useful freshwater that is mixed with the saline water, and this freshwater may have to be wasted by simply discharging it to an appropriate location.

The control method (or methods) used depends on the exact conditions under which seawater intrusion occurs. This would require an analysis to be made before seawater intrudes into the freshwater aquifer, through the investigation of various mitigation alternatives.

9. Summary

This section summarizes the results of the conceptual model, empirical data, numerical modeling, and analytical approaches with respect to seawater intrusion.

9.1. Assessment of Susceptible Areas

The two areas of the Westside Basin that were determined to be susceptible to seawater intrusion are (1) the Pacific Coast from the south side of Lincoln Park to Lake Merced, and (2) the San Francisco Bay Coast from the Visitacion Valley Basin to the San Mateo Plain Basin (Figure 10.3-1).

Along the Pacific Coast, sediments are more permeable, and reductions in head along the Coast could move the seawater wedge inland. There is no physical barrier to seawater intrusion into the Shallow Aquifer because the sediments here are fairly coarse-grained and in direct communication with the Ocean offshore. The offshore San Andreas Fault may represent a physical control on seawater intrusion into the Primary Production and Deep Aquifers, although discontinuities in the -100-foot clay may serve as locations where seawater could intrude into the Primary Production Aquifer from the Shallow Aquifer above.

In general, the San Francisco Bay Coast is not particularly susceptible to seawater intrusion due to the presence of the Bay Mud and a subsurface bedrock ridge that provides some protection to the southern portion of the South Westside Basin from potential seawater intrusion from San Francisco Bay. Chloride levels in the Shallow Aquifer at the SFO cluster are very high, near those of Bay water. However, this could be due to the presence of connate water in the Bay Mud itself, which may be easier to mobilize locally than it would be for seawater to intrude from the Bay to the freshwater aquifer through the Bay Mud. It should be noted that the chloride concentrations in the Primary Production Aquifer, where head levels are well below sea level and seawater intrusion would occur more quickly, are much lower than in the Shallow Aquifer.

Non-susceptible parts of the basin are areas where some sort of physical control precludes the current and future intrusion of seawater into the Basin. The inland parts of the basin, separated from the coast by the mountain ranges located on the northeastern and southwestern boundaries of the basin, are not susceptible to seawater intrusion. Parts of the North Westside Basin where the bedrock surface is above sea level are also not susceptible. The southern part of the Basin’s Pacific Coast, where the Serra Fault represents a barrier between the Ocean and inland areas, seems to not be susceptible to seawater intrusion.

9.2. GSR-Only Scenario

The GSR Project is a conjunctive use project that would allow for increased groundwater supplies in the Westside Basin during periods of drought and emergencies (MWH, 2008). The conjunctive use project is based on the concept of providing available surplus surface water from the SFPUC Regional Water System to the Partner Agencies (PAs). This water would be used by the PAs instead (or "in-lieu") of pumping groundwater from the Westside Basin.

The project is planned to provide up to 60,500 af of in-lieu recharge. During the take cycle, both SFPUC and the PAs would be pumping groundwater; however, SFPUC would not take more than the amount of in-lieu recharge available in the SFPUC Storage Account.

Pumping in the South Westside Basin for the GSR-only Scenario (2) would have a minimal effect on head in the North Westside Basin. South of Lake Merced the Serra Fault likely presents a physical barrier to seawater intrusion. The operation of the GSR Project would not change the potential for seawater intrusion relative to Scenario 1 because groundwater head at wells in the North Westside Basin along the Pacific Coast would not substantially change.

Along the San Francisco Bay Coast, the changes to groundwater pumping do not show a substantial effect on seawater intrusion compared to what may occur under Scenario 1 conditions. The freshwater flux out of the aquifer into the San Francisco Bay is quite low under existing conditions, and is not modified to any great degree by the pumping configurations simulated in the MODFLOW model.

Based on this analysis, the likelihood of seawater intrusion resulting from the GSR Project would be considered low along either the Pacific Coast or the San Francisco Bay Coast.

9.3. SFGW-Only Scenarios

The SFGW Project would construct up to four wells (along with conversion of two irrigation wells) and associated facilities in the western part of San Francisco and extract an annual average of up to 4 mgd of water from the North Westside Basin (SFPUC, 2009a). The SFGW wells would pump at this rate on a near-continuous basis over periods of many years.

Two model scenarios incorporate the pumping of the SFGW Project (3a and 3b). The results of these scenarios indicate that there is the potential for the landward migration of the seawater-freshwater interface along the Pacific Coast as a result of increased groundwater pumping from the SFGW Project. Many of the heads, especially in the southern half of the North Westside Basin, are projected by the numerical model to be below sea level for some to most of the simulation period; even in the northern half of the North Westside Basin, head would drop everywhere near and along the Pacific coast, possibly low enough to induce seawater intrusion.

It is important to note that the groundwater head in the Deep Aquifer at the Zoo monitoring well cluster has been almost uniformly below sea level since monitoring began in 2003. Despite this, and despite the fact that the cluster is only about 300 feet from the Ocean, the chloride concentration has remained steady between 50 and 60 mg/L over the same time period, indicating that this location has not yet been affected by seawater intrusion. This indicates one or more of the following: 1) that conditions ideal for seawater intrusion (i.e., groundwater head below sea level) must be present for some time (in this case more than at least 9 years) before the intrusion actually occurs; 2) the assumption of a coastal location for the discharge point is not applicable for these aquifers (i.e., the discharge point is further offshore); and 3) the Deep Aquifer is separated from the Ocean by a physical barrier, such as the W-clay. Without more knowledge of offshore geologic structures and their ability to act as physical controls, and the locations where freshwater discharges from the different aquifers, the exact reason that seawater has not shown itself to be intruding into the freshwater aquifer is unknown.

Similarly, measured head elevations in wells along the west end of Golden Gate Park have repeatedly dipped below the single-aquifer and Shallow Aquifer exclusion heads in the recent past (TM#1), and this area has been subject to relatively continuous groundwater pumping for irrigation since the 1920's. Despite this, there has been no appreciable increase in chloride concentrations in the production wells at the North Windmill and South Windmill locations over many years of monitoring. Unlike the Deep Aquifer at the Zoo monitoring well cluster (see above), the aquifers along the west end of Golden Gate Park seem to be in fairly direct contact with seawater (see Figure 10.3-2), so there does not seem to be a specific physical control that would prevent seawater intrusion. The fact that seawater intrusion does not seem to have had an effect on chloride concentrations in this area may indicate that the seasonal rebound in head that occurs in the winter (when head in the Shallow Aquifer is above the single-aquifer and Shallow Aquifer exclusion heads) effectively compensates for seasonal excursions below the exclusion heads, or that the small fine-grained layers present in the area break the sediments into multiple thin aquifers, which are theoretically less susceptible to seawater intrusion than would be a single thick aquifer.

Along the San Francisco Bay coast, the freshwater aquifer would not be vulnerable to seawater intrusion due to the operation of the SFGW Project primarily because of the distance from the SFGW groundwater pumping to the San Francisco Bay. The freshwater flux out of the aquifer into the San Francisco Bay is quite low, and would not be modified to any great degree by the pumping configurations for the SFGW Project. Therefore, the model results indicate that there is not a substantial change in the potential for seawater intrusion along the San Francisco Bay as a result of the SFGW Project.

9.4. Cumulative Scenario

The cumulative scenario (4) assumes the operations of the GSR and SFGW Projects at the same time. The cumulative scenarios also include other reasonably foreseeable future projects, such as the Daly City Vista Grande Drainage Basin Improvements Project and Holy Cross cemetery future build-out.

The Daly City Vista Grande Drainage Basin Improvements Project involves diverting stormwater from the Vista Grande Canal into Lake Merced with baseflow to Lake Merced being maintained via a wetland. The addition of water to Lake Merced to maintain lake levels would have the net effect of recharging the groundwater system locally.

Because the GSR Project pumping is concentrated in the South Westside Basin, the results of cumulative Scenario 4 are very similar to those of Scenario 3b.

Similar to both the GSR and SFGW Projects, the changes to groundwater pumping under the Cumulative Scenario do not show a substantial effect on seawater intrusion along the San Francisco Bay Coast compared to what may occur under Scenario 1 conditions. The freshwater flux out of the aquifer into the San Francisco Bay is quite low, and is not modified to any great degree by the pumping configurations simulated in the MODFLOW model.

These results indicate that there is the potential for the landward migration of the seawater-freshwater interface along the Pacific Coast as a result of increased groundwater pumping from the SFGW Project under the cumulative scenario. In addition,, the results of the Cumulative Scenario generally do not indicate an increased risk of seawater intrusion along the San Francisco Bay Coast.

9.5. Analytical Evaluation Along the Pacific Coast

The exclusion head analysis was performed to evaluate the potential for the landward migration of the seawater-freshwater interface under the Westside Basin Groundwater-Flow Model Results for Scenarios 3a, 3b, and 4. The results suggest that the lowering of groundwater head along the coast would increase the potential for the landward migration of the seawater-freshwater interface along several portions of the Pacific Coast. However, the rate analysis suggests that any seawater intrusion would occur at rates on the order of feet per year. It should be noted that the analytical method employed assumes a horizontal aquifer base, and that the actual intrusion into the sloped aquifers of the North Westside Basin would be slightly smaller than shown by the method.

The potential rate of seawater intrusion was estimated for the North Westside Basin using analytical equations. These results indicate that the rate of possible seawater intrusion would be on the order of 4 feet after 1 year, about 20 feet after 10 years, and about 60 feet after 50 years under implementation of the SFGW Project, a very slow rate of intrusion. Therefore, careful groundwater monitoring would be able to indicate the potential for seawater intrusion to occur with sufficient time to take proper actions to correct the situation.

Therefore, seawater intrusion along the Pacific Coast would occur slowly and would be recognizable in the Coastal Groundwater Monitoring Network before it could affect the beneficial use of pumping wells in the North Westside Basin. Historical data have shown that chloride levels along the Pacific Coast have remained low, even when there have been periods of relatively substantial groundwater pumping in the North Westside Basin in the past (5.5 mgd from 1930 to 1935; note that this rate is higher than the 3.0 to 4.0 mgd of municipal pumping proposed for the SFGW Project). This confirms that, although the potential for seawater intrusion exists, there may be other geologic factors that are limiting both the occurrence and rate of seawater intrusion along the Pacific Coast.

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Figure List

Table List

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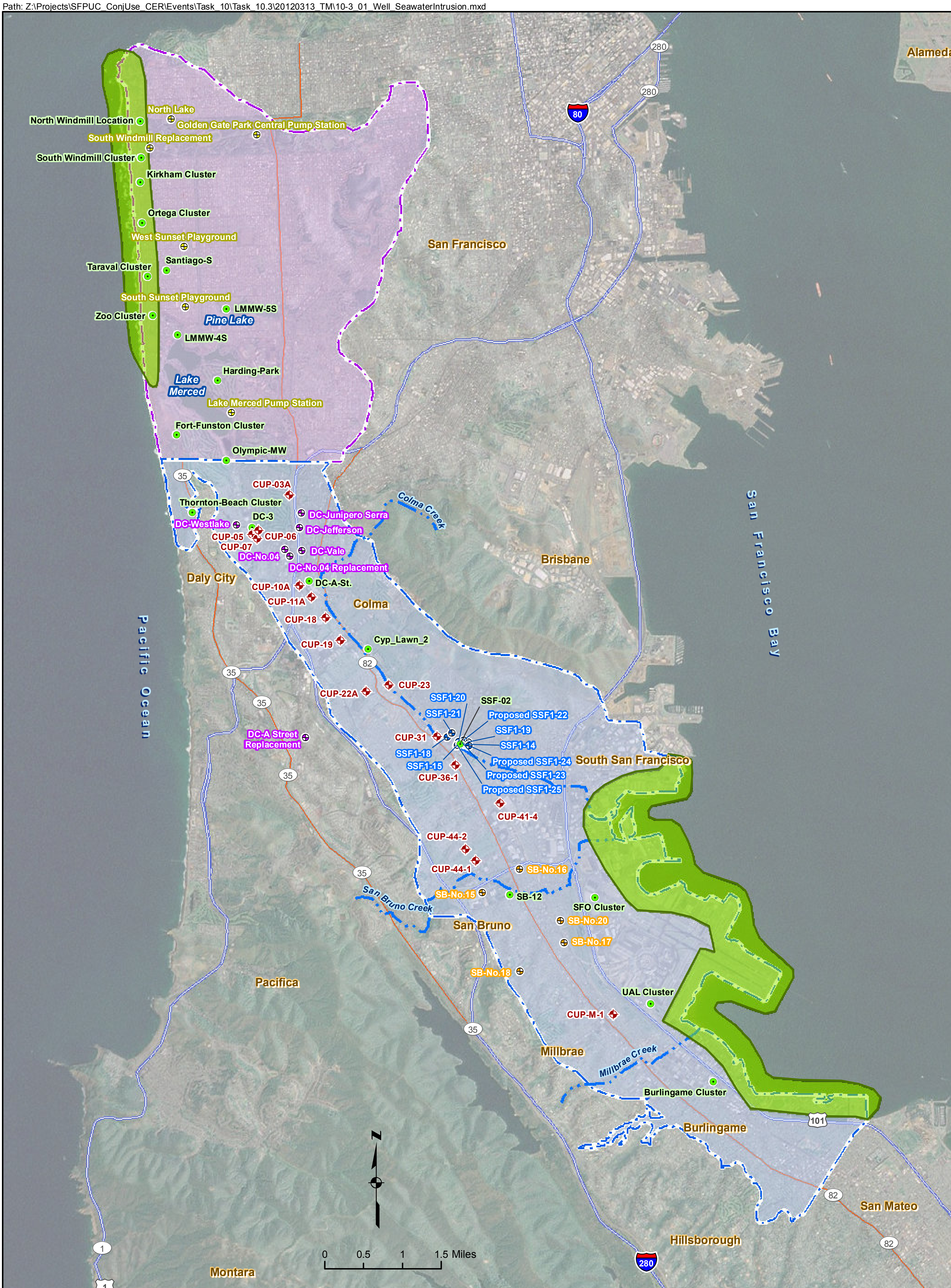

Aerial Photo Source: World Imagery from ESRI. Copyright:© 2009 ESRI, AND, TANA, UNEP-WCMC

Note:
The North Windmill Location is a location used by the Westside Basin Groundwater-Flow Model to track the model-simulated groundwater head. It represents a historical well location, but is not the current location of an active monitoring well.

Legend

- GSR Proposed Municipal Wells
- SFGW Proposed Municipal Wells
- Selected Representative Monitoring Location
- Cal Water Municipal Wells
- Daly City Municipal Wells
- San Bruno Municipal Wells
- North Westside Groundwater Basin
- South Westside Groundwater Basin
- Approximate Areas Susceptible to Seawater Intrusion

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
ENGINEERING MANAGEMENT BUREAU

WELL LOCATIONS AND AREAS POTENTIALLY SUSCEPTIBLE TO SEAWATER INTRUSION

Kennedy/Jenks Consultants
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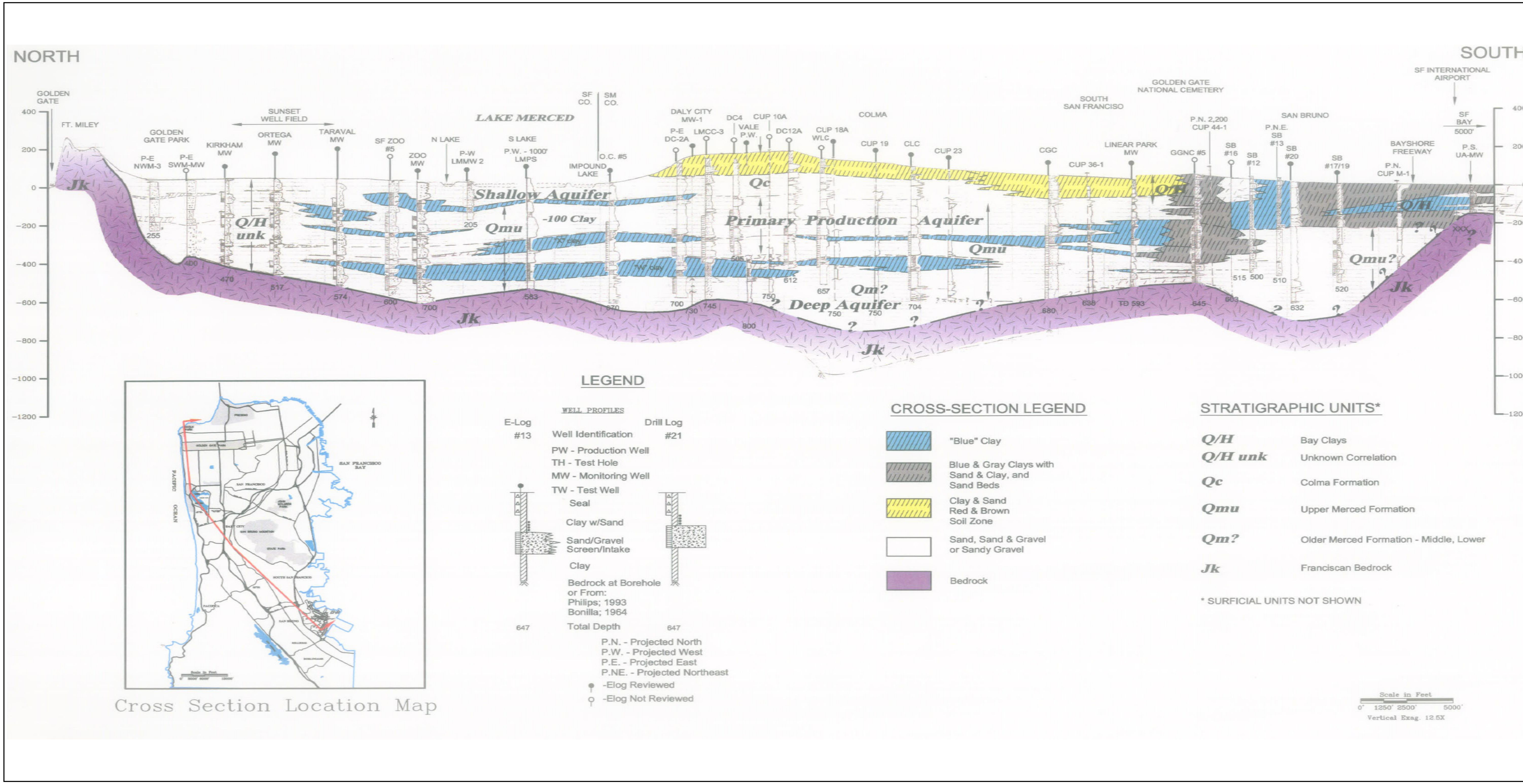
San Francisco, CA 94107

Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Figure
10.3-1

Date
April 2012



Source: Final Task 8B Technical Memorandum No.1, Hydrologic Setting of the Westside Basin, LSCE, May 2010.

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San Francisco Public Utilities Commission

Westside Basin Regional Subsurface Hydrogeology

K/J 0864001
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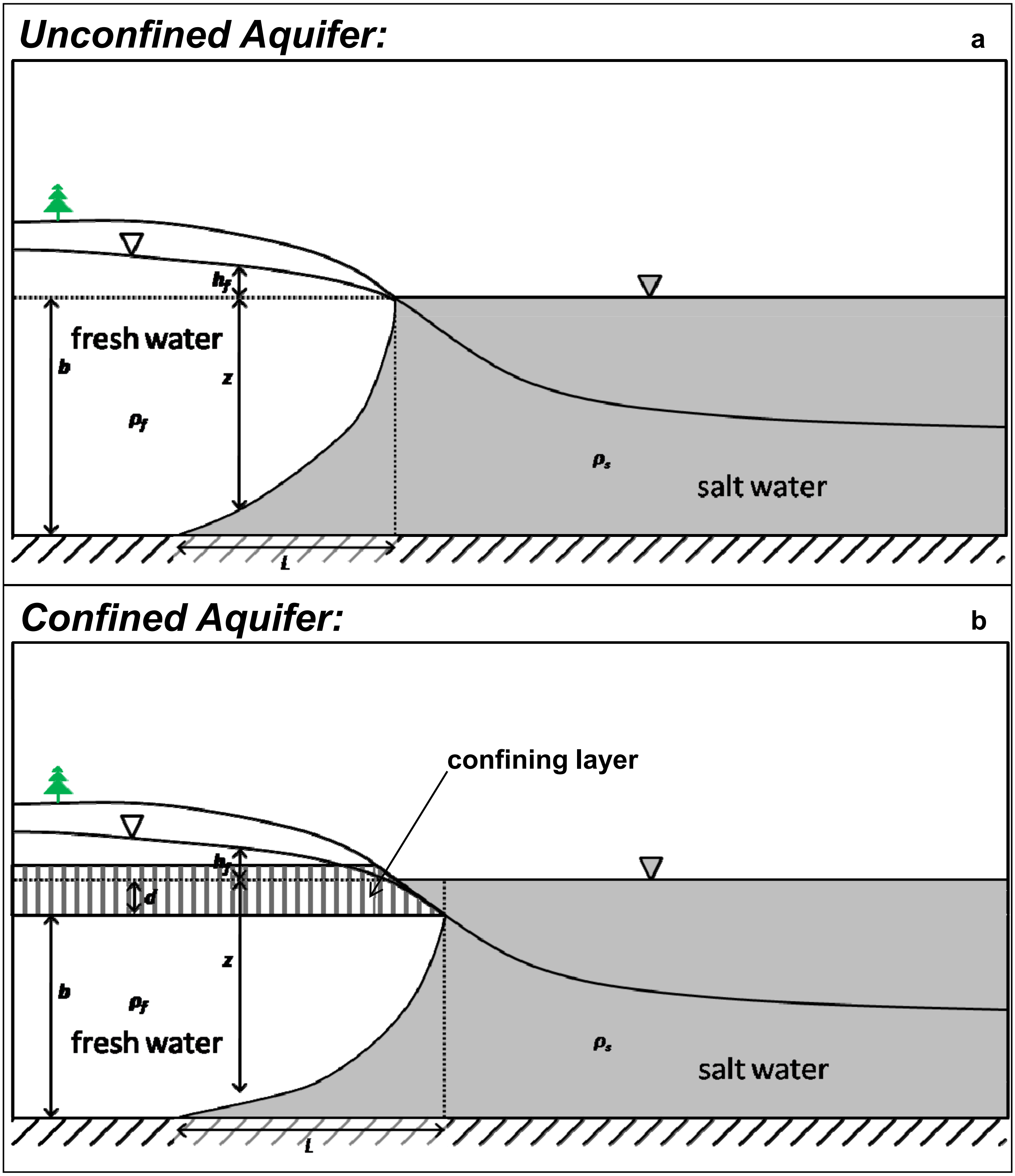
Figure 10.3-2



Explanation of Variables:

- ρ_f = density of freshwater (mass/volume)
- ρ_s = density of seawater (mass/volume)
- z = depth of freshwater-seawater interface below sea level (length)
- h_f = freshwater head above sea level (length)
- b = depth below sea level to aquifer base (length); unconfined conditions
- b = aquifer thickness (length); confined conditions
- d = depth below sea level of base of confining layer (length)
- L = length of intruding wedge (length)

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Seawater Intrusion Schematics for Unconfined and Confined Aquifers

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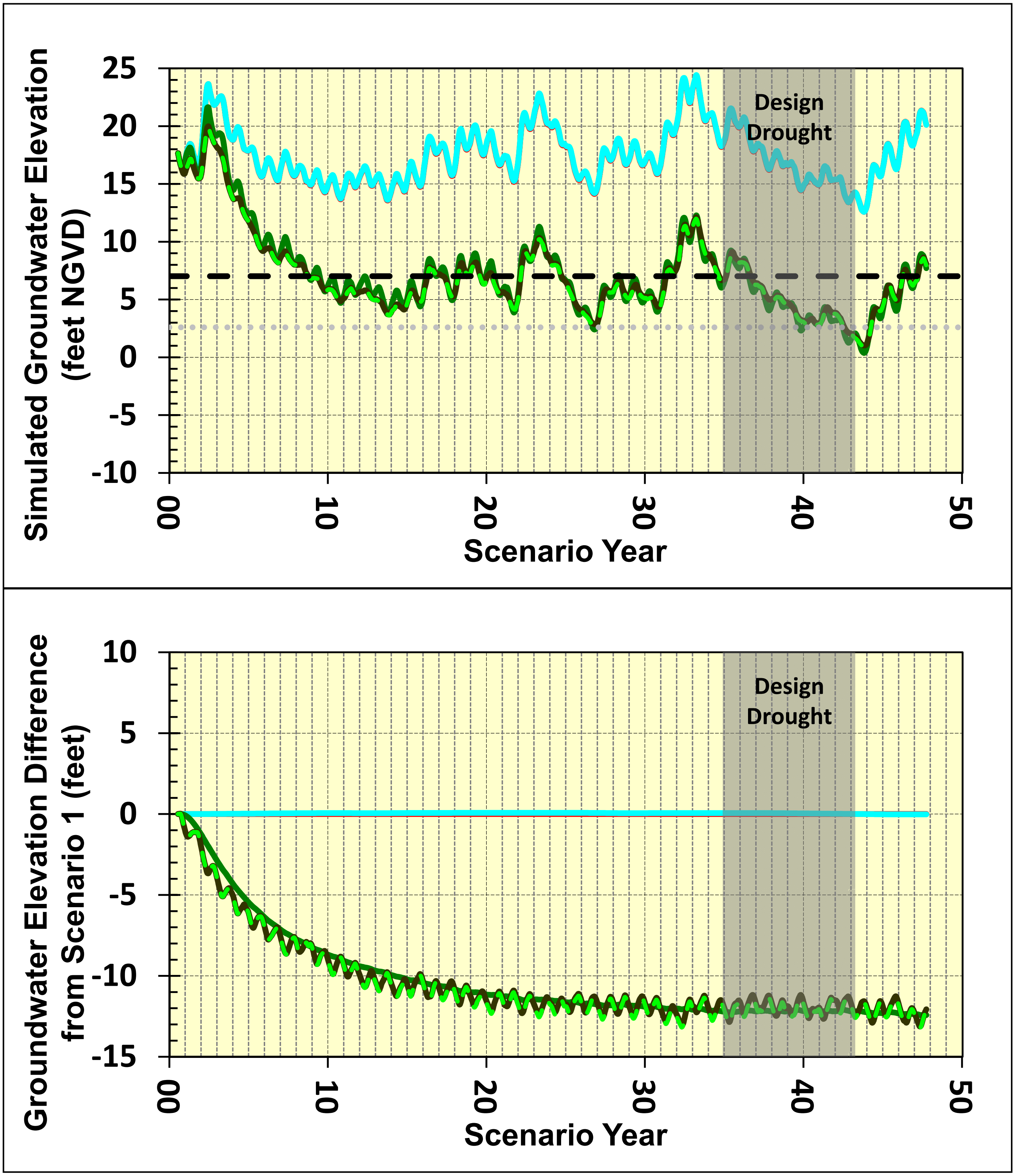
Figure 10.3-3



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:
- Single-Aquifer
- Shallow Aquifer

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Model Layer 1 Hydrographs for North Windmill Location

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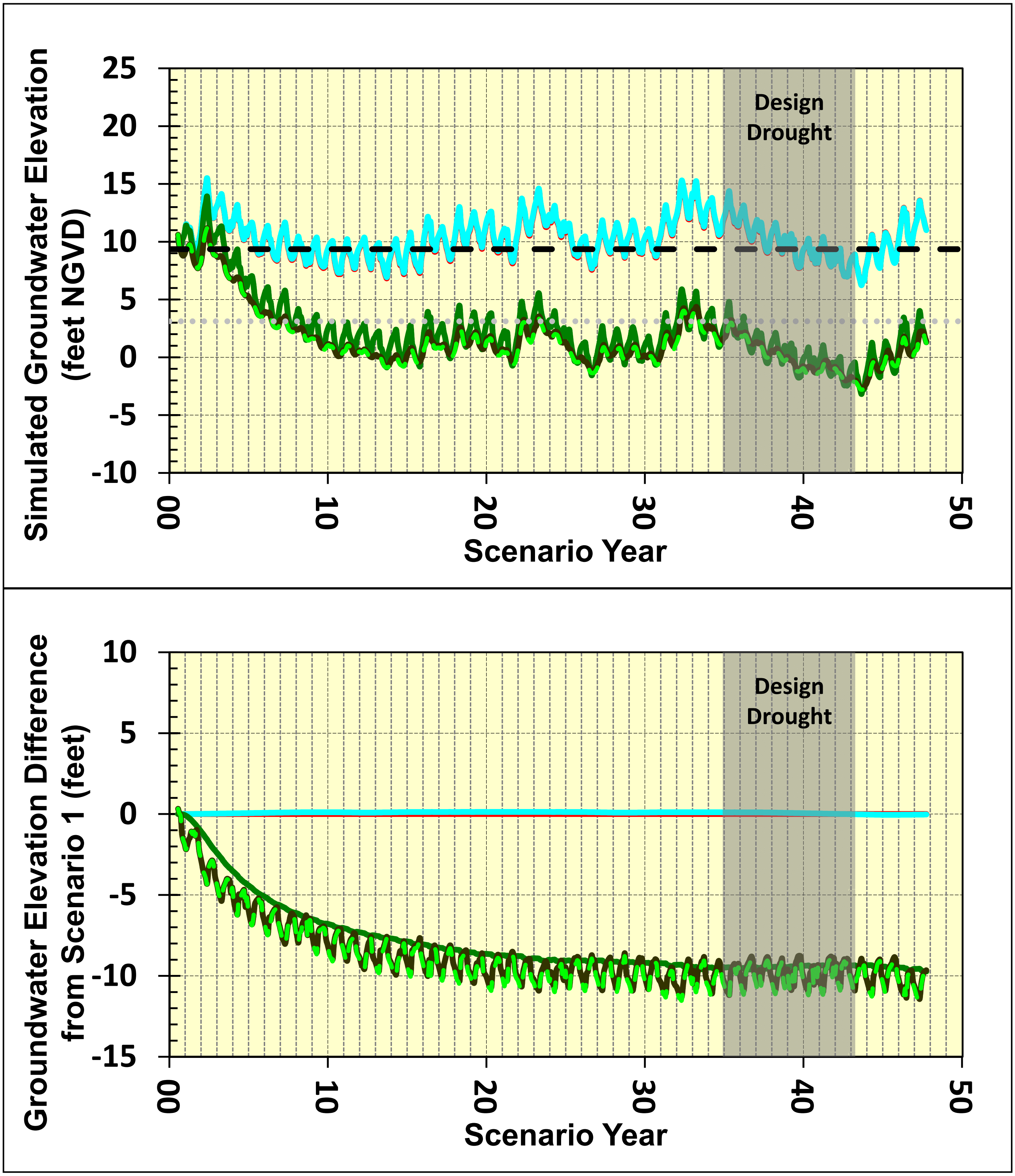
Figure 10.3-4



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:

- Single-Aquifer
- Shallow Aquifer

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Model Layer 1 Hydrographs for South Windmill Cluster

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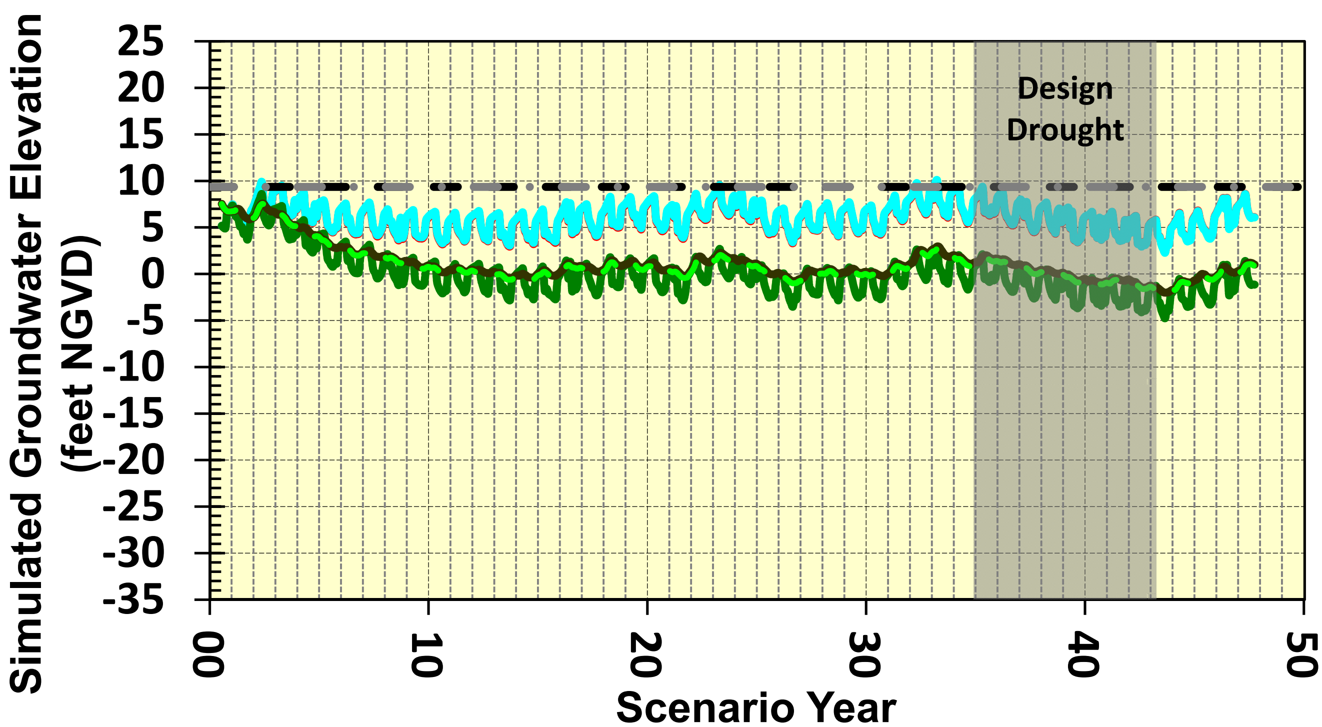
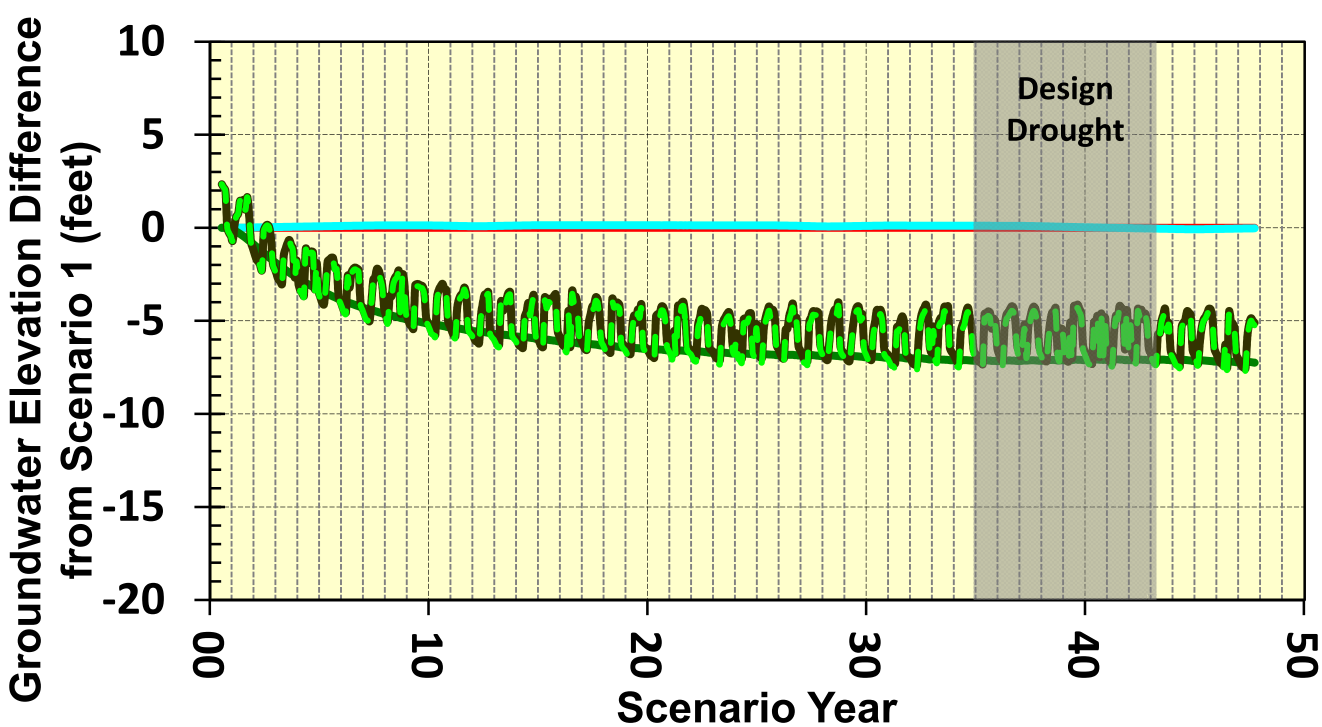
Figure 10.3-5a





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

Exclusion Heads:
Single-Aquifer
Primary Production Aquifer

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Model Layer 4 Hydrographs for South Windmill Cluster

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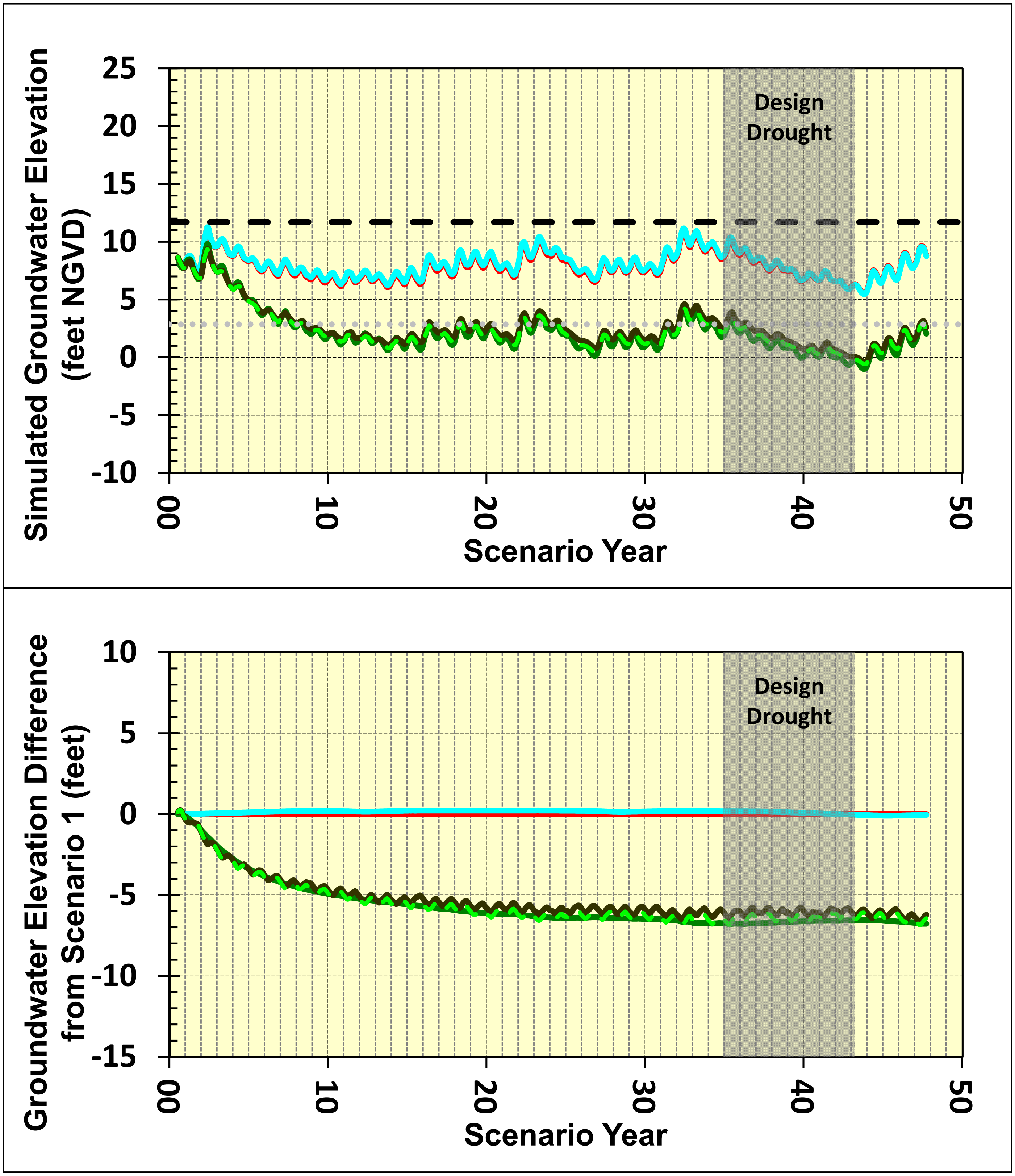
Figure 10.3-5b



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

Exclusion Heads:

Single-Aquifer
Shallow Aquifer

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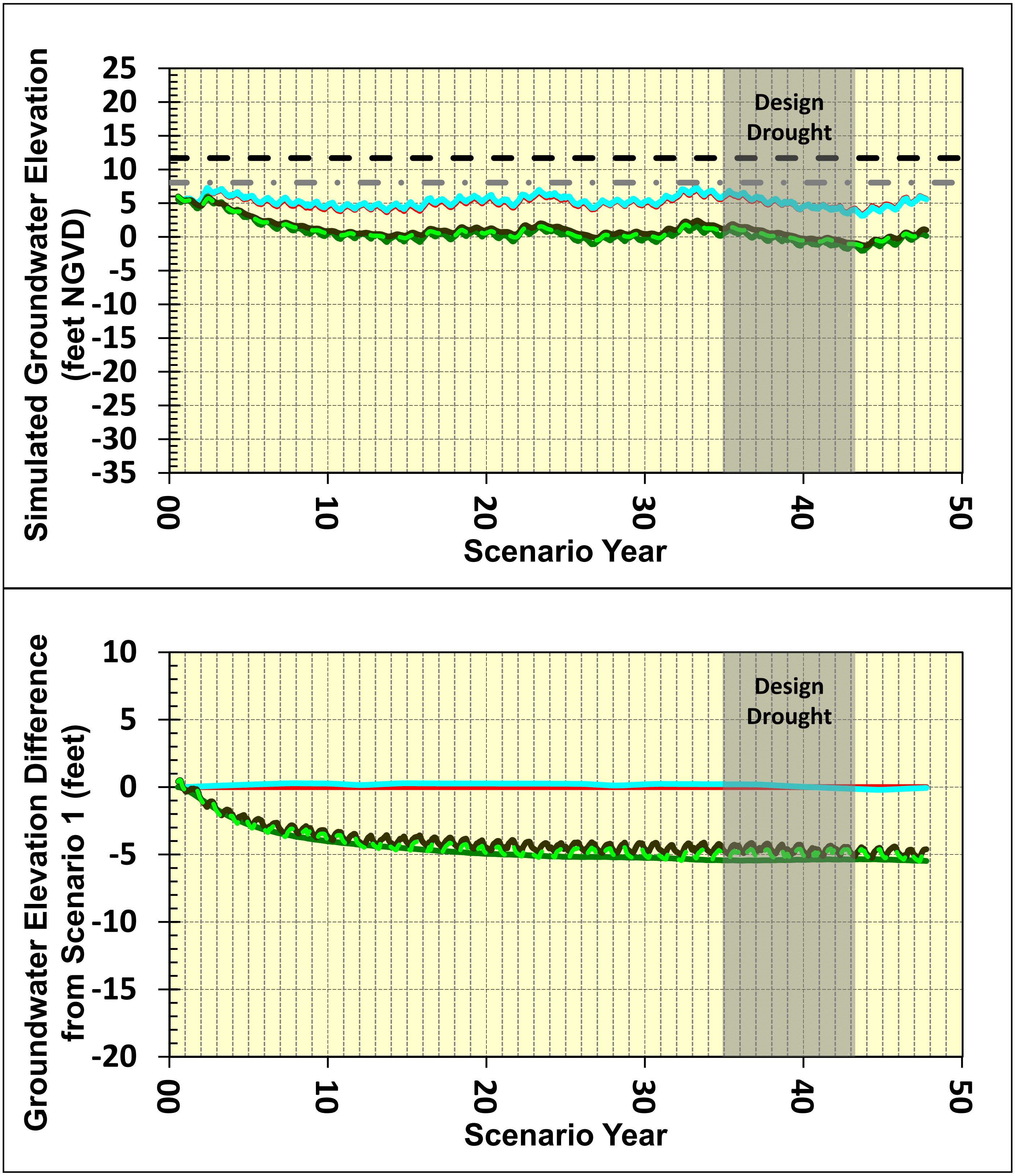
Model Layer 1 Hydrographs for Kirkham Cluster

K/J 0864001
April 2012

Figure 10.3-6a



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

Exclusion Heads:
Single-Aquifer
Primary Production Aquifer

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Model Layer 4 Hydrographs for Kirkham Cluster

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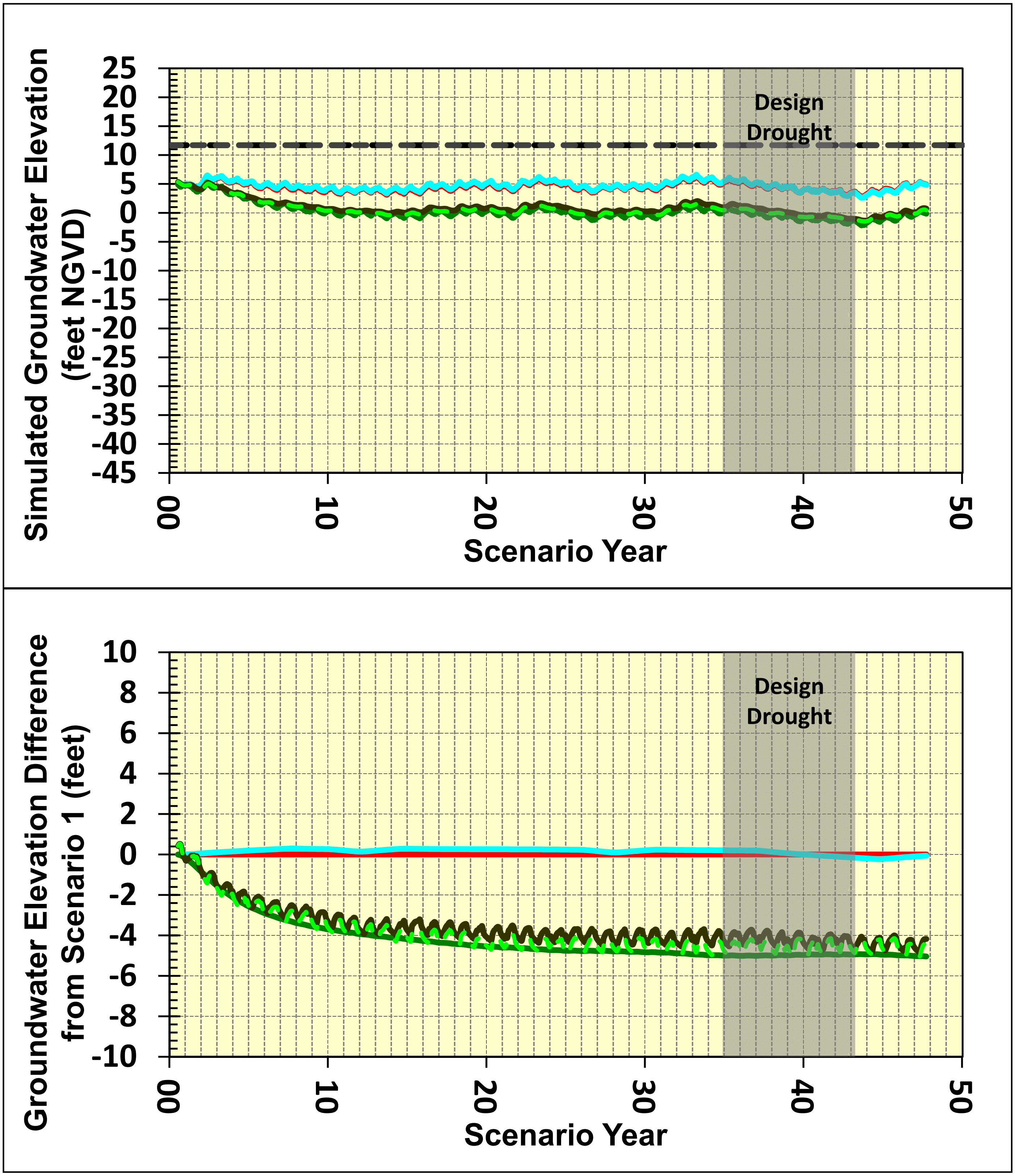
April 2012
Figure 10.3-6b



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

Exclusion Heads:
Single-Aquifer
Deep Aquifer

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Model Layer 5 Hydrographs for Kirkham Cluster

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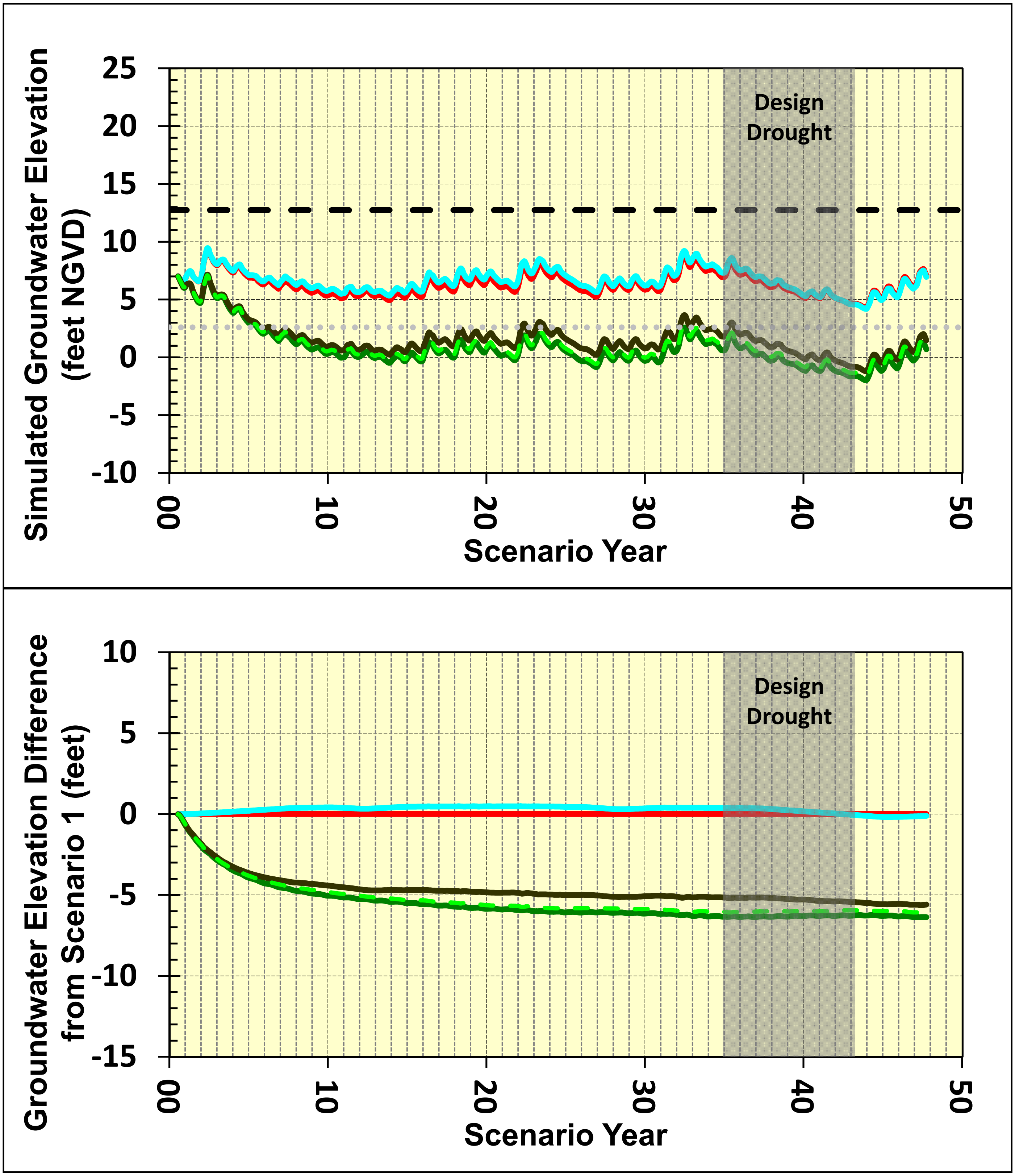
April 2012

Figure 10.3-6c



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

Exclusion Heads:
Single-Aquifer
Shallow Aquifer

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Regional Groundwater Storage and Recovery Project
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Model Layer 1 Hydrographs for Ortega Cluster

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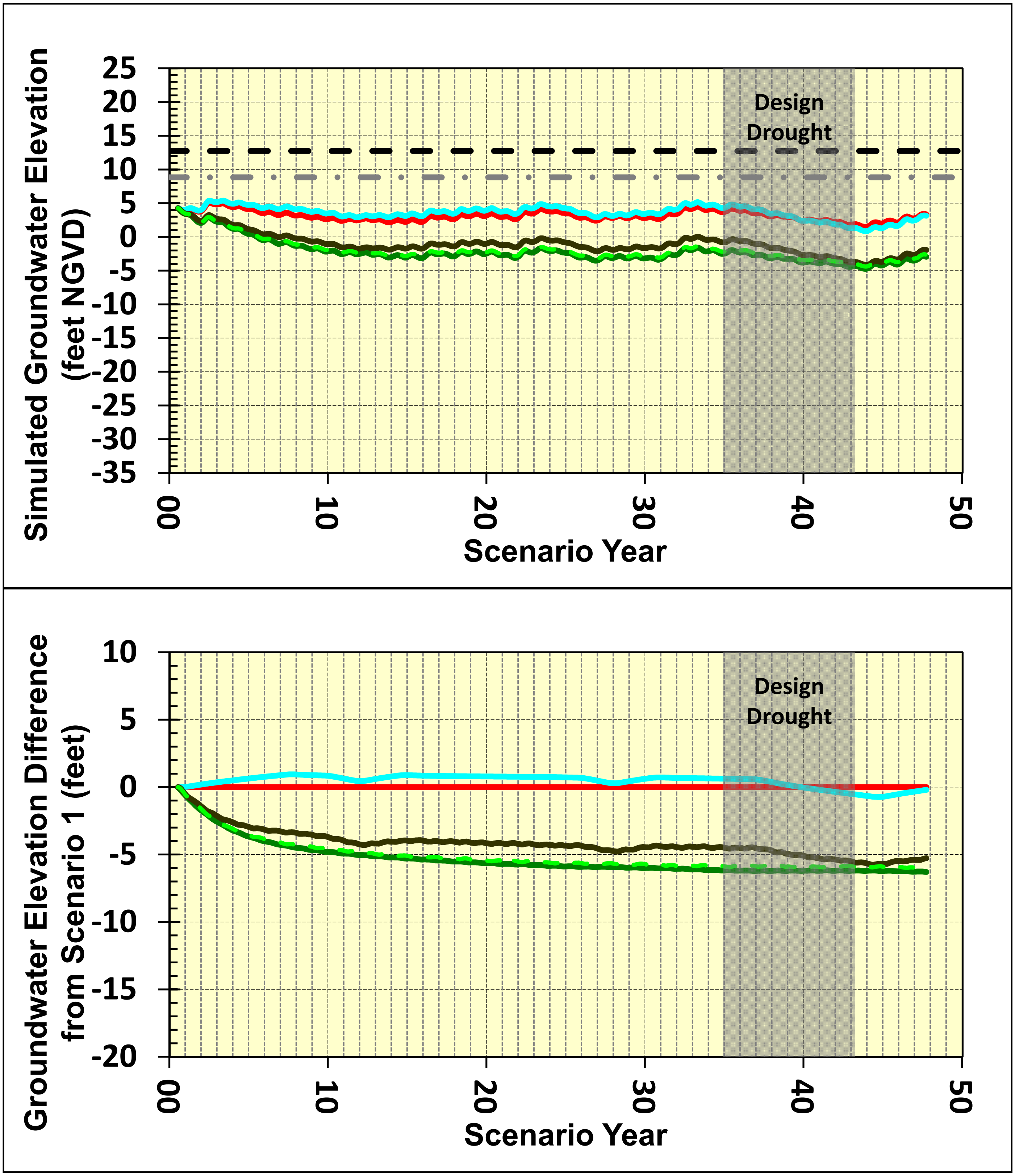
April 2012
Figure 10.3-7a



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

Exclusion Heads:

Single-Aquifer
Primary Production Aquifer

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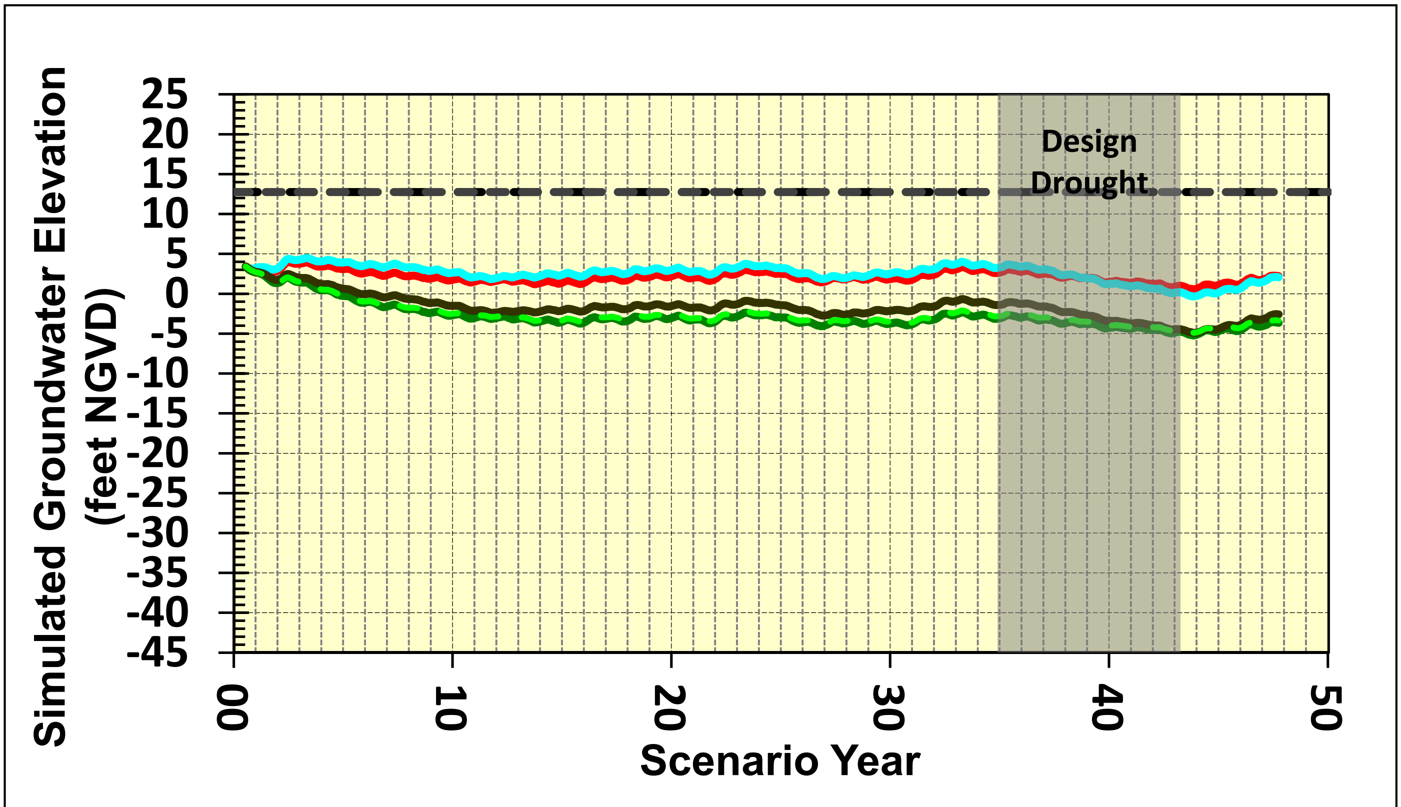
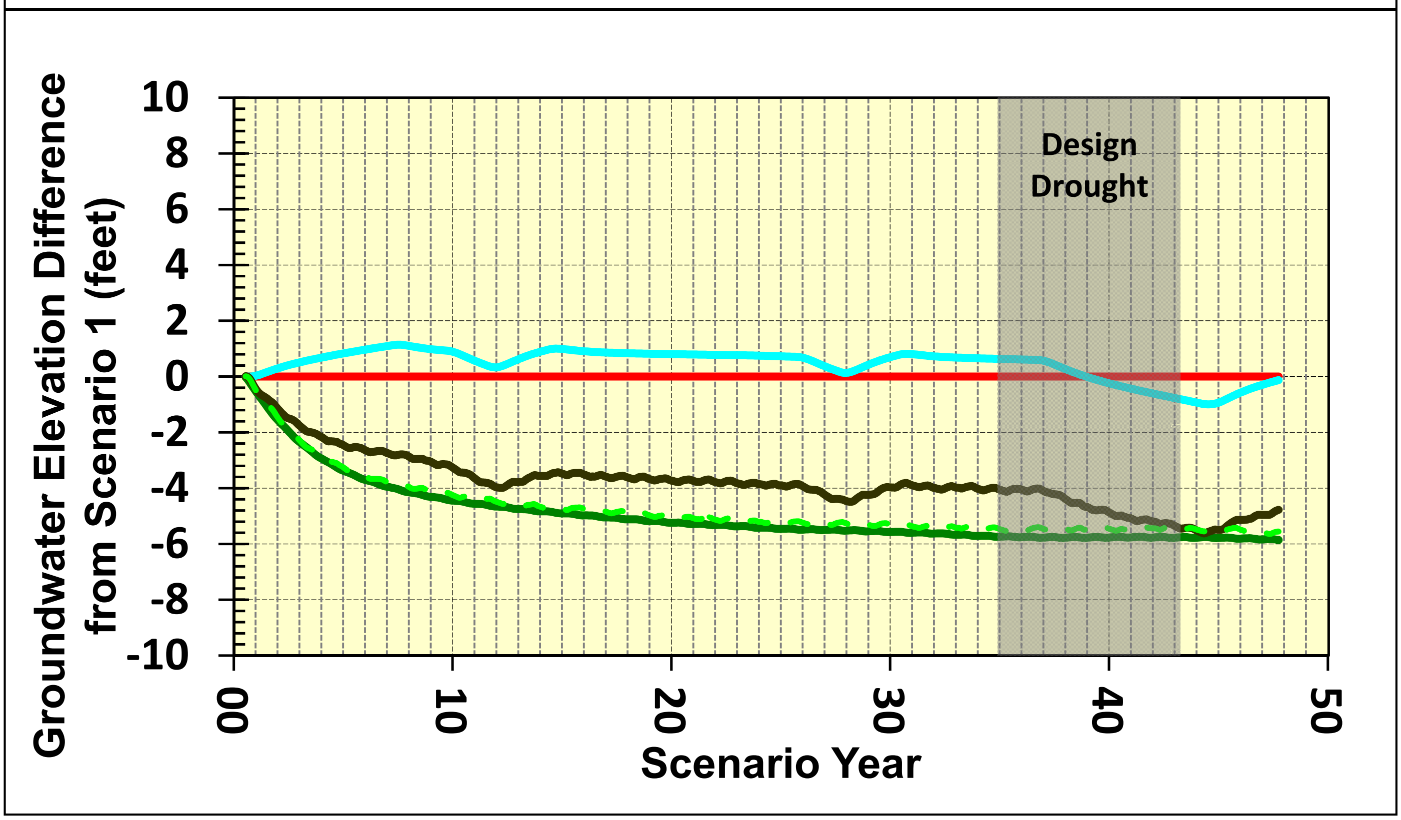
Model Layer 4 Hydrographs for Ortega Cluster

K/J 0864001
April 2012
Figure 10.3-7b





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:

- Single-Aquifer
- Deep Aquifer

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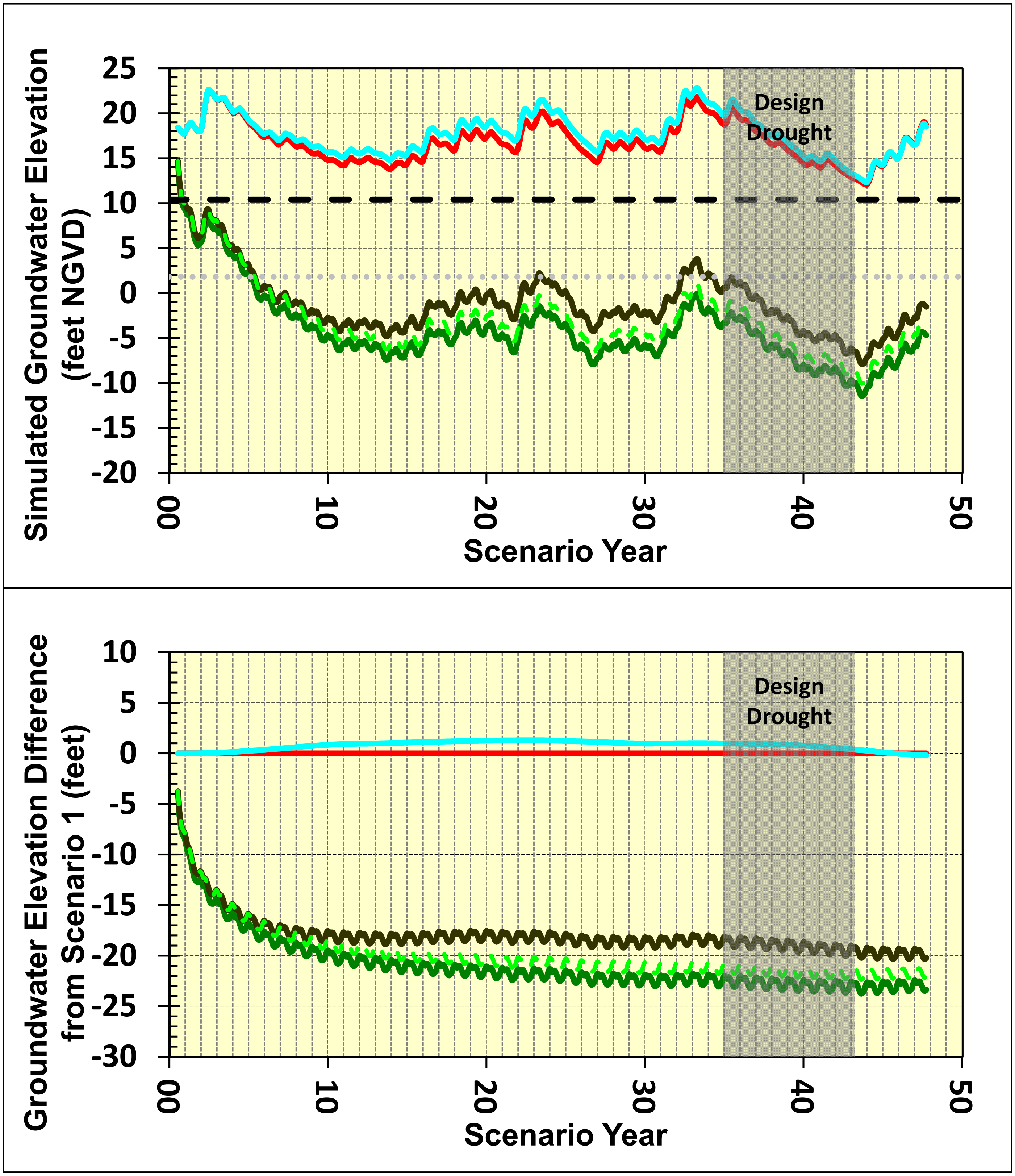
Model Layer 5 Hydrographs for Ortega Cluster

K/J 0864001
April 2012
Figure 10.3-7c



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

Scenario 1 | Scenario 2

Scenario 3a | Scenario 3b

Scenario 4

Exclusion Heads:

Single-Aquifer | Shallow Aquifer

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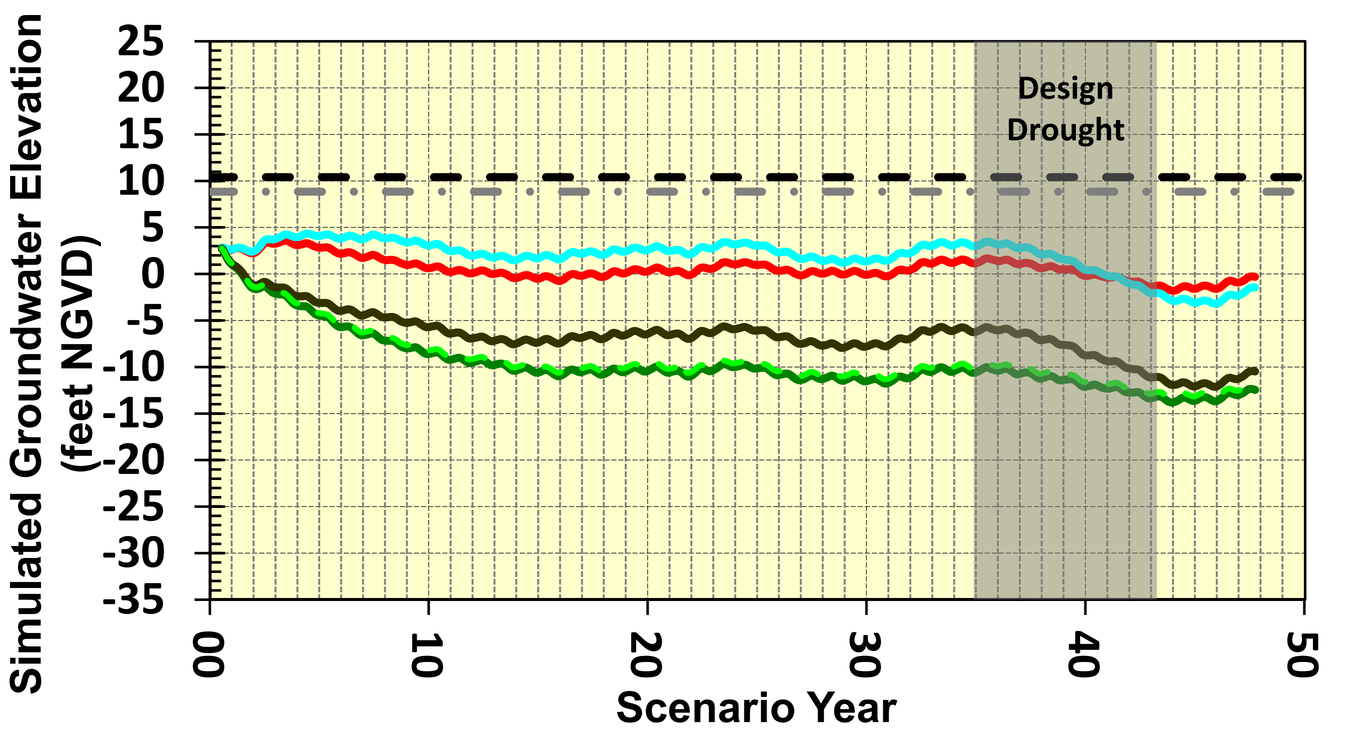
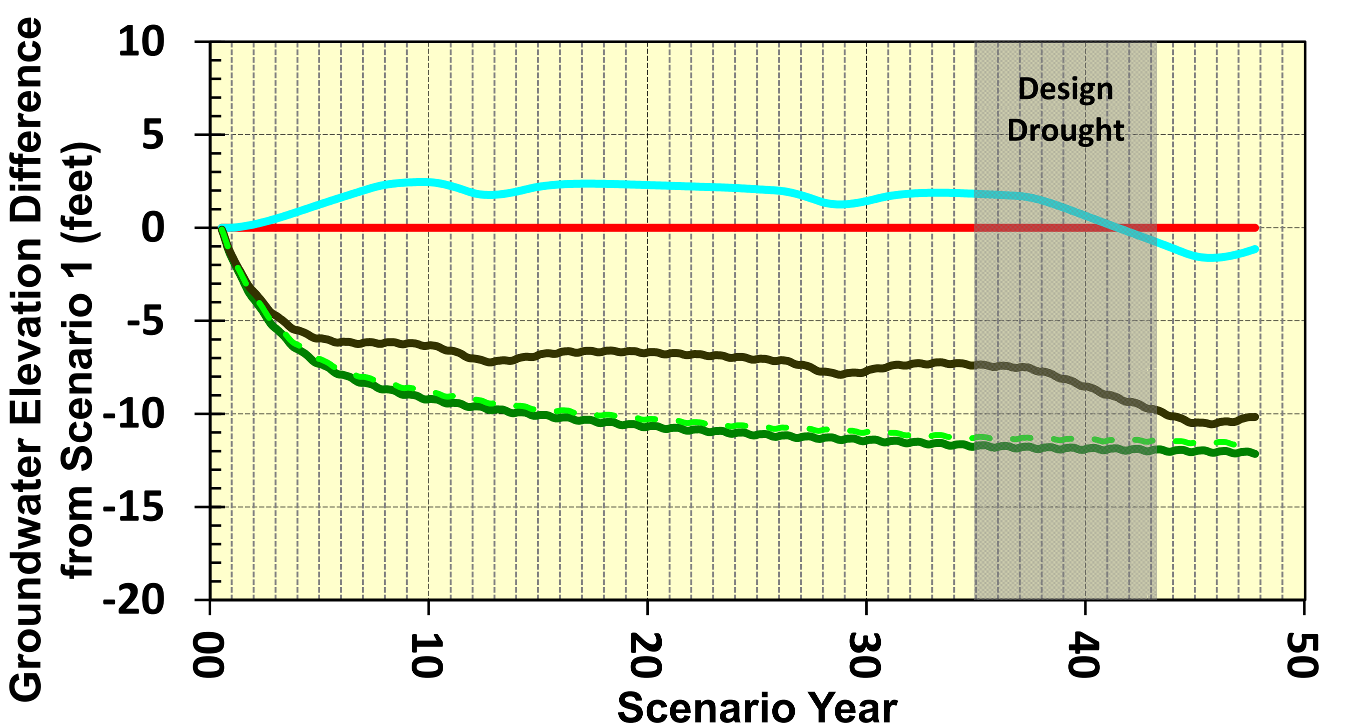
San Francisco Public Utilities Commission

Model Layer 1 Hydrographs for West Sunset Playground Well

K/J 0864001
April 2012
Figure 10.3-8a





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:

- Single-Aquifer
- Primary Production Aquifer

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Model Layer 4 Hydrographs for West Sunset Playground Well

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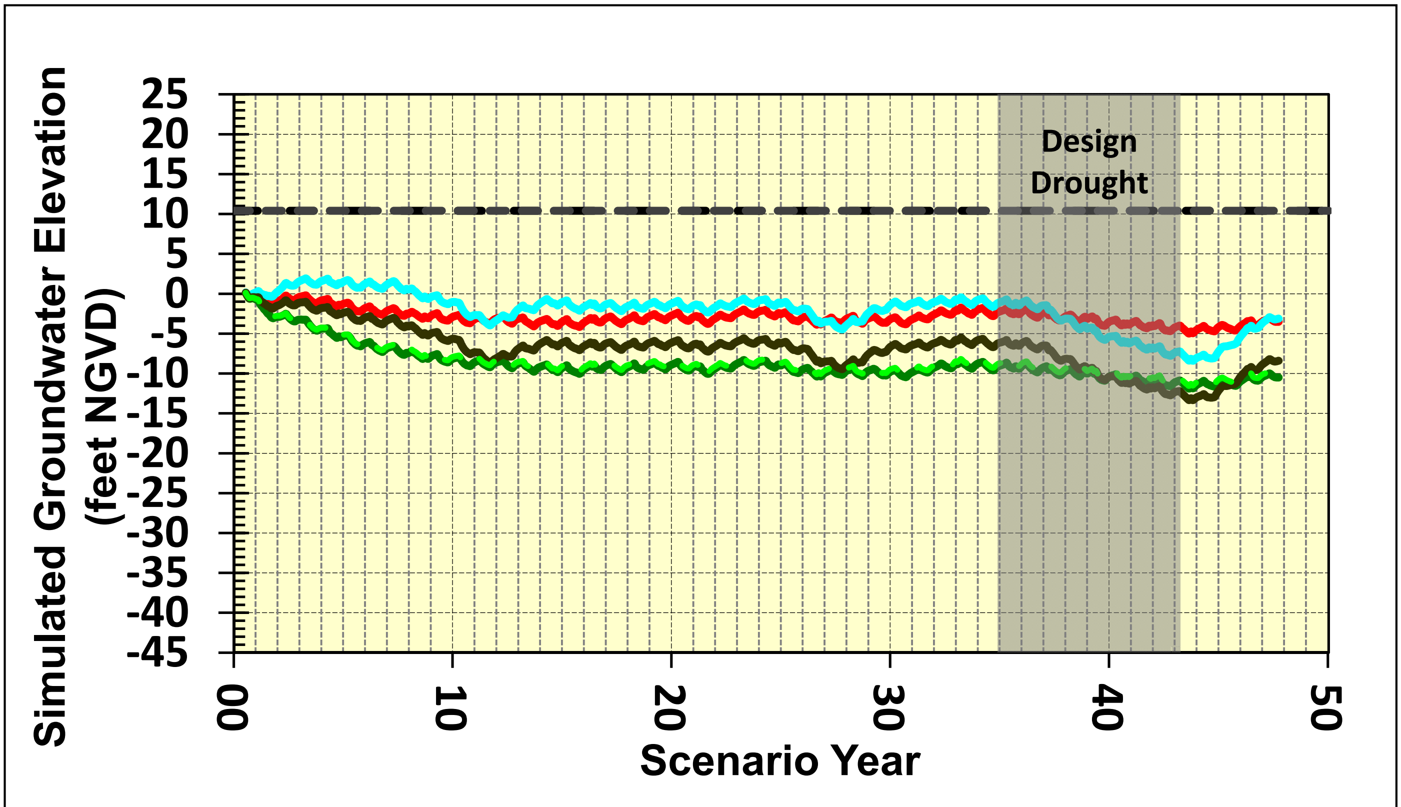
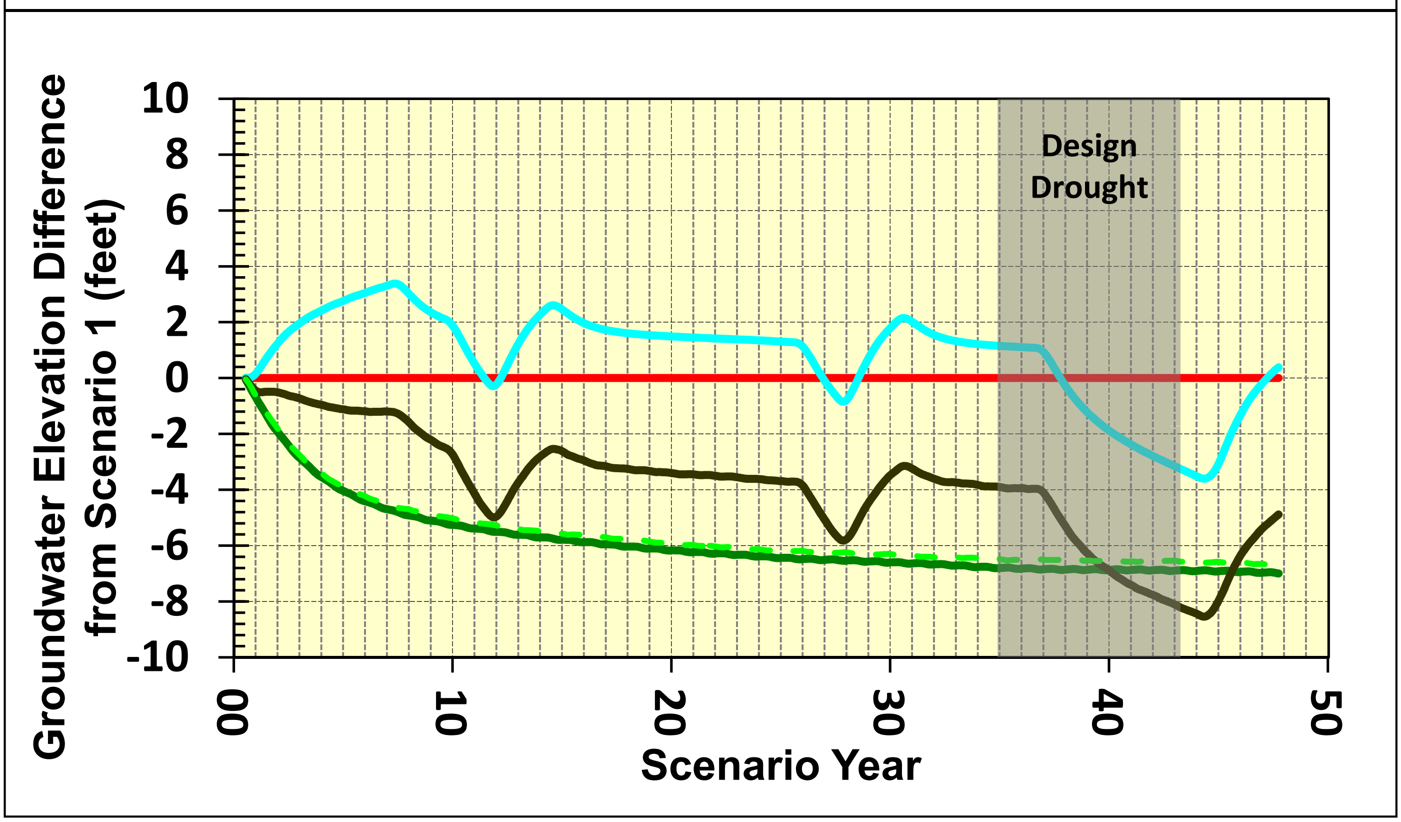
Figure 10.3-8b





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- **Scenario 1**
- **Scenario 2**
- **Scenario 3a**
- **Scenario 3b**
- **Scenario 4**

Exclusion Heads:

- **Single-Aquifer**
- **Deep Aquifer**

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Model Layer 5 Hydrographs for West Sunset Playground Well

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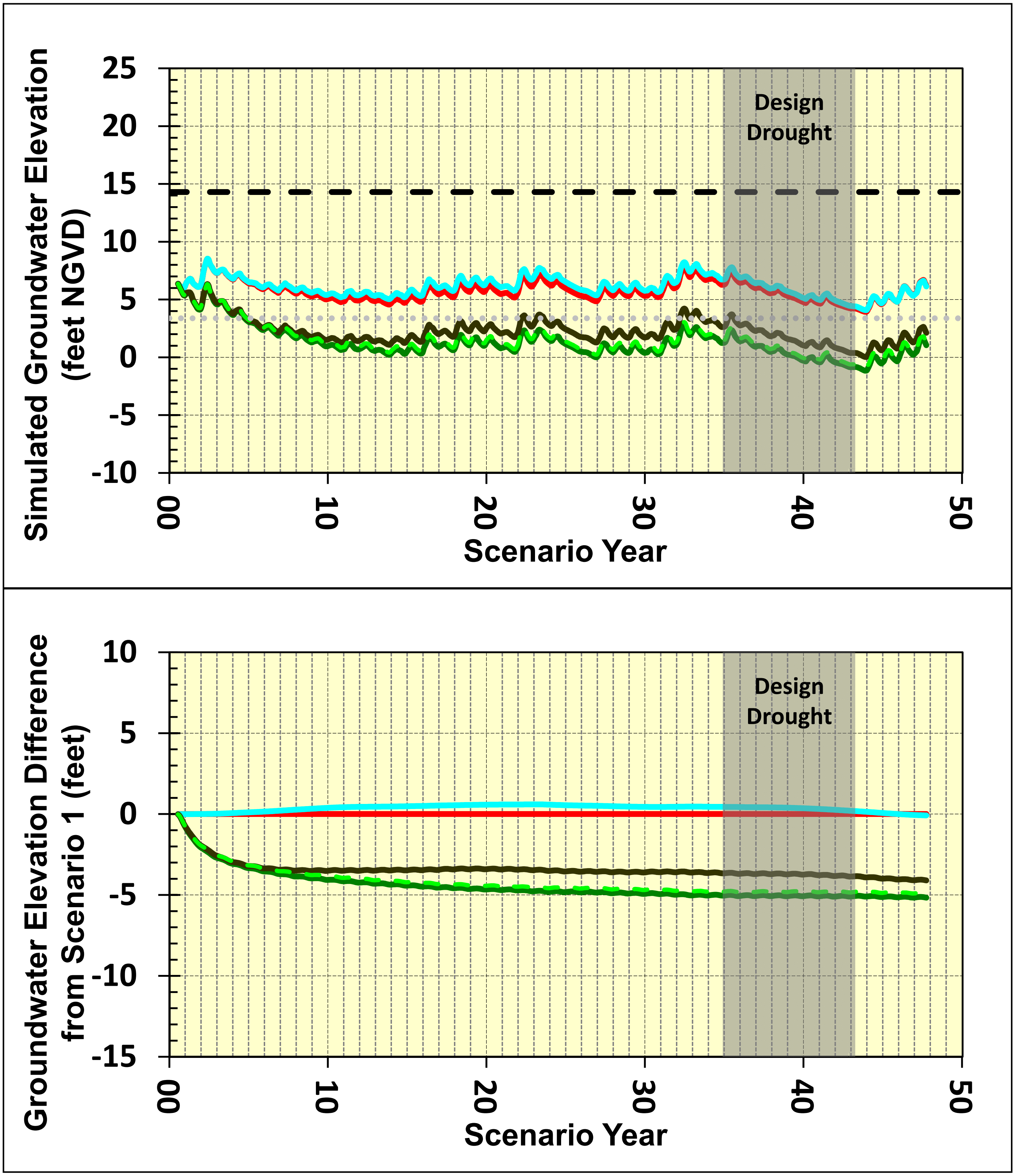
Figure 10.3-8c



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

Exclusion Heads:

Single-Aquifer
Shallow Aquifer

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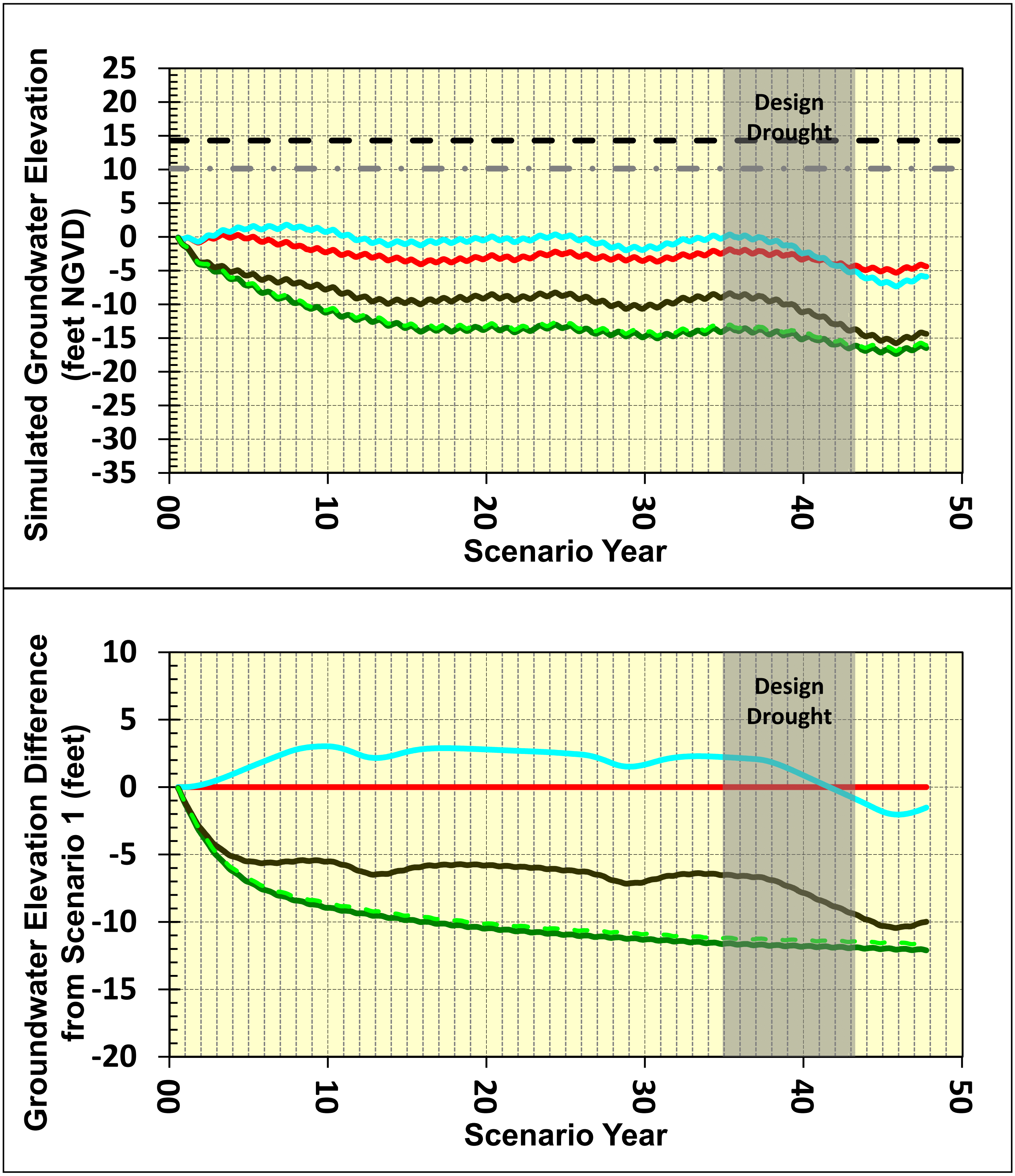
Model Layer 1 Hydrographs for Taraval Cluster

K/J 0864001
April 2012
Figure 10.3-9a



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:

- Single-Aquifer
- Primary Production Aquifer

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Model Layer 4 Hydrographs for Taraval Cluster

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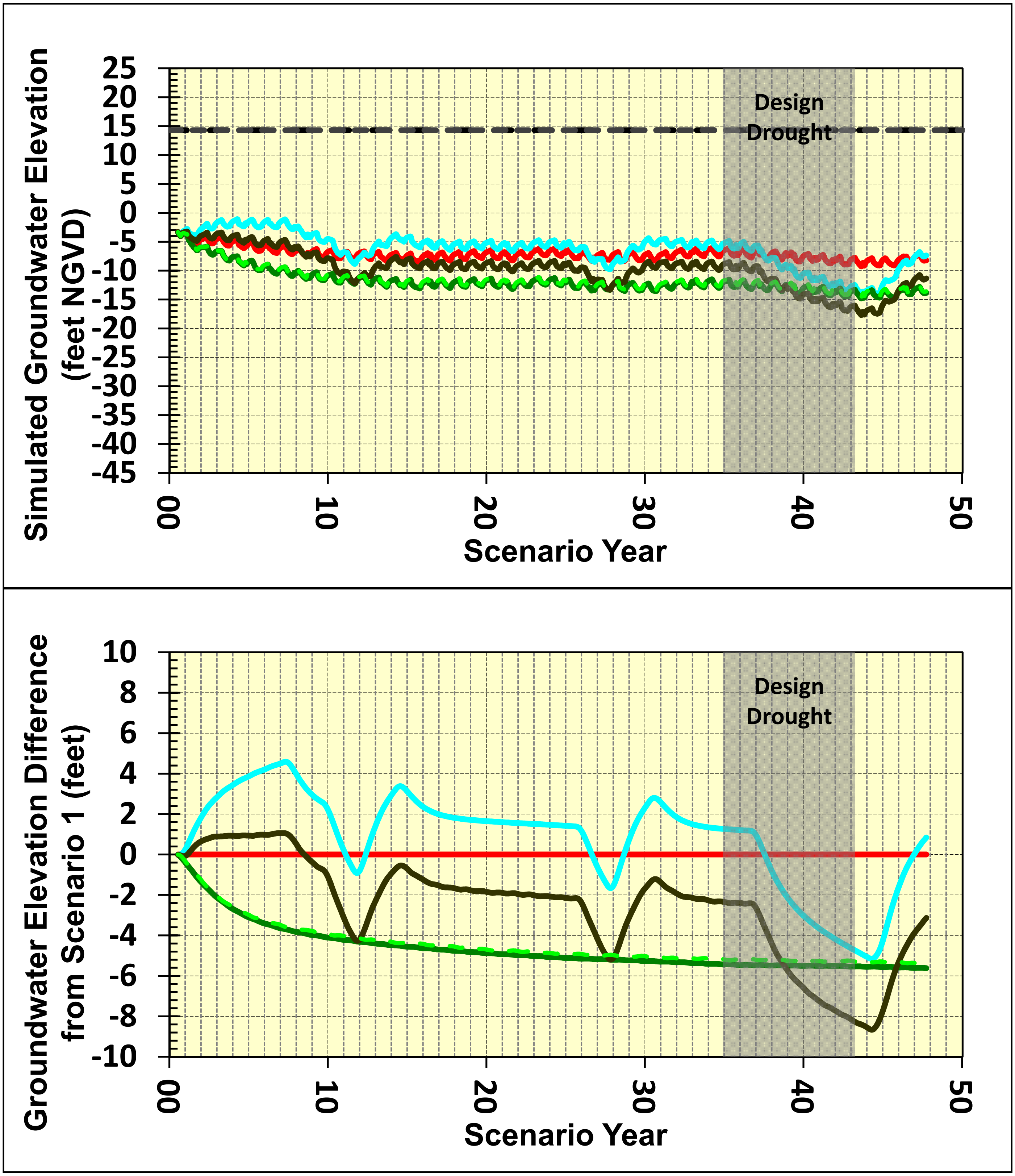
Figure 10.3-9b



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

Exclusion Heads:

Single-Aquifer
Deep Aquifer

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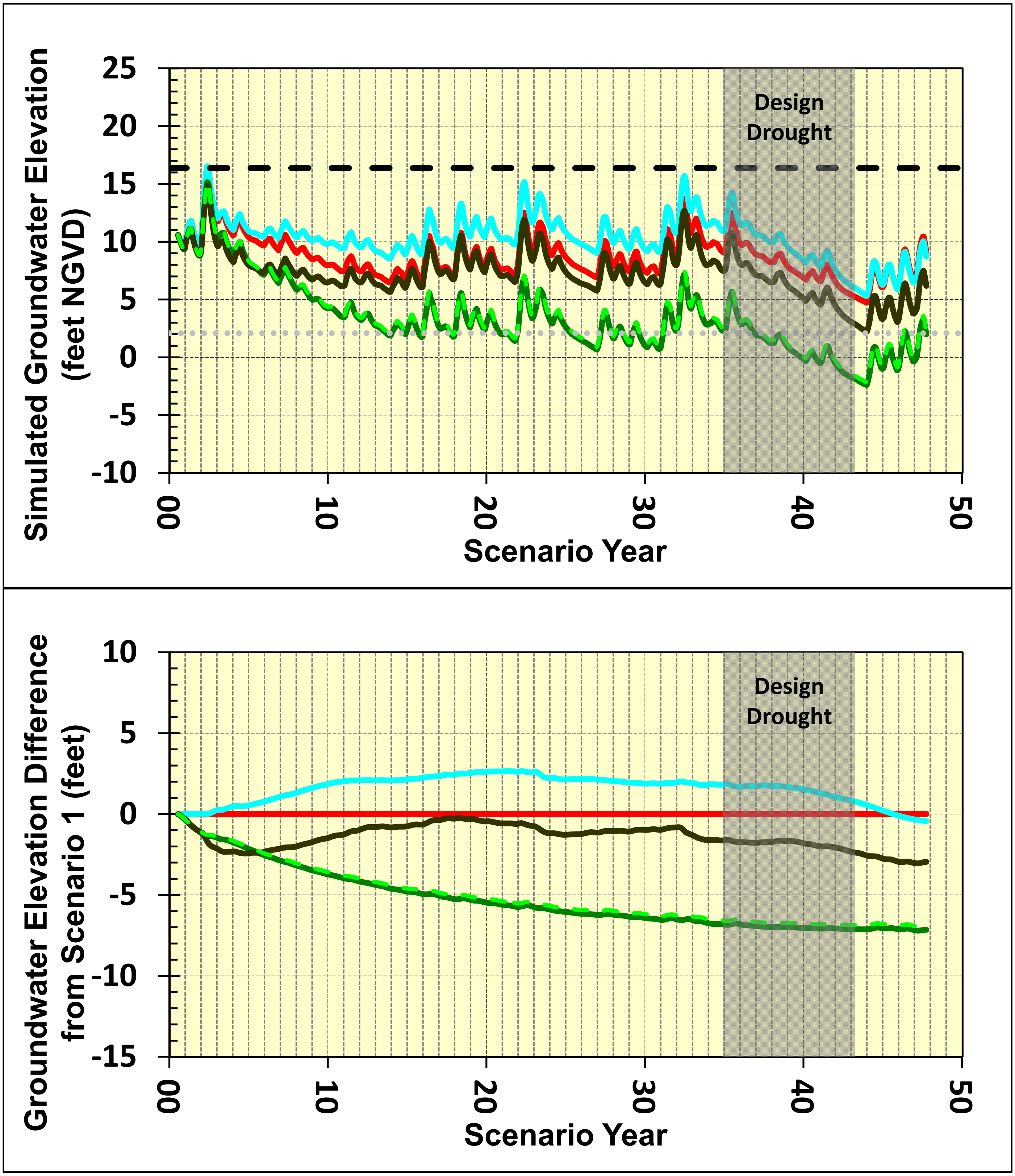
Model Layer 5 Hydrographs for Taraval Cluster

K/J 0864001
April 2012
Figure 10.3-9c



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:

- Single-Aquifer
- Shallow Aquifer

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Model Layer 1 Hydrographs for Zoo Cluster

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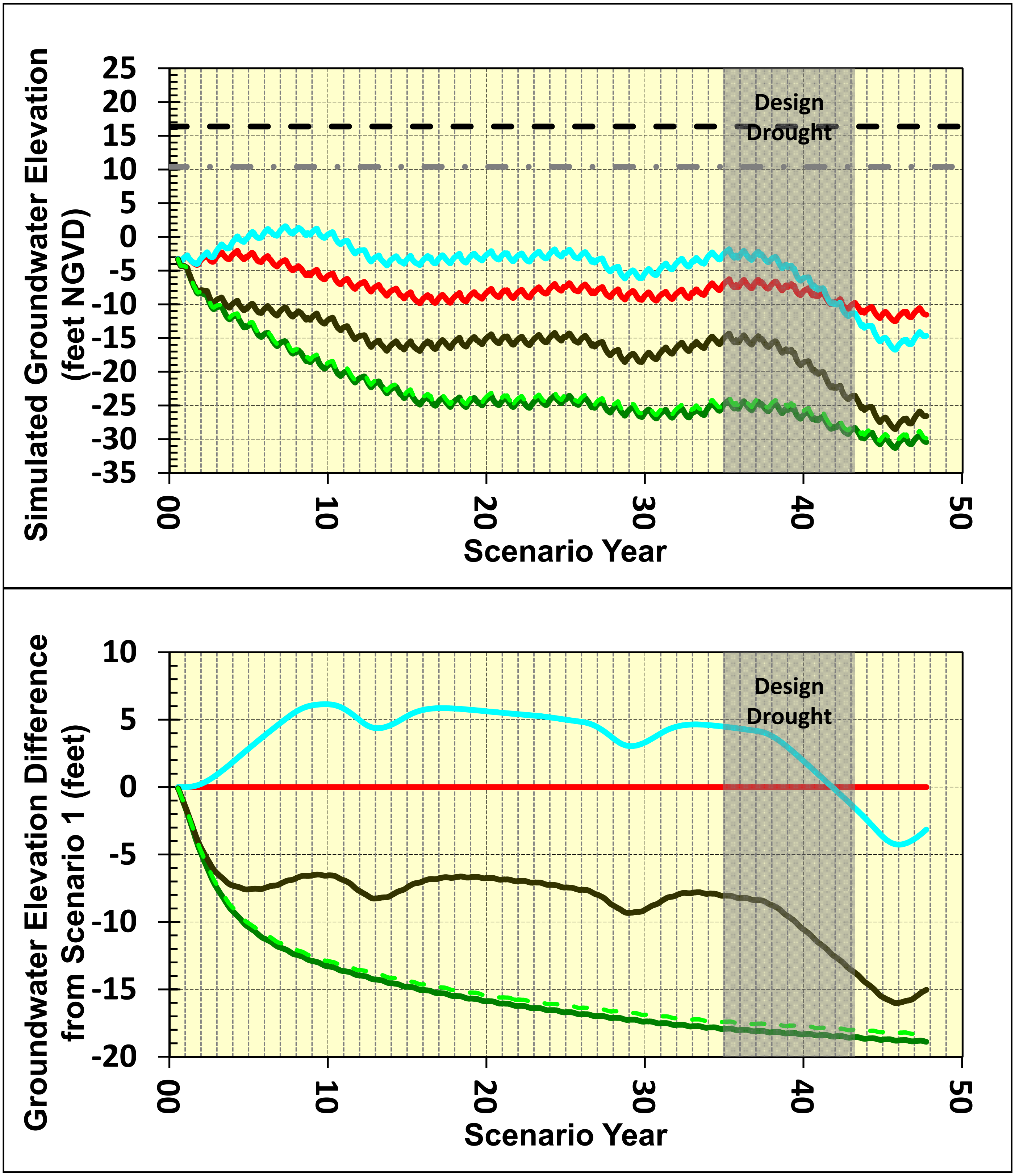
Figure 10.3-10a



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:
Scenario 1 — Scenario 2
Scenario 3a — Scenario 3b
Scenario 4

Exclusion Heads:
Single-Aquifer — Primary Production Aquifer

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Model Layer 4 Hydrographs for Zoo Cluster

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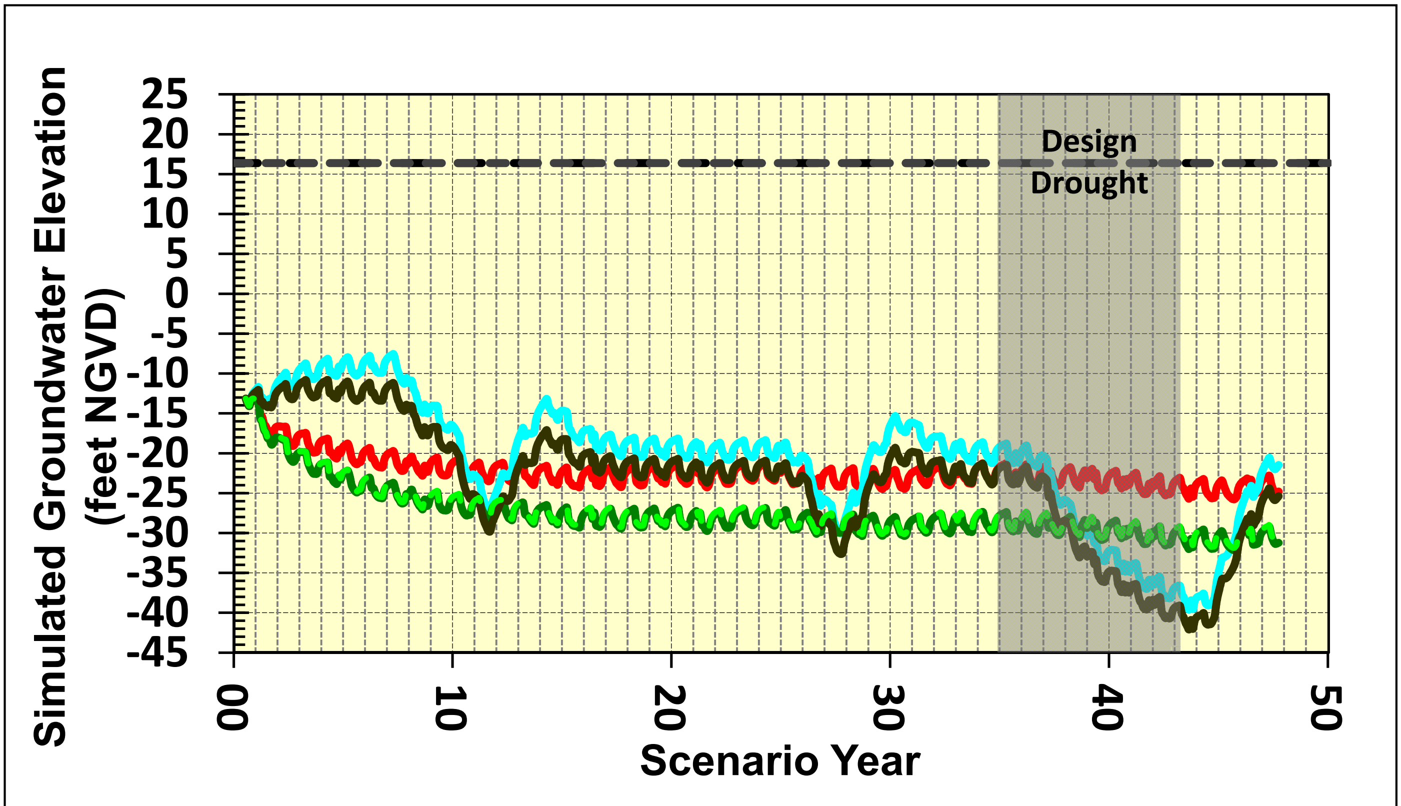
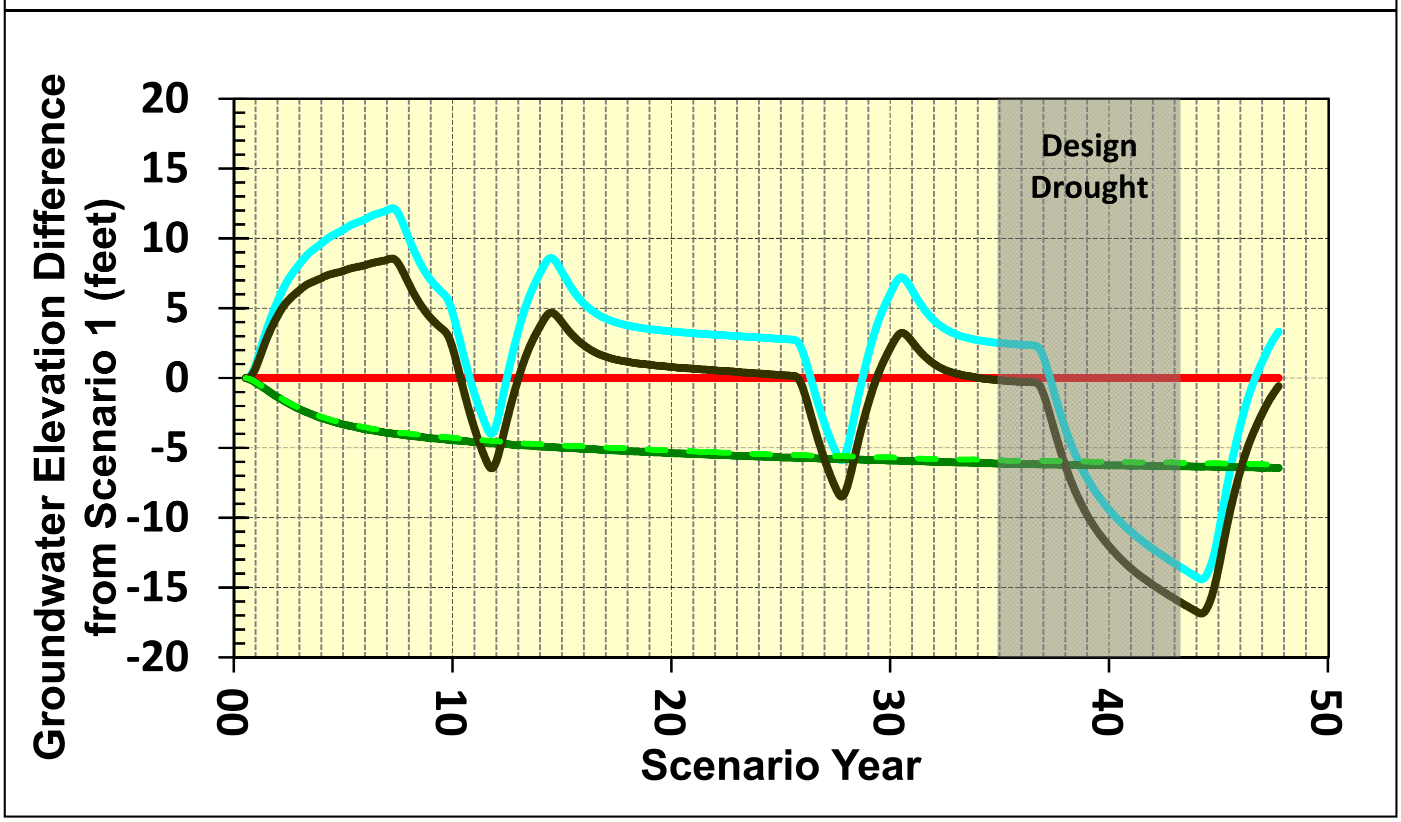
April 2012
Figure 10.3-10b





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:

- Single-Aquifer
- Deep Aquifer

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Model Layer 5 Hydrographs for Zoo Cluster

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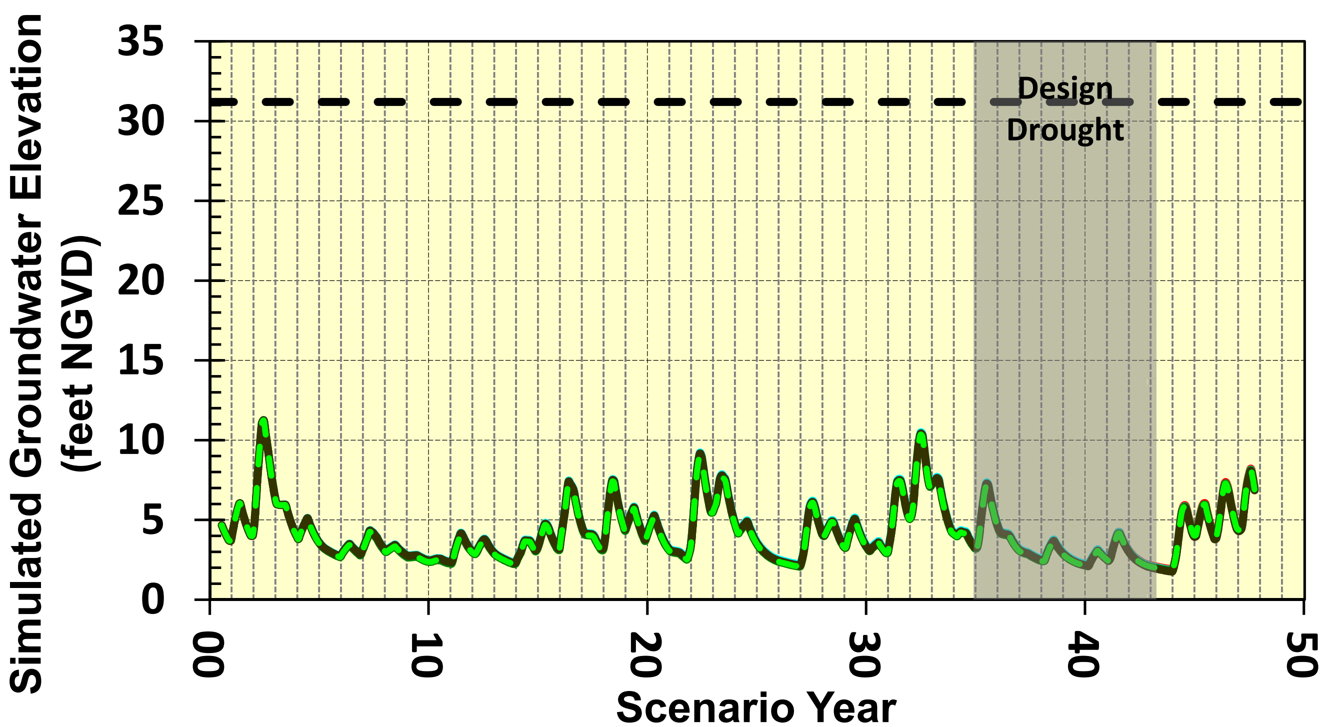
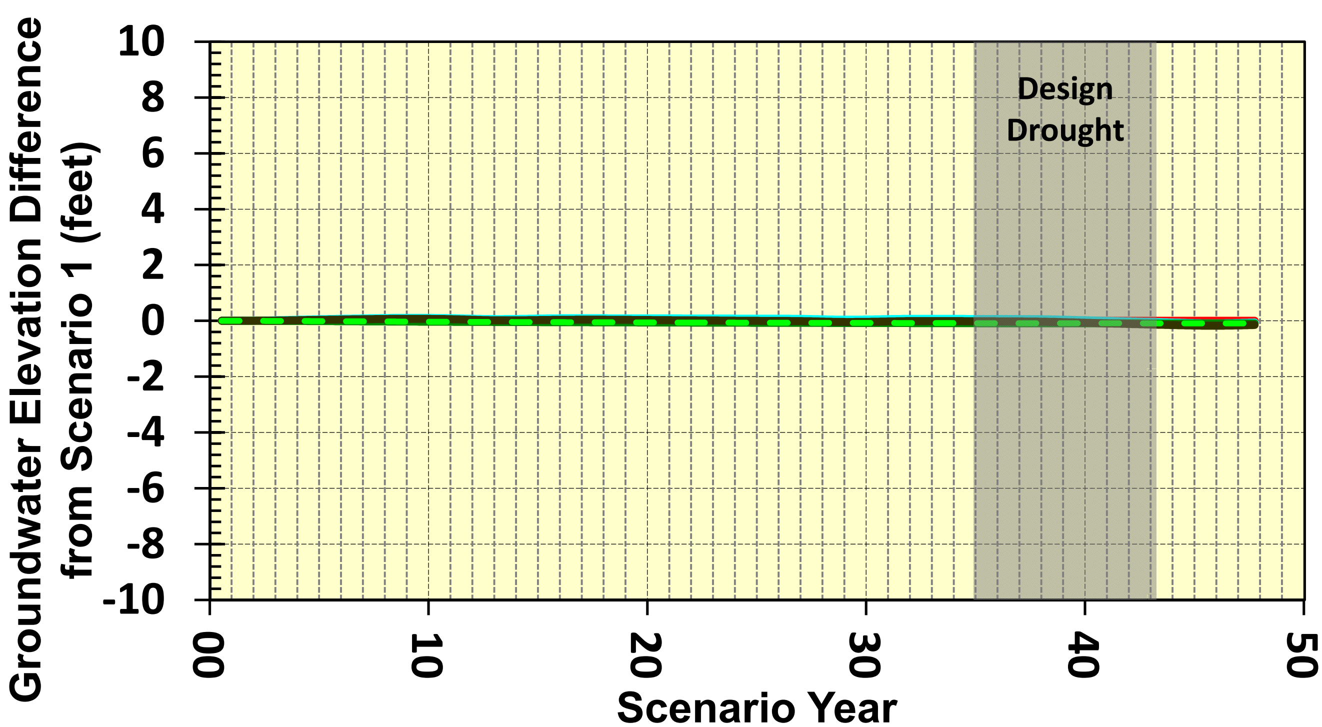
Figure 10.3-10c





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:

- Single-Aquifer

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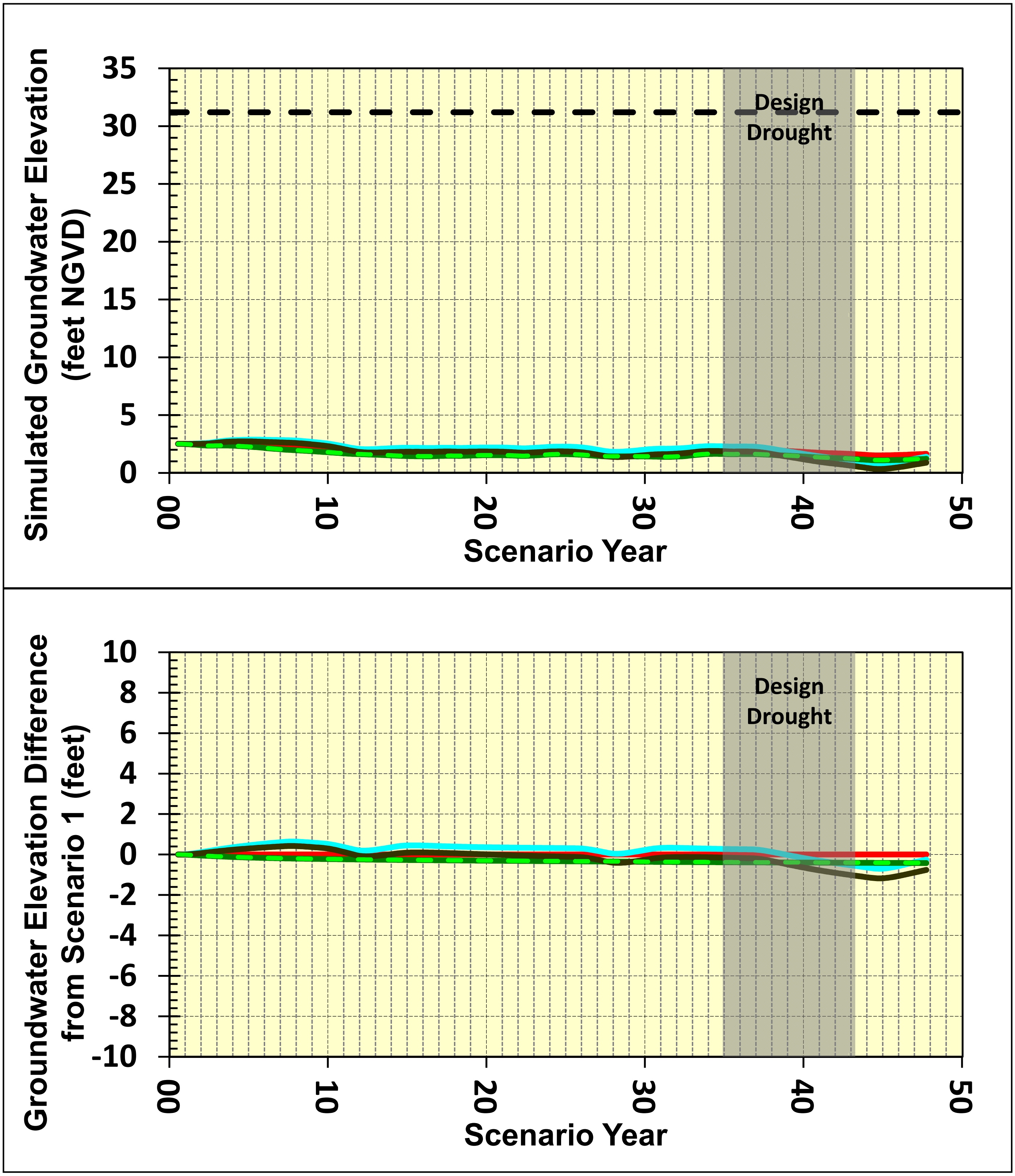
Model Layer 1 Hydrographs for Fort Funston Cluster

K/J 0864001
April 2012

Figure 10.3-11a



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:
- Single-Aquifer

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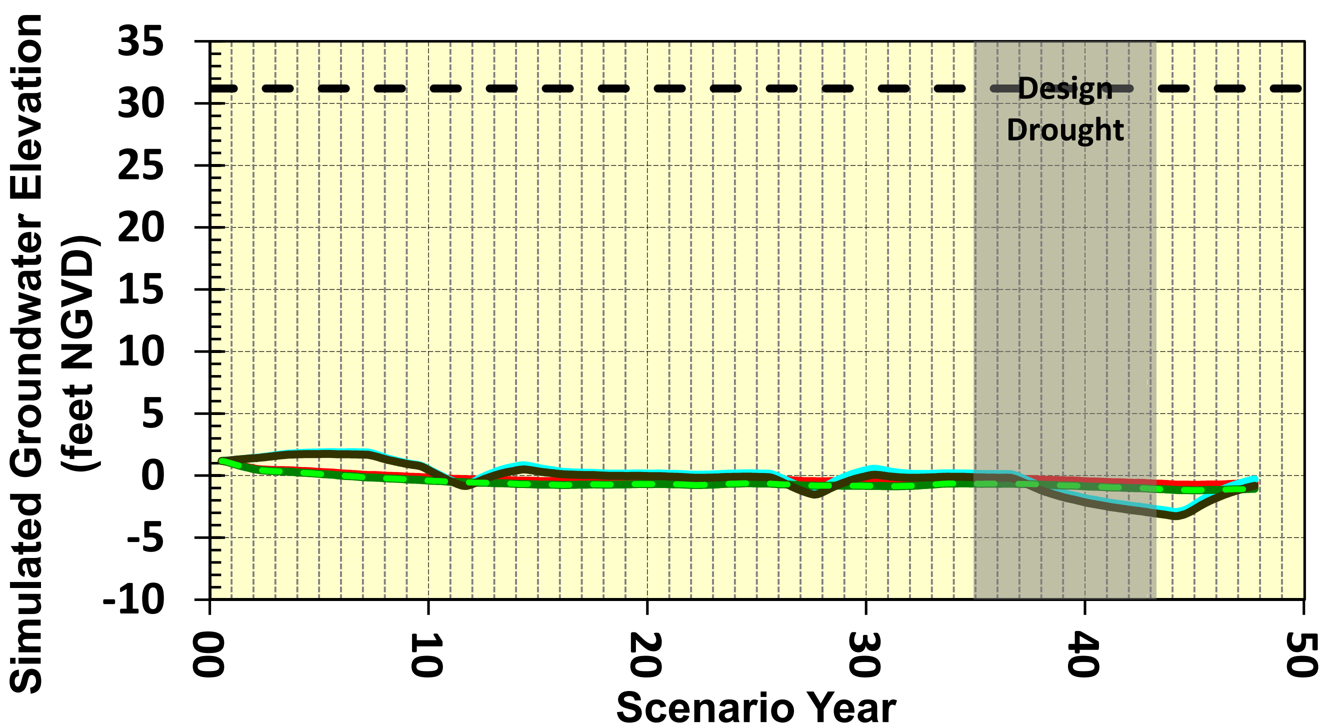
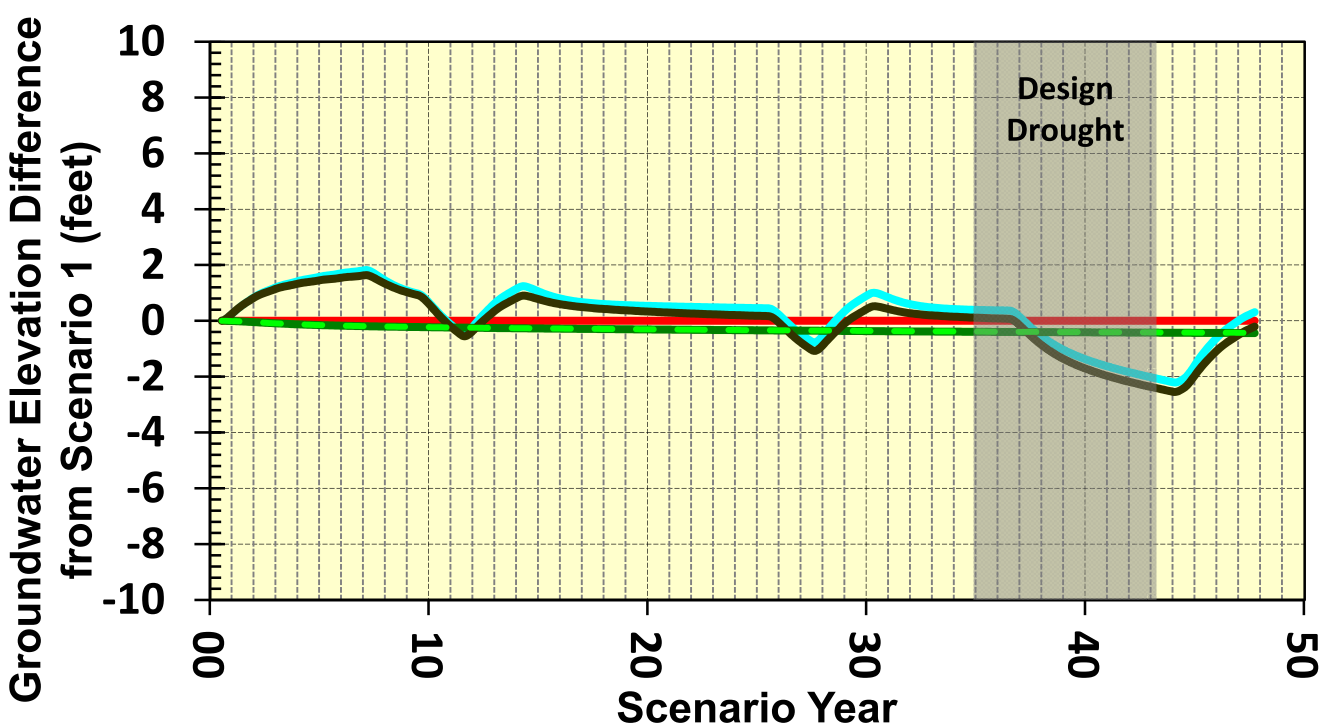
Model Layer 4 Hydrographs for Fort Funston Cluster

K/J 0864001
April 2012
Figure 10.3-11b





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:

- Single-Aquifer

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Regional Groundwater Storage and Recovery Project
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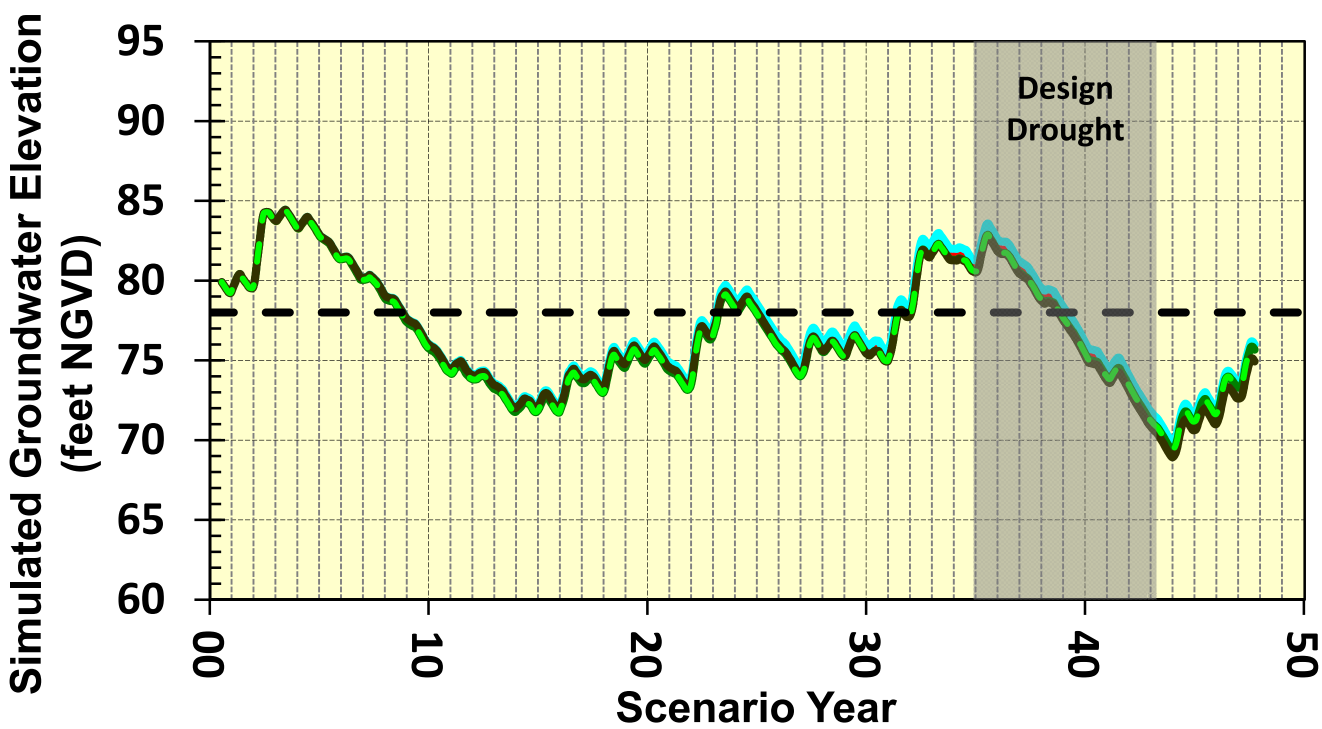
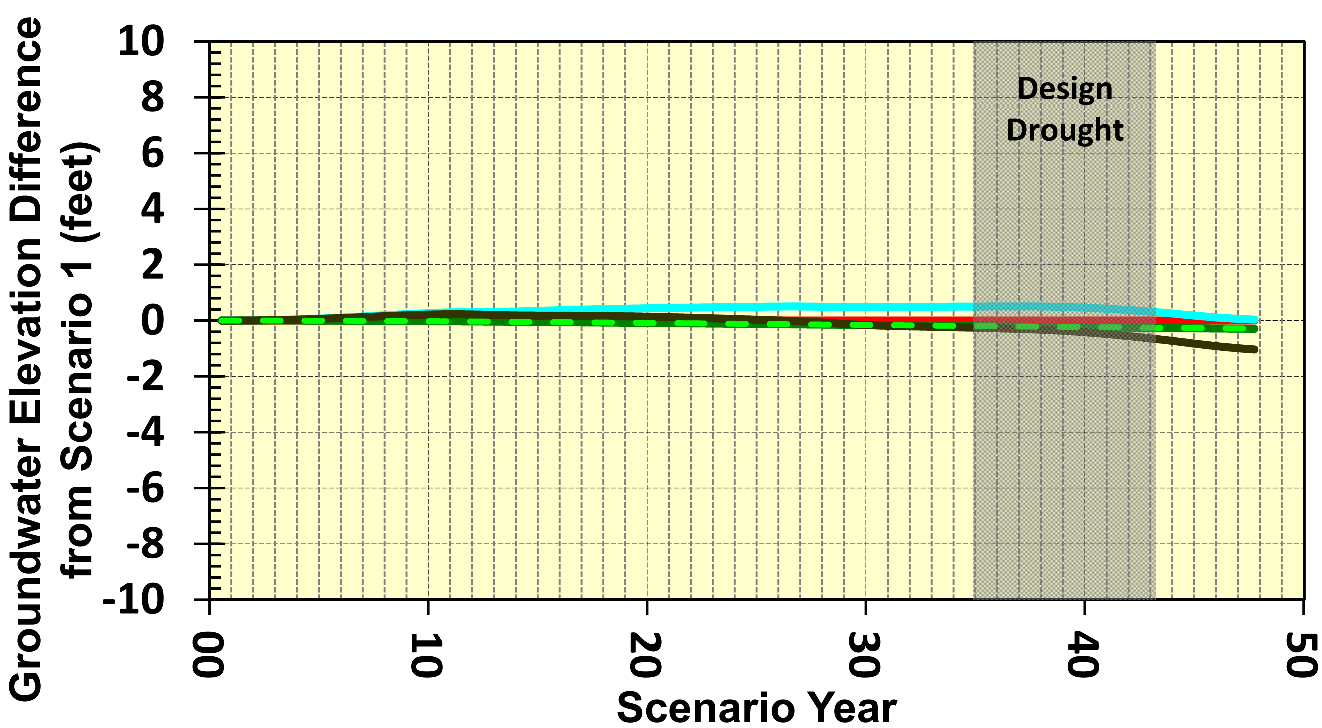
Model Layer 5 Hydrographs for Fort Funston Cluster

K/J 0864001
April 2012
Figure 10.3-11c





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:
- Single-Aquifer

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Regional Groundwater Storage and Recovery Project
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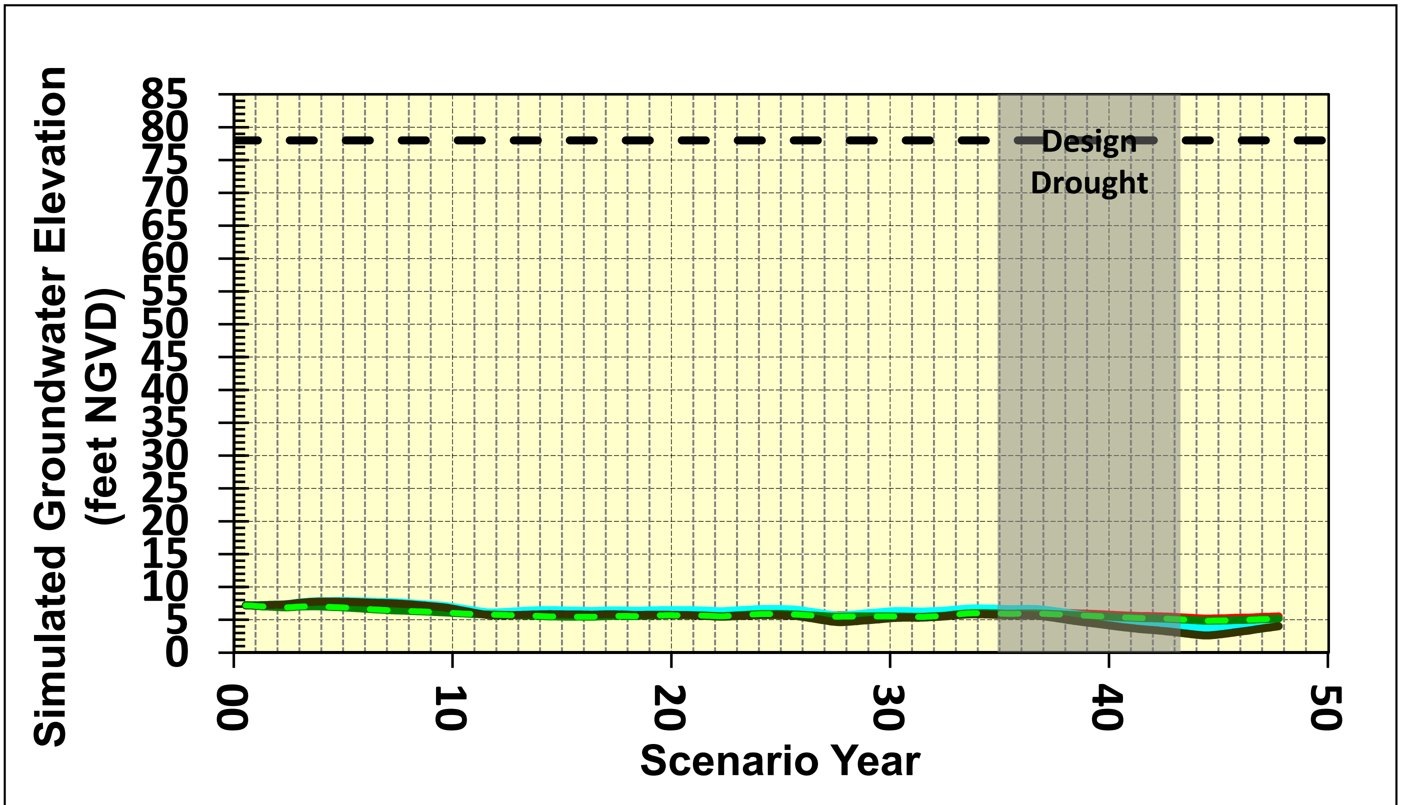
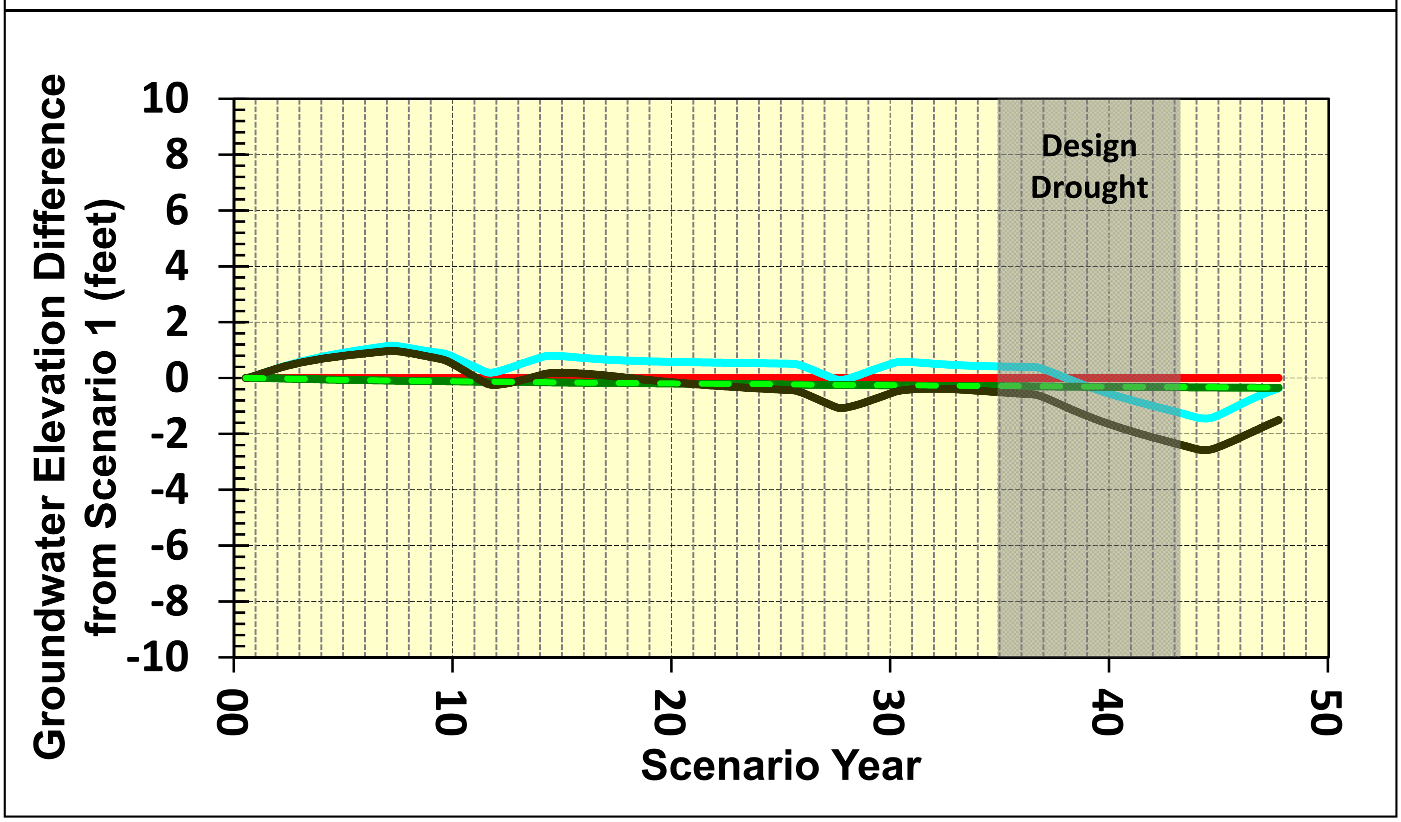
Model Layer 1 Hydrographs for Thornton Beach Cluster

K/J 0864001
April 2012
Figure 10.3-12a





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:
- **Scenario 1**
- **Scenario 2**
- **Scenario 3a**
- **Scenario 3b**
- **Scenario 4**

Exclusion Heads:
- **Single-Aquifer**

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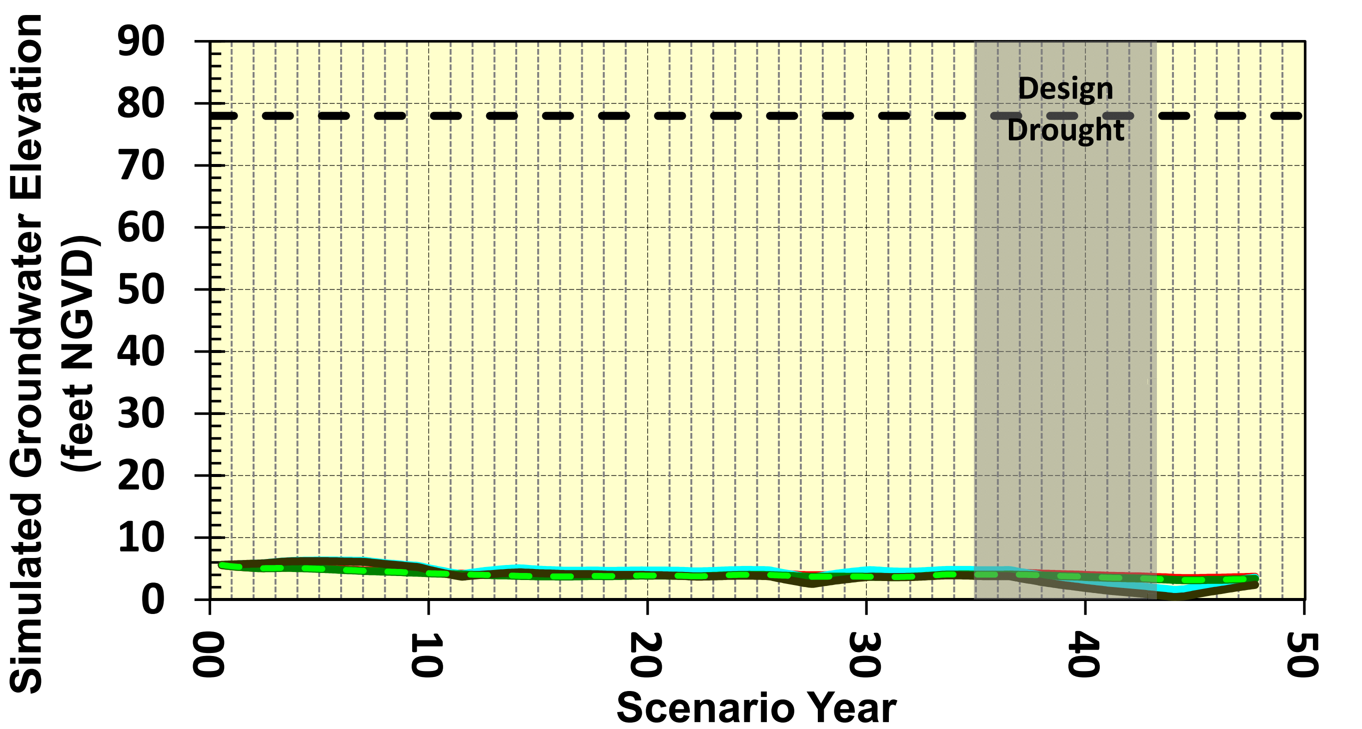
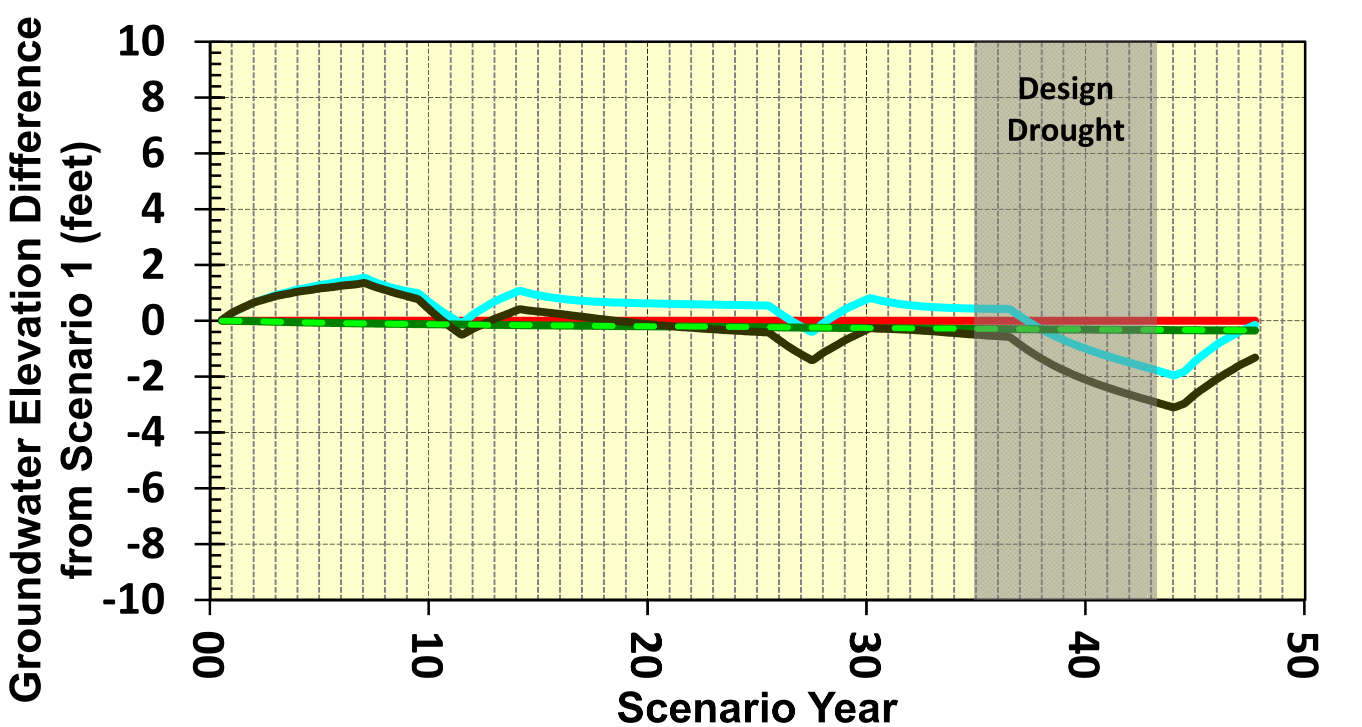
Model Layer 4 Hydrographs for Thornton Beach Cluster

K/J 0864001
April 2012
Figure 10.3-12b





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:
- Single-Aquifer

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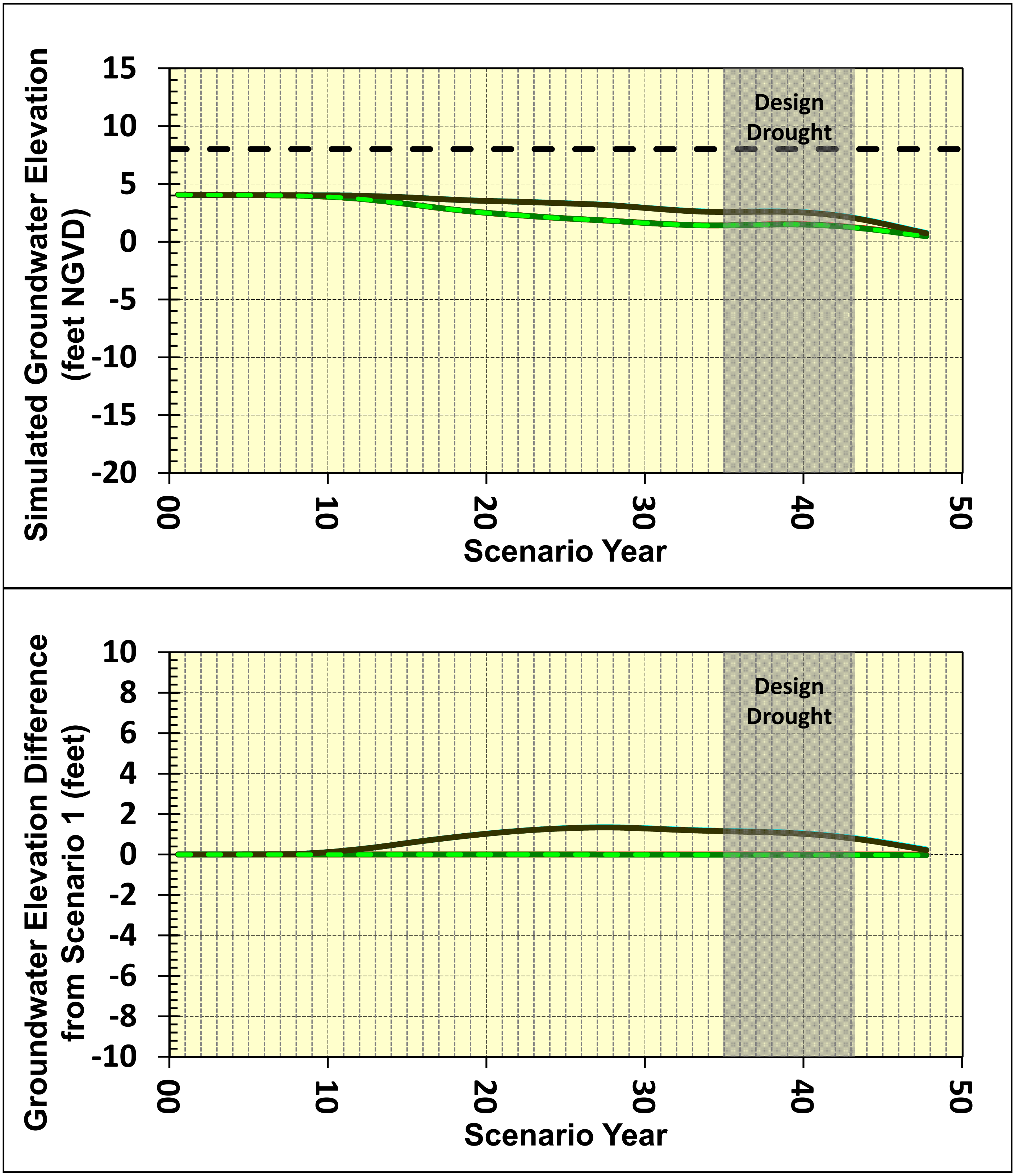
Model Layer 5 Hydrographs for Thornton Beach Cluster

K/J 0864001
April 2012
Figure 10.3-12c



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:

- Single-Aquifer

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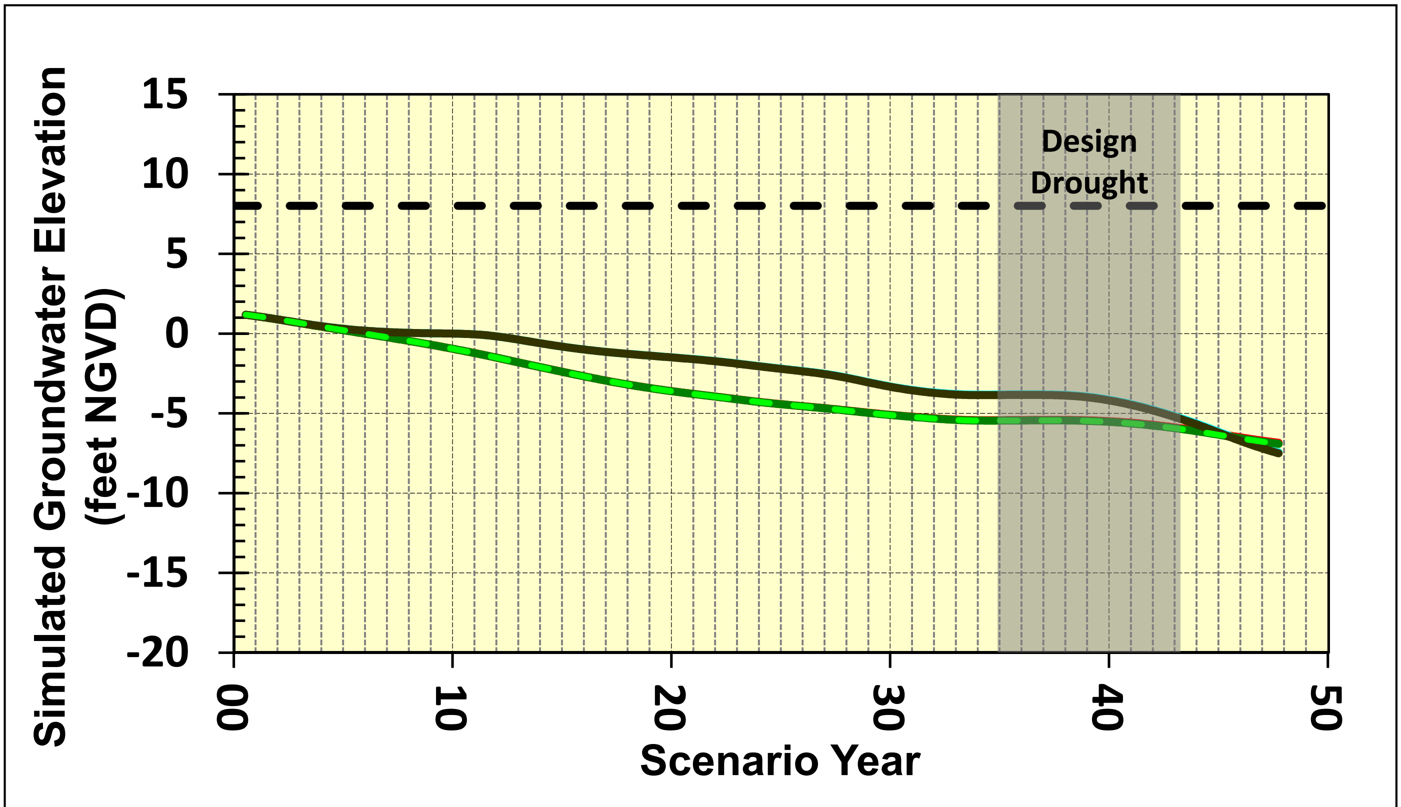
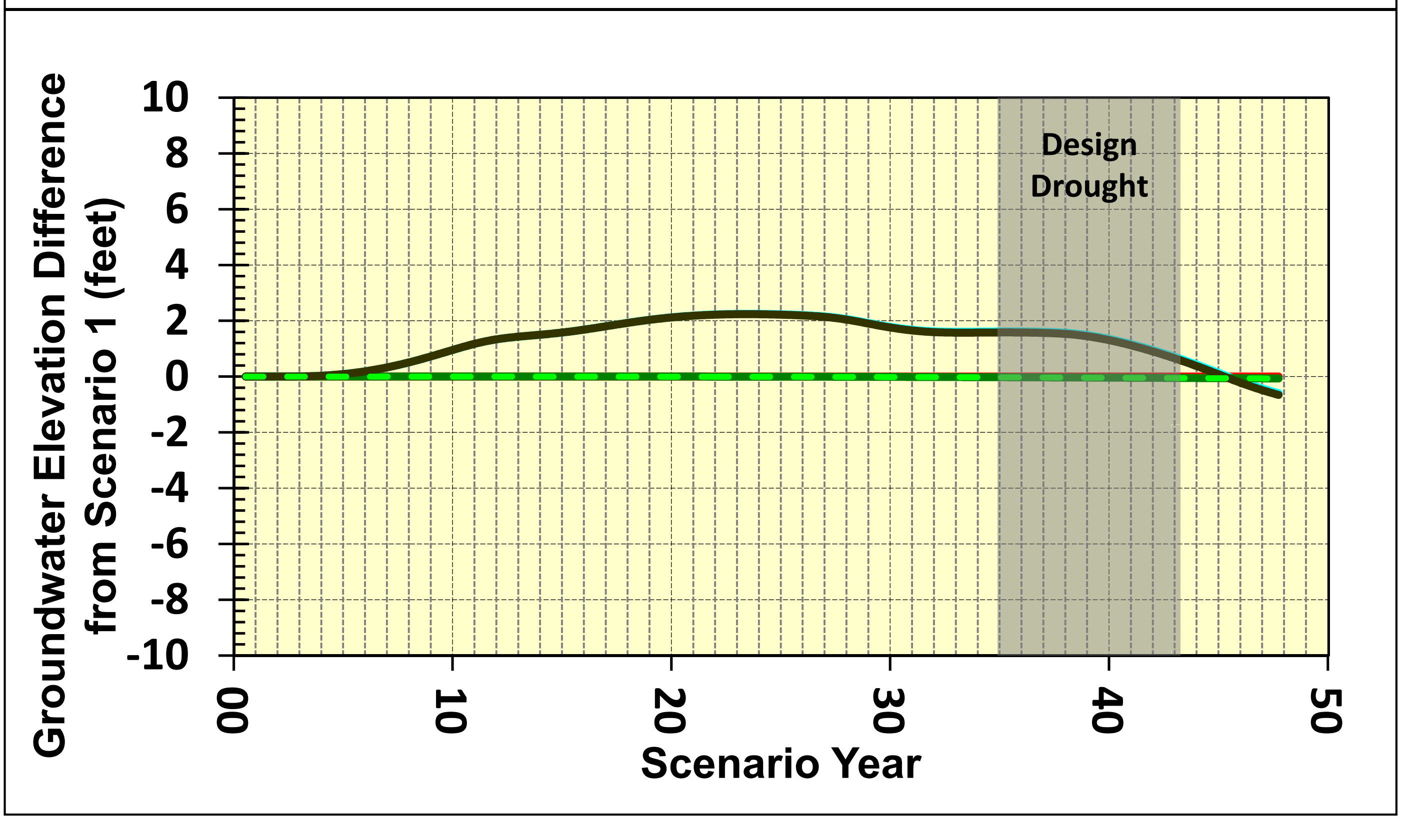
Model Layer 1 Hydrographs for Burlingame Cluster

K/J 0864001
April 2012

Figure 10.3-13a





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:

- Single-Aquifer

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Model Layer 4 Hydrographs for Burlingame Cluster

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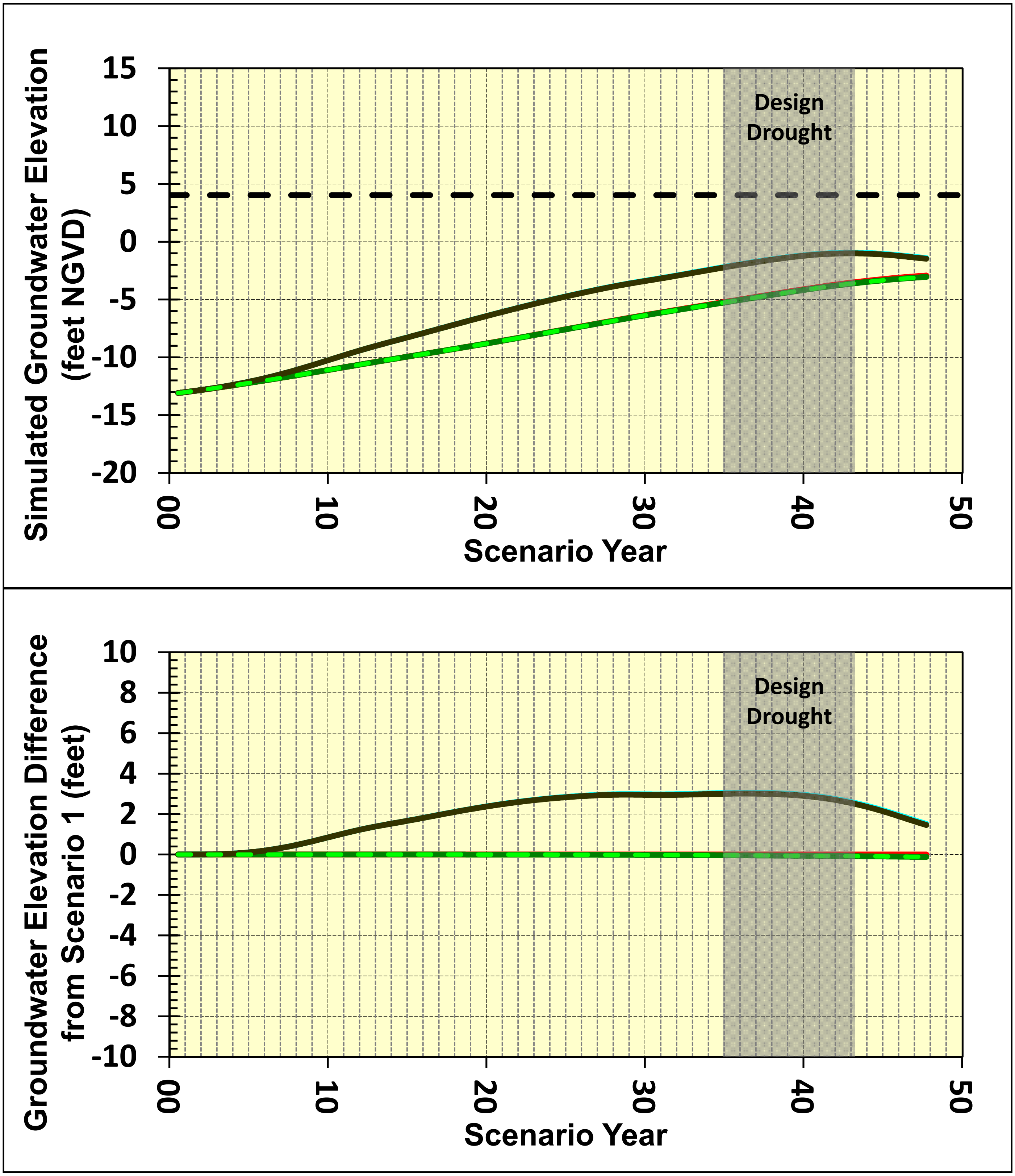
Figure 10.3-13b



Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:

- Single-Aquifer

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Regional Groundwater Storage and Recovery Project
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Model Layer 1 Hydrographs for SFO Cluster

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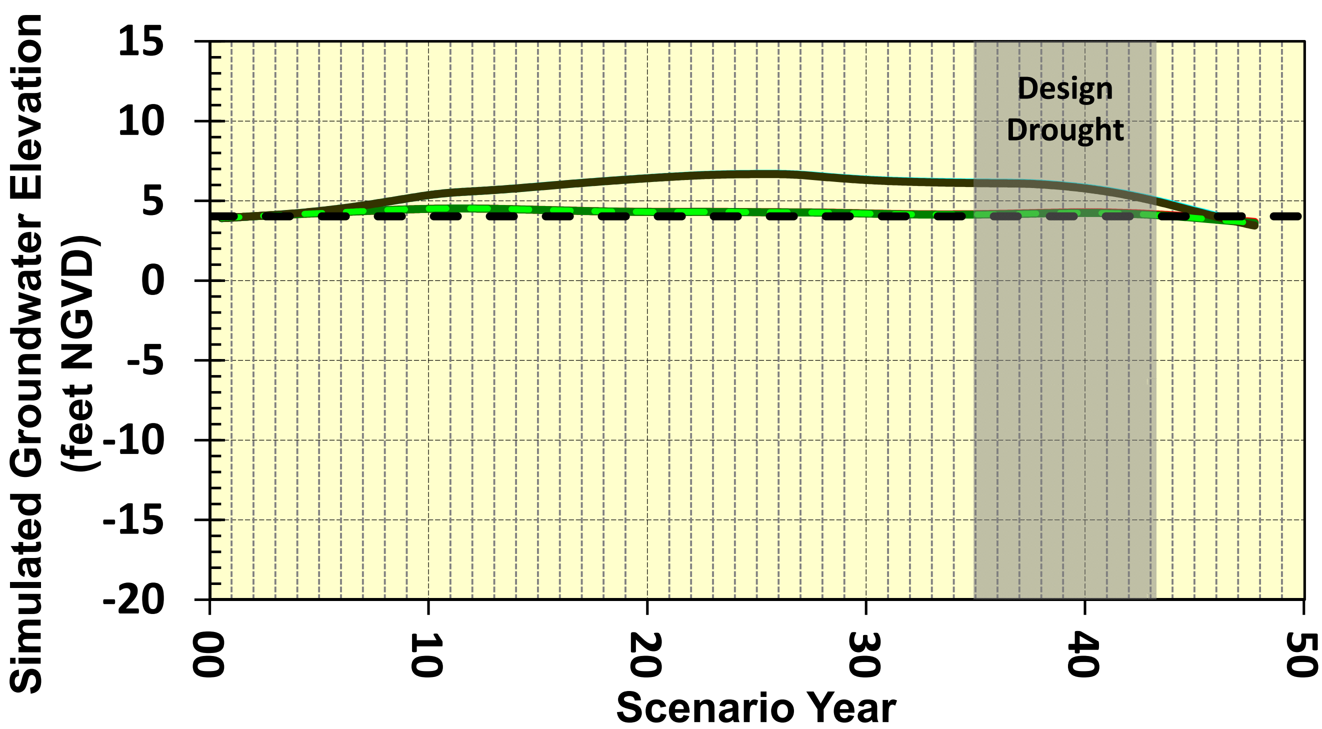
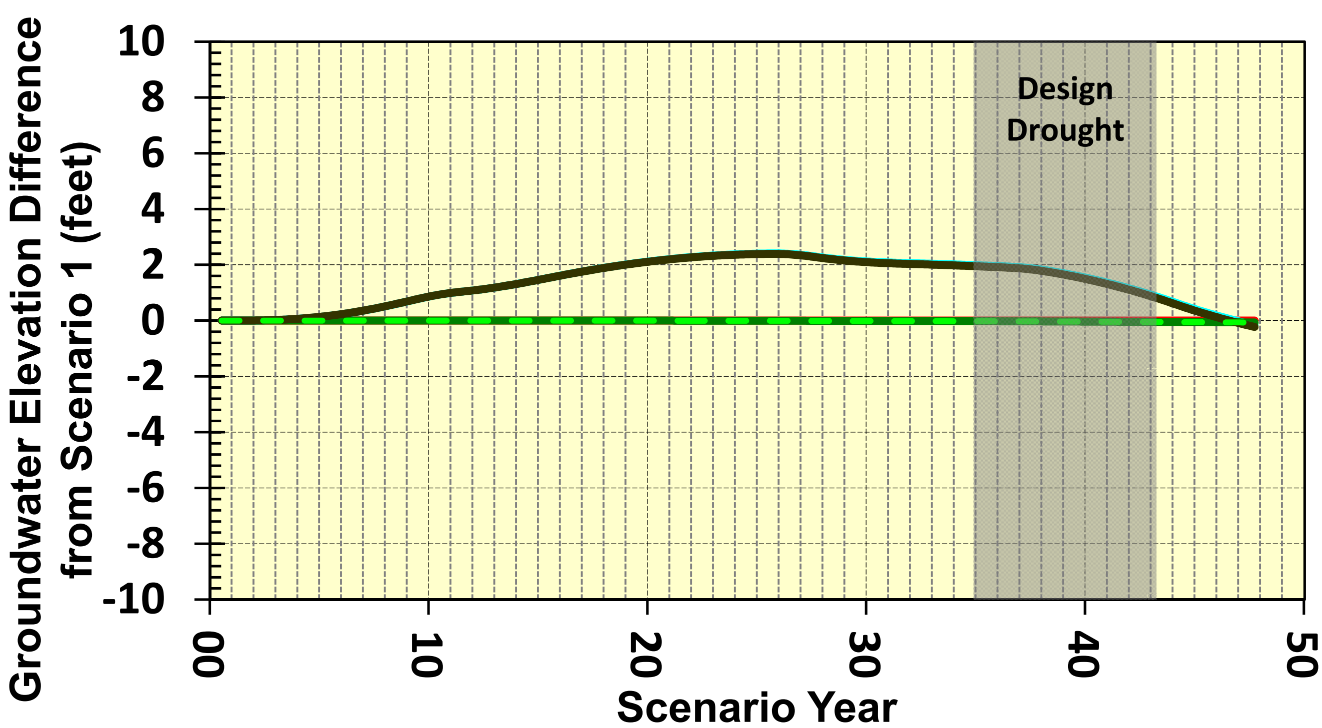
April 2012
Figure 10.3-14





Note: Zero elevation is equivalent to mean sea level NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Exclusion Heads:

- Single-Aquifer

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Regional Groundwater Storage and Recovery Project
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Model Layer 1 Hydrographs for UAL Cluster

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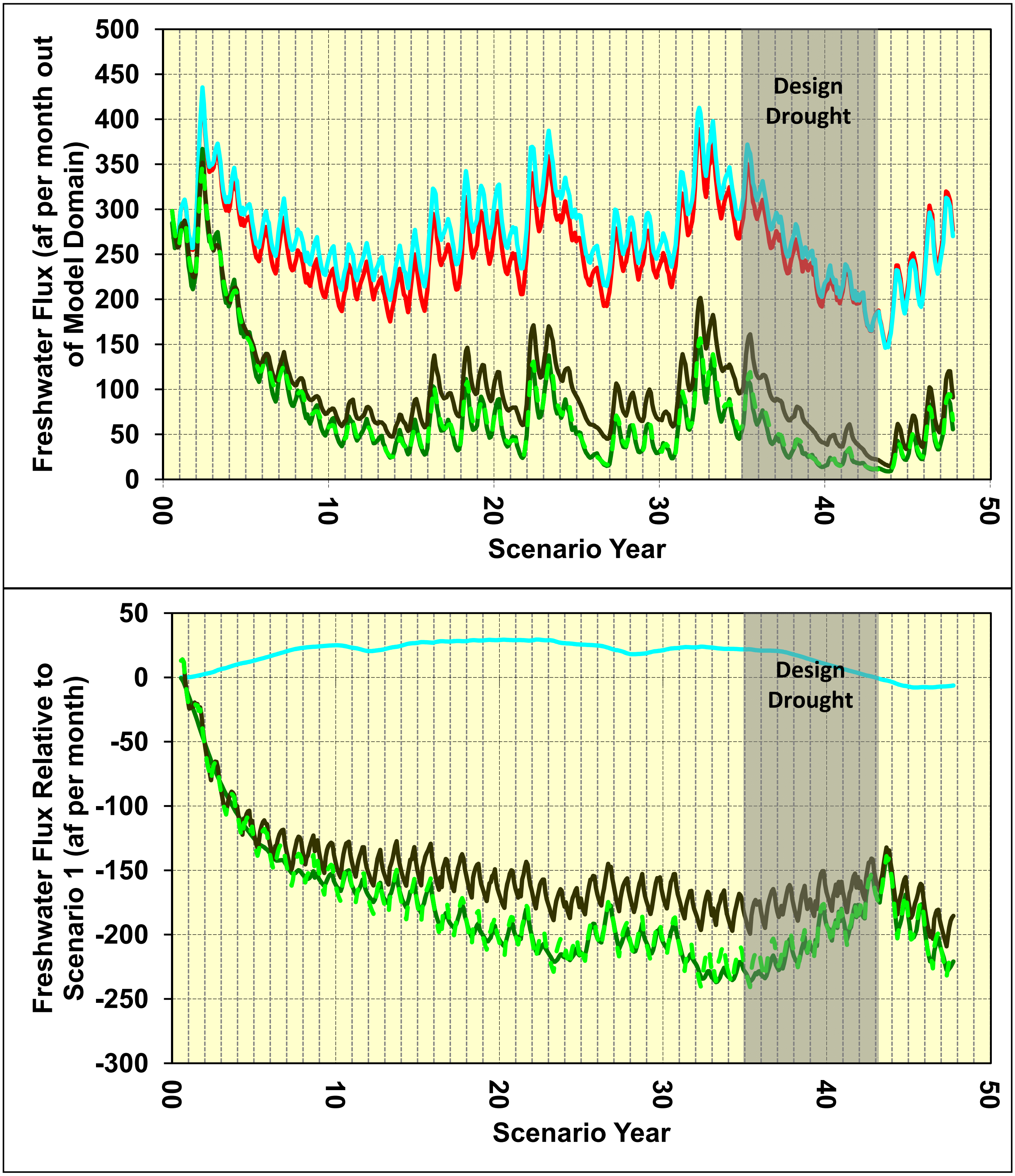
April 2012
Figure 10.3-15



Freshwater Fluxes:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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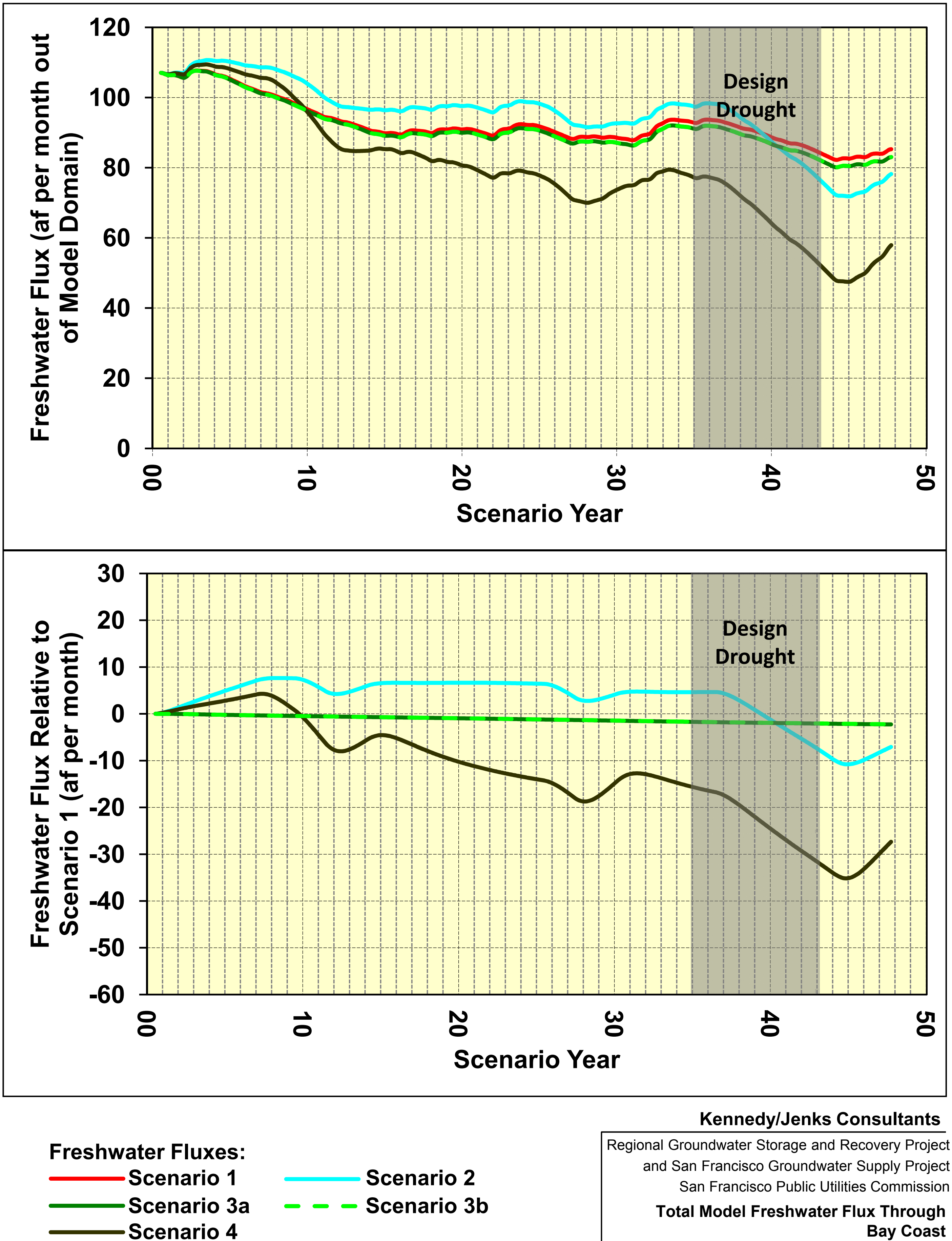
Total Model Freshwater Flux Through Pacific Coast

K/J 0864001
April 2012

Figure 10.3-16



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Total Model Freshwater Flux Through Bay Coast

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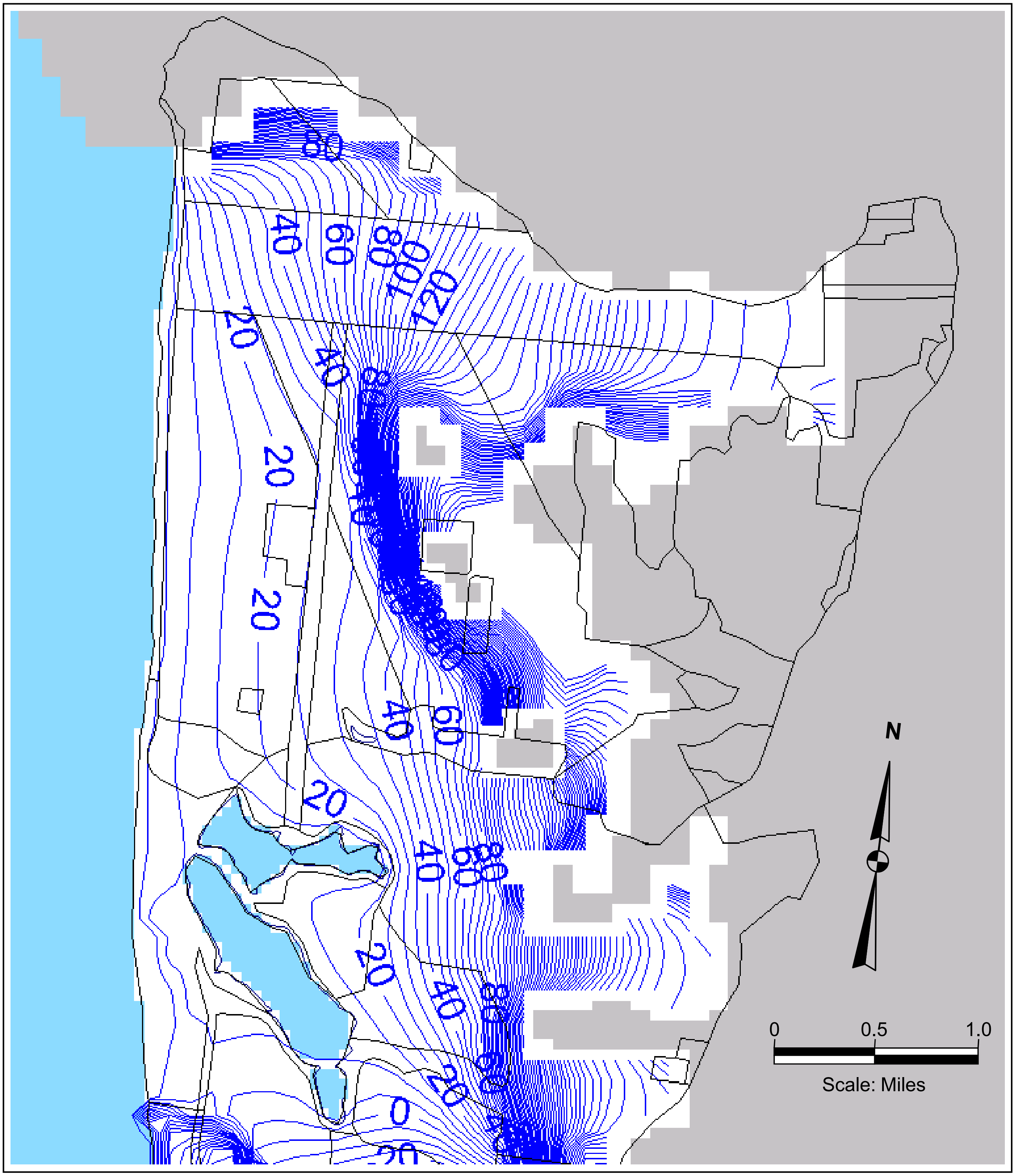
April 2012
Figure 10.3-17



Note: Elevations are in feet NGVD 29. Contour interval is 5 feet.

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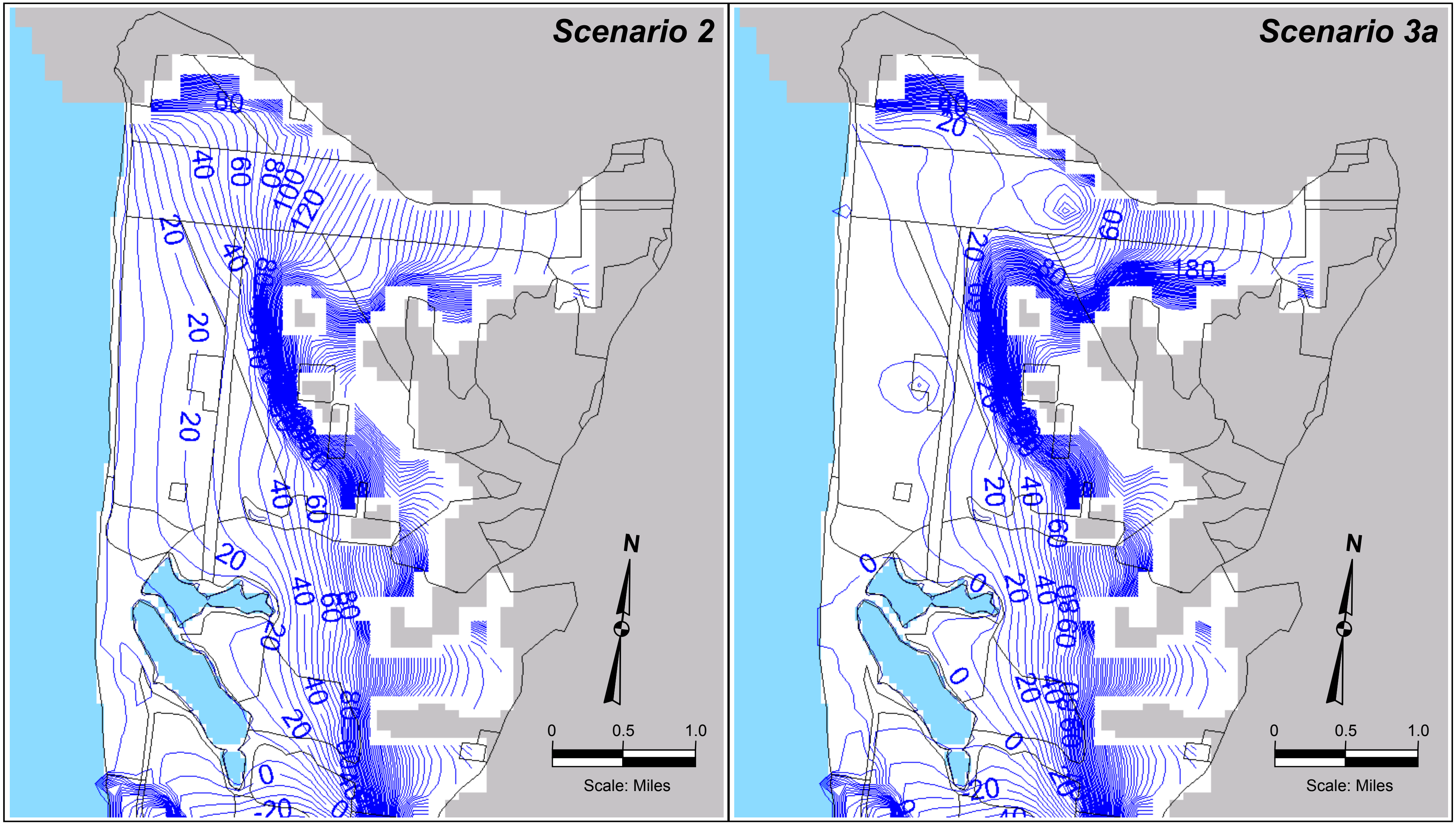
Water Table Elevation at End of Scenario 1 (Model Layer 1)

K/J 0864001
April 2012
Figure 10.3-18



Note: Elevations are in feet NGVD 29. Contour interval is 5 feet.

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Water Table Elevation at End of Scenarios 2 and 3a (Model Layer 1)

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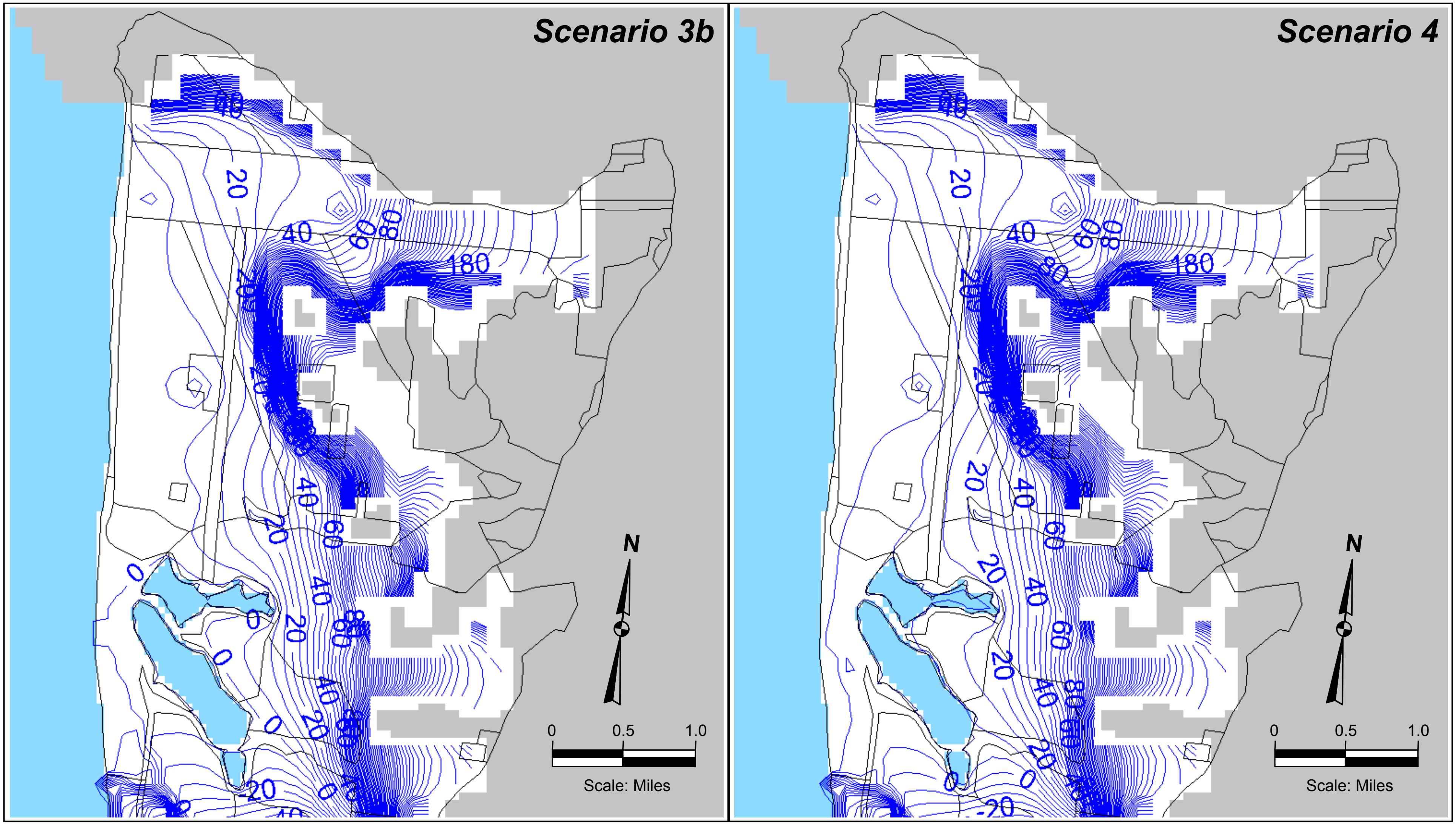
April 2012

Figure 10.3-19



Note: Elevations are in feet NGVD 29. Contour interval is 5 feet.

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Water Table Elevation at End of Scenarios 3b and 4 (Model Layer 1)

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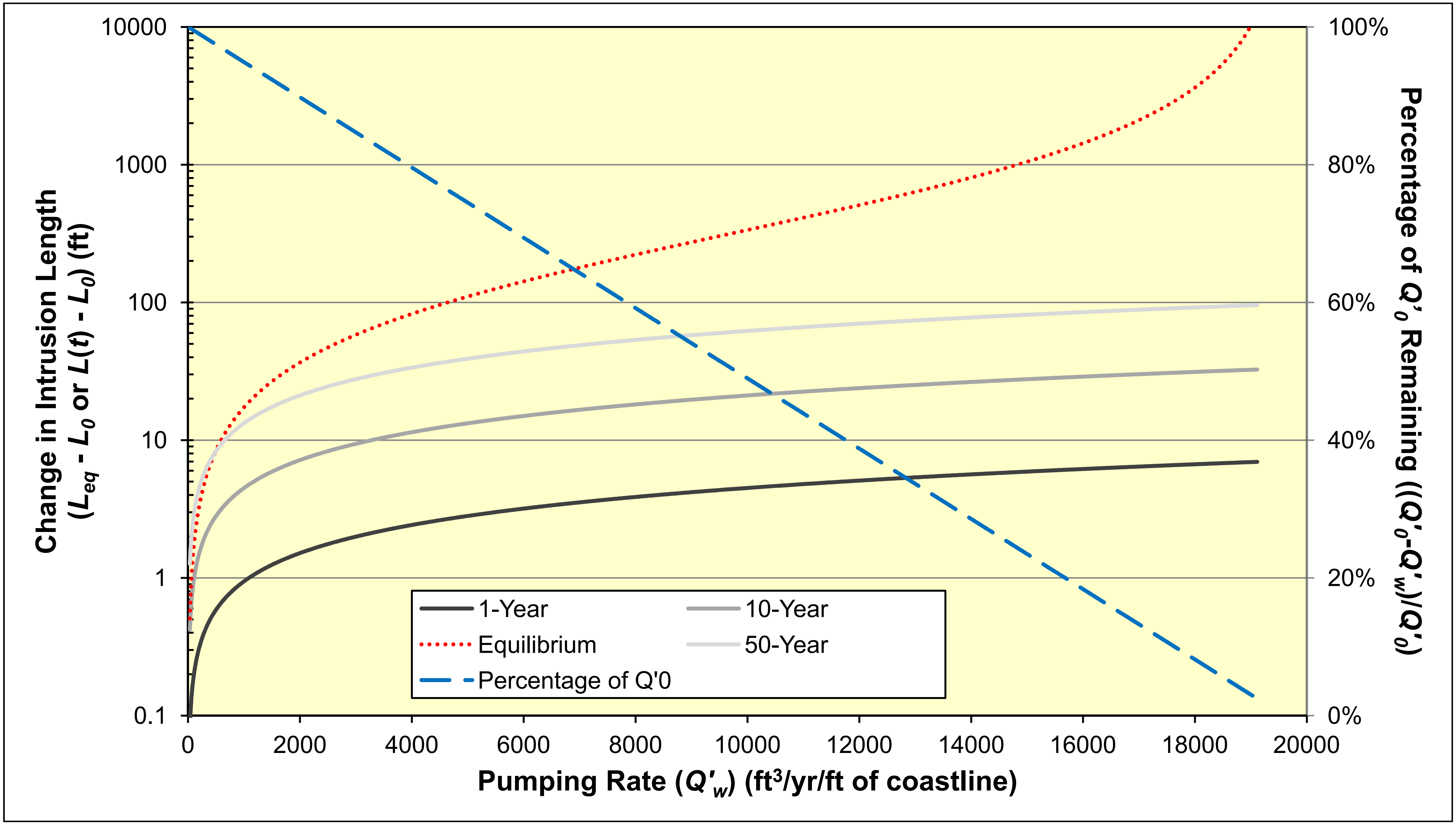
April 2012
Figure 10.3-20



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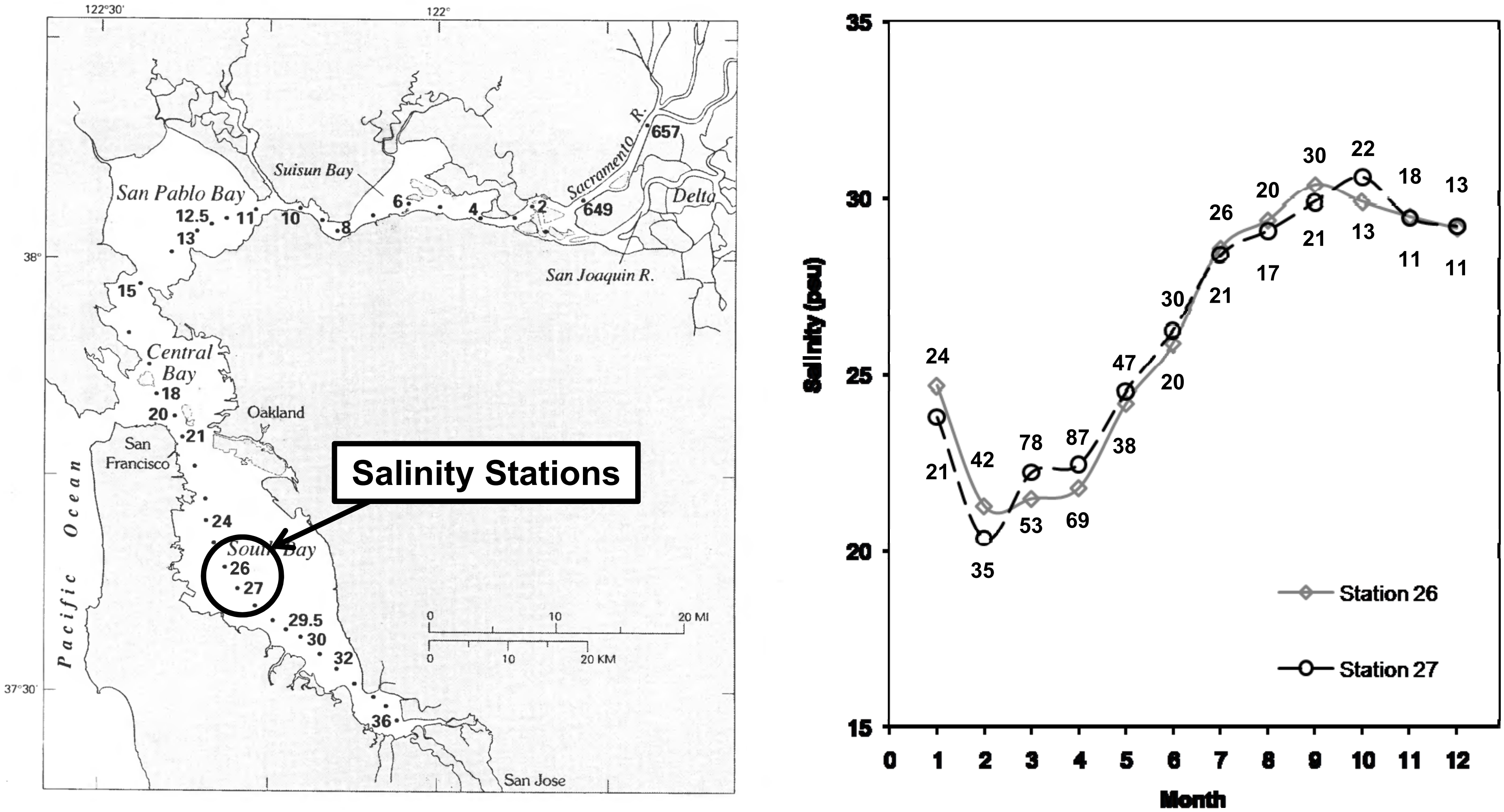
Analytical Model of Rate of Change of Intrusion Length versus Pumping

K/J 0864001
April 2012

Figure 10.3-21



Note: Data from the U.S. Geological Survey; see for example Baylosis et al. (1998). Period of record is 1969 to 1998. Readings are from 1 meter depth. Numbers above the data are the number of records for Station 26, while numbers below the data are the number of records for Station 27. Map is modified from Baylosis et al. (1998).

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San Francisco Public Utilities Commission

Monthly Salinity in the South San Francisco Bay

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April 2012
Figure 10.3-22

Tables

Table 10.3-1: Summary of Model Scenario Pumping Assumptions

Model Scenarios		Scenario 1 Existing Conditions	Scenario 2 GSR	Scenario 3a SFGW	Scenario 3b SFGW	Scenario 4 Cumulative
Establish Initial Conditions		Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence
	June 2009 Condition	√	√	√	√	√
Model Scenario Simulation Period						
	47.25 years (including Design Drought) Hydrologic Sequence: July 1996 to September 2003 -> October 1958 to November 1992 -> December 1975 to June 1978 -> July 2003 - September 2006		√	√	√	√
Pumping Assumptions for Municipal Use						
PA Municipal Wells (mgd)						
	"Take" Periods	6.84	6.90	6.84	6.84	6.90
	"Put" Periods	6.84	1.38	6.84	6.84	1.38
	"Hold" Periods	6.84	6.90	6.84	6.84	6.90
GSR Project Proposed Municipal Wells (mgd)						
	"Take" Periods	0.0	7.23	0.0	0.0	7.23
	"Put" Periods	0.0	0.04	0.0	0.0	0.04
	"Hold" Periods	0.0	0.04	0.0	0.0	0.04
SFGW Project Proposed Municipal Wells (mgd)						
	Year-Round Pumping	0.0	0.0	3.0	4.0	4.0
Total Municipal Pumping (PA + GSR + SFGW)						
	"Take" Periods	***6.84***	***14.13***	***9.84***	***10.84***	***18.13***
	"Put" Periods	***6.84***	***1.42***	***9.84***	***10.84***	***5.42***
	"Hold" Periods	***6.84***	***6.94***	***9.84***	***10.84***	***10.94***
Irrigation and Other Non-Potable Pumping Assumptions (mgd)(1)						
Golden Gate Park	Elk Glen (GGP)	0.081	0.081	0.081	0.000	0.000
	South Windmill (GGP)	0.498	0.498	0.498	0.000	0.000
	North Lake (GGP)	0.563	0.563	0.563	0.000	0.000
	Sub-Total	***1.142***	***1.142***	***1.142***	***0.000***	***0.000***
Golf Courses	Burlingame Golf Club	0.150	0.150	0.150	0.150	0.150
	California Golf No. 02	0.192	0.192	0.192	0.192	0.192
	Green Hills No. 05	0.099	0.099	0.099	0.099	0.099
	Lake Merced Golf No. 01	0.004	0.004	0.004	0.004	0.004
	Lake Merced Golf No. 02	0.004	0.004	0.004	0.004	0.004
	Lake Merced Golf No. 03	0.010	0.010	0.010	0.010	0.010
	Olympic Club No. 09(2)	0.002	0.002	0.002	0.002	0.002
	SF Golf West	0.035	0.035	0.035	0.035	0.035
	Sub-Total	***0.495***	***0.495***	***0.495***	***0.495***	***0.495***
Cemeteries	Cypress Lawn No. 02	0.020	0.020	0.020	0.020	0.020
	Cypress Lawn No. 03	0.144	0.144	0.144	0.144	0.144
	Eternal Home	0.013	0.013	0.013	0.013	0.013
	Hills of Eternity No. 02	0.020	0.020	0.020	0.020	0.020
	Holy Cross No. 03(3)	0.190	0.190	0.190	0.190	0.230
	Home of Peace No. 02	0.039	0.039	0.039	0.039	0.039
	Italian Cemetery	0.033	0.033	0.033	0.033	0.033
	Olivet	0.098	0.098	0.098	0.098	0.098
	Woodlawn No. 02	0.085	0.085	0.085	0.085	0.085
	Sub-Total	***0.641***	***0.641***	***0.641***	***0.641***	***0.681***
Other	Hillsborough Residents No. 1-12	0.291	0.291	0.291	0.291	0.291
	Edgewood Development Ctr.	0.009	0.009	0.009	0.009	0.009
	Zoo No.05	0.321	0.321	0.321	0.321	0.321
	Stern Grove	0.004	0.004	0.012	0.013	0.013
	Sub-Total	***0.626***	***0.626***	***0.634***	***0.635***	***0.635***
Total Irrigation and Other Non-Potable Pumping		***2.90***	***2.90***	***2.91***	***1.77***	***1.81***

Key:
afy - acre-feet per year
mgd - million gallons per day
PA - Partner Agencies
GGP - Golden Gate Park
GSR - Regional Groundwater Storage and Recovery
SFGW - San Francisco Groundwater Supply
SFPUC - San Francisco Public Utilities Commission

Notes:
(1) Pumping wells that are listed identify the wells in the model scenarios whose pumping assumptions were modified compared to the 2008 No-Project Scenario by HydroFocus (May, 2011, ver. 3.1), as a result of revised Soil Moisture Budget (SMB). Pumping rates for the three wells in GGP and the California Golf No. 02, Edgewood Development Center, Zoo No. 05, and Stern Grove wells were further modified compared to the results of revised SMB.
(2) Olympic Club No. 09 values include pumping for both Olympic Golf Club wells.
(3) Holy Cross No. 3 well irrigation pumping for Scenarios 1, 2, 3a, and 3b is based on the results of revised SMB. Based on the projected future build-out at the Holy Cross cemetery, an additional pumping of 0.04 mgd (45 afy) was estimated to occur under Scenario 4 (Cumulative).

Table 10.3-2a: Statistics for Relative Differences Between Model Scenario Groundwater Head and Scenario 1 Head in Model Layer 1

	Scenario	2				3a				3b				4			
	Location	Maximum Difference[a]	Minimum Difference[b]	Avgerage Difference[c]	Average Offset[d]	Maximum Difference	Minimum Difference	Avgerage Difference	Average Offset	Maximum Difference	Minimum Difference	Avgerage Difference	Average Offset	Maximum Difference	Minimum Difference	Avgerage Difference	Average Offset
Pacific Coast	North Windmill	0.1	0.0	0.0	0.0	0.0	-12.4	-10.2	-12.2	0.0	-13.2	-10.5	-12.1	0.0	-13.1	-10.4	-12.0
Pacific Coast	South Windmill	0.1	-0.1	0.1	0.0	0.0	-9.7	-7.9	-9.5	0.3	-11.5	-8.9	-10.1	0.3	-11.4	-8.7	-9.9
Pacific Coast	Kirkham	0.2	-0.1	0.1	0.0	0.0	-6.8	-5.6	-6.6	0.2	-6.9	-5.5	-6.4	0.2	-6.7	-5.3	-6.1
Pacific Coast	Ortega	0.5	-0.2	0.3	0.0	0.0	-6.4	-5.5	-6.3	0.0	-6.1	-5.3	-6.0	0.0	-5.6	-4.7	-5.4
Pacific Coast	West Sunset Playground	1.3	-0.2	0.8	0.5	-4.0	-23.8	-20.9	-23.0	-3.7	-22.4	-19.8	-21.6	-3.7	-20.3	-18.0	-19.4
Pacific Coast	Taraval	0.6	-0.1	0.4	0.2	0.0	-5.2	-4.4	-5.1	0.0	-4.9	-4.2	-4.8	0.0	-4.1	-3.4	-3.8
Pacific Coast	Zoo	2.7	-0.4	1.6	0.9	0.0	-7.2	-5.3	-7.1	0.0	-6.9	-5.1	-6.8	0.0	-3.0	-1.4	-2.3
Pacific Coast	Fort Funston	0.1	-0.1	0.0	0.0	0.0	-0.1	-0.1	-0.1	0.0	-0.1	-0.1	-0.1	0.1	-0.2	0.0	-0.1
Pacific Coast	Thornton Beach	0.5	0.0	0.3	0.3	0.0	-0.3	-0.1	-0.3	0.0	-0.3	-0.1	-0.3	0.2	-1.0	-0.1	-0.6
Bay Coast	Burlingame	1.3	0.0	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.7	0.8
Bay Coast	SFO	3.1	0.0	2.0	2.5	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	3.0	0.0	2.0	2.5
Bay Coast	UAL	2.4	-0.2	1.4	1.0	0.0	-0.1	0.0	0.0	0.0	-0.1	0.0	0.0	2.4	-0.2	1.4	1.0

Notes: (a) Maximum positive difference from Scenario 1. If this value is negative, the head was lower than Scenario 1 at all times.
(b) Maximum negative difference from Scenario 1. If this value is positive, the head was higher than Scenario 1 at all times.
(c) Average difference from Scenario 1.
(d) Average difference from Scenario 1 over Scenario Years 37 to 47.

Table 10.3-2b: Statistics for Relative Differences Between Model Scenario Groundwater Head and Scenario 1 Head in Model Layer 4

	Scenario	2				3a				3b				4			
	Location	Maximum Difference[a]	Minimum Difference[b]	Avgerage Difference[c]	Average Offset[d]	Maximum Difference	Minimum Difference	Avgerage Difference	Average Offset	Maximum Difference	Minimum Difference	Avgerage Difference	Average Offset	Maximum Difference	Minimum Difference	Avgerage Difference	Average Offset
Pacific Coast	North Windmill	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pacific Coast	South Windmill	0.1	-0.1	0.1	0.0	0.0	-7.3	-6.0	-7.1	2.3	-7.7	-5.1	-6.0	2.3	-7.6	-4.9	-5.8
Pacific Coast	Kirkham	0.3	-0.2	0.2	0.0	0.0	-5.5	-4.6	-5.4	0.5	-5.5	-4.3	-5.0	0.5	-5.3	-4.0	-4.7
Pacific Coast	Ortega	0.9	-0.7	0.5	-0.2	0.0	-6.3	-5.3	-6.2	0.0	-6.0	-5.1	-5.9	0.0	-5.8	-4.2	-5.3
Pacific Coast	West Sunset Playground	2.5	-1.6	1.3	-0.2	-0.1	-12.2	-10.2	-11.9	-0.1	-11.7	-9.8	-11.5	-0.1	-10.6	-7.2	-9.3
Pacific Coast	Taraval	3.0	-2.0	1.6	-0.2	-0.1	-12.1	-10.1	-11.9	-0.1	-11.7	-9.7	-11.4	-0.1	-10.4	-6.5	-8.8
Pacific Coast	Zoo	6.1	-4.3	3.3	-0.4	-0.1	-18.9	-15.4	-18.5	-0.1	-18.3	-14.9	-17.9	-0.1	-16.0	-8.5	-12.6
Pacific Coast	Fort Funston	0.6	-0.7	0.2	-0.3	0.0	-0.4	-0.3	-0.4	0.0	-0.4	-0.3	-0.4	0.4	-1.2	-0.2	-0.8
Pacific Coast	Thornton Beach	1.2	-1.4	0.3	-0.7	0.0	-0.3	-0.2	-0.3	0.0	-0.3	-0.2	-0.3	1.0	-2.6	-0.5	-1.8
Bay Coast	Burlingame	2.3	-0.6	1.3	0.7	0.0	-0.1	0.0	0.0	0.0	-0.1	0.0	-0.1	2.2	-0.7	1.2	0.7
Bay Coast	SFO	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bay Coast	UAL	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes: (a) Maximum positive difference from Scenario 1. If this value is negative, the head was lower than Scenario 1 at all times.
(b) Maximum negative difference from Scenario 1. If this value is positive, the head was higher than Scenario 1 at all times.
(c) Average difference from Scenario 1.
(d) Average difference from Scenario 1 over Scenario Years 37 to 47.

Table 10.3-2c: Statistics for Relative Differences Between Model Scenario Groundwater Head and Scenario 1 Head in Model Layer 5

	Scenario	2				3a				3b				4			
	Location	Maximum Difference[a]	Minimum Difference[b]	Avgerage Difference[c]	Average Offset[d]	Maximum Difference	Minimum Difference	Avgerage Difference	Average Offset	Maximum Difference	Minimum Difference	Avgerage Difference	Average Offset	Maximum Difference	Minimum Difference	Avgerage Difference	Average Offset
Pacific Coast	North Windmill	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pacific Coast	South Windmill	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pacific Coast	Kirkham	0.3	-0.2	0.2	-0.1	0.0	-5.0	-4.2	-5.0	0.5	-5.1	-3.9	-4.5	0.5	-4.8	-3.6	-4.3
Pacific Coast	Ortega	1.1	-1.0	0.5	-0.4	0.0	-5.9	-4.9	-5.8	0.0	-5.6	-4.7	-5.5	0.0	-5.6	-3.8	-5.0
Pacific Coast	West Sunset Playground	3.4	-3.6	0.8	-1.7	-0.1	-7.0	-5.9	-6.9	0.0	-6.7	-5.6	-6.6	0.0	-8.5	-3.9	-6.8
Pacific Coast	Taraval	4.6	-5.2	0.8	-2.6	0.0	-5.6	-4.7	-5.5	0.0	-5.4	-4.5	-5.3	1.1	-8.7	-2.6	-6.2
Pacific Coast	Zoo	12.2	-14.4	1.5	-7.5	0.0	-6.4	-5.2	-6.3	0.0	-6.2	-5.0	-6.1	8.5	-16.9	-1.3	-10.3
Pacific Coast	Fort Funston	1.8	-2.2	0.2	-1.2	0.0	-0.4	-0.3	-0.4	0.0	-0.4	-0.3	-0.4	1.6	-2.5	0.0	-1.5
Pacific Coast	Thornton Beach	1.5	-2.0	0.3	-1.0	0.0	-0.3	-0.2	-0.3	0.0	-0.3	-0.2	-0.3	1.4	-3.1	-0.5	-2.1
Bay Coast	Burlingame	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bay Coast	SFO	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bay Coast	UAL	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes: (a) Maximum positive difference from Scenario 1. If this value is negative, the head was lower than Scenario 1 at all times.
(b) Maximum negative difference from Scenario 1. If this value is positive, the head was higher than Scenario 1 at all times.
(c) Average difference from Scenario 1.
(d) Average difference from Scenario 1 over Scenario Years 37 to 47.

Table 10.3-3: Aquifer Thicknesses and Exclusion Head Values at Westside Basin Coastal Monitoring Points

	Well or Cluster	Single Aquifer		Multi-Aquifer					
				Shallow		Primary Production		Deep	
		b [a]	E_h [b]	*b*	E_h	*b+d* [c]	E_h	*b+d*	E_h
Pacific Coast	North Windmill	270	7.0	100	2.6	270	7.0	--	--
	South Windmill	360	9.4	120	3.1	360	9.4	--	--
	Kirkham	450	11.7	110	2.9	310	8.1	450	11.7
	Ortega	490	12.7	100	2.6	340	8.8	490	12.7
	West Sunset Playground	400	10.4	70	1.8	340	8.8	400	10.4
	Taraval	550	14.3	130	3.4	390	10.1	550	14.3
	Zoo	630	16.4	80	2.1	400	10.4	630	16.4
	Fort Funston	1200	31.2	--	--	--	--	--	--
	Thornton Beach	3000	78.0	--	--	--	--	--	--
Bay Coast	Burlingame	308	8.0	--	--	--	--	--	--
	SFO	155	4.0	--	--	--	--	--	--
	UAL	155	4.0	--	--	--	--	--	--

Notes:

(a) *b* = Depth (below sea level) of aquifer bottom (for Single-Aquifer and Shallow Aquifer cases), or aquifer thickness (for Primary Production and Deep Aquifer cases) (see Figure 10.3-3).

(b) *Eh* = Exclusion head, defined in Section 3.5.1.

(c) *d* = Depth (below sea level) of bottom of the confining unit (see Figure 10.3-3).

Table 10.3-4: Seasonal Fluctuation in Head for Model Layers 1, 4, and 5 at the Pacific Ocean and San Francisco Bay Monitoring Network Wells

Scenario	1			2			3a			3b			4		
Model Layer / Location	1	4	5	1	4	5	1	4	5	1	4	5	1	4	5
North Windmill	1.7	--	--	1.7	--	--	1.6	--	--	0.8	--	--	0.8	--	--
South Windmill	0.7	-0.7	--	0.7	-0.7	--	0.6	-0.8	--	0.7	0.3	--	0.7	0.3	--
Kirkham	0.9	0.3	0.3	0.9	0.3	0.3	0.9	0.3	0.2	0.6	0.3	0.2	0.6	0.3	0.2
Ortega	0.6	0.3	0.3	0.6	0.3	0.3	0.6	0.3	0.2	0.6	0.2	0.2	0.6	0.2	0.2
West Sunset Playground	0.7	0.3	0.1	0.7	0.3	0.1	0.5	0.3	0.1	0.5	0.2	0.0	0.5	0.3	0.1
Taraval	0.5	0.4	-0.1	0.5	0.3	-0.1	0.5	0.3	-0.1	0.5	0.3	-0.2	0.5	0.3	-0.2
Zoo	1.3	0.3	-0.5	1.3	0.2	-0.5	1.2	0.1	-0.6	1.2	0.1	-0.6	1.3	0.2	-0.5
Fort Funston	1.3	0.0	0.0	1.3	0.0	0.0	1.3	0.0	0.0	1.3	0.0	0.0	1.3	0.0	0.0
Thornton Beach	0.6	0.0	0.0	0.6	0.0	0.0	0.6	0.0	0.0	0.6	0.0	0.0	0.6	0.0	0.0
Burlingame	0.0	-0.1	--	0.0	-0.1	--	0.0	-0.1	--	0.0	-0.1	--	0.0	-0.1	--
SFO	0.1	--	--	0.1	--	--	0.1	--	--	0.1	--	--	0.1	--	--
UAL	0.0	--	--	0.0	--	--	0.0	--	--	0.0	--	--	0.0	--	--

Note:
Table cells containing "--" indicate that this Model Layer is not present in this location. Seasonal fluctuation is defined as the average difference between May head (generally representing the highest head annually) and November head (generally representing the lowest head annually).

Table 10.3-5: Model-Predicted Flux Through the Pacific Ocean and San Francisco Bay Coasts, Both Absolute and Relative to Scenario 1 (in acre-feet per month)

	Location	Scenario	1	2	3a	3b	4
Absolute	Pacific	AMax[a]	432	435	367	351	352
		AMin[b]	149	146	9	9	15
		AAvg[c]	255	273	75	77	103
	Bay	AMax	108	111	108	108	109
		AMin	82	72	80	80	47
		AAvg	93	96	91	91	80
Relative	Pacific	RMax[d]	--	29	-1	14	14
		RMin[e]	--	-8	-237	-241	-209
		RAvg[f]	--	17	-181	-179	-153
	Bay	RMax	--	8	0	0	4
		RMin	--	-11	-2	-2	-35
		RAvg	--	3	-1	-1	-13

Notes:

(a) Maximum absolute freshwater flux.

(b) Minimum absolute freshwater flux.

(c) Average absolute freshwater flux.

(d) Maximum flux difference from Scenario 1; if this value is negative, flux is always lower than in Scenario 1.

(e) Minimum flux difference from Scenario 1; if this value is positive, flux is always higher than in Scenario 1.

(f) Average flux difference from Scenario 1.

Table 10.3-6a: Percentage of Simulation Duration Below the Freshwater Exclusion Head (Model Layer 1)

Single-Aquifer Case						
	Location	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4
Pacific Coast	North Windmill	0%	0%	**57%**	**60%**	**59%**
	South Windmill	**33%**	**31%**	**95%**	**98%**	**98%**
	Kirkham	100%	100%	100%	100%	100%
	Ortega	100%	100%	100%	100%	100%
	West Sunset Playground	0%	0%	**99%**	**99%**	**99%**
	Taraval	100%	100%	100%	100%	100%
	Zoo	100%	100%	100%	100%	100%
	Fort Funston	100%	100%	100%	100%	100%
	Thornton Beach	**63%**	**61%**	**64%**	**64%**	**64%**
Bay Coast	Burlingame	100%	100%	100%	100%	100%
	SFO	100%	100%	100%	100%	100%
	UAL	**10%**	**7%**	**11%**	**11%**	**7%**

Shallow Aquifer						
	Location	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4
Pacific Coast	North Windmill	0%	0%	**5%**	**4%**	**4%**
	South Windmill	0%	0%	**73%**	**85%**	**83%**
	Kirkham	0%	0%	**77%**	**75%**	**66%**
	Ortega	0%	0%	**89%**	**89%**	**83%**
	West Sunset Playground	0%	0%	**90%**	**90%**	**85%**
	Taraval	0%	0%	**91%**	**91%**	**86%**
	Zoo	0%	0%	**35%**	**30%**	**0%**
	Fort Funston	--	--	--	--	--
	Thornton Beach	--	--	--	--	--
Bay Coast	Burlingame	--	--	--	--	--
	SFO	--	--	--	--	--
	UAL	--	--	--	--	--

Notes:

(1) Percentage represents the percentage of timesteps (i.e. months) with head below the exclusion head (see Section 3.5.1).

(2) -- = Model Layer is not present at this location.

Table 10.3-6b: Percentage of Simulation Duration Below the Freshwater Exclusion Head (Model Layer 4)

	Single-Aquifer Case					
	Location	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4
Pacific Coast	North Windmill	--	--	--	--	--
	South Windmill	**99%**	**99%**	100%	100%	100%
	Kirkham	100%	100%	100%	100%	100%
	Ortega	100%	100%	100%	100%	100%
	West Sunset Playground	100%	100%	100%	100%	100%
	Taraval	100%	100%	100%	100%	100%
	Zoo	100%	100%	100%	100%	100%
	Fort Funston	100%	100%	100%	100%	100%
	Thornton Beach	100%	100%	100%	100%	100%
Bay Coast	Burlingame	100%	100%	100%	100%	100%
	SFO	--	--	--	--	--
	UAL	--	--	--	--	--

	Primary Production Aquifer					
	Location	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4
Pacific Coast	North Windmill	--	--	--	--	--
	South Windmill	**99%**	**99%**	100%	100%	100%
	Kirkham	100%	100%	100%	100%	100%
	Ortega	100%	100%	100%	100%	100%
	West Sunset Playground	100%	100%	100%	100%	100%
	Taraval	100%	100%	100%	100%	100%
	Zoo	100%	100%	100%	100%	100%
	Fort Funston	--	--	--	--	--
	Thornton Beach	--	--	--	--	--
Bay Coast	Burlingame	--	--	--	--	--
	SFO	--	--	--	--	--
	UAL	--	--	--	--	--

Notes:

(1) Percentage represents the percentage of timesteps (i.e. months) with head below the exclusion head (see Section 3.5.1).

(2) -- = Model Layer is not present at this location.

Table 10.3-6c: Percentage of Simulation Duration Below the Freshwater Exclusion Head (Model Layer 5)

Single-Aquifer Case						
	Location	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4
Pacific Coast	North Windmill	--	--	--	--	--
	South Windmill	--	--	--	--	--
	Kirkham	100%	100%	100%	100%	100%
	Ortega	100%	100%	100%	100%	100%
	West Sunset Playground	100%	100%	100%	100%	100%
	Taraval	100%	100%	100%	100%	100%
	Zoo	100%	100%	100%	100%	100%
	Fort Funston	100%	100%	100%	100%	100%
	Thornton Beach	100%	100%	100%	100%	100%
Bay Coast	Burlingame	--	--	--	--	--
	SFO	--	--	--	--	--
	UAL	--	--	--	--	--

Deep Aquifer						
	Location	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4
Pacific Coast	North Windmill	--	--	--	--	--
	South Windmill	--	--	--	--	--
	Kirkham	100%	100%	100%	100%	100%
	Ortega	100%	100%	100%	100%	100%
	West Sunset Playground	100%	100%	100%	100%	100%
	Taraval	100%	100%	100%	100%	100%
	Zoo	100%	100%	100%	100%	100%
	Fort Funston	--	--	--	--	--
	Thornton Beach	--	--	--	--	--
Bay Coast	Burlingame	--	--	--	--	--
	SFO	--	--	--	--	--
	UAL	--	--	--	--	--

Notes:

(1) Percentage represents the percentage of timesteps (i.e. months) with head below the exclusion head (see Section 3.5.1).

(2) -- = Model Layer is not present at this location.

Table 10.3-7: Descriptions, Values, and Sources for Parameters Used in Analytical Rate Estimation Model (see Section 7.1)

Parameter	Type	Description	Value	Units	Source
b_u	parameter	Thickness of the unconfined aquifer below sea level	360	feet	LSCE, 2010
b_c	parameter	Thickness of the confined aquifer	240	feet	LSCE, 2010
d	parameter	Depth to the top of the confined aquifer below sea level	120	feet	LSCE, 2010
n_e	parameter	Effective (or available) porosity	0.2	--	CH2MHILL, 1995
x	variable	Horizontal location within the aquifer	--	feet	--
h_f	calculated	Freshwater head above sea level at location x	--	feet	--
K_h	parameter	Horizontal hydraulic conductivity of the aquifer	3652.5	ft/yr	CH2MHILL, 1995
ρ_f	constant	Density of fresh water	1	g/cm^3	Standard
ρ_s	constant	Density of salt water	1.026	g/cm^3	Standard
α	constant	Elasticity of the aquifer materials	1.00E-08	Pa^{-1}	Freeze and Cherry, 1979
β	constant	Compressibility of water	4.40E-10	Pa^{-1}	Freeze and Cherry, 1979
S_s	parameter	Specific storage of the confined aquifer	0.00002	ft^{-1}	Yates et al., 1990
Q'_0	parameter	Freshwater flux to the ocean per foot of shoreline prior to pumping	19600	ft^3/yr/ft of coastline	Yates et al., 1990
Q'_w	input	Rate of pumping per foot of shoreline	--	ft^3/yr/ft of coastline	--
Δt	input	Time period over which pumping is applied	--	years	--
z	calculated	Depth to saltwater interface below sea level	--	feet	--
L	calculated	Length from the discharge point to the toe of the wedge	--	feet	--

Table 10.3-8: Average Water Quality for Westside Basin Monitoring Wells

	Calcium	n	Magnesium	n	Sodium	n	Potassium	n	Total Alkalinity	n	Chloride	n	Sulfate	n	Specific Conductance	n	Total Dissolved Solids	n	Hardness as $CaCO_3$	n	pH	n
North Westside Basin																						
Kirkham MW-130	28.5	3	25.8	3	26.3	3	1.5	3	123	3	33.3	13	33.5	3	447	14	258	14	172	4	8.0	4
Kirkham MW-255	28.1	3	30.3	3	22.4	3	1.4	3	133	3	36.3	13	30.0	3	460	14	274	14	196	4	7.9	4
Kirkham MW-385	56.1	3	7.4	3	25.8	3	4.9	3	119	3	34.6	13	64.2	3	455	14	285	14	166	4	8.1	4
Kirkham MW-435	46.9	3	4.0	3	35.2	3	7.4	3	113	3	31.2	13	60.3	3	445	14	277	14	132	4	8.2	4
Ortega MW-125	26.8	3	22.1	3	26.3	3	1.3	3	106	3	30.8	14	36.3	2	436	14	257	13	147	4	7.9	4
Ortega MW-265	14.4	3	12.4	3	20.9	3	1.0	3	81	2	26.1	14	12.2	2	353	13	210	12	86	3	8.1	3
Ortega MW-400	16.2	3	12.7	3	22.7	3	1.4	3	90	2	23.0	14	10.7	3	274	14	178	14	92	3	8.2	3
Ortega MW-475	13.3	3	1.9	3	43.2	3	3.1	3	78	3	28.9	14	14.1	3	285	14	173	14	42	4	8.3	4
Taraval MW-145	29.4	3	25.8	3	29.6	3	1.8	3	132	2	36.6	13	24.4	3	483	14	296	14	171	3	7.9	3
Taraval MW-240	21.8	3	20.1	3	23.1	3	1.7	3	104	2	34.2	14	18.9	3	376	14	228	14	137	3	7.8	3
Taraval MW-400	18.4	3	15.4	3	21.9	3	1.6	3	90	2	27.2	14	26.3	2	308	14	189	12	116	3	8.2	3
Taraval MW-530	11.7	2	5.4	2	51.1	2	2.4	2	120	2	24.6	14	8.8	2	326	14	199	14	56	3	8.4	3
Zoo MW-275	20.4	5	18.7	4	37.3	4	4.4	5	115	4	67.0	12	7.3	4	466	14	264	13	116	5	8.6	5
Zoo MW-450	22.5	5	25.4	5	41.7	5	2.6	5	134	4	43.8	12	18.8	5	483	14	287	14	142	5	8.4	5
Zoo MW-565	27.6	4	10.2	4	67.5	4	3.4	4	167	3	53.2	13	7.3	3	503	13	293	13	103	4	8.3	4
SWM MW-57	--	0	--	0	--	0	--	0	--	0	160.1	8	53.0	1	1191	8	667	7	--	0	--	0
SWM MW-140	--	0	--	0	--	0	--	0	--	0	60.8	8	39.0	1	675	8	381	7	--	0	--	0
Edgewood School	24.7	2	25.3	2	25.2	3	1.4	2	116	4	30.5	4	35.9	4	448	4	258	3	170	4	7.4	4
Elk Glen 2	34.6	5	37.1	5	27.1	5	1.0	4	142	5	40.2	6	52.4	6	575	6	367	6	227	6	7.7	6
LMMW1S	60.4	4	90.4	4	102.1	4	2.8	4	317	4	252.5	4	108.3	4	1545	4	853	4	568	4	6.8	4
LMMW1D	30.0	2	45.0	2	47.5	2	3.2	2	161	2	105.0	2	27.5	2	781	2	435	2	265	2	7.9	2
LMMW-2S	40.0	4	32.7	4	59.5	4	2.9	4	214	4	95.0	4	30.5	4	777	4	417	4	260	4	7.5	4
LMMW-2D	41.1	4	33.6	4	58.9	4	3.2	4	222	4	95.3	4	30.4	4	790	4	432	4	258	4	7.5	4
LMMW3S	45.5	11	50.6	10	46.1	11	1.8	10	310	10	51.9	10	28.5	10	786	10	453	10	287	9	7.2	10
LMMW3D	29.8	11	32.1	11	42.0	11	1.9	10	180	10	76.5	11	13.3	11	600	11	339	11	204	10	7.6	11
LMMW4SS	37.1	2	41.5	2	33.0	2	1.7	2	194	1	55.5	1	44.5	1	624	1	464	1	244	1	7.3	1
LMMW6D	27.8	11	28.4	10	36.9	11	1.4	10	127	10	52.7	11	32.5	11	556	11	334	11	186	10	8.0	11
LMMW7SS	43.2	3	44.4	3	55.6	3	1.4	3	240	2	44.4	2	46.4	2	753	2	476	2	271	2	7.6	2
(NE) Windmill	28.6	1	36.2	1	30.6	1	1.7	1	174	2	48.0	2	36.0	2	575	2	269	2	221	2	7.5	2
New GG Park (N) Lake	26.0	4	31.6	4	27.8	4	1.1	4	143	4	42.7	4	27.5	4	505	4	304	4	193	4	7.6	4
New GG Park (S) Windmi	29.5	4	35.8	4	28.0	4	1.5	4	149	5	42.8	4	43.7	3	562	4	340	4	234	4	7.9	4
(NW) Windmill	20.0	1	24.3	1	24.6	1	1.3	1	140	3	42.7	3	20.0	3	467	3	173	2	174	3	7.8	3
Olympic Club #8	38.5	1	39.7	1	46.0	1	2.0	1	189	1	84.0	1	30.5	1	685	1	--	0	--	0	8.1	1
Pine Lake Prod Well	32.7	1	33.4	1	36.4	1	1.1	1	144	1	35.3	1	37.0	1	565	1	336	1	244	1	7.2	1
(S) Windmill	26.5	3	29.1	3	26.1	3	1.4	3	133	4	40.3	5	26.7	5	476	5	262	4	185	5	7.7	5
West Sunset Playground	17.5	9	18.1	9	23.0	9	1.0	9	88	8	28.1	9	28.7	9	353	9	222	9	124	9	8.5	9
(S) Sunset Playground	30.2	3	32.6	3	36.8	3	1.3	3	159	2	41.7	3	33.0	3	573	3	366	3	205	3	7.4	3
CPS MW-190	44.2	3	44.7	3	44.4	3	1.5	3	267	3	42.3	3	44.0	3	725	3	413	3	295	3	7.6	3
CPS MW-270	29.9	3	23.0	3	46.0	3	1.5	3	171	3	70.3	3	9.7	3	552	3	297	3	168	3	7.9	3
LMPS MW-155	26.7	4	25.0	4	36.5	3	2.2	4	106	4	38.6	3	45.7	3	492	2	317	4	175	3	7.7	4
LMPS MW-270	24.2	4	17.6	4	55.9	4	1.5	4	127	4	43.7	3	34.7	3	522	3	323	4	134	4	7.8	3
LMPS MW-440	19.3	4	21.2	4	30.8	4	1.3	4	109	4	50.3	3	8.0	3	412	3	247	4	135	4	8.2	4
South Westside Basin																						
Burlingame-S	49.5	9	33.3	9	423	9	5.0	9	240	9	342	9	448	9	2,401	8	1,393	9	--	0	7.3	8
Burlingame-M	31.4	9	19.0	9	69.7	9	3.1	9	181	9	82.3	9	61.9	9	656	8	464	9	--	0	7.2	8
Burlingame-D	35.6	9	20.9	9	83.2	9	4.6	9	206	9	64.1	9	43.3	9	596	8	402	9	--	0	7.3	8
SFO-D	55.0	9	34.3	9	179	8	9.2	9	234	9	609	9	76.4	9	2,036	9	1,202	9	--	0	7.5	8
SFO-S	423.7	9	519.7	9	4,689	9	66.9	9	610	9	9,910	9	802	9	30,757	7	16,300	8	--	0	7.3	9

Notes:

(1) Data from SFPUC 2010 Annual Groundwater Monitoring Report (SFPUC, 2011). Data marked "anomalous or questionable result" were removed from these averages.

(2) n is the number of samples included in the average.

(3) All analytes except Specific Conductance and pH are reported in units of milligrams per liter; Specific Conductance is reported in micromhos per centimeter, while pH is reported in pH units.

Attachment A

Analytical Approach

Attachment A: Analytical Approach

A. Analytical Approach

Because the numerical groundwater model is not perfectly suited to simulating the occurrence of seawater intrusion, an analytical approach to the problem of seawater intrusion is also applied in this section. This method combines a physical treatment of the relation between freshwater head and the depth to the seawater interface with a Darcy's Law approach to relating freshwater flux to the location of the interface. This approach does not explicitly deal with the problem of the transition zone (i.e., it assumes a sharp interface). It should be noted that the analytical solutions presented here deal with simplified aquifer constructions, and are not meant to exactly model reality, but rather provide another useful estimate of the future occurrence of seawater intrusion under a variety of conditions.

A.1. Ghyben-Herzberg Relation

The analytical solution to seawater intrusion was first developed in the late nineteenth (Badon-Ghyben, 1888) and early twentieth (Herzberg, 1901) centuries. Independently of each other, these two investigators found that the seawater-freshwater interface in coastal aquifers occurs at a depth below sea level about 38 times the freshwater head at a given location (Cheng and Ouazar, 1999). This is due to the difference in densities between seawater and freshwater.

Assuming that the seawater and freshwater zones are in approximate hydrostatic equilibrium, the pressure in each zone is defined based on the head in the aquifer:

$$p_s = zg\rho_s$$

$$p_f = g\rho_f \left(z + h_f\right)$$

where p_s is the pressure on the seawater side of the interface, z is the depth (below msl) to the interface, g is the acceleration due to gravity, ρ_s is the density of seawater, p_f is the pressure on the freshwater side of the interface, ρ_f is the density of freshwater, and h_f is the water table elevation (height above msl). Because the pressure must be the same on both sides of this interface, these two equations can be related:

$$zg\rho_s = g\rho_f \left(z + h_f\right)$$

$$z = \frac{\rho_f}{\rho_s - \rho_f} h_f$$

With standard values of density for freshwater (1.0 g/cm^3) and seawater (1.026 g/cm^3), this equates to:

$$z = 38h_f$$

With this proportionality in mind, a schematic of a simplified aquifer can be constructed (Figure 10.3-3). The shape of the head profile in this schematic is dictated by the flux through the aquifer and the hydraulic conductivity (see Section A.3.4); the seawater-freshwater interface and the freshwater head gradient both steepen approaching the discharge point because the freshwater flux (which is assumed to be equal at all horizontal locations up to the discharge point) must pass through a progressively smaller thickness of freshwater aquifer. According to Darcy's law (see Section A.3.4), the flux is proportional to the product of the aquifer thickness and the head gradient, so as the freshwater aquifer thickness declines the head gradient must increase to compensate.

For this simplified treatment of a coastal aquifer, a number of assumptions are made:

- Flow is steady, i.e., flow does not change over time.
- The interface between the seawater and freshwater sections of the aquifer is sharp, i.e., there is no transition zone.
- The seawater portion of the aquifer is under hydrostatic conditions, i.e., there is no flow within this section of the aquifer.
- Flow in the freshwater aquifer is essentially horizontal, which amounts to the Dupuit-Forchheimer assumption in an unconfined aquifer.
- The aquifer top (where applicable) and base (whether a fine-grained layer or the bedrock surface) are horizontal.

The first assumption listed, that of steady flow, runs counter to the purpose of this TM, i.e., determining how changes in the flow regime will affect seawater intrusion. However, considering the timescales involved in seawater intrusion, the assumption of steady flow is safe for a screening-level analysis.

A.2. Upconing of the Seawater-Freshwater Interface

While the Ghyben-Herzberg relationship can predict the depth to the interface between freshwater and salt water in the aquifer away from active wells, in the vicinity of these wells the relationship does not hold. If a well is screened over only a portion of the aquifer, the reduced pressure around the screen leads to upward movement of groundwater below the well. The Ghyben-Herzberg relationship assumes horizontal flow, while, with a well that is not screened across the entire aquifer thickness, a significant component of vertical flow exists in the vicinity of the well. If a seawater-freshwater interface exists below the well, the upward movement of groundwater deflects this interface upward, a process called "upconing."

Bouwer (1978) developed a solution to the location of the interface below a well when upconing is occurring. This method starts with the results of the Ghyben-Herzberg solution (i.e., the depth to the interface at the well location), and modifies them slightly to determine the extent of upconing:

$$Z = \frac{\rho_f}{\rho_s - \rho_f} \frac{Q}{2\pi K z_i}$$

where Z is the height of the cone beneath the center of the well (measured from the location of the interface determined by the Ghyben-Herzberg relationship), Q is the discharge in the well, K is the horizontal hydraulic conductivity, and z_i is the depth of the Ghyben-Herzberg interface below the bottom of the well.

Attachment A: Analytical Approach

A.3. Key Data Sets

The specifics of the analytical method are described in Section A.4 below. For the solutions provided below, the pertinent data are the freshwater head, the flux of freshwater into the ocean, the horizontal hydraulic conductivity of the aquifer, the thickness of the aquifer, and the location of the discharge of freshwater into the ocean. Most of these numbers can be derived directly from the numerical groundwater model, but the purpose of this section is to provide an analysis of the issue of seawater intrusion that is as independent of the numerical model as possible. Therefore, values for these variables and parameters will be based on independent estimates from previously published reports or actual field observations. The numerical model will be used to provide values of freshwater head under the various model scenarios, as the effects of the changes in the pumping regime have not been independently quantified.

A.3.1. Freshwater Head

The freshwater head in the aquifer is determined based on field measurements of depth to groundwater in the various monitoring wells present throughout the Basin. These measurements are not a perfect method for determining the head in the aquifer for several reasons. For this analysis, horizontal flow is assumed, meaning that there is no vertical head gradient within the aquifer. In any column of an actual aquifer, the head is not the same everywhere, and the wells in the monitoring network sample across a fairly tightly constrained thickness of the aquifer. Head can also vary significantly between layers in a stacked aquifer structure such as that present in the Westside Basin, although the monitoring well network was constructed carefully to not sample multiple layers. The monitor well network also does not sample all horizontal locations in the aquifer. The monitor well is a discrete point within a continuous and extensive aquifer, and the data measured within a network of monitor wells must not be considered to capture all variability within the aquifer.

With these caveats in mind, head must be defined for this analysis based on actual measurements from the existing monitoring well network, the details of which are summarized in Section 2.2.2 above. Head has been measured in the North Westside Basin since 2002 for the Zoo cluster, 2003 for the Thornton Beach cluster, 2004 for the Kirkham, Ortega, and Taraval clusters, and 2006 for the South Windmill cluster. Hydrographs for these wells are presented in the annual groundwater monitoring reports for the Westside Basin (i.e., SFPUC, 2011). These hydrographs, along with head values measured at some wells further inland (e.g., the West Sunset Playground well), are used to assess current conditions according to the analytical method.

In addition to the current conditions, future conditions will be assessed. To do so, head levels predicted by the numerical model will be considered in relation to the freshwater head needed at each monitoring location to prevent seawater intrusion to occur at that point.

A.3.2. Horizontal Hydraulic Conductivity

Horizontal hydraulic conductivity (K_h) is an empirical proportionality constant that dictates the degree to which an aquifer allows water to pass through it. This parameter is not easily predicted based solely on the physical properties of the aquifer, although numerous hydrologic textbooks provide ranges of values for typical rocks and unconsolidated deposits (i.e., Freeze and Cherry, 1979, p.29). Instead, K_h is usually determined at individual wells using aquifer tests, calculated based on established time-drawdown relationships. These tests have been performed at a number of locations in the Basin in the past, and this section summarizes those published values.

In the North Westside Basin, K_h values were collected from various references by Phillips et al. (1993). These values, measured mostly in Golden Gate Park or along the Pacific coast between Golden Gate Park and Lake Merced, varied from 5 to 31 ft/d, with an average value of 17.3 ft/d, an arithmetic mean of 16.5 ft/d, and a geometric mean of 15.4 ft/d.

CH2M HILL (1995) performed a seawater intrusion model analysis on the North Westside Basin. K_h was determined for three model layers, roughly corresponding (from lowest to highest) with the Merced Formation, the Colma Formation, and the surficial dune sands (plus unconfined portions of the Colma Formation). While initial estimates were based on the values presented in Phillips et al. (1993), calibration of the model resulted in values of K_h of 10 ft/d for the upper two layers and 8 ft/d for the lowest layer. While these calibrated values are useful for giving additional insight into the likeliness of values within the existing range, they cannot be considered to be exact, due to the non-uniqueness inherent in a numerical solution within a complex model domain.

LSCE (2005) presented the results of an aquifer test performed at the South Sunset Playground well. The constant-rate test was run for 4.6 days at an average discharge rate of 409 gallons per minute. Using the Cooper-Jacob method, the aquifer transmissivity was determined to be about 27,100 gallons per day per foot (gpd/ft). No aquifer thickness is reported, so K_h cannot be calculated (transmissivity, T, is equal to the product of K_h and the aquifer thickness, B).

Rather than choose a single value of K_h for the Pacific Coast, a range of values (5 to 31 ft/d) will be used. The part of the analytical method that uses values of K_h (see Section A.6) was not performed for the Bay Coast due to the lack of an independent estimate for freshwater flux (see Section A.3.4).

A.3.3. Aquifer Thickness

The aquifer thickness is likely the most likely parameter to determine accurately. The aquifer materials are well-defined at the individual well locations and can be interpolated in between. The movement of a seawater-freshwater interface through a real aquifer happens in a very complex manner, due to the heterogeneity of the aquifer.

Seawater tends to intrude along the base of an aquifer, atop a relatively impermeable layer (Figure 10.3-3). In a complex aquifer, with multiple low-permeability lenses, the seawater may intrude at multiple levels, depending on the continuity of these lenses; for a seawater intrusion front to intrude along a low-permeability lens surrounded on both top and bottom by higher-permeability aquifer layers, that lens must stretch continuously into the saline portion of the aquifer (i.e., Figure 5.2 in Bear, 1999). Until the intrusion front comes on-land, the area where it resides (i.e., offshore) is very poorly understood because no sediment profiles have been constructed beneath the Ocean or the Bay. Low-permeability layers that are very extensive onshore may be assumed to be continuous to the ocean floor, but this is unsure.

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According to the cross-sections presented in LSCE (2010), all of the clay layers are discontinuous in the North Westside Basin (i.e., Figure 8 in Appendix A of LSCE, 2010). In the northernmost two cross-sections perpendicular to the coast (J-J' and Z-Z'), clay layers are either specifically discontinuous (i.e., J-J') or thin enough that they are unlikely to be continuous from the Great Highway a significant distance offshore. The southernmost cross-section north of Lake Merced (Y-Y') does have a thick, seemingly continuous clay layer present between the Shallow and Primary Production Aquifers, as well as a series of clay layers between the Primary Production and Deep Aquifers, so the analysis may have to consider the aquifer in three sections in this southern area. For completeness, both a sectioned aquifer and a non-sectioned aquifer will be considered. At the coast, the aquifer thickness varies from 450 ft at Golden Gate Park to 510 ft at the Ortega cluster to 630 ft at the Zoo cluster. If the area of the Zoo cluster is partitioned into three aquifers, their thicknesses are approximately 60, 290, and 120 ft (Shallow, Primary Production, and Deep Aquifers, respectively).

The same cross-sections do not extend all the way into the Bay (LSCE, 2010). However, the two southernmost cross-sections perpendicular to the Bay (N-N' and O-O') indicate that most or all of the subsurface sediments are made up of fine-grained sediments from at least the Bay Plain into the San Francisco Bay. Again, as with the North Westside Basin, there are no sediment profiles beneath the Bay itself, but it is safe to assume that the deposits in this area are continuous. Because the cross-sections do not stretch offshore, the aquifer thicknesses given here are measured at South Airport Boulevard. At cross-section N-N', the aquifer thickness is about 170 ft, while the thickness at cross-section O-O' is about 130 ft.

A.3.4. Freshwater Flux

The flux of freshwater toward the Ocean (or Bay) is important for keeping the seawater-freshwater interface offshore. Unlike the groundwater head elevation, this flux is not monitored directly anywhere in the Basin. Few estimates have been made of the flux. Yates et al. (1990) used a water budget calculation for 1988 to determine that a total of 0.45 acre-feet (af) (19,600 cubic feet) of outflow occurred per foot of coastline in the Golden Gate Park area, while about 640 af of freshwater flowed into the Ocean in the Lake Merced area. Outflows have not previously been estimated for the coastline between these two areas. Outflows have also not been independently estimated for the Bay Coast.

Flux can also be calculated based on Darcy's Law, which is an empirical relationship between the head gradient in an aquifer and the flux through it:

$$Q' = -KBi$$

where Q' is the flux through the aquifer [L^3/T], K is the hydraulic conductivity [L/T], B is the aquifer thickness [L], and i is the head gradient [L/L]. The values of K and B are discussed in Sections A.3.2 and A.3.3 above. Values of i can be determined based on values of head (see Section A.3.1).

A.4. Seawater Wedge Toe Location Methodology

An analytical solution can be created for the location of the toe of the seawater intrusion wedge under both unconfined and confined conditions using a combination of the Ghyben-Herzberg solution and Darcy's Law. This analytical solution has previously been developed in various sources, for example Bear (1972) and Strack (1976).

A.4.1. Unconfined Solution

A schematic of seawater intrusion into an unconfined aquifer is shown in Figure 10.3-3a. At any location within the freshwater aquifer, Darcy's Law can be used to relate the head gradient to the flux through the aquifer. To do this, the basic version of Darcy's Law presented in Section A.3.4 is modified by replacing the aquifer thickness (*B* in the above equation) with the thickness of freshwater above the seawater wedge in the interface area and expressing the head gradient in terms of the change in freshwater head over distance:

$$Q' = -K\left(z + h_f\right)\frac{dh_f}{dx}$$

where *Q'* is the freshwater flux through the aquifer and *x* is measured as the distance seaward from the toe of the seawater wedge (*x* = 0). The Ghyben-Herzberg solution relates *z* to h_f using the relationship between ρ_s and ρ_f, and can be used to remove *z* from this equation:

$$Q' = -Kh_f\left(\frac{\rho_s}{\rho_s - \rho_f}\right)\frac{dh_f}{dx}$$

which can be rearranged to:

$$Q' = -\frac{K}{2}\left(\frac{\rho_s}{\rho_s - \rho_f}\right)\frac{dh_f^2}{dx}$$

This equation can be solved by integrating over *x* (and rearranged):

$$\frac{\rho_s - \rho_f}{\rho_s}\frac{2Q'x}{K} = -h_f^2 + const$$

The constant in this equation is the freshwater head at *x* = 0, the location of the toe of the wedge:

$$\frac{\rho_s - \rho_f}{\rho_s}\frac{2Q'x}{K} = h_f^2\Big|_{x=0} - h_f^2$$

Evaluated at *x* = *L*, the assumed location of freshwater discharge (and the point where the freshwater head (h_f) and aquifer thickness diminish to zero), the equation becomes:

$$h_f^2\Big|_{x=0} = \frac{\rho_s - \rho_f}{\rho_s}\frac{2Q'L}{K}$$

The Ghyben-Herzberg solution also contains a relationship for the value of h_f at *x* = 0 (because at this point the value of *z* is by definition to the aquifer thickness, as thickness of the seawater

Attachment A: Analytical Approach

wedge in the freshwater aquifer is equal to zero), which can then replace the left-hand side of the equation:

$$h_f^2\Big|_{x=0} = \left(\frac{\rho_s - \rho_f}{\rho_f}\right)^2 b^2$$

$$\left(\frac{\rho_s - \rho_f}{\rho_f}\right)^2 b^2 = \frac{\rho_s - \rho_f}{\rho_s}\frac{2Q'L}{K}$$

where *b* is the thickness of the aquifer lying below sea level (note the difference from the entire aquifer thickness, *B*, introduced above; $b = B - h_f$). Finally, this equation can be rearranged to solve for *L* as a function of *Q'*:

$$L = \frac{\rho_s}{\rho_f}\frac{\rho_s - \rho_f}{\rho_f} b^2 \frac{K}{2Q'}$$

It should be noted that this solution does not depend on the freshwater head, except as its gradient affects the value of *Q'*. The values of ρ_s and ρ_f are constant, so applying this simplified solution requires knowledge of *K* (Section A.3.2), *b* (Section A.3.3), and *Q'* (Section A.3.4).

A.4.2. Confined Solution

A schematic for seawater intrusion in a confined aquifer is given in Figure 10.3-3b. In terms of the parameters involved in the analytical solution, the difference between the two aquifer constructions is that the thickness of the confined aquifer changes only due to the shape of the seawater wedge at the base of the aquifer, whereas the thickness of the unconfined aquifer also changes due to the changing water table surface. Because the entire thickness of the aquifer is, by definition, at or below the elevation of the assumed discharge point of the aquifer, *b* in the following equation is equal to *B* in Section A.3.3.

The Darcy's Law application for a confined aquifer is given by the equation:

$$Q' = -K(z - d)\frac{dh_f}{dx}$$

where d is the depth from msl to the top of the aquifer. The Ghyben-Herzberg solution can then be used to replace the value of *z*:

$$Q' = -K\left(\frac{\rho_f}{\rho_s - \rho_f} h_f - d\right)\frac{dh_f}{dx}$$

This equation can then be integrated over *x*:

$$Q'x = -K\left(\frac{\rho_f}{\rho_s - \rho_f}\frac{h_f^2}{2} - h_f d\right) + const$$

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Again, this constant is defined by solving for the value of h_f at $x = 0$:

$$Q'x = K\frac{\rho_f}{\rho_s - \rho_f}\frac{h_f^2\big|_{x=0} - h_f^2}{2} - Kd\left(h_f\big|_{x=0} - h_f\right)$$

Solving at $x = L$:

$$Q'L = K\frac{\rho_f}{\rho_s - \rho_f}\frac{h_f^2\big|_{x=0} - h_f^2\big|_{x=L}}{2} - Kd\left(h_f\big|_{x=0} - h_f\big|_{x=L}\right)$$

The Ghyben-Herzberg solution equates the freshwater head with the various vertical aquifer parameters. This changes depending on location. At $x = 0$, the location of the toe of the wedge, the depth to the interface is equal to about 38 times the freshwater head above msl; this depth is equal to the aquifer thickness (b) plus the depth to the top of the aquifer (d):

$$h_f\big|_{x=0} = \frac{\rho_s - \rho_f}{\rho_f}\left(b + d\right)$$

At the coast, the depth to the interface is equal to the depth of the aquifer, as the freshwater thickness diminishes to zero:

$$h_f\big|_{x=L} = \frac{\rho_s - \rho_f}{\rho_f}d$$

These values can be substituted into the equation above:

$$Q'L = \frac{K}{u}\frac{\left[u\left(b+d\right)\right]^2 - \left[ud\right]^2}{2} - Kd\left[u\left(b+d\right) - ud\right]$$

where:

$$u = \frac{\rho_s - \rho_f}{\rho_f}$$

Rearranging the above equation and simplifying yields:

$$Q'L = Ku\frac{\left(b+d\right)^2 - d^2}{2} - Kubd$$

$$Q'L = Ku\left(\frac{b^2 + 2bd + d^2 - d^2}{2} - bd\right)$$

$$Q'L = Ku\left(\frac{b^2}{2} + bd - bd\right)$$

Attachment A: Analytical Approach

Rearranging this equation can be used to express the intrusion length (*L*) in terms of the freshwater flux (*Q'*):

$$L = \frac{\rho_s - \rho_f}{\rho_f} b^2 \frac{K}{2Q'}$$

It should be noted that the depth to the top of the aquifer (*d*) does not appear in the solution for intrusion length for a confined aquifer. As with the unconfined solution, the values of *K*, *Q'*, and *b* must be known to use this solution.

A.5. Exclusion Head Methodology

As implied by the analytical solutions presented in Section A.4, there is a simple relationship between freshwater head (h_f) and aquifer thickness (*b*) at the location of the most extensive intrusion of the seawater wedge into an unconfined freshwater aquifer, termed the toe of the wedge:

$$h_{f,toe} = \frac{\rho_s - \rho_f}{\rho_f} b$$

It should be remembered that the value of *b* used in this formulation is the thickness of the aquifer below sea level only. For a confined aquifer, the freshwater head is:

$$h_{f,toe} = \frac{\rho_s - \rho_f}{\rho_f} (b + d)$$

where b is the aquifer thickness and d is the depth below sea level of the top of the aquifer.

This simple relationship for freshwater head at the toe can be used as a management tool; to prevent intrusion from reaching any given location in the freshwater aquifer, the toe of the seawater wedge must be kept seaward of the location. To do so, the freshwater head at that location must be kept above the level at which it would be were the toe of the wedge to reach that location. This head is here termed the "exclusion head," and is equivalent to the "potential constraint" used in a management study by Mantoglou (2003), which showed this approach to be a conservative management tool.

To apply the exclusion head methodology, the parameter *b* (and *d* where conditions are confined) must be defined. The exclusion head is then calculated using assumed values of the densities of seawater and freshwater (see Section A.1).

A.6. Rate of Seawater Intrusion at Golden Gate Park

In an effort to quantify the rate of seawater intrusion into the freshwater aquifer under various pumping conditions, a simplified mathematical model was created to estimate the change in the position of the toe of the seawater wedge over time. This mathematical model is based on the analytical model presented in Section A.4. The model was developed by assuming that the movement of the wedge could be described by assuming that the interface moves in the short

Attachment A: Analytical Approach

term due to changes in the amount of freshwater present in the aquifer. This section describes the development of the model and its application to an idealized case designed to resemble conditions at the South Windmill Cluster in Golden Gate Park. A similar analysis was not performed for the Bay Coast because of the lack of an independent estimate of freshwater flux (see Section A.3.4).

The theory behind this method is that the movement of the seawater-freshwater interface can be described by assuming that the well pumping over a given time period can be converted to a volume of water removed. This approach makes a number of assumptions, most of which are similar to the analytical method for estimating the intrusion length (see Section A.4). Additional assumptions include:

- The pumping rate is a small percentage of the freshwater flux.
- The aquifer thickness landward of the intrusion wedge toe is approximately constant.
- The discharge point does not move from the coast.
- The system is unconfined and functions as a single aquifer.

The second assumption greatly simplifies the mathematical solution. Implicit in this assumption is that the head gradient landward of the wedge toe is approximately flat; this does not introduce substantial error into the analysis because head gradients in permeable alluvial sediments are typically very flat compared to the total aquifer thickness; Yates et al. (1990) reported a maximum gradient in the North Westside Basin of 0.035 ft/ft in the Lake Merced area, with typical gradients on the order of 0.010 ft/ft, including in the Golden Gate Park area). It should be noted that the analytical solution presented below does not depend on the head or head gradient directly, so the assumption of a constant aquifer thickness (and therefore flat gradient) does not preclude freshwater flux toward the ocean and is an appropriate approximation.

The last assumption is required because the confined solution is much more complicated than is the unconfined solution, due to the effects of aquifer elasticity and water compressibility (together contributing to the specific storage of the confined aquifer). This assumption is applicable at the western end of Golden Gate Park because the -100 foot clay is absent, leaving the Shallow and Primary Production Aquifers in direct communication; this implies that they can be considered a single aquifer. Elsewhere in the North Westside Basin, where the clay layers are present, this assumption would not apply.

As shown in Section A.4, the intrusion length into the aquifer (i.e., the distance from the discharge point to the toe of the wedge) is equal to:

$$L = \frac{K}{2Q'_0}\frac{\rho_s}{\rho_f}\frac{\rho_s - \rho_f}{\rho_f}b^2$$

where Q'_0 is the initial freshwater flux per foot of coastline before modification by pumping (all other terms are defined in Section A.4). The volume of water within any slice of the aquifer of infinitesimal width dx is equal to:

$$dV' = h_f n_e \frac{\rho_s}{\rho_s - \rho_f} dx$$

Attachment A: Analytical Approach

where n_e is the effective porosity of the aquifer[6]. Integrating from the coast to the toe of the wedge, the total initial volume of freshwater per foot of coastline above the wedge is equal to:

$$V_0' = -\left(\frac{\rho_s}{\rho_s - \rho_f}\right)^2 \frac{n_e K}{3Q_0'}\left[\left[\left(\frac{\rho_s - \rho_f}{\rho_f}\right)^2 b^2 - \frac{\rho_s - \rho_f}{\rho_f}\frac{2Q_0' L_0}{K}\right]^{3/2} - \left[\left(\frac{\rho_s - \rho_f}{\rho_f}\right)^2 b^2\right]^{3/2}\right]$$

which, when substituting the above equation for computing L, simplifies to:

$$V_0' = \frac{n_e K}{3Q_0'}\left(\frac{\rho_s}{\rho_f}\right)^2 \frac{\rho_s - \rho_f}{\rho_f} b^3$$

Pumping removes a volume of water from the aquifer (V'_w) that is equal to the product of the pumping rate and the time over which it is applied:

$$V_w'(t) = Q_w'(t - t_0)$$

where Q'_w is the pumping rate, t is the time, and t_0 is the time when pumping was initiated. In this case, the pumping rate must be converted to an equivalent flux per foot of shoreline, which implies that the pumping in the basin results in a uniform decrease in the freshwater flux rate. This pumping from the aquifer induces some movement of the intrusive wedge inland (as extra recharge would move the wedge closer to the ocean). The volume of water removed from the aquifer from the new location of the toe of the wedge to the coast is equal to the volume of water removed from the aquifer. The volume of freshwater contained in the aquifer from the location of the new toe to the coast prior to pumping is equal to the volume of freshwater above the seawater-freshwater interface plus the volume of water in the stretch of aquifer that becomes intruded by the wedge during its movement. Assuming that the freshwater head is approximately flat landward of the toe of the wedge, the freshwater head is equal everywhere to its value at the toe of the wedge, which is equal to:

$$h_{f,toe} = \frac{\rho_s - \rho_f}{\rho_f} b$$

The volume of freshwater in the aquifer that becomes intruded by the wedge is equal to:

$$V_i' = n_e b \frac{\rho_s}{\rho_f}\left(L(t) - L_0\right)$$

where $L(t)$ is the distance from the coast to the toe of the wedge at time t. The total volume of freshwater in the aquifer from the coast to the new location of the wedge of the toe prior to pumping is:

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[6] Note that this assumes that the intruding seawater does not interact with the non-effective porosity of the aquifer, i.e. $n - n_e$. In reality, this non-effective porosity will lead to (very slightly) lower salinity behind an intruding wedge, and the leaving of salts behind by a retreating wedge.

Attachment A: Analytical Approach

$$V'_{0,Total} = V'_0 + V'_i = \frac{n_e K}{3Q'_0}\left(\frac{\rho_s}{\rho_f}\right)^2 \frac{\rho_s - \rho_f}{\rho_f} b^3 + n_e\left(L(t) - L_0\right)\frac{\rho_s}{\rho_f} b$$

The wedge at time *t* has a volume equal to:

$$V'_t = V'_{0,Total} - V'_w(t)$$

Combining this with earlier equations produces an equation for the total volume of freshwater above the transient wedge at time *t*:

$$V'_t = \frac{n_e K}{3Q'_0}\left(\frac{\rho_s}{\rho_f}\right)^2 \frac{\rho_s - \rho_f}{\rho_f} b^3 + n_e\left(L(t) - L_0\right)\frac{\rho_s}{\rho_f} b - Q'_w\left(t - t_0\right)$$

Assuming the value of Q'_0 is not significantly changed by the pumping, this volume can also be computed by:

$$V'_t = -\left(\frac{\rho_s}{\rho_s - \rho_f}\right)^2 \frac{n_e K}{3Q'_0}\left[\left[\left(\frac{\rho_s - \rho_f}{\rho_f}\right)^2 b^2 - \frac{\rho_s - \rho_f}{\rho_f}\frac{2Q'_0 L(t)}{K}\right]^{3/2} - \left[\left(\frac{\rho_s - \rho_f}{\rho_f}\right)^2 b^2\right]^{3/2}\right]$$

The assumption that Q'_0 is not changed significantly is only applicable if the value of Q'_w is small compared to Q'_0, i.e., most of the initial freshwater flux is not captured by the wells. Results based on values of Q'_w that represent a significant fraction of Q'_0 should be used with caution. The value of Q'_0 reported by Yates et al. (1990) was 19,600 ft^3/yr per foot of coastline; the pumping entailed by the SFGW Project is about 8,810 ft^3/yr per foot of coastline above the pumping reported by Yates et al. (1990) for Scenario 3a, and about 9,220 ft^3/yr per foot of coastline above for Scenario 3b; the large magnitude of these changes relative to the initial freshwater flux indicates that this assumption is not completely valid in this case, and the results should be considered approximate.

These two values for the total volume of freshwater can be equated to each other. The equation for the value of L_0 can be substituted into this equation to simplify it to:

$$Q'_w\left(t - t_0\right) - n_e b\frac{\rho_s}{\rho_f} L_0 = \left(\frac{\rho_s}{\rho_f}\right)^2 \frac{2n_e b^2}{3L_0^{1/2}}\left[L_0 - L(t)\right]^{3/2} - n_e b\frac{\rho_s}{\rho_f} L(t)$$

or

$$\frac{Q'_w\left(t - t_0\right)}{n_e b}\frac{\rho_f}{\rho_s} = \frac{\rho_s}{\rho_f}\frac{2b}{3L_0^{1/2}}\left(L_0 - L(t)\right)^{3/2} + \left(L_0 - L(t)\right)$$

This equation cannot be solved for $L(t)$ using separation of variables. Instead, this model must be solved iteratively. This iterative solution can be performed in any spreadsheet software (e.g., Microsoft Excel) by minimizing the difference between the specified pumping rate and the pumping rate calculated using the equation above by optimizing values of $L(t)$.

A.7. Effect of a Sloping Aquifer Base

The above analytical methods assume a horizontal aquifer. As shown in LSCE (2010), the actual aquifer bases in the North Westside Basin have been shown to be sloped toward the Ocean. A similar analytical method assuming a sloping aquifer base could not be constructed because the solution is inseparable. Abarca et al. (2007) performed numerical simulations that investigated the effect of a sloping aquifer boundary, both parallel and perpendicular to the coastal boundary. Their results indicated that a slope toward the Ocean slightly decreases the intrusion length into an aquifer, but not substantially. The presence of a slope parallel to the coast, on the other hand, can greatly increase the length of seawater intrusion into the lowest parts of the aquifer base. Mulligan et al. (2007) demonstrate that freshwater flux tends to be concentrated in paleochannels, which would represent the low points in the aquifer base demonstrated by Abarca et al. (2007) to be locations of greater intrusion; the concentration of freshwater flux into these same areas may keep this intrusion at bay.

24 April 2012

Task 10.4 Technical Memorandum

San Francisco Public Utilities Commission

Changes in Groundwater Levels and Storage for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

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1. Introduction

This Technical Memorandum (TM) was prepared to document work performed by Kennedy/Jenks Consultants (Kennedy/Jenks) for the San Francisco Public Utilities Commission (SFPUC) pursuant to the amended Task Order (TO) authorizations CUW30103-TO-1.12 of the Proposed Regional Groundwater Storage and Recovery (GSR) Project and CUW30102-TO-2.7 of the Proposed San Francisco Groundwater Supply (SFGW) Project. These projects are funded by the SFPUC's Water System Improvement Program (WSIP).

1.1. GSR and SFGW Project Description

The GSR Project is a conjunctive use project that would allow for increased groundwater supplies in the southern portion of the Westside Basin (South Westside Basin) during periods of drought when SFPUC surface water supplies become limited (MWH, 2008). The project would be designed to provide up to 60,500 acre-feet (af) of stored water to meet SFPUC system demands during the last 7.5 years of SFPUC's Design Drought. The SFPUC plans to install 16 new production wells for the GSR Project to recover the stored groundwater. Under the Draft GSR Operating Agreement, the SFPUC would "store" water in the South Westside Groundwater Basin through the mechanism of in-lieu recharge by providing surface water as a substitute for groundwater pumping by the Partner Agencies (PAs). As a result of the in-lieu deliveries, up to 60,500 af of groundwater storage or "put" credits could accrue to the SFPUC Storage Account. During shortages of SFPUC system water due to drought, emergencies, or scheduled maintenance, the PAs would return to pumping from their existing wells, and SFPUC would extract groundwater from their new wells as long as a positive balance exists in the SFPUC Storage Account.

The SFGW Project would provide a reliable, local source of high-quality groundwater in the northern portion of the Westside Basin (North Westside Basin) to supplement the San Francisco municipal water system. The SFGW Project would construct up to six wells and associated facilities in the western part of San Francisco and extract an annual average of up to 4.0 million gallons per day (mgd) of water from the North Westside Basin (SFPUC, 2009b). The extracted groundwater, which would be used both for regular and emergency water supply purposes, would be blended in small quantities with imported surface water before entering the municipal drinking water system for distribution. The SFGW Project includes two phases, In phase one, SFPUC would build four new groundwater wells at the Lake Merced Pump Station, West Sunset Playground, South Sunset Playground, and the Golden Gate Park Central Pump Station. In phase two, SFPUC would modify two existing irrigation wells (South Windmill Replacement and North Lake) in Golden Gate Park, converting them into municipal water supply wells.

The locations of existing and proposed GSR and SFGW wells, existing PA wells, and monitoring wells are shown on Figure 10.4-1. Additional detailed discussion of the GSR and SFGW Projects is provided in the Task 10.1 Technical Memorandum - Groundwater Modeling Analysis for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project (TM-10.1).

1.2. Objective

Implementation of the proposed GSR and SFGW Projects would influence groundwater levels and storage in the Westside Groundwater Basin (Westside Basin or Basin). Depending on the magnitude of these changes to Basin groundwater conditions, various existing and planned beneficial uses of Basin groundwater could be affected. Evaluation of the potential groundwater effects is a key management issue for the long-term sustainability of the groundwater resources and overall Basin management.

The purpose of this TM is to evaluate potential changes in future groundwater levels and regional changes in groundwater storage resulting from the proposed operation of the GSR and SFGW Projects, primarily with respect to long-term water supply and groundwater management of the Westside Basin. This TM presents information on the past, current, and projected future conditions in the subsurface related to the issue of groundwater storage. The scope of work includes a discussion of Basin hydrogeology and the physical processes that could cause long-term declines in groundwater storage that may affect the existing and planned water uses in the Basin.

2. Approach and Conceptual Understanding

Presented within this section is a basic framework for understanding the natural hydrogeologic processes and anthropogenic factors that can affect groundwater levels and storage in the Westside Basin.

2.1. General Approach

The general approach used to evaluate potential changes in groundwater storage resulting from implementation of the GSR and SFGW Projects is based on an analysis of measured groundwater data and evaluation of groundwater modeling results. This combined approach is considered to be a screening-level analysis to be used for regional groundwater management, with a focus on evaluating whether or not the GSR and SFGW projects would be expected to affect the long-term capability of groundwater users to maintain groundwater pumping for existing or planned land uses.

The groundwater model allows evaluation of the complex interactions produced by the GSR and SFGW projects by simulating potential future conditions. The Westside Basin Groundwater-Flow Model, a regional, basin-wide groundwater model developed by HydroFocus (2007, 2009, and 2011) for the City of Daly City (Daly City), was reviewed with assistance from California Water Service Company (Cal Water), the City of San Bruno (San Bruno), and SFPUC, and the model was accepted for use in selected applications by all parties as capable of supporting water resources planning and management in the Westside Basin. For this evaluation, five model scenarios were constructed and simulated to evaluate potential groundwater and related hydrological effects from the GSR and SFGW Projects and from the Cumulative Scenario that involves the GSR and SFGW Projects and other reasonable foreseeable future projects. The development of the model scenarios is documented in TM-10.1.

For this evaluation, existing data and reports were reviewed and summarized to provide a discussion of how the Basin has responded to historical pumping and other hydrogeologic conditions. Evaluating historical conditions (based on an analysis of measured data) provides a context against which to assess the groundwater modeling results.

2.2. Westside Groundwater Basin

This section provides a brief overview of the physical setting and hydrogeology of the Westside Basin More detailed descriptions of the evaluations of the hydrogeology of the Westside Basin are presented LSCE (2010) and TM10.1. Figure 10.4-2 provides a representative cross section from north to south across the Westside Basin. There are three aquifer systems that are commonly referred to in the Westside Basin. These include:

- Shallow Aquifer: this aquifer is present in the northern part of the Basin, in the vicinity of Lake Merced and the southern portion of the Sunset district of San Francisco. The base of the Shallow Aquifer is defined as the top of the “-100 foot clay.”

- Primary Production Aquifer: this aquifer is present throughout the Basin, overlying the "W-clay" where present. Where the W-clay is not present in locations to the south (in the South San Francisco area), the Primary Production Aquifer is divided into shallow and deep units separated by a clay unit at an elevation of approximately -300 feet mean sea level (msl).
- Deep Aquifer: this aquifer underlies the W-clay, and thus its extent is limited to the generally-known extent of that clay unit (LSCE, 2010).

The three aquifer systems are separated by thick, extensive clay units (e.g., the -100 ft clay and W-clay). Because of the discontinuous nature of these clay layers, the basin is considered to be a semi-confined aquifer system where limited flow occurs between the different aquifer systems where local geologic conditions permit (LSCE, 2010).

2.3. Existing Groundwater Monitoring and Reporting Activities

Over the last decades, there has been a substantial increase in data collection efforts and cooperative management of groundwater resources in the Westside Basin among the SFPUC, the City of San Bruno, the City of Daly City, and California Water Service Company (Cal Water, municipal water purveyor to South San Francisco). Annual monitoring reports have been published by the SFPUC since 2006 (LSCE, 2006 and SFPUC, 2007, 2008 and 2009) and summarized in (LSCE (2010) and TM10.1.

2.4. Conceptual Understanding of Groundwater Levels and Storage

Groundwater levels and storage within a basin are affected by changes in the water balance for that basin. A water balance is an accounting of the amount of groundwater entering (inflow) and leaving (outflow) the groundwater basin. Simply stated, based on the law of conservation of mass, a water balance for a groundwater system is expressed as:

Change in Groundwater Storage = Total Groundwater Inflow – Total Groundwater Outflow

Typical inflow components to a groundwater basin include precipitation, groundwater (subsurface) inflow, and return flow from irrigation. Common outflow components include groundwater (subsurface) outflow and pumping. Interactions between the aquifer and lakes, bays and oceans (groundwater-surface water interactions) can either be groundwater inflow or outflows depending upon the relative difference in head between the groundwater and the surface water body. As indicated by the above expression, the difference between total groundwater inflow and total groundwater outflow results in a change to the volume of groundwater stored in the basin, referred to as "groundwater storage" (Fetter, 1988). Changes in groundwater storage are manifested as changes in groundwater levels measured in wells; net positive changes in groundwater storage result in increased water levels, and net negative changes result in lowered water levels.

3. Groundwater Model Analysis

To evaluate groundwater conditions that may result from the operation of the GSR and SFGW Projects, a series of model scenarios was developed using the Westside Basin Groundwater-Flow Model (HydroFocus 2007, 2009, and 2011). The development of the model assumptions and scenarios is documented in TM-10.1. This section provides an evaluation of model-predicted changes in groundwater levels and storage related to implementation of the GSR and SFGW Projects based on the model scenarios.

3.1. Modeling Scenarios

Five model scenarios were constructed and simulated to evaluate potential groundwater and related hydrological effects from the GSR and SFGW Projects and from the Cumulative Scenario that involves the GSR and SFGW Projects and other reasonably foreseeable future projects. The following is a summary of the five scenarios used for the groundwater model analysis:

1. Scenario 1, Existing Conditions: Scenario 1 Existing Conditions, does not include the SFPUC Projects (either the GSR or SFGW Project). Groundwater pumping by the PAs and irrigation pumping are representative of the existing pumping conditions (as of June 2009). As described in TM10.1, the PA pumping was established based on the historical pumping rates, using the median of the 1959-2009 pumping data for individual agencies.
2. Scenario 2, GSR Project Only: Scenario 2 represents implementation of the GSR Project operations including: “Put” periods represent when groundwater pumping by SFPUC and the PAs does not occur and groundwater is placed into the SFPUC Storage Account through in-lieu recharge; “Hold” periods represent when the PAs are pumping and no in-lieu recharge is occurring because the SFPUC Storage Account is full; and “Take” periods represent when both SFPUC and the PAs are pumping from the South Westside Basin.
3. Scenario 3a, SFGW Project Only (3 mgd): For Scenario 3a, the four new wells constructed for the SFGW Project would pump at an annual average rate of 3.0 mgd; however, the two existing irrigation wells in Golden Gate Park would remain irrigation wells, and their irrigation pumping rates would be the same as in Scenario 1.
4. Scenario 3b, SFGW Project Only (4 mgd): For Scenario 3b, the four new wells constructed for the SFGW Project and the two modified irrigation wells in Golden Gate Park would pump at an annual average rate of 4.0 mgd. Irrigation in Golden Gate Park is assumed to be replaced by the Westside Recycled Water Project. Total combined pumping for Scenario 3b is slightly less than under Scenario 3a, because the total SFGW Project pumping in Scenario 3b would increase by 1.0 mgd; however, the irrigation pumping that was replaced would be slightly more than 1.0 mgd.
5. Scenario 4, Cumulative Scenario: Scenario 4 represents implementation of both the GSR and SFGW Projects (Scenarios 2 and 3b) along with other reasonably foreseeable

future projects. The other foreseeable projects are discussed in more detail in TM10-1 but primarily include the Daly City Vista Grande Drainage Area Improvements Project, which increases stormwater diversions into Lake Merced, the Daly City A-Street Replacement Well which shifts some of the Daly City pumping outside the South Westside Basin, and a minor increase in irrigation pumping based on the planned build-out of the Holy Cross cemetery.

As discussed in TM-10.1, the strongest predictive ability of the existing model is in relative changes over time, rather than the simulated groundwater levels. Therefore, it is more appropriate to analyze the results of the groundwater model using differences in water levels relative to a base case rather than simulated groundwater elevations. Scenario 1, the Existing Conditions scenario, forms the base case against which the results of the GSR-only, SFGW-only, and Cumulative Scenarios are compared.

To allow for the model scenarios to be directly comparable, all five model scenarios are set up using similar initial conditions and background hydrology. All of the modeled scenarios have the same projected simulation period of 47.25 years and use initial groundwater conditions that represent June 2009 conditions. All five model scenarios use the same hydrologic sequence, which includes an 8.5-year Design Drought period used in the Program Environmental Impact Report (PEIR; SFPUC, 2007; SFPUC, 2009a). The Design Drought repeats the December 1975 to March 1978 drought period following the dry conditions of July 1987 to November 1992. To incorporate the Design Drought, the historical hydrological sequence was rearranged. A more detailed discussion of the development of the background hydrology is presented in TM-10.1.

The GSR-Only Scenario and the Cumulative Scenario (Scenarios 2 and 4) involve the SFPUC Storage Account. The SFPUC Storage Account is a bookkeeping method that tracks the volume of groundwater stored in the Basin from in-lieu recharge during put periods minus the amount of groundwater pumped from the SFPUC Storage Account during take periods. As part of the initial conditions, the accrued volume in the SFPUC Storage Account at the start of the model scenarios is approximately 20,000 acre-feet (af) based on records of in-lieu exchange with the Partner Agencies prior to July 2009. During the Design Drought, the SFPUC Storage Account is taken from a full condition of 60,500 af to an empty condition of no in-lieu storage available at the end of the Design Drought. During a recovery period following the Design Drought, the scenarios include a 3-year put period that adds 20,000 af to the SFPUC Storage Account. Using this condition, the SFPUC Storage Account begins and ends with 20,000 af for both Scenarios 2 and 4. This allows for a more direct comparison in evaluating the long-term changes in groundwater levels and storage without having to factor in differences in the amount of in-lieu storage.

Table 10.4-1 presents a summary of the estimated Basin-wide average pumping rates corresponding to each of the model scenarios. Note that in addition to the anticipated GSR and SFGW Project wells, average pumping rates are also provided for the PA wells and for irrigation wells in Golden Gate Park.

3.2. Evaluation of Model-Predicted Changes in Groundwater Levels

The groundwater model simulates monthly changes in groundwater levels throughout the Westside Basin for each model scenario. The following discussion summarizes the model results for changes in groundwater elevations.

3.2.1. Methodology

The evaluation of groundwater levels proceeds with groups of wells or other analyzed locations from north to south through the Westside Basin. The analyzed locations begin in the North Westside Basin with well locations in the Golden Gate Park and Lake Merced subarea, and end in the South Westside Basin with locations in the San Bruno subarea (Figure 10.4-1). Progressing with the analysis in this manner helps to emphasize the relative geographic extent that each of the evaluated Project Scenarios (SFGW-Only, GSR-Only, and Cumulative) is expected to have on Basin groundwater conditions.

To facilitate this analysis, model-predicted groundwater levels corresponding to Model Layers 1 and 4 were evaluated. Model Layer 1 results provide information related to expected changes in the Shallow Aquifer, whereas Model Layer 4 results give an indication of groundwater level changes anticipated in the heavily-pumped Primary Production Aquifer. For each location analyzed within the Westside Basin, hydrographs are presented on Figures 10.4-3 through 10.4-13. Figure numbers that end in “a” (e.g., Figure 10.4-4a) pertain to Model Layer 1 results, whereas figure numbers that end in “b” (e.g., Figure 10.4-3b) show Model Layer 4 output. The following locations were selected to evaluate model-predicted changes in groundwater levels corresponding to each scenario:

- SWM-GS (Figure 10.4-3)
- Ortega MW (Figure 10.4-4)
- Santiago-S MW (Figure 10.4-5)
- LMMW-4S (Figure 10.4-6)
- Harding Park MW (Figure 10.4-7)
- Olympic MW (Figure 10.4-8)
- DC-3 (Figure 10.4-9)
- DC-A-St (Figure 10.4-10)
- Cypress Lawn 2 (Figure 10.4-11)
- SSF-02 (Figure 10.4-12)
- SB-12 (Figure 10.4-13)

On each figure, the upper hydrograph shows model-simulated groundwater elevation in feet (NGVD 1929), while the lower pane shows the relative difference between the groundwater levels of each Project Scenario and those of Scenario 1. Positive differences indicate that the Project Scenario has a higher groundwater elevation relative to Scenario 1, while negative results indicate that the Project Scenario has a lower groundwater elevation relative to Scenario 1. The groundwater elevation differences are normalized for fluctuations in the Existing Conditions Scenario, and so provide an evaluation of the direct effect on groundwater levels due to the GSR, SFGW and Cumulative scenarios.

3.2.2. North Westside Basin Area (Golden Gate Park to South Lake Merced)

The North Westside Basin extends from Golden Gate Park to Lake Merced (Figure 10.4-1). The locations evaluated in the North Westside Basin include SWM-GS, Ortega MW, Santiago-S MW, LMMW-4S, Harding Park MW, and Olympic-MW. Hydrographs corresponding to these well locations are presented as Figures 10.4-3 through 10.4-8.

Scenario 1 represents groundwater elevation results without either the GSR or SFGW Projects, and defines the background conditions including wet, normal and dry precipitation years. In the North Westside Basin, these climatic variations are clearly shown on the hydrograph, but the variations are more pronounced in Model Layer 1 than in Model Layer 4. After a sharp increase in groundwater levels representing a period of above average precipitation during Scenario Years 1 to 4, the groundwater levels fluctuate within a narrow range in response to climatic conditions. As discussed in TM-10.1, the hydrologic sequence used for all scenarios includes a Design Drought with below normal precipitation from Scenario Years 36 to 44.

In the northern locations (SWM-GS, Ortega MW, and Santiago-S MW; Figures 10.4-3 through 10.4-5) groundwater levels at the end of the 47.25-year Scenario return to approximately the same levels as at the beginning of the Scenario. Groundwater levels show seasonal variations due to irrigation pumping that are more pronounced in Model Layer 1 than in Model Layer 4. The locations near Lake Merced (LMMW-4S, Harding Park MW and Olympic-MW; Figures 10.4-6 through 10.4-8) show fairly distinct responses in Model Layer 1 versus Model Layer 4; in Model Layer 1, the groundwater level trends are similar to those at the more northern locations, showing strong responses to climatic conditions, whereas variations in groundwater levels in Model Layer 4 are more subdued. This is due to the presence of the -100 foot clay in the Lake Merced vicinity, greater depth to Model Layer 4, and the influence of groundwater conditions in the South Westside Basin on these locations. The difference in groundwater elevations between Model Layers 1 and 4 is smallest in the north (near Golden Gate Park) and greatest in the south (near Lake Merced).

Scenario 2 represents the operation of the GSR Project, which is located in the South Westside Basin. The model results show that all the North Westside Basin locations have at least some response to GSR Project operation. From the beginning of the Scenario to the start of the Design Drought, groundwater levels are higher than under Scenario 1. During the Design Drought, groundwater levels drop below Scenario 1 for the more southerly locations, showing the effects of increased pumping during this period. The recovery period following the Design Drought shows that groundwater levels recover to near-Scenario 1 levels after 3 years of in-lieu recharge.

Results for Scenario 2 for the northern locations in Golden Gate Park and north of Lake Merced (SWM-GS, Ortega MW, and Santiago-S MW; Figures 10.4-3 through 10.4-5) show little change relative to Scenario 1. For example, at the Ortega MW location (Figure 10.4-4), groundwater levels are generally about 0.5 to 1.0 foot higher relative to Scenario 1, but drop to less than 0.5 foot below Scenario 1 at the end of the Design Drought. The subdued response of groundwater conditions in these more northerly locations is expected because of the distance to the GSR and PA wells in the South Westside Basin.

The locations near Lake Merced (LMMW-4S, Harding Park MW and Olympic-MW; Figures 10.4-6 through 10.4-8) show more pronounced effects from the GSR Project. Overall, groundwater levels are generally higher relative to Scenario 1 throughout the Scenario in both Model Layers 1 and 4. This is due to the general decrease in pumping in the South Westside Basin and the effects of in-lieu recharge. Groundwater levels near Lake Merced are generally 5 to 10 feet higher relative to Scenario 1; however, groundwater levels in Model Layer 4 at the Olympic-MW location are about 10 to 30 feet higher relative to Scenario 1 until the start of the Design Drought.

The effects of pumping during the take periods are more pronounced in the southern part of the North Westside Basin than the northern part, and are also more pronounced in Model Layer 4 than in Model Layer 1. At the Olympic-MW location, the three take periods have more of an effect on water levels than further north. In general, groundwater levels in both Model Layers 1 and 4 remain higher than under Scenario 1 until the Design Drought, when both the SFPUC and PA wells are pumping. The lowest groundwater levels occur at the conclusion of the Design Drought.

The 3 years from the end of the Design Drought to the end of the scenario are put years. At the end of this period, groundwater levels have recovered to within 1 to 5 feet of those of Scenario 1 in all of the North Westside Basin locations for both Model Layers 1 and 4.

<u>Scenarios 3a and 3b</u> simulate the operation of the SFGW Project, which is located in the North Westside Basin. Scenario 3a assumes 1.142 mgd of irrigation pumping in Golden Gate Park and 3.0 mgd of project pumping for water supply throughout the North Westside Basin, whereas Scenario 3b assumes 4.0 mgd of project pumping for water supply, and that pumping of groundwater for irrigation in Golden Gate Park is replaced by recycled water. In total, Scenario 3b assumes 0.142 mgd less total pumping than Scenario 3a. Pumping is redistributed among the SFGW Project wells so that there is a 0.072 mgd decrease in pumping in the Golden Gate Park area. Because this overall change in pumping is minor, the regional response of groundwater levels to these scenarios is comparable; therefore, the results for Scenarios 3a and 3b will be discussed together.

In general, all locations evaluated in the North Westside Basin area show a similar declining trend relative to Scenario 1 for groundwater levels due to the SFGW Project operations. There is an initial decrease in groundwater levels relative to Scenario 1 in the first 5 to 10 years of the scenario, followed by a leveling out over the rest of the simulation period. In the northern locations, the rate of change relative to Scenario 1 after about Scenario Year 20 is near zero, whereas the locations near Lake Merced show a steady decline in groundwater levels relative to Scenario 1, but at a rate much less than the initial decline.

In the northern locations (SWM-GS, Ortega MW, and Santiago-S MW; Figures 10.4-3 through 10.4-5), groundwater levels decline by about 5 to 10 feet within the first 10 years of Scenarios 3a and 3b. After this initial decline, groundwater level declines relative to Scenario 1 are greatly reduced to near stable for the remainder of the Scenarios, including the period of the Design Drought. In these northern locations, the change in groundwater levels relative to Scenario 1 is similar for both Model Layers 1 and 4.

The locations near Lake Merced (LMMW-4S, Harding Park MW and Olympic-MW; Figures 10.4-6 through 10.4-8) show a slower rate of decline in the first 10 to 15 years than observed further north, but the decline relative to Scenario 1 continues at a reduced rate throughout the scenario instead of leveling off. The largest groundwater level declines occur in Model Layer 4 at the Harding Park MW and Olympic-MW locations, with a maximum decline of approximately 30 feet relative to the Scenario 1 by the end of the simulation period (Figures 10.4-7 and 10.4-8).

Scenario 4 represents the combined effects of the GSR (Scenario 2) and SFGW (Scenario 3b) Projects. As such, the resulting groundwater level responses in the North Westside Basin tend to be intermediate between the responses seen for Scenarios 2 and 3b. Groundwater levels are more similar to Scenario 3b in Golden Gate Park and north of Lake Merced, and more similar to Scenario 2 near and south of Lake Merced. Scenario 4 also includes additional water being diverted into Lake Merced; however, the response in groundwater levels to these changes to Lake Merced is not clearly recognizable, being overshadowed by the pumping changes in Scenario 2.

In the northern locations (SWM-GS, Ortega MW, and Santiago-S MW; Figures 10.4-3 through 10.4-5), groundwater levels follow a similar trend to those of Scenario 3b. This is expected because Scenario 2 has little effect on groundwater levels in this area. Groundwater levels for Scenario 4 are generally 0 to 5 feet higher than those for Scenario 3b, but still 5 to 10 feet below those of Scenario 1. The responses are similar in Model Layers 1 and 4.

The locations near Lake Merced (LMMW-4S, Harding Park MW and Olympic-MW; Figures 10.4-6 through 10.4-8) show trends similar to Scenario 2, but with groundwater levels about 10 to 20 feet lower than under Scenario 2, and 10 to 20 feet higher than under Scenario 3b. Relative to Scenario 1, groundwater levels are similar in Model Layer 1, but about 10 to 20 feet lower in Model Layer 4. As with the Scenario 3b results, the greatest projected water level declines were observed in Model Layer 4 at the Olympic MW location (Figure 10.4-8b). Figures 10.4-6 and 10.4-7 also show that the LMMW-4S and Harding Park locations appear to be equally affected by the operation of the proposed GSR and SFGW Projects. The effects of the additional water being diverted into Lake Merced should be most apparent in these wells in Model Layer 1; however, no clearly recognizable response is seen. It may be that the scale of the effects from the changes to Lake Merced is small and results in only minor variations. Alternatively, it is possible that the interaction of the GSR project (which generally raises water levels in the Lake Merced area) and the SFGW project (which generally lowers water levels) in Scenario 4 partially obscures the effect of the Lake Merced diversions upon groundwater levels.

3.2.3. South Westside Basin Area (Daly City to San Bruno)

The South Westside Basin area extends from Daly City in the north to San Bruno in the south. Locations evaluated in this area include DC-3, DC-A-St, Cypress Lawn No. 02, SSF-02, and SB-12. Hydrographs corresponding to these locations are presented in Figures 10.4-9 through 10.4-13. As discussed previously, historic groundwater pumping in the South Westside Basin has resulted in sustained declines in groundwater levels in the area.

Scenario 1 represents the change in groundwater elevations without either the GSR or SFGW Project and defines the background conditions, including wet, normal and dry precipitation years. In considering these results it should be recalled that the initial conditions include 20,000 af of storage in the SFPUC Storage Account and that the first seven years of the simulation correspond to a very wet period. These factors may contribute to high groundwater levels early in the simulation, with lower levels occurring later under the corresponding average and dry precipitation years.

- For the Daly City locations (DC-3 and DC-A-St; Figures 10.4-9 and 10.4-10), groundwater levels in both Model Layers 1 and 4 show a similar trend of steady decline from the initial conditions of about 40 feet over the 47-year Scenario. Groundwater elevations in Model Layer 1 and 4 are within 10 to 20 feet of each other.
- For the Colma and South San Francisco locations (Cypress Lawn No. 02 and SSF-02; Figures 10.4-11 and 10.4-12), groundwater levels in Model Layers 1 and 4 decline from the initial conditions steadily over the 47-year scenario, by about 10 to 30 feet in Model Layer 1 and 40 to 50 feet in Model Layer 4. Groundwater levels in Model Layer 1 are about 80 to 170 feet higher than those in Model Layer 4.
- In the San Bruno area (SB-12; Figure 10.4-13), groundwater levels in Model Layer 1 show an increasing trend from the initial conditions with a total rise of about 20 feet over the 47-year simulation period, whereas groundwater levels in Model Layer 4 show a decreasing trend from the initial conditions with a total decline of about 50 feet. The difference in groundwater levels between Model Layers 1 and 4 is about 200 to 250 feet.

Climatic variations are subdued on the hydrographs for Model Layer 4, Scenario 1. This is because groundwater levels are relatively deep in the South Westside Basin and tend to be less responsive to annual variations in recharge.

Scenario 2 represents the operation of the GSR Project, which is located in the South Westside Basin. Overall, all South Westside Basin locations show a distinct groundwater level response to the GSR Project. Groundwater levels increase during put periods and decrease during take periods. The greatest increase in groundwater level occurs after the first extended put period from Scenario Years 1 to 7, then groundwater levels slowly decline. Two take periods (from Scenarios Year 9 to 12 and Scenarios Year 25 to 28) show distinct declines in groundwater levels; however, levels recover to near their pre-take-period levels after the subsequent put periods. All locations evaluated in the South Westside Basin area have their lowest groundwater levels just after the Design Drought. During the Design Drought, pumping occurs from both the PA and SFPUC wells; the greatest declines in groundwater levels during the Design Drought correspond to well locations in the Daly City and Colma areas, because most of the GSR Project extraction wells would be located in this area.

After the end of the 8.5-year Design Drought, the South Westside Basin locations show a rise in groundwater levels because the three years from the end of the Design Drought to the end of the Scenario are put years. In Model Layer 4 representing the Primary Production Aquifer, groundwater levels recover 70 to 100 feet from the end of the Design Drought. At this time, the SFPUC Storage Account is at about 20,000 af which is about one-third of the SFPUC Full Storage Account at 60,500 af. Groundwater levels are generally about 20 to 40 feet below the levels for Scenario 1 at the end of the Scenario 2.

For the Daly City locations (DC-3 and DC-A-St; Figures 10.4-9 and 10.4-10), groundwater levels remain above Scenario 1 levels throughout Scenario 2, including two take periods, until the Design Drought. During the Design Drought, groundwater levels drop below Scenario 1 levels by about 40 feet in Model Layer 1 and from 70 to 100 feet in Model Layer 4. After the Design Drought, groundwater levels recover to about 20 to 50 feet in Model Layer 1 and are 2 to 20 feet below Scenario 1 levels at the end of the simulation. For Model Layer 4, groundwater levels recover about 70 to 80 feet and range from 10 feet above to 20 feet below Scenario 1 levels at the end of the simulation period.

For the Colma and South San Francisco locations (Cypress Lawn No. 02 and SSF-02; Figures 10.4-11 and 10.4-12), groundwater levels show a similar pattern to those of the Daly City area. In Model Layer 1, the responses to put and take periods are more subdued, and groundwater levels are about 10 to 15 feet higher than under Scenario 1. During the Design Drought, groundwater levels are from 0 to 20 feet below those of Scenario 1. Groundwater levels in Model Layer 4 respond more strongly to the put/take/hold pattern, but groundwater levels are lower than observed in Daly City. Groundwater levels drop below Scenario 1 during the first two take periods. At the start of the Design Drought, groundwater levels are near those of Scenario 1 and decline by 120 to 140 feet by the end of the Design Drought. During the three year put period at the end of the scenario, groundwater levels recover to 25 to 50 feet below Scenario 1 levels.

In the San Bruno area (SB-12; Figure 10.4-13), groundwater levels in Model Layer 1 show an increasing trend that does not reflect the pattern of put and take periods, with groundwater levels about 5 to 10 feet higher than under Scenario 1. Rising groundwater levels for Model Layer 1 at this location were also experienced in the HydroFocus 2008 No-Project Scenario and are discussed by HydroFocus (2011). Model Layer 4 shows a similar pattern to the Colma and South San Francisco locations, with similar magnitudes.

Scenarios 3a and 3b represent the operation of the SFGW Project, which is located in the North Westside Basin. Therefore, groundwater level changes in the South Westside Basin show little to no change relative to Scenario 1 in either Model Layer 1 or 4. The effects of the SFGW Project are greatest in the Daly City area and diminish southward. The maximum groundwater level decline relative to Scenario 1 for Scenarios 3a and 3b is approximately 20 feet in Model Layer 4 at the Daly City locations (Figures 10.4-9b and 10.4-10b), whereas in Model Layer 4 at SB-12, in the San Bruno area, there is a barely discernible decline in predicted groundwater levels (Figure 10.4-13b).

Scenario 4 represents the combined effects of pumping in the SFGW and GSR Project wells, and also other reasonably foreseeable future projects. Groundwater levels for Scenario 4 in the South Westside Basin generally match the results for Scenario 2. Although Scenario 4 includes simulated pumping stresses for both the SFGW and GSR Project production wells, the general patterns of groundwater level responses more closely approximate the levels for Scenario 2 due to the proximity of GSR Project wells.

In the Daly City area (Figures 10.4-9 and 10.4-10), groundwater levels in Model Layer 1 closely follow the same trends as observed in Model Layer 4, but are generally about 20 to 40 feet higher. In both Model Layers 1 and 4, groundwater levels for Scenario 4 are generally 1 to 15 feet higher compared to Scenario 2 levels. Since both Scenario 2 and Scenario 4 use the same GSR Project pumping assumptions, the differences are attributed to the other reasonably foreseeable future projects applied in the Cumulative Scenario. Since locations nearer to Lake Merced, such as the Olympic MW location (Figure 10.4-10) on the south side of Lake Merced show Scenario 2 groundwater levels higher relative to Scenario 4, the observed condition in Daly City cannot be attributed to water additions at Lake Merced. Instead, the higher Scenario 4 groundwater levels demonstrate the local effects of the Daly City A-Street Replacement Well. For Scenario 4, the pumping from the Daly City A-Street Well is shifted to the proposed Daly City A-Street Replacement Well, which is located on the west side of the Serra Fault (Figure 10.4-1). This change in location has a substantial effect because about 17 percent of the Daly City groundwater production would be shifted from the main basin to a location east of the Serra Fault. The conceptual understanding is that the Serra Fault is a barrier to groundwater flow; therefore, the change in the pumping location has the net effect of reducing pumping in the main basin east of the Serra Fault by about 475 afy. The result is that Scenario 4 groundwater levels in the Daly City area are higher than Scenario 2 groundwater levels because there is a decrease in pumping in the Daly City area relative to Scenario 2.

South of Daly City, groundwater levels for Scenario 4 are nearly identical to groundwater levels for Scenario 2. In the Colma, South San Francisco and San Bruno areas, the effect of SFGW Project pumping is generally diminished, as is the effects of the proposed Daly City A-Street Replacement Well described above. As with Scenario 2, the effects from the GSR Project pumping are seen primarily in Model Layer 4 with limited effects from GSR Project pumping on groundwater levels in Model Layer 1.

For Scenario 4, the lowest simulated groundwater levels correspond to take periods, with substantial recovery of levels during put periods. For Scenario 4, the greatest predicted declines in groundwater levels occur during the Design Drought at locations in the Daly City and Colma areas, with groundwater levels in Model Layer 4 ranging from approximately 60 to 135 feet below those of Scenario 1 (Figures 10.4-9b through 10.4-13b). During the three-year put period following the Design Drought, groundwater levels in Model Layer 4 recover 60 to 100 feet. At the end of the simulation, groundwater levels in Model Layer 4 range from about 10 feet higher to 50 feet lower relative to Scenario 1 levels in the South Westside Basin.

3.3. Evaluation of Model-Simulated Changes in Groundwater Storage

The groundwater model provides a mechanism to evaluate the changes in groundwater storage predicted for each scenario. The net difference between inflows (e.g. recharge) and outflows (e.g. pumping) in a groundwater system (water balance) results in a change in groundwater storage, which in turn results in a corresponding change in groundwater levels (Section 2.4).

3.3.1. Methodology

For the Basin-wide storage evaluation, the groundwater model was used to determine the changes in groundwater storage for both the whole Basin and for specific subareas for each model scenario, and these results were compared to the storage changes computed for Scenario 1. Based on the model scenario results, volumetric water budget graphs and tables were prepared for the entire simulation period. The water budget includes the major components of inflows to and outflows from the Westside Basin. This water budget analysis was conducted at three different regional scales listed below, with results for each scale for each scenario :

- Westside Basin (Figures 10.4-14 and 10.4-15, and Tables 10.4-2 through 10.4-6).
- Comparison of the SFPUC Storage Account to Scenario 2 aquifer storage (Figure 10.4-16).
- North and South Westside Basins (Figures 10.4-17 through 10.4-20).
- Five subareas that are collectively referred to by HydroFocus (2009 and 2011) as "Developed Subbasin" (Figures 10.4-21 through 10.4-24 and Table 10.4-7).

Separate water balances were established for each of the five model scenarios, and are presented in Attachment C for TM-10.1. Table 10.4-2 presents the annual water balance for the entire Westside Basin for Scenario 1. Tables 10.4-3 through 10.4-6 present the annual water balance for the entire Westside Groundwater Basin for Scenarios 2, 3a, 3b, and 4 relative to Scenario 1. Figure 10.4-14 plots model-simulated total changes in groundwater storage for the entire Westside Basin for all evaluated scenarios, and Figure 10.4-15 shows the simulated storage change for each scenario relative to Scenario 1.

Figure 10.4-16 provides a graphical comparison of the volume of water in the SFPUC Storage Account to the aquifer storage calculated by MODFLOW model for the GSR Project Scenario (Scenario 2) relative to Scenario 1.

Figures 10.4-17 through 10.4-20 present a graphical comparison of water balance components for Scenarios 2, 3a, 3b, and 4 relative to Scenario 1 to demonstrate where the water for the

GSR and SFGW Project pumping is sourced. Graphs are based on the data presented in Attachment 10.1-D in TM-10.1. Since the GSR Project is located in the South Westside Basin and the SFGW Project is located in the North Westside Basin, these graphs are provided to illustrate the relative effects on the North and South Westside Basins from the Project conditions applied for each scenario.

Similar to the approach taken by HydroFocus (2009 and 2011), a water budget was developed for five water budget zones that are collectively referred to as the Developed Subbasin: Lake Merced/Golden Gate Park, Daly City, Colma, Cal Water, and San Bruno. The water balance components were calculated using the U.S. Geological Survey post-processor ZONEBUDGET (Harbaugh, 1990). Table 10.4-7 contains summary tables of the water budgets developed for each of the five model subareas. Results for the five model subareas (both simulated and relative to Scenario 1) are also presented on Figures 10.4-21 through 10.4-24 for the Project Scenarios (Scenarios 2, 3a, 3b, and 4).

The evaluation of Basin-wide changes in groundwater storage provides an overall analysis of the effects related to the various scenarios.

3.3.2. Scenario 1 - Existing Conditions

Scenario 1 represents the change in groundwater elevations without either the GSR or SFGW Projects and defines the background conditions, including wet, normal and dry precipitation years. Groundwater storage for Scenario 1 shows an initial increase in Scenario Years 1 and 2, but that is followed by a general decline over the scenario period except for periods of increase during Scenario Years 21 to 23 and Years 30 to 35. There is a substantial decline during the Design Drought period, followed by an increase in Scenario Years 44 to 47. By the end of Scenario 1, groundwater storage has declined approximately 28,000 af for the entire Westside Basin (Figure 10.4-14).

The 28,000-af decline in groundwater storage in Scenario 1 is due to the assumptions used for the background hydrology as necessitated by the inclusion of the Design Drought for consistency with the PEIR. The Design Drought repeats the 1976-77 drought. The result of repeating the drought is that there is an overall rainfall deficit over the 47-year scenario of nearly 20 inches compared to the 1958-2005 year sequence used in the HydroFocus 2008 No-Project Scenario (HydroFocus, 2011). Over the duration of the HydroFocus 2008 No-Project Scenario there is little to no change in groundwater storage. Recharge from precipitation and irrigation return flow (also dependent on rainfall) is calculated by the Soil Moisture Budget procedure discussed in TM-10.1 and documented in HydroFocus (2007, 2009, and 2011). Comparing the recharge calculated by the Soil Moisture Budget for the SFPUC scenarios with the HydroFocus 2008 No-Project Scenario shows that the 28,000-af decline in groundwater storage in Scenario 1 can be accounted for by the difference in rainfall between the different sets of background hydrology assumptions used. Therefore, the background hydrologic assumptions used in Scenario 1 provide a conservative analysis of the potential changes in groundwater storage. In evaluating groundwater storage, the results will primarily be discussed in terms of relative differences from Scenario 1 (Figure 10.4-15).

3.3.3. Scenario 2 - GSR Project

Scenario 2 represents the operation of the GSR Project, which is located in the South Westside Basin. The key components of the GSR Project are: in-lieu recharge during the put periods when groundwater pumping by SFPUC and the PAs does not occur and groundwater is placed into the SFPUC Storage Account using in-lieu recharge; hold periods when the PAs are pumping and no in-lieu recharge is occurring because the SFPUC Storage Account is full; and take periods which represent periods when both SFPUC and the PAs are pumping from the South Westside Basin. Scenario 2 starts with June 2009 initial groundwater levels that includes 20,000 af already in the SFPUC Storage Account from activities between 2002 and 2009 (LSCE, 2005). .

Scenario 2 begins with a 6.5-year put period that is reflected by an increased groundwater storage of 36,000 af across the whole Basin (not the SFPUC Storage Account) relative to Scenario 1 (Figure 10.4-15). From Scenario Years 7 through 36, there is a general decline in groundwater storage that is interrupted by sharp decreases during the two take periods followed by an equally sharp increase during the put period that returns the groundwater storage to the general declining trend relative to Scenario 1 (Figure 10.4-15). The Design Drought is an extended take period when the entire SPPUC Storage Account of 60,500 af is depleted. Over the duration of the Design Drought, there is an approximately 60,000-af decline in groundwater storage relative to Scenario 1. Following the Design Drought, about 20,000 af of in-lieu recharge is added to the Basin during the subsequent put period, and that is reflected by the 20,000-af increase in groundwater storage in the Basin.

Figure 10.4-15 shows that by the end of the simulation period the model-predicted aggregate reduction in groundwater storage is approximately 20,000 af. This means that at the conclusion of Scenario 2 there is predicted to be approximately 20,000 af less groundwater in storage in the entire Westside Basin than if the GSR Project were not implemented. However, as shown on Figure 10.4-15, Scenario 2 has a surplus of Basin groundwater storage relative to Existing Conditions is anticipated to exist for most of the entire simulation duration. Groundwater storage in the Basin is projected to decline, but still remains above Existing Condition storage levels, in response to the simulated take period around Scenario Year 11 and 27. This is due to increased pumping by GSR production wells during those drought periods, when available surface water supplies would be curtailed. However, it is not until sometime after the start of the Design Drought that Basin-wide groundwater storage is predicted to fall below that under the Existing Conditions Scenario. A relatively rapid recovery in groundwater storage volume is projected after the conclusion of the Design Drought period.

Scenario 2 assumes that there is an initial condition of 20,000 af of groundwater storage in the SFPUC Storage Account at the beginning of the scenario and that the SFPUC Storage Account is returned to a value of 20,000 af as a result of the put periods following the Design Drought. Figure 10.4-16 shows the SFPUC Storage Account and MODFLOW simulated aquifer storage on separate axes to illustrate that the SFPUC Storage Account is tracked separately. The total change in storage over the whole Basin does not represent any surpluses or deficits in the SFPUC Storage Account. Therefore, the groundwater storage deficit of 20,000 af relative to

Scenario 1 at the end of Scenario 2 indicates that the storage efficiency of the whole Basin is less than 100 percent. Averaged over the 47-year simulation period, the average annual loss is 425 afy.

Decline in groundwater storage primarily takes place when the groundwater storage is higher relative to Scenario 1. For example, during the 6.5-year put period at the beginning of the scenario, approximately 40,500 af of in-lieu recharge is added to the Basin; however, the increase in storage in the entire Basin relative to Scenario 1 is only 36,000 af (Figure 10.4-16). This indicates that about 4,500 af of storage is lost during the extended put period. During the following 30-year period, the SFPUC Storage Account is typically at 60,500 af with two short put-take cycles during this time. At the beginning of the Design Drought period, 40,500 af of the net additions of groundwater have been added to the basin through the GSR Project as represented by the SFPUC Storage Account (Figure 10.4-16). However, the MODFLOW model results show a steady decline in aquifer storage such that aquifer storage at the beginning of the Design Drought is only 20,000 af higher relative to Scenario 1.

Conversely, during the Design Drought and the following recovery period, the changes in groundwater storage more closely match the additions and subtractions under the operations of the GSR Project (Figure 10.4-16). Therefore, higher aquifer storage losses occur during periods when groundwater storage is higher relative to Scenario 1 and less aquifer storage losses occur when groundwater storage is lower relative to Scenario 1.

Therefore, a one to one ratio of supplemental surface water deliveries to the PAs does not result in an equal amount of simulated aquifer storage accrual via in-lieu recharge during put periods. During hold periods, when aquifer storage is above recent historic levels, some amount of aquifer storage loss occurs which is not accounted for in the SFPUC Storage Account.

The “efficiency” of the GSR Project is defined as the relative difference between the SFPUC Storage Account and the change in aquifer storage for Scenario 2 relative to Scenario 1. Based on this analysis, the efficiency of the GSR Project with respect to overall groundwater storage varies depending upon Basin conditions. During the initial filling process over the first seven years of put periods, the GSR Project is about 88 percent efficient. During the long period of primarily hold periods after this initial filling to the beginning of the Design Drought, the GSR Project has an efficiency of about 67 percent. During the Design Drought and recovery after the Design Drought, the GSR Project has nearly 100 percent efficiency. The overall average efficiency of the GSR Project over the 47.25 year simulation period is approximately 78 percent. This average efficiency is conservative because Scenario 2 includes a relatively long (30 year) period when the basin is largely full which magnifies the losses. Verification of actual losses can be conducted in the future by comparing modeled and actual groundwater elevations.

For comparison, a 2008 survey (MWH, 2009) found that loss factors used in seven conjunctive use programs in California in “ranged from 0 percent to 15 percent. These loss factors were intended to attain or maintain positive storage balances, account for evaporation/transpiration, account for operational/non-recoverable basin losses, and to minimize political concerns.” These losses factors imply an efficiency of 85 percent to 100 percent in the surveyed programs.

The GSR Project thus has a lower efficiency range of 67 percent to 100 percent (average 78 percent).

In comparing the water balance summary for Scenarios 1 and 2 for the North and South Westside Basins subareas (Figure 10.4-17 and TM10.1 Attachment 10.1-D), the changes in pumping from the GSR Project primarily result in a change in aquifer storage in the South Westside Basin and a shift in groundwater flow between the North and South Westside Basins. Other water balance components show only minor variations as result of GSR Project operations. During put periods, most of the reduced pumping (in-lieu recharge) results in an increase in aquifer storage with a minor amount resulting in a change in groundwater flow from the South to the North Westside Basin. Conversely, during take periods, most of the increased pumping is derived from a decline in aquifer storage with a minor amount resulting in a change in groundwater flow from the North to the South Westside Basin. During hold periods, there are only minor declines in aquifer storage. Overall, the changes in the North Westside Basin are minor relative to those observed in the South Westside Basin. With increasing groundwater levels, the hydraulic gradient in the North Westside Basin shifts to a more westward direction, resulting in slight increases in outflows to Lake Merced and to the Pacific Ocean.

For Scenario 2, the conservation of basin groundwater storage expected for the GSR Project is shown by positive relative storage changes for all five Developed Subbasin model subareas, but is particularly evident in the central South Westside Basin where GSR wells are concentrated (Table 10.4-7 and Figure 10.4-21). For the Daly City and San Bruno subareas, the proposed pumpage rates are smaller than under the Existing Conditions Scenario, which reflects the cessation or reduction of pumping during put periods. The largest relative storage increases, 140 and 141 afy, are shown for the Colma and Cal Water (South San Francisco) subareas, respectively, both located in the central South Westside Basin. In essence, the relative groundwater storage increases in the Colma and Cal Water subareas are provided by groundwater flow from adjacent subareas (Daly City and San Bruno, respectively). The Lake Merced/GGP subarea is shown to be relatively unaffected during GSR Project operation, except for somewhat less groundwater flow to the Daly City subarea to the south.

3.3.4. Scenario 3a and 3b - SFGW Project

Scenarios 3a and 3b represent the operation of the SFGW Project, which includes additional groundwater pumping in the North Westside Basin. The changes in groundwater storage are similar for Scenarios 3a and 3b (Figures 10.4-14 and 10.4-15). Basin-wide groundwater storage shows a steady decline over the duration of the scenario, but the rate of decline decreases over the simulation period. At the end of the simulation period, groundwater storage declines by approximately 32,000 and 30,000 af for Scenarios 3a and 3b, respectively. The slight differences in storage changes between the two scenarios are attributable primarily to the somewhat greater total Basin pumping rate in Scenario 3a (12.75 mgd) compared to Scenario 3b (12.61 mgd; Table 10.4-1).

Figures 10.4-18 and 10.4-19 show the water balance components for Scenario 3a and 3b, respectively, relative to Scenario 1 in the North Westside Basin. The results for Scenario 3a and

3b are similar so they are discussed together. Figures 10.4-18 and 10.4-19 indicate that the majority of the increased pumping would initially come from groundwater storage (i.e. loss of groundwater storage). Loss of groundwater storage is highest in the first five years of the simulation. Over the first 10 to 15 years of the simulation, annual storage loss resulting from SFGW Project pumping would continue to decline, while the interception of groundwater flow to the Pacific Ocean would continue to increase. This represents that after the initial decline in groundwater levels, groundwater pumping by the SFGW Project is primarily sustained by the interception of groundwater flow that would otherwise have discharged to the Pacific Ocean. There are little to no changes in the South Westside Basin due to the increased pumping from the SFGW Project.

For Scenarios 3a and 3b, pumping associated with SFGW Project wells located in the North Westside Basin is shown on Table 10.4-7 and Figures 10.4-22 and 10.4-23 as substantial increases in pumping rates for the Lake Merced/Golden Gate Park subarea relative to Scenario 1. Based on this subarea zone budget analysis, 76 percent of the increased groundwater pumping from the SFGW Project wells in the North Westside Basin is offset the interception of groundwater flow to the Ocean, while the decrease in storage represents only 15 percent of the increased groundwater pumping. As expected, the effects of Scenarios 3a and 3b on the subareas in the South Westside Basin is small compared to the changes seen in the Lake Merced/Golden Gate Park subarea.

3.3.5. Scenario 4 – Cumulative Scenario

Scenario 4 represents the combined effects of operations of the GSR (Scenario 2) and SFGW (Scenario 3b) Projects. Scenario 4 also includes additional water being diverted into Lake Merced.

For Scenario 4, Figure 10.4-15 shows that groundwater storage increases to about 22,000 af above that of Scenario 1 after the initial 7-year put period. Groundwater storage steadily declines over following 30 years closely following the trend of Scenario 2 but about 15,000 to 20,000 af lower relative to Scenario 2 reflecting the influence of the SFGW Project. At the beginning of the Design Drought, the groundwater in storage is about 4,000 af lower than under Scenario 1. During the Design Drought, the combined pumping of the GSR and SFGW Projects lowers the groundwater storage to about 65,000 af lower than under Scenario 1. After the put period at the end of the simulation period, groundwater storage for the entire Westside Basin is approximately 45,000 af less than under Scenario 1. Because of the similar trends in groundwater storage between Scenario 2 and 4, the storage efficiency for Scenario 4 is considered to be similar to Scenario 2. Because Scenario 4 includes assumptions not included in Scenario 1, a direct comparison to estimate efficiency is not appropriate.

The overall trend in groundwater storage changes for Scenario 4 follows that of Scenario 2, but the volume of groundwater storage for Scenario 4 is lower, reflecting the increased pumping by the SFGW Project (Figure 10.4-15). However, the difference in storage between Scenarios 2 and 4 is less than the decrease of storage under Scenarios 3a and 3b. This discrepancy is the primarily the result of additional recharge under Scenario 4 due to the stormwater additions to Lake Merced under the Daly City Vista Grande Basin Improvements Project.

Figure 10.4-20 shows the net change in the water balance for the North and South Westside Basins. In general, the graphs look like a composite of Scenarios 2 and 3b, as would be expected. The influence of the other foreseeable projects under the Cumulative Scenario is relatively small with respect to groundwater storage. A portion of the increase in groundwater storage in Scenario 4 compared to Scenario 1 is a result of additional seepage from Lake Merced, amounting to about 4,000 af by the end of Scenario 4. This can be seen on Figure 10.4-20 and Table 10.4-6 (also see TM 10.1 Attachment 10.1-D) where Lake Merced has an overall net discharge to groundwater due to the stormwater additions from the Daly City Vista Grande Basin Improvements Project.

For the Developed Subbasin subareas, storage changes related to pumping of the SFGW Project in the North Westside Basin and pumping of the GSR Project in the South Westside Basin are shown on Table 10.4-7 and Figure 10.4-24. By combining the Design Drought pumping conditions of Scenario 2 with the year-round pumping of the SFGW Project wells in the North Westside Basin, Scenario 4 has the maximum Basin storage declines during the Design Drought among the Project Scenarios relative to the Existing Conditions.

4. Historical Data Evaluation and Qualitative Assessment

The results of significant groundwater modeling efforts, such as the Westside Basin Groundwater-Flow Model, are often substantiated by other independent means. While the model development process involves internal calibration and validation (using comparisons to observed groundwater levels), additional efforts are often undertaken to evaluate the "reasonableness" of model results as they relate to observable measurements or practical expectations. The process of comparing model results to observed data, or evaluating the results from the perspective of what might be reasonable based on scientific principles, is termed "empirical analysis." The purpose of conducting an empirical analysis of groundwater modeling results is to provide an additional, independent confirmation of the model results.

4.1. Groundwater Level Analysis

The empirical analysis conducted for this TM involved comparing groundwater level changes predicted by the model to historic groundwater levels measured within the Westside Basin. To facilitate the comparisons, the ranges of groundwater levels (low to high) simulated by the model for each scenario were compared to the ranges of recorded historic groundwater levels.

The historic groundwater levels were measured in wells that are included in the Westside Basin Groundwater Monitoring Network. Most of the continuous water level data available from these wells were collected from the early 2000s through 2009 (SFPUC, 2010). However, some of the well measurement data extend back to the mid-1990s, a period during which extreme drought conditions (and thus very low local groundwater levels) were experienced in the Westside Basin. Actual groundwater level measurements from that recent drought period are particularly useful for comparing to model results because both sets of measurements, actual and simulated, reflect groundwater levels under particularly stressed Basin conditions.

Table 10.4-8 provides a summary of the comparison between historic and model-predicted groundwater levels corresponding to each of the evaluated scenarios (refer to Figure 10.4-1 for the locations of wells listed on the table). The selected well locations provided in Table 10.4-8 encompass representative portions of the Basin, from Golden Gate Park in the north to Burlingame in the south. The monitoring wells are grouped according to whether they are completed in the Shallow Aquifer or the Primary Production Aquifer and the period when measured data are available for each location is shown.

This comparison of the range of observed groundwater levels to the range of simulated groundwater levels for each scenario provides context for evaluating the simulation results for the GSR and SFGW Projects to the range of groundwater levels that have been observed in the Basin. A direct comparison is limited because the historical conditions represent a different set of conditions than those included in the scenarios. Rather the intent is to compare whether the GSR and SFGW Project scenario results show groundwater levels that are substantially higher or lower than was has been experienced historically.

From Table 10.4-8, the results of the comparisons show the following:

- For Scenario 1, the simulated groundwater levels are generally within the range of historical groundwater levels measured in the Basin over the past 5 to 15 years.
- For Scenario 2, groundwater levels in the North Westside Basin and the Shallow Aquifer are generally within the historical range whereas groundwater levels in the South Westside Basin and the Primary Production Aquifer show a range wider than the historical range representing the effects of the put-take-hold conditions of the GSR Project operations.
- For Scenarios 3a and 3b, groundwater levels in the North Westside Basin are typically below the historical range showing the effects of the SFGW Project operations. In the South Westside Basin, groundwater levels are generally within the historical range.
- For Scenario 4, groundwater levels in the North Westside Basin are generally below the historical range, representing the effects of the SFGW Project. In the South Westside Basin and the Primary Production Aquifer show a range wider than the historical range representing the effects of the put-take-hold conditions of the GSR Project operations.

Overall, this empirical analysis demonstrates that the ranges of model-predicted changes in groundwater levels for each of the scenarios fall reasonably within the ranges measured in the Basin over the past 15 years or so.

4.2. In-Lieu Recharge Demonstration Study

From fall 2002 to spring 2005, SFPUC, in coordination with the PAs, conducted an In-Lieu Recharge Demonstration Study (Demonstration Study; also known as the Westside Basin Conjunctive Use Pilot Project) in the Westside Basin. The primary purpose of the Demonstration Study was to evaluate the response of Basin groundwater conditions to reduced pumping by the PAs (i.e. implementation of “in-lieu” recharge). The manner in which the Demonstration Study was conducted is closely representative of planned operations for the proposed GSR Project. Therefore, the response of Basin groundwater conditions observed during the Demonstration Study is an important indicator for forecasting the potential Basin response to future implementation of the GSR Project.

4.2.1. Project Overview

The In-Lieu Recharge Demonstration Study involved the cessation of municipal pumping in the South Westside Basin by Daly City, Cal Water, and San Bruno. Supplemental surface water provided by SFPUC to each of the PAs was used to replace the water supply normally obtained by pumping in the Basin.

The Demonstration Study occurred mostly from October 2002 through March 2005, when it was discontinued in the San Bruno area (LSCE, 2005b and 2010). Between January 2003 to March 2005, SFPUC delivered approximately 3,900 af of water to San Bruno, 6,200 af to Daly City, and 1,820 af to Cal Water. After the completion of the Demonstration Study in 2005, SFPUC continued to deliver supplemental surface water to Cal Water through January 2007 and to Daly City through April 2007, resulting in reduced groundwater pumping in these areas. With the continued surface water delivery of SFPUC to Cal Water and Daly City, the total surface water delivery to the PAs from October 2002 through April 2007 reached approximately 20,000 afy. No supplemental deliveries were conducted from May 2007 to May 2009.

After cessation of the Demonstration Study in March 2005, San Bruno pumping resumed at about 1,800 to 2,300 afy (LSCE, 2010). Groundwater pumping for municipal supply by Cal Water in the South San Francisco area resumed on a limited basis in March 2008 and totaled 206 af during 2008 (LSCE, 2010). Daly City pumping was about 3,600 af for 2008.

4.2.2. Results

Results from the Demonstration Study indicated that in-lieu recharge in the Westside Basin can be successfully accomplished by reducing pumping, resulting in increases in groundwater storage. During the Demonstration Study, groundwater levels were measured in select wells located throughout the Basin to document the recovery, or rise, in groundwater levels resulting from reduced pumping. From these data, the amount of groundwater storage increase associated with the rising water levels was estimated for the three areas of the Basin encompassed by each of the PAs. Groundwater levels rose by about 20 feet in the Daly City area, 13 feet in the South San Francisco area, and 12 feet in the San Bruno area during the period of the Demonstration Study (LSCE, 2005b). Details of the changes in groundwater levels are discussed in more detail in reports by LSCE (2005b, 2010).

For the entire area within the three PA service areas, the total increase in groundwater storage in the South Westside Basin during the Demonstration Study was estimated to be approximately 13,000 af (LSCE, 2005b). At the start of the Demonstration Study, Daly City reduced groundwater production by 2.9 mgd from October 2002 to March 2005. In other words, the aquifer in the Daly City area was being recharged, by in-lieu means, at the rate of approximately 2.9 mgd for approximately 2 years and 5 months. By the end of that period, it was estimated that approximately 6,300 af of in-lieu recharge had occurred in Daly City. Cal Water reduced groundwater pumping by 1.2 mgd for approximately 2 years and 4 months (from November 2002 to March 2005), which resulted in an estimated resultant groundwater storage increase of approximately 3,600 af. The storage increase for San Bruno was estimated to be 3,000 af (LSCE, 2005b).

For Scenarios 2 and 4, 13,000 af of groundwater recharge occurred during the major put periods of the simulation including the first three years of the simulation, the recovery after two take periods during the simulation, and after the Design Drought. In these cases, the simulated groundwater levels rose by about 50 feet in the Daly City area, 50 feet in the South San Francisco area, and 40 feet in the San Bruno area. The model results show some differences because the drawdown during the preceding take period included the operation of both the GSR Project and PA municipal wells which is different than the conditions of the Demonstration Study. Therefore, a portion of the rise in groundwater levels includes an aquifer recovery from the decreased pumping. Therefore, it is considered that the model results are comparable to the observed conditions from the Demonstration Study.

The results of the Demonstration Study show the responsiveness of the Westside Basin aquifers to in-lieu recharge, the increase in Basin groundwater storage related to cessation of large-scale municipal pumping. The Demonstration Study results are likely not directly applicable to full-scale implementation of the proposed GSR Project due to the variable subsurface conditions present throughout the entire Basin, and due to the Basin storage inefficiencies discussed previously. However, the approximate relationship of reduced large-scale pumping to increases in groundwater storage demonstrated by the Demonstration Study gives an indication of the magnitude of storage increases that could be reasonably expected in the Basin with GSR Project implementation.

4.3. Westside Groundwater Basin Water Budget

A groundwater budget for the entire Westside Basin was produced as part of the calibration of the Westside Basin Groundwater-Flow Model (HydroFocus, 2007, 2009, and 2011). Groundwater budgets have been developed for Golden Gate Park, the Golden Gate Park and Lake Merced area, and the Daly City area, and are presented in LSCE (2010).

Under existing conditions the predominant inflow component is percolating rain and irrigation water, which together are the primary recharge mechanisms in the Westside Basin system (HydroFocus, 2007). Inflow from Lake Merced and the GGP lakes is relatively minor, with modeled inflow from the Ocean and Bay even smaller and limited to the coastal fringe areas. The primary outflow component is large-scale pumping from municipal and irrigation wells in the Basin. Outflows to the Ocean and Bay are relatively modest (although substantially greater than simulated inflow rates from the same), and outflow seepage to Lake Merced is lower still (but greater on average than simulated inflows to the lake).

The average annual recharge for the Westside Basin from the period 1959 through 2009 was estimated by the groundwater model to be 14,740 afy (HydroFocus, 2011). Of that, 7,006 afy were apportioned to the North Westside Basin and 7,734 afy to the South Westside Basin. For the North Westside Basin, recharge was estimated by LSCE (2007) to be 6,800 afy, while Phillips et al. (1993) estimated 4,850 afy of recharge for 1988 and 1989, the first two years of an extended drought period. The estimate by Phillips et al. (1993) was developed for a drought period, and is not considered representative of long-term average conditions. No other estimates of total recharge for the South Westside Basin have been documented.

In discussing the water balance, the HydroFocus (2011) report focuses on the Developed Basin. The results of the 2008 No-Project Scenario (HydroFocus, 2011) are compared to the results of Scenario 1 (Table 10.4-7) for the Developed Basin. Key observations are that the recharge from precipitation and return flows are higher in the 2008 No-Project Scenario (11,532 afy compared to 10,310 afy annual average) as expected because Scenario 1 uses a more conservative hydrologic sequence that incorporates the Design Drought (TM 10.1). Pumpage rates are comparable with an annual average of 10,551 afy for the 2008 No-Project Scenario and

10,227 afy for Scenario 1. The differences are due to minor changes to the pumping assumptions as discussed in TM 10.1. Similarly, outflow to the Pacific Ocean is comparable with an annual average of 3,258 afy for the 2008 No-Project Scenario and 3,139 afy for Scenario 1. There is a difference in the net change in groundwater storage due primarily to the differences in recharge. The annual average change in aquifer storage is an increase of 3 afy for the 2008 No-Project Scenario and a decrease of 613 afy for Scenario 1.

This comparison of the 2008 No-Project Scenario to Scenario 1 shows that the overall model assumptions are similar. The use of the new hydrologic sequence makes Scenario 1 more conservative with respect to aquifer storage due to the overall decrease in groundwater recharge with the addition of the Design Drought to Scenario 1.

4.4. Total Groundwater Volume in Westside Basin

A volumetric calculation was made to evaluate a reasonable estimate for the total volume of groundwater currently present in the Westside Basin. The volumetric estimate is based the volume of the aquifer from the Westside Basin Groundwater Model and an estimate of the available pore space, or porosity, within the aquifer to store water. This is a static calculation of the total groundwater present in the Basin and does not consider recharge or the long-term effects of pumping. This volumetric estimate provides additional context for evaluating the scale of aquifer storage changes from the GSR and SFGW Project scenarios. This analysis compares the total groundwater storage changes from each model scenario and compares that to the total groundwater in the basin. The purpose of this comparison is only to provide a sense of the scale of the potential aquifer storage changes relative to the size of the groundwater basin. This analysis is not intended to provide an assessment of the sustainable yield or operational storage of the Westside Basin.

The method used to estimate the total groundwater in the Basin was based on results from the Westside Basin Groundwater-Flow Model (HydroFocus, 2011). Because the spatial distributions of the five Model Layers are different, the total groundwater volume was estimated separately for each layer. The upper surface of each Model Layer cell was defined as the lower of either the top aquifer elevation or, for Model Layer 1, the June 2009 groundwater elevation. The lower surface of each layer was the bottom aquifer elevation. The aquifer thickness is the difference between the upper and lower surface elevations. This process was repeated to determine the volume of each of the five Model Layers individually, and these volumes were then summed to determine the total aquifer volume.

To define the groundwater volume, the aquifer volume of each Model Layer was multiplied by the specific yield values used in the Westside Basin Groundwater-Flow Model (HydroFocus, 2011). The specific yield provides a representative estimate of the effective porosity of the aquifer. The specific yield used in the calibrated Westside Basin Groundwater-Flow Model (HydroFocus, 2011) was 0.14 for Model Layers 1 through 4 and 0.05 for Model Layer 5.

Using the above method results in a total saturated storage capacity, a reasonable maximum storage based on June 2009 groundwater levels calculated by the model. To facilitate this analysis, the Westside Basin is defined as three onshore subareas. The two offshore subareas included in the MODFLOW model underlying the Pacific Ocean and San Francisco Bay are not included in this analysis. The results of the volumetric calculations for the three onshore subareas are summarized below:

- The North Westside Basin subarea was defined as the portion of the Basin north of the San Mateo-San Francisco County Line and east of either Ocean Beach or the Serra Fault (where it is located onshore). The total estimated groundwater volume in this subarea is 223,000 af.
- The South Westside Basin subarea was defined as the portion of the Basin east of the Serra Fault, south of the San Mateo-San Francisco County Line, and west of the San Francisco International Airport. The total estimated groundwater volume in this subarea is 513,000 af.
- The Serra Block subarea was defined as the portion of the Basin east of the Pacific coast and west of the Serra Fault (where it is located onshore). The total estimated groundwater volume in this subarea is 340,000 af.

The total groundwater volume in the onshore Westside Basin estimated using this method was 1,078,000 af.

For the GSR-Only Scenario (2), the change in groundwater storage relative to the Existing Conditions Scenario (1) was a decrease of approximately 420 afy for a total change in storage over the 47-year simulation period of about -19,530 af. This volume represents about 1.8 percent of the total groundwater volume in the entire Westside Basin and 3.8 percent of the total groundwater volume of the South Westside Basin subarea.

For the SFGW-Only Scenario 3a, the change in groundwater storage relative to the Existing Conditions Scenario (1) was a decrease of approximately 680 afy for a total change in storage over the 47-year simulation period of about -32,170 af, representing about 3.0 percent of the total groundwater volume in the entire Westside Basin at the end of the simulation period and 14.4 percent of the total groundwater volume of the North Westside Basin subarea. For Scenario 3b, the change in groundwater storage relative to the Existing Conditions Scenario (1) was a decrease of about 640 afy, for a total change in storage over the 47-year simulation period of about -30,080 af, representing about 2.8 percent of the total groundwater volume in the entire Westside Basin and 13.5 percent of the total groundwater volume of the North Westside Basin subarea.

For the Cumulative Scenario (4), the change in groundwater storage relative to the Existing Conditions Scenario (1) was a decrease of approximately 970 afy for a total change in storage over the 47-year simulation period of about -45,480 af, representing about 4.2 percent of the total groundwater volume in the entire Westside Basin.

5. Summary

This section summarizes the results of the numerical modeling and analytical approaches with respect to changes in groundwater levels and storage in the Westside Basin.

5.1. Existing Conditions (Scenario 1)

Scenario 1 simulates Basin conditions without either the GSR or SFGW Projects and defines the background conditions against which the other model scenarios are compared, including wet, normal and dry precipitation years. By the end of Scenario 1, groundwater storage would decline approximately 28,000 af for the entire Westside Basin (Figure 10.4-14). The 28,000-af decline in groundwater storage in Scenario 1 is due to the assumptions used for the background hydrology, which include a Design Drought as necessitated by the need for consistency with the PEIR. The Design Drought repeats the historical 1976-77 drought, resulting in an overall rainfall deficit of nearly 20 inches over the 47-year simulation period. This rainfall deficit is nearly equivalent to losing a full year of precipitation and its associated recharge for the entire basin. Comparing the recharge calculated by the Soil Moisture Budget for the SFPUC scenarios with the HydroFocus 2008 No-Project Scenario shows that the decline in groundwater storage in Scenario 1 can be accounted for by the difference in rainfall between the different sets of background hydrology assumptions used. The background hydrology assumptions used for all of the scenarios therefore provide a conservative analysis with respect to the potential changes in groundwater levels and storage.

In the North Westside Basin, groundwater levels generally fluctuate within a narrow range in response to climatic conditions. Both groundwater levels and storage for Scenario 1 show an initial increase in Scenario Years 1 and 2, followed by a general decline over the scenario period except for periods of increase during Scenario Years 21 to 23 and Years 30 to 35. There is a substantial decline during the Design Drought period followed by an increase in Scenario Years 45 to 47.

In the South Westside Basin, groundwater levels in Model Layer 4 show a similar trend of steady decline over the 47-year simulation period. In Model Layer 1, groundwater levels show an increasing trend, with about a 20-foot rise over 47 years. The difference in groundwater elevations in the Shallow and Primary Production Aquifers (Model Layers 1 and 4) ranges from 10 to 20 feet in the Daly City area to 200 to 250 feet in the San Bruno area.

5.2. GSR Project Only (Scenario 2)

Scenario 2 represents the operation of the GSR Project, which is located in the South Westside Basin. Groundwater levels and storage show increases during put periods and decrease during take periods (see Section 3 for a definition of put/take/hold periods). Because of the Project location, the largest changes in groundwater levels and storage are primarily in the South Westside Basin. The general response to the GSR operations is greatest in the Primary

Production Aquifer (Model Layer 4) and more subdued to absent in the Shallow Aquifer (Model Layer 1), especially in the South San Francisco and San Bruno areas.

In general, groundwater levels and storage increase during put/hold periods and decrease during take periods. The greatest increase occurs during the first extended put period from Scenario Years 1 to 7, which is followed by a slow decline. Two take periods from Scenario Years 9 to 12 and Scenario Years 25 to 28 show up distinctly with declines in groundwater levels and storage. All locations have their lowest groundwater levels and storage at the end of the Design Drought when pumping from both the SFPUC and PA wells occurs. The greatest declines occur in the Daly City, South San Francisco and Colma areas because most of the GSR Project wells are located in this area. At the start of the Design Drought, groundwater levels and storage are well above Scenario 1 levels, but decline to well below Scenario 1 levels by the end of the Design Drought. During the 3-year put period from the end of the Design Drought to the end of the scenario, groundwater levels generally recover to near or above Scenario 1 levels.

In the North Westside Basin, the greatest effects of the GSR Project occur in locations near the southern end of Lake Merced primarily in the Primary Production Aquifer (Model Layer 4). Locations north of Lake Merced and in Golden Gate Park show little to no change in groundwater levels or storage due to the GSR Project.

Scenario 2 assumes that there is 20,000 af of groundwater in the SFPUC Storage Account at the beginning of the scenario (represented in the initial conditions) and 20,000 af in the SFPUC Storage Account at the end of the scenario due to the put period immediately following the Design Drought. Therefore, the reduction in groundwater storage of about 20,000 af relative to Scenario 1 is not due to any change in the SFPUC Storage Account, but rather to the fact that the storage efficiency of the Basin is less than 100 percent. Most of this decline occurs when groundwater levels are higher than under Scenario 1 during Scenario Years 7 through 36. Most of this loss in storage is attributed to declines in groundwater inflows from the North to the South Westside Basin. With the increased groundwater levels simulated under Scenario 2, the hydraulic gradient in the North Westside Basin shifts to a more westward direction, resulting in increased outflows to Lake Merced and to the Pacific Ocean. Based on this analysis, the overall average efficiency of the GSR Project of the 47.25 year simulation period is approximately 78 percent.

Based on this analysis, groundwater levels and storage during Scenario Years 1 through 36 are generally higher than Scenario 1. During the Design Drought, groundwater levels and storage decline below Scenario 1 levels, but show a strong recovery after the Design Drought. Therefore, from a groundwater Basin management perspective, the operation of the GSR Project is not expected to deplete or interfere with Basin groundwater supplies in a manner that would result in a substantial regional deficit in aquifer storage.

5.3. SFGW Project Only (Scenarios 3a and 3b)

The SFGW Project would construct up to six wells and associated facilities in the western part of San Francisco and pump either 3.0 mgd (Scenario 3a) or 4.0 mgd (Scenario 3b) of groundwater from the North Westside Basin (SFPUC, 2009). Scenario 3a assumes 3.0 mgd of pumping for water supply and 1.142 mgd irrigation pumping in Golden Gate Park, whereas Scenario 3b assumes 4.0 mgd of pumping for water supply, with pumping of groundwater for irrigation in Golden Gate Park replaced by recycled water. Because this overall change in pumping is minor, the regional response of groundwater levels to these scenarios is comparable, and the results for Scenarios 3a and 3b are discussed together.

In general, all well locations evaluated in the North Westside Basin area show a similar declining trend in groundwater levels relative to Scenario 1 due to the SFGW Project operations. There is an initial decrease in groundwater levels in the first 5 to 10 years of the scenarios. Following this, the rate of change in groundwater levels relative to Scenario 1 is much less. In the northern locations, the rate of change relative to Scenario 1 after about Scenario Year 20 is near zero, whereas the locations near Lake Merced show a steady decline in groundwater levels relative to Scenario 1, but at a rate much lower than during the initial decline.

In the South Westside Basin, modest groundwater level and storage declines occur in the Daly City area, but these effects diminish to the south and are barely discernible in the San Bruno area.

At the end of the scenarios, the reductions in Basin groundwater storage are approximately 30,000 af for both Scenarios 3a and 3b. For locations in the North Westside Basin, the results show that groundwater levels and storage tend to stabilize after an initial period of steeper declines. During the early simulation period, the majority of the increased pumping initially comes from groundwater storage. Over time, storage provides less of the SFGW Project pumping, and groundwater pumping is instead primarily sustained by the interception of groundwater flow to the Pacific Ocean. Therefore, from a long-term regional groundwater basin management perspective, the operation of the SFGW Project is not expected to deplete or interfere with Basin groundwater supplies in a manner that would result in a substantial regional deficit in aquifer storage or produce continuing long-term declines in groundwater levels.

5.4. Cumulative Project Scenario (Scenario 4)

Scenario 4 represents the combined effects of operations of the GSR (Scenario 2) and SFGW (Scenario 3b) Projects. The resulting groundwater level responses in the North Westside Basin tend to be intermediate between the responses seen for Scenarios 2 and 3b. Scenario 4 also includes additional stormwater being diverted into Lake Merced. The effect of these stormwater additions substantially improves lake levels in Lake Merced. Also, increases in groundwater levels resulting from the additional seepage due to these lake additions are primarily concentrated in the Shallow Aquifer in the vicinity of Lake Merced. Another change for Scenario 4 is the planned replacement of the Daly City A-Street Well with a production well located west of the Serra Fault, which is away from the main part of the Westside Basin. This change has the effect of reducing pumping in the Daly City area east of the Serra Fault due to the low groundwater flow across the fault.

In general, Scenario 4 responses in the North Westside Basin closely resemble those of Scenario 3b, whereas in the South Westside Basin the responses closely resemble those of Scenario 2. The Lake Merced and Daly City areas represent the transition zone, where a combined effect is seen. In these areas, the responses vary by aquifer; Shallow Aquifer (Model Layer 1) responses more closely resemble those of Scenario 3b, whereas Primary Production Aquifer (Model Layer 4) responses more closely resemble those of Scenario 2. The Daly City area also shows a slight increase in groundwater levels and storage relative to Scenario 1 due to the change in the location of the Daly City A-Street Well.

The overall trend in groundwater storage changes for Scenario 4 follows that of Scenario 2, but the volume of groundwater storage in Scenario 4 is lower, reflecting the increased pumping by the SFGW Project. However, the difference in storage between Scenarios 2 and 4 is less than the decrease in storage seen under Scenarios 3a and 3b. There is a slight increase in groundwater storage in Scenario 4 relative to Scenario 1 resulting from the additional seepage from Lake Merced, amounting to about 4,000 af by the end of Scenario 4. The storage efficiency is similar in Scenario 4 to Scenario 2 as the trends are very close to parallel.

With respect to regional groundwater management issues, the cumulative operation of the SFGW and GSR Projects, along with other reasonably foreseeable future projects, is not expected to deplete or interfere with Basin groundwater supplies in a manner that would result in a substantial regional deficit in aquifer storage.

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San Francisco Public Utilities Commission (SFPUC) 2008. 2007 Annual Groundwater Monitoring Report, Westside Basin, San Francisco and San Mateo Counties, California. Dated April 2008.

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San Francisco Public Utilities Commission (SFPUC) 2010. Final 2009 Annual Groundwater Monitoring Report, Westside Basin, San Francisco and San Mateo Counties, California. Dated May 2010.

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Figure List

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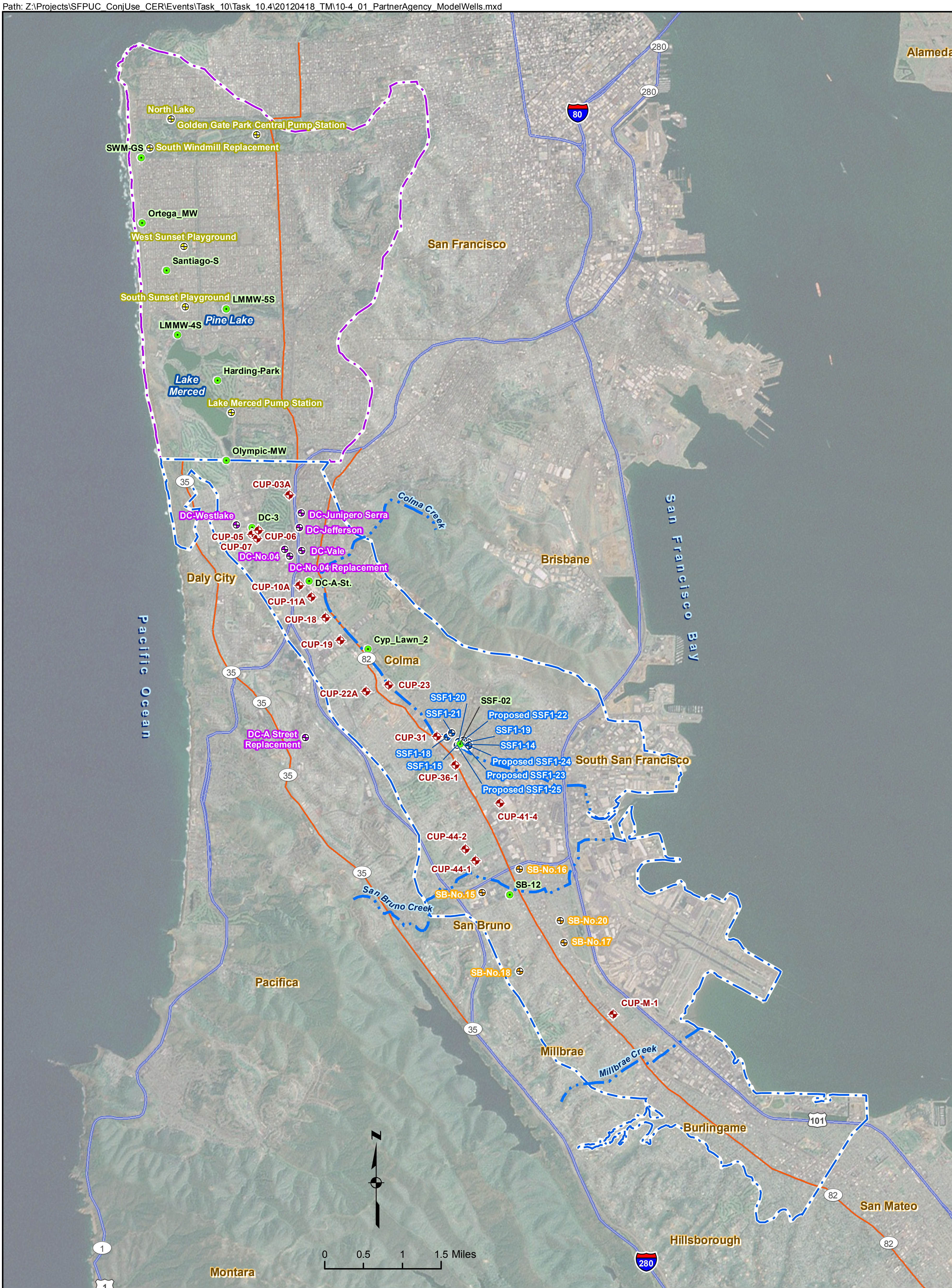

Aerial Photo Source: World Imagery from ESRI. Copyright:© 2009 ESRI, AND, TANA, UNEP-WCMC

Note:
The Santiago-S Location and the Harding Park Location are locations used by the Westside Basin Groundwater-Flow Model to track the model-simulated water levels. They represent historical well locations, but are not the current locations of active monitoring wells

Legend

- GSR Proposed Municipal Wells
- SFGW Proposed Municipal Wells
- Selected Representative Monitoring Wells
- Cal Water Municipal Wells
- Daly City Municipal Wells
- San Bruno Municipal Wells
- South Westside Groundwater Basin
- North Westside Groundwater Basin

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
ENGINEERING MANAGEMENT BUREAU

LOCATIONS OF PARTNER AGENCY WELLS, PROPOSED GSR AND SFGW PROJECT MUNICIPAL WELLS, AND SELECTED REPRESENTATIVE MONITORING WELLS WITH MODEL RESULTS

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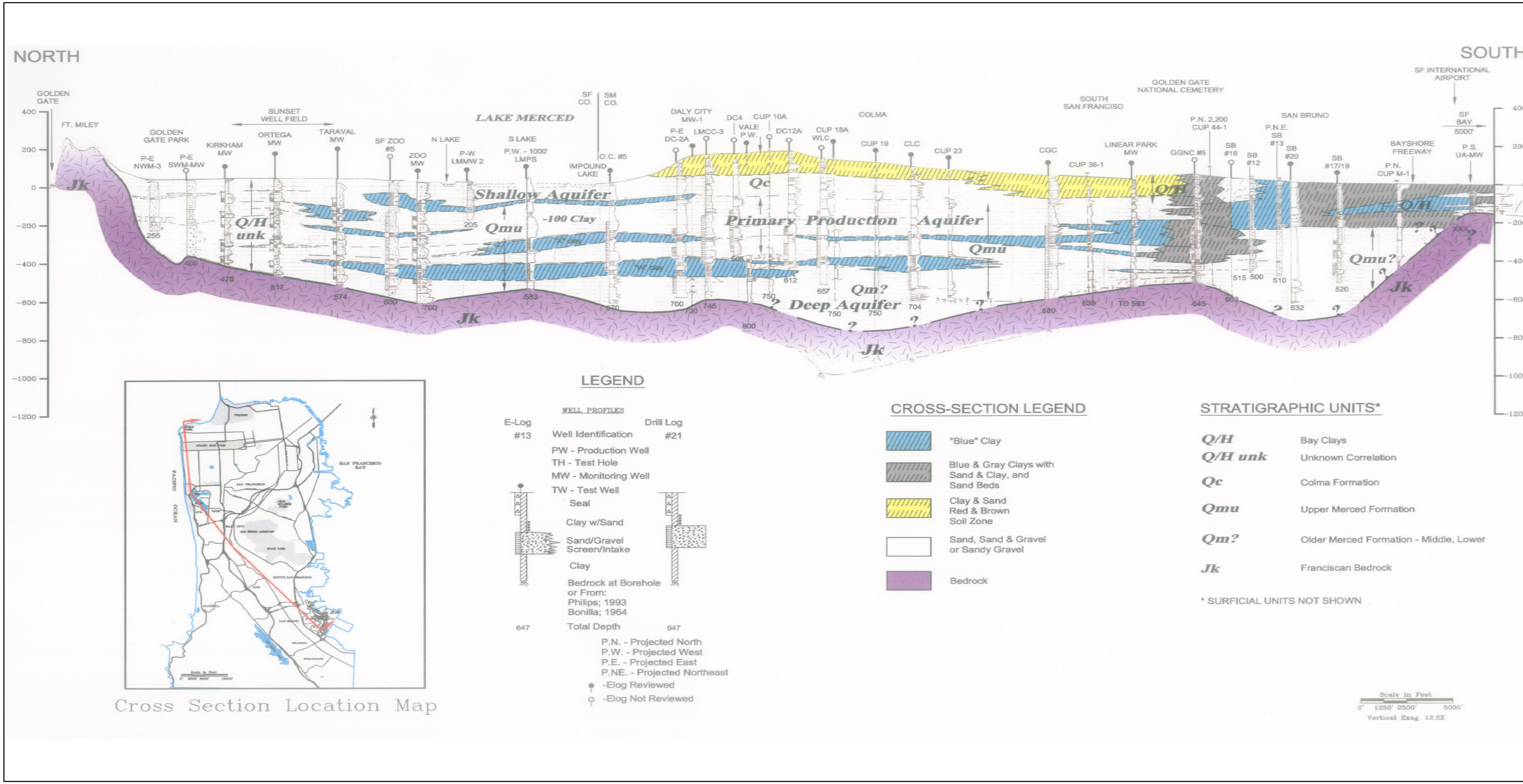
San Francisco, CA 94107

Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Figure
10.4-1

Date
April 2012



Source: Final Task 8B Technical Memorandum No.1, Hydrologic Setting of the Westside Basin, LSCE, May 2010.

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Westside Basin Regional Subsurface Hydrogeology

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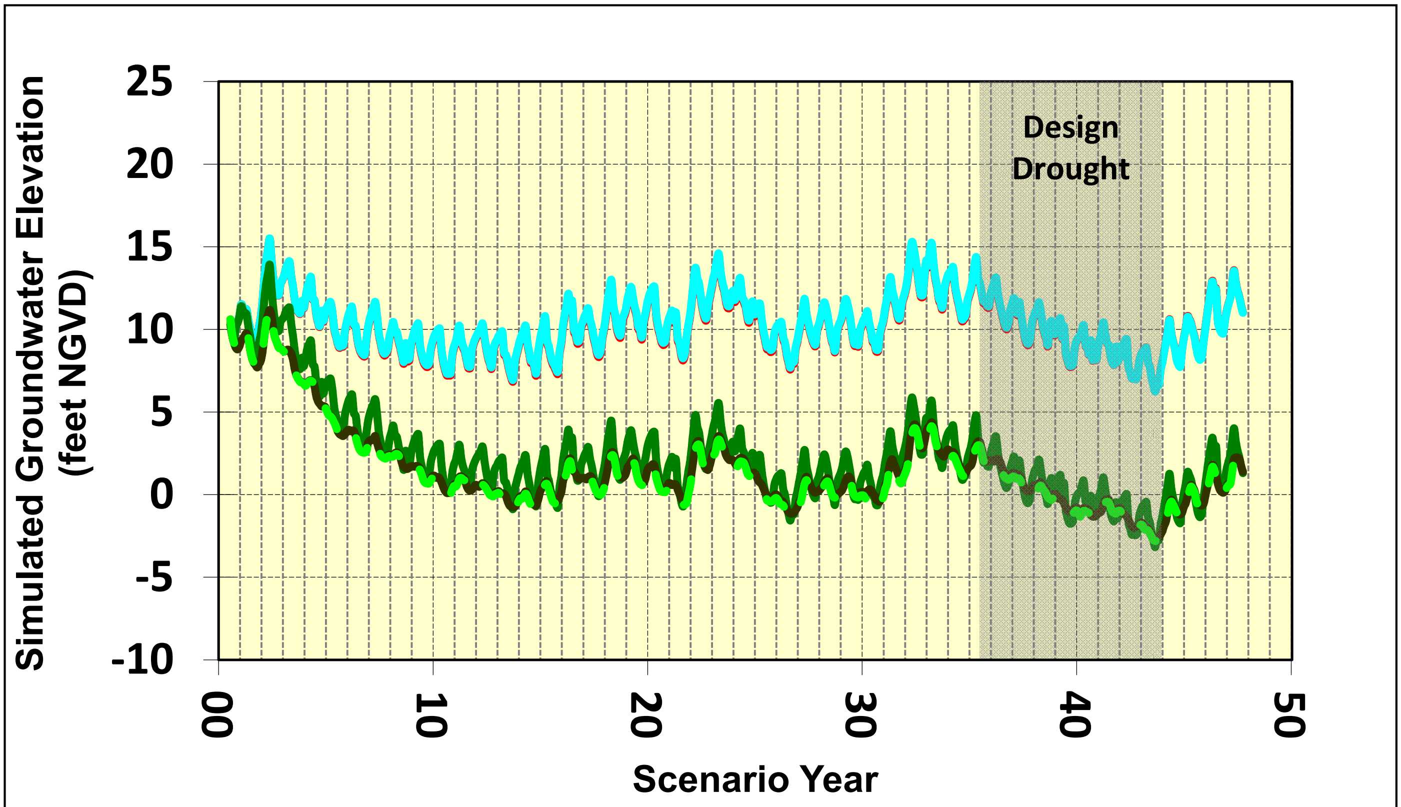
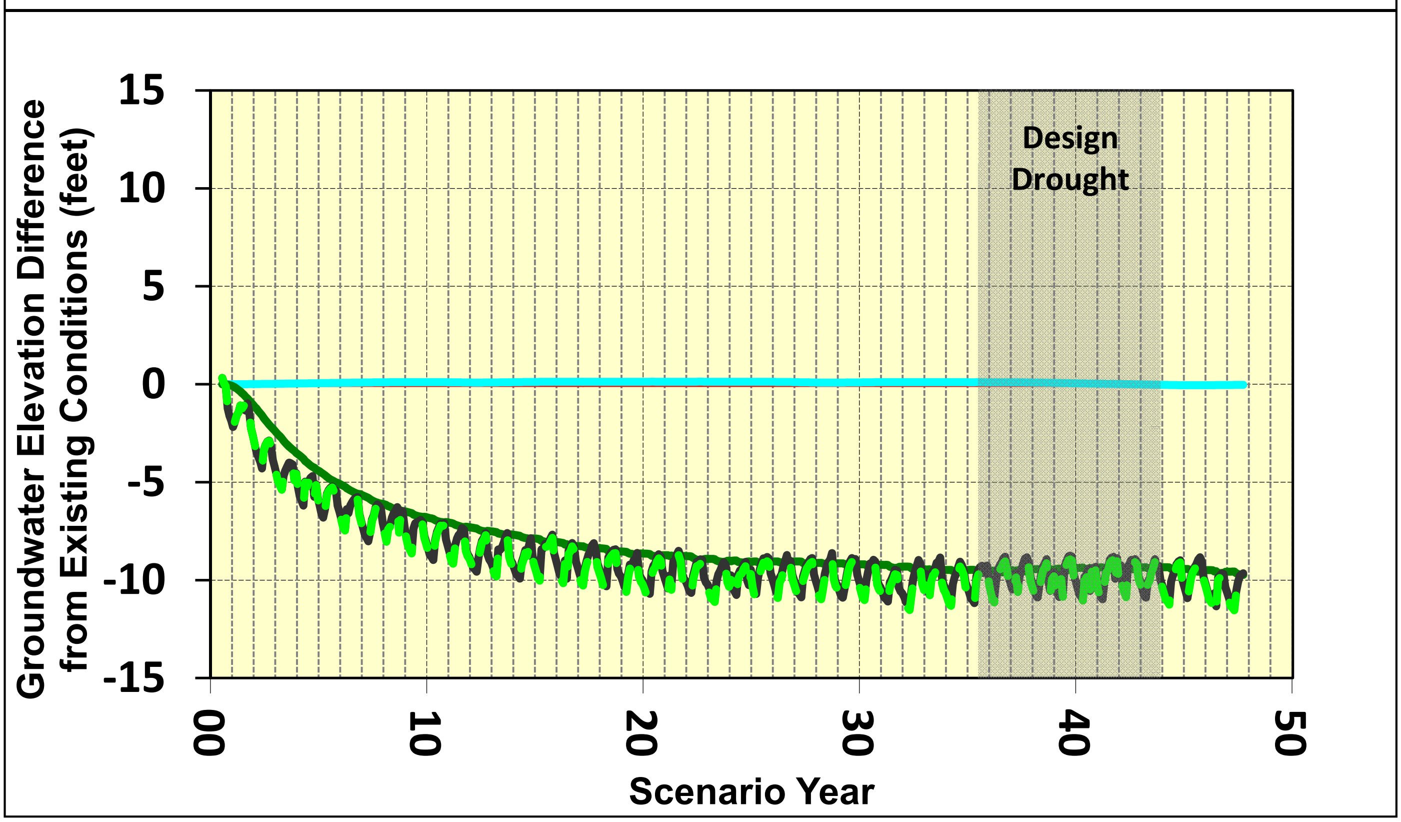
Figure 10.4-2





Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

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Model Layer 1 Hydrographs for SWM-GS

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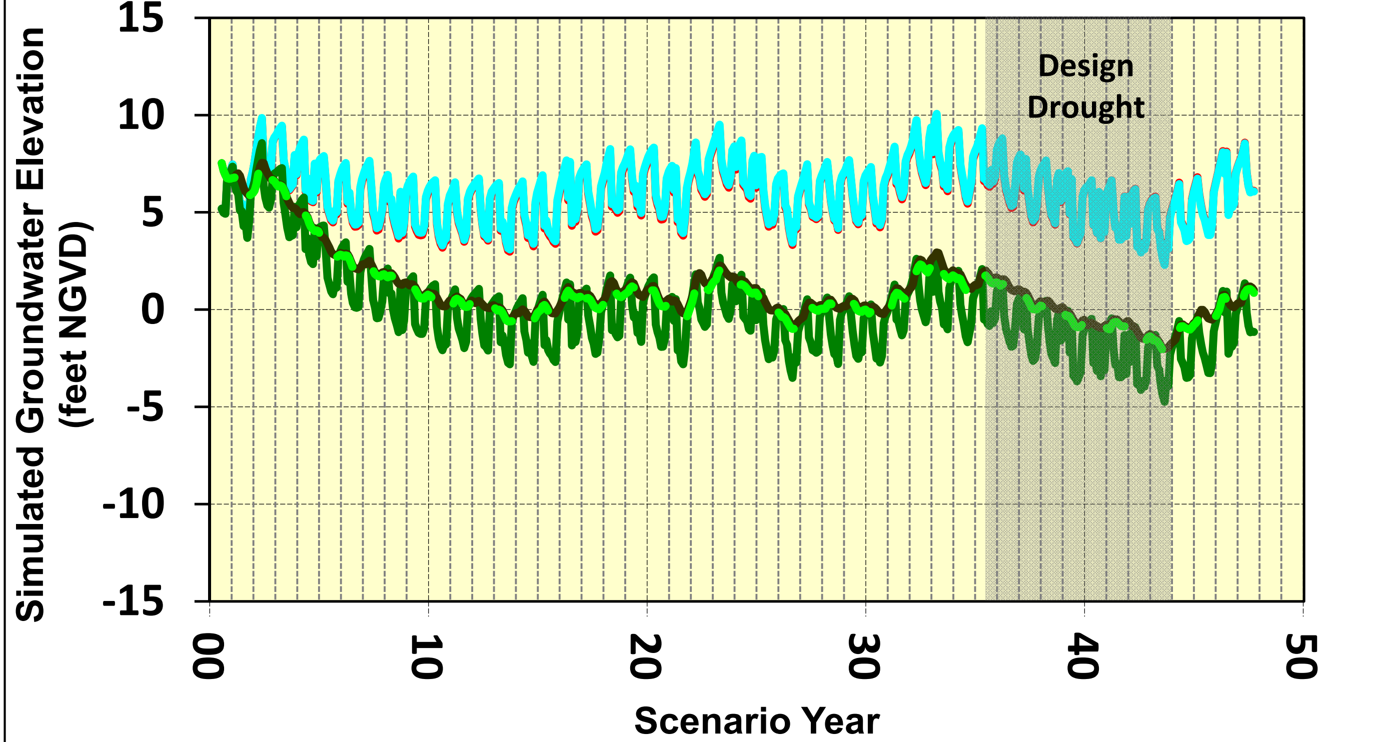
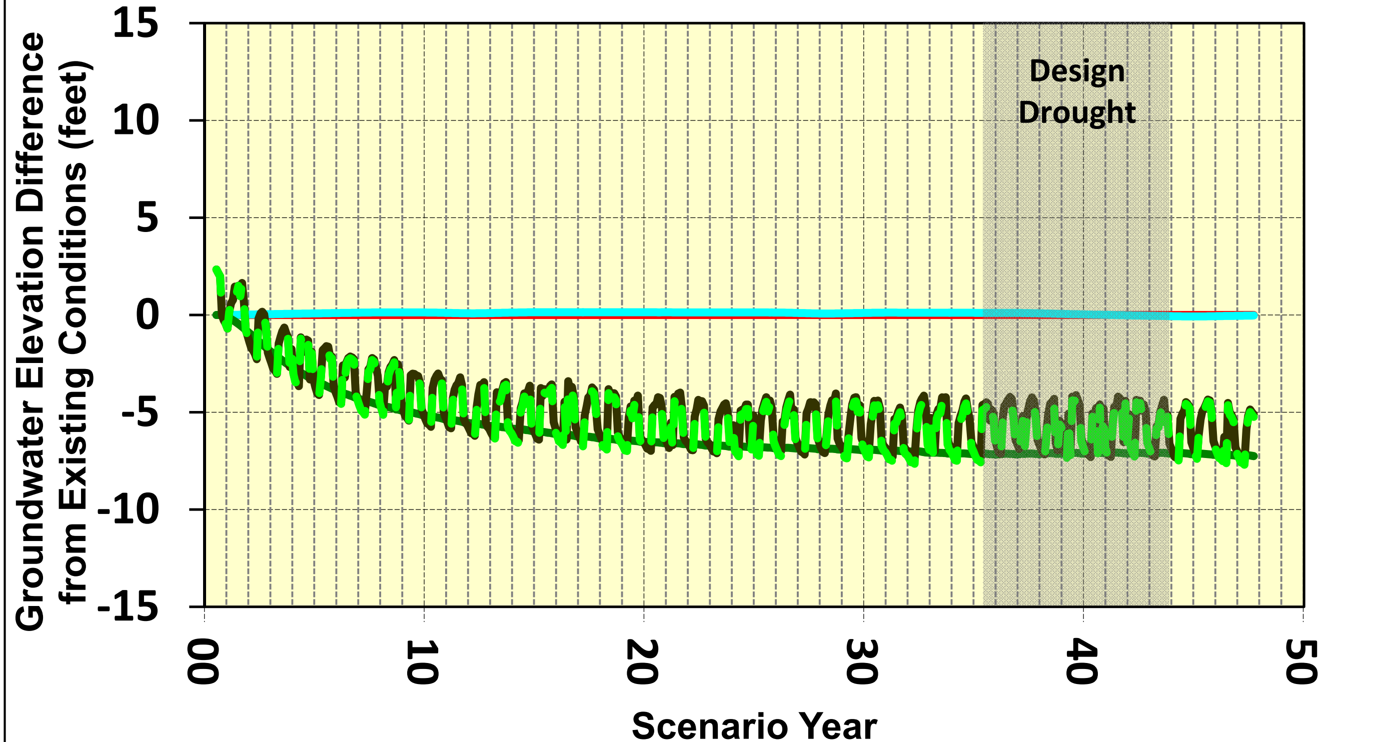
Figure 10.4-3a





Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 4 Hydrographs for SWM-GS

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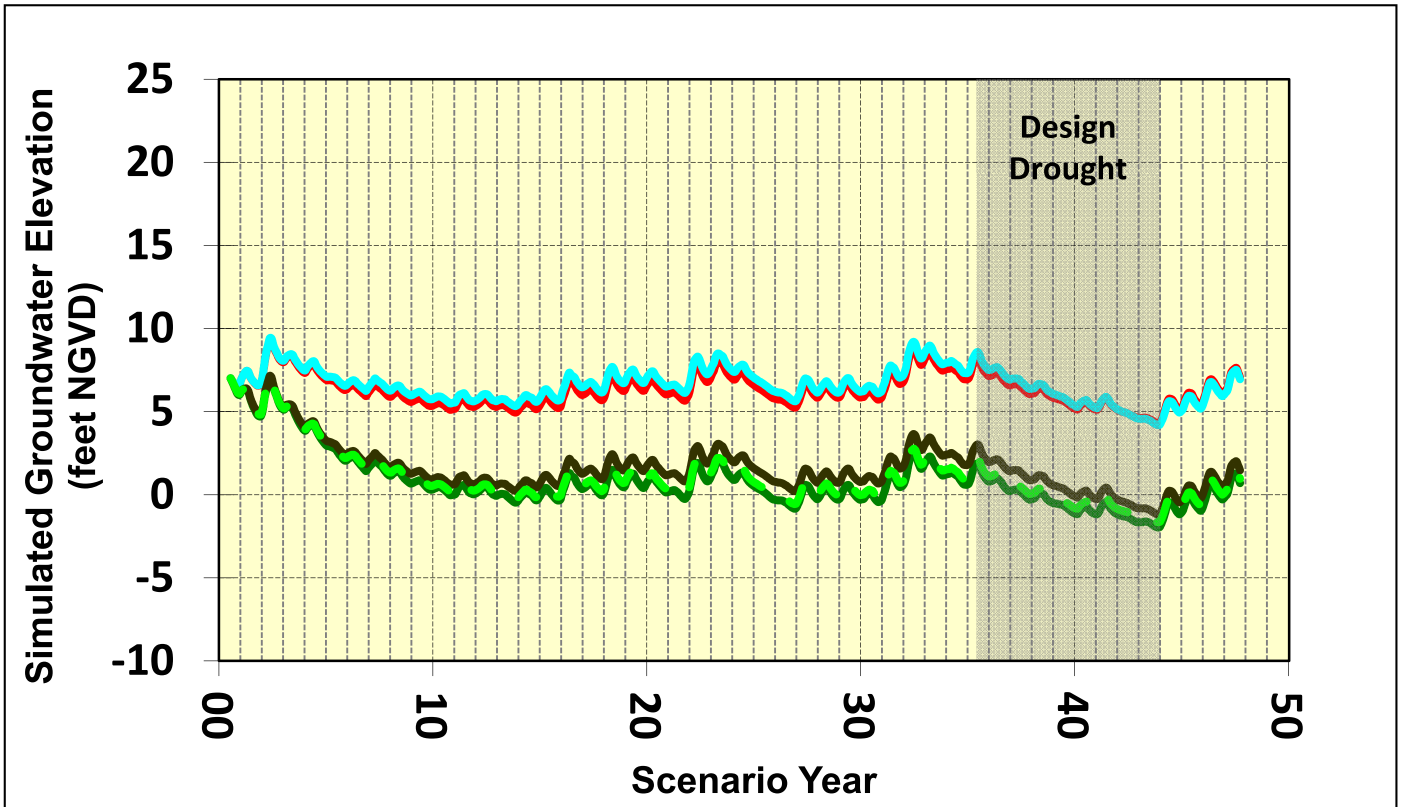
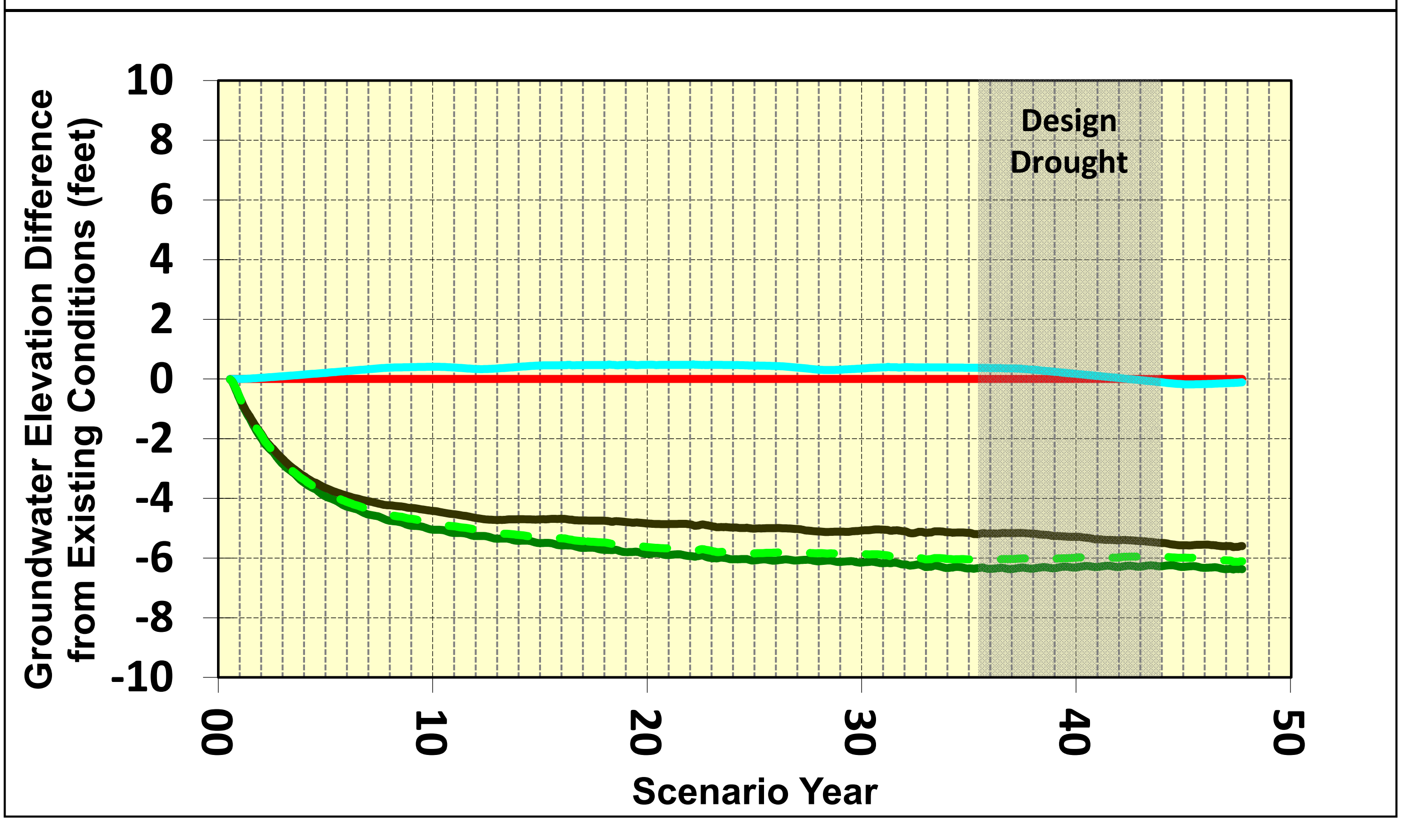
Figure 10.4-3b





Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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Model Layer 1 Hydrographs for Ortega MW

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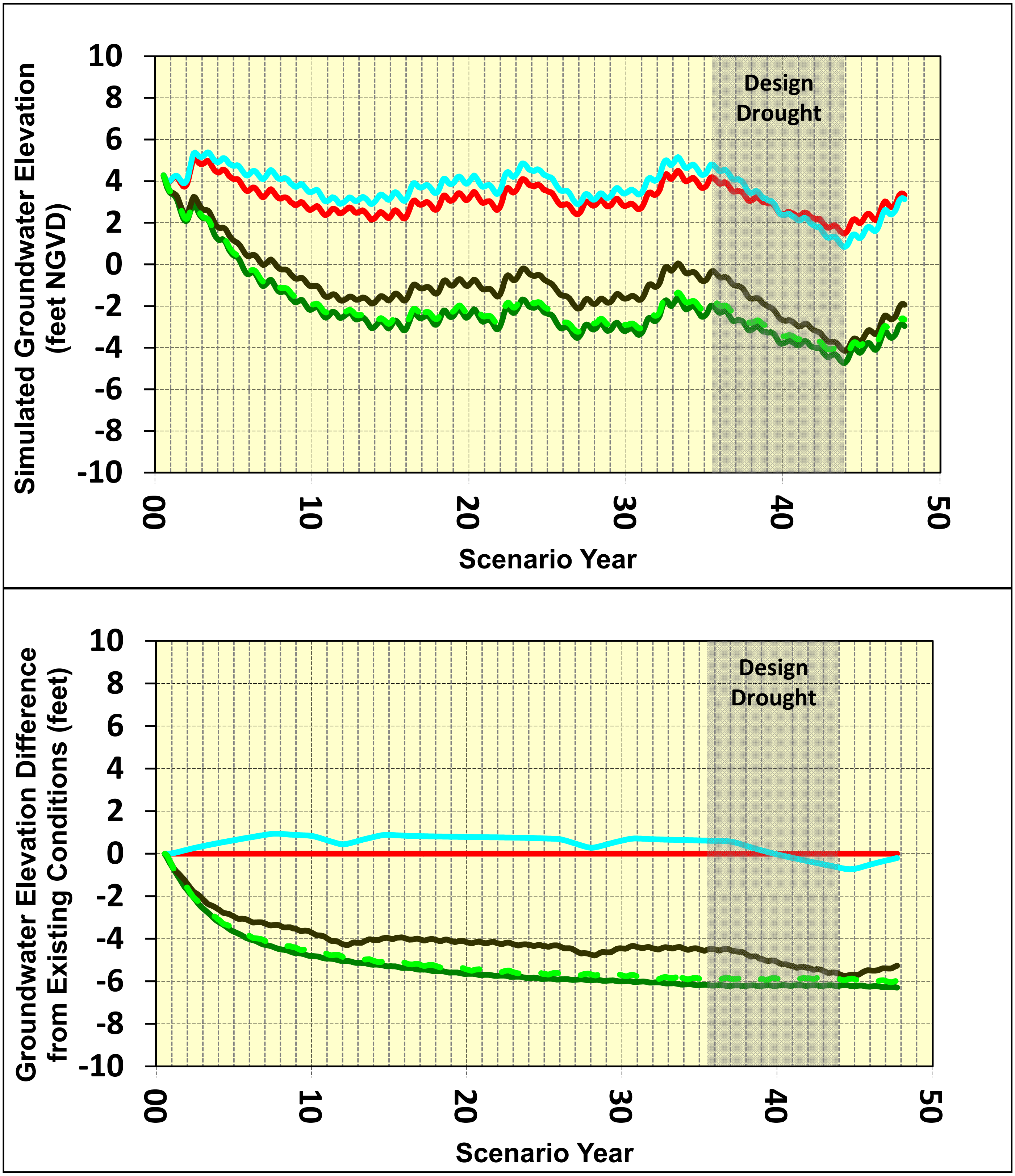
Figure 10.4-4a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
Scenario 1 | Scenario 2
Scenario 3a | Scenario 3b | Scenario 4

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Model Layer 4 Hydrographs for Ortega MW

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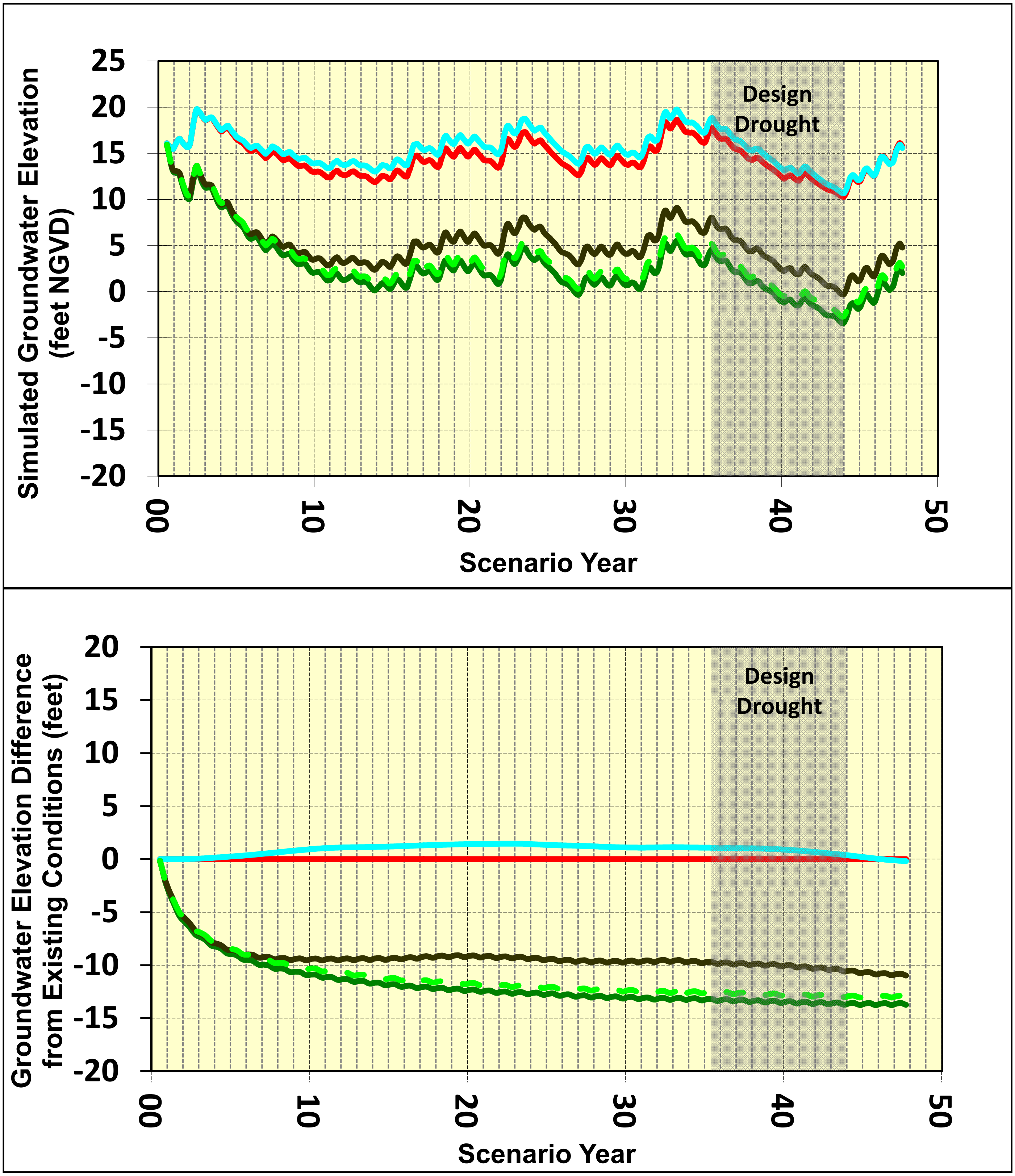
Figure 10.4-4b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 1 Hydrographs for Santiago-S MW

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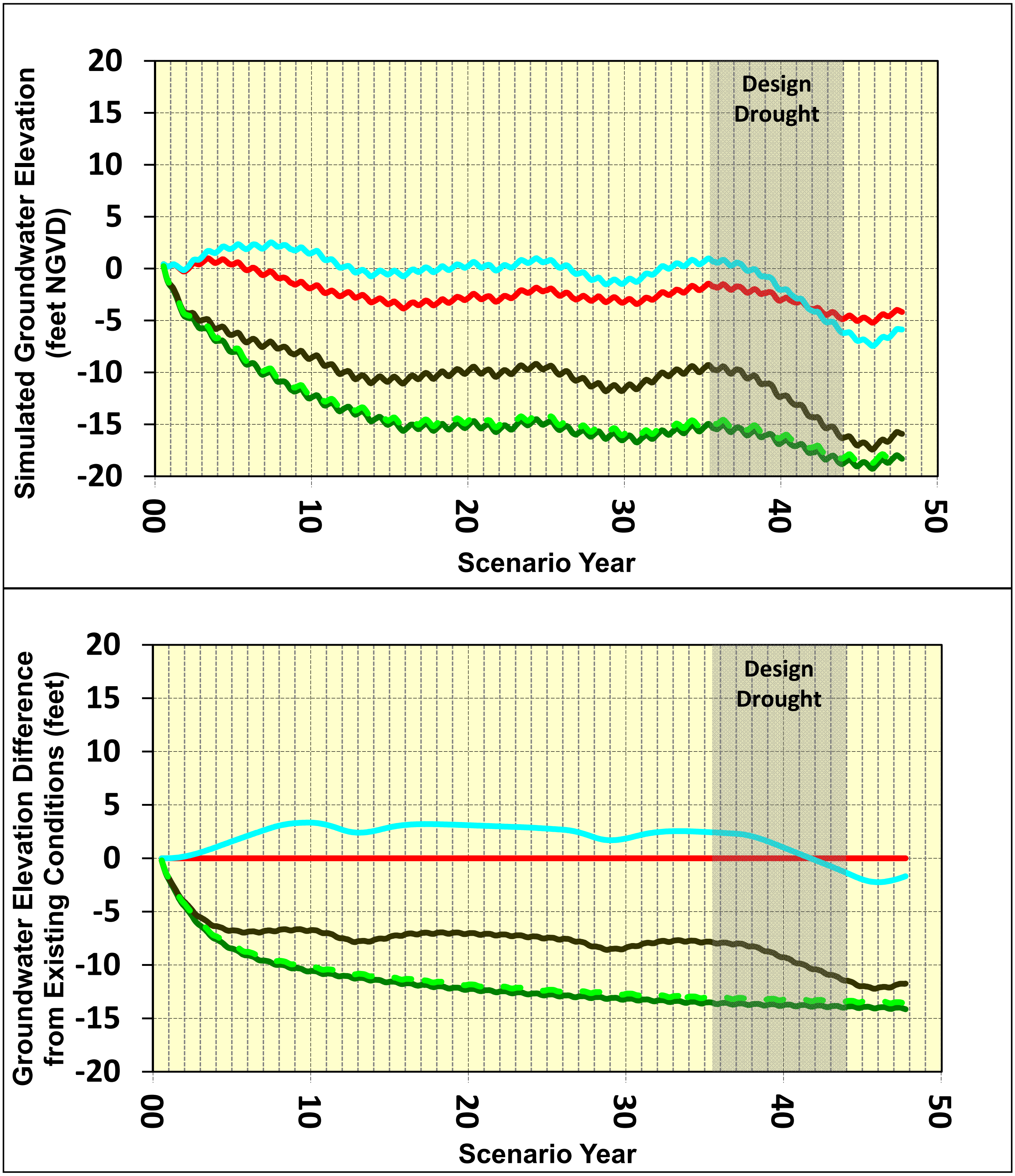
Figure 10.4-5a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

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Model Layer 4 Hydrographs for Santiago-S MW

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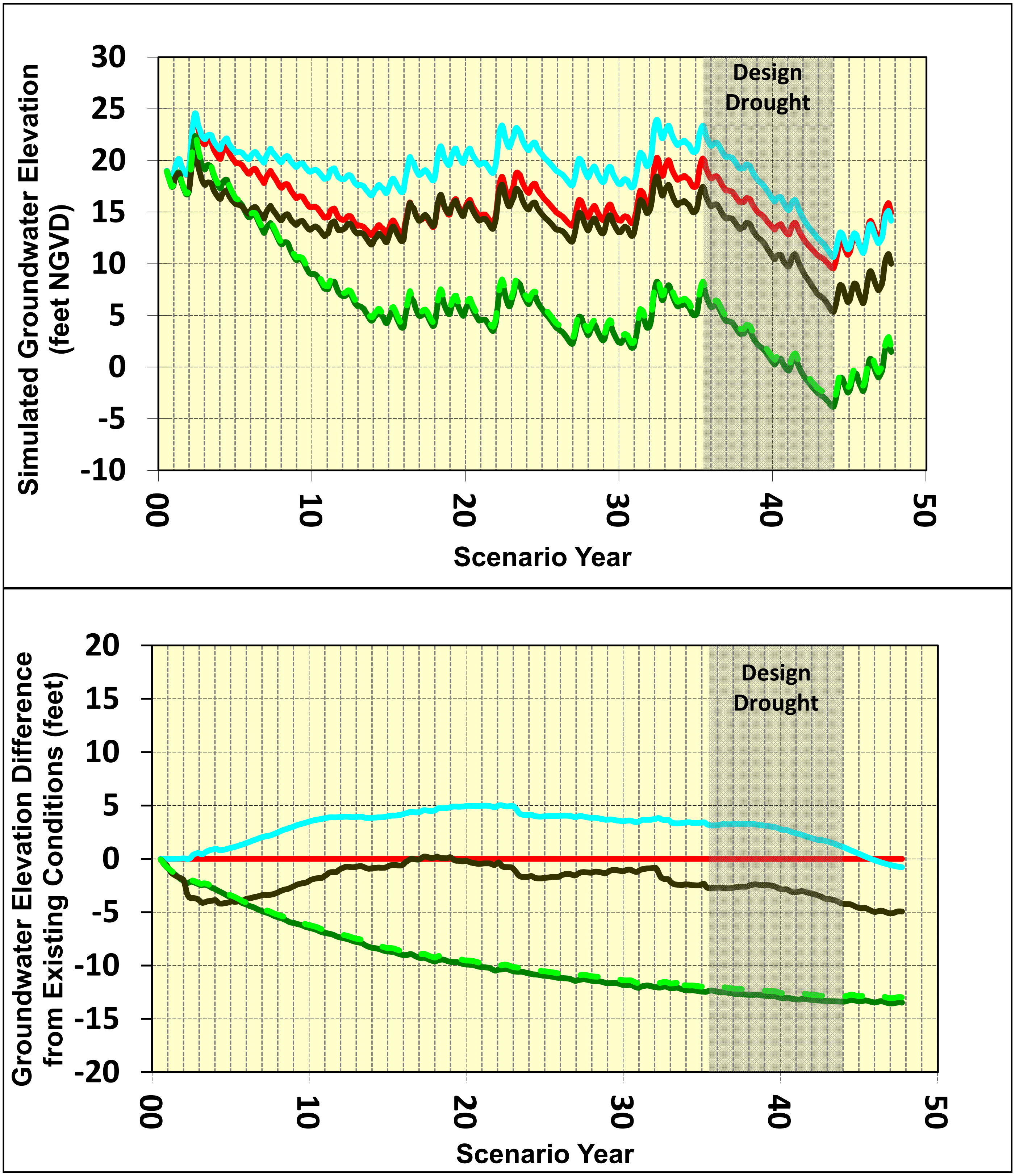
Figure 10.4-5b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 1 Hydrographs for LMMW-4S

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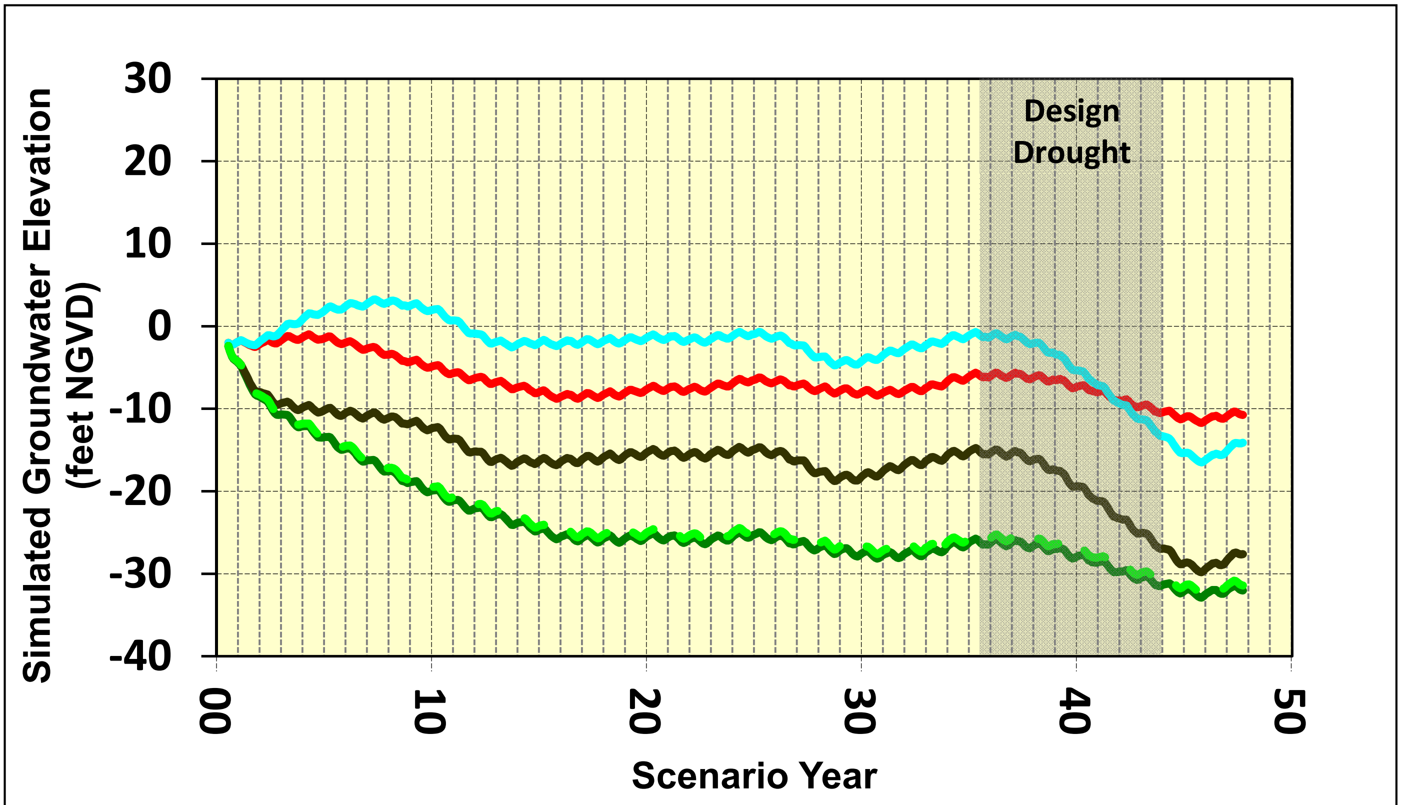
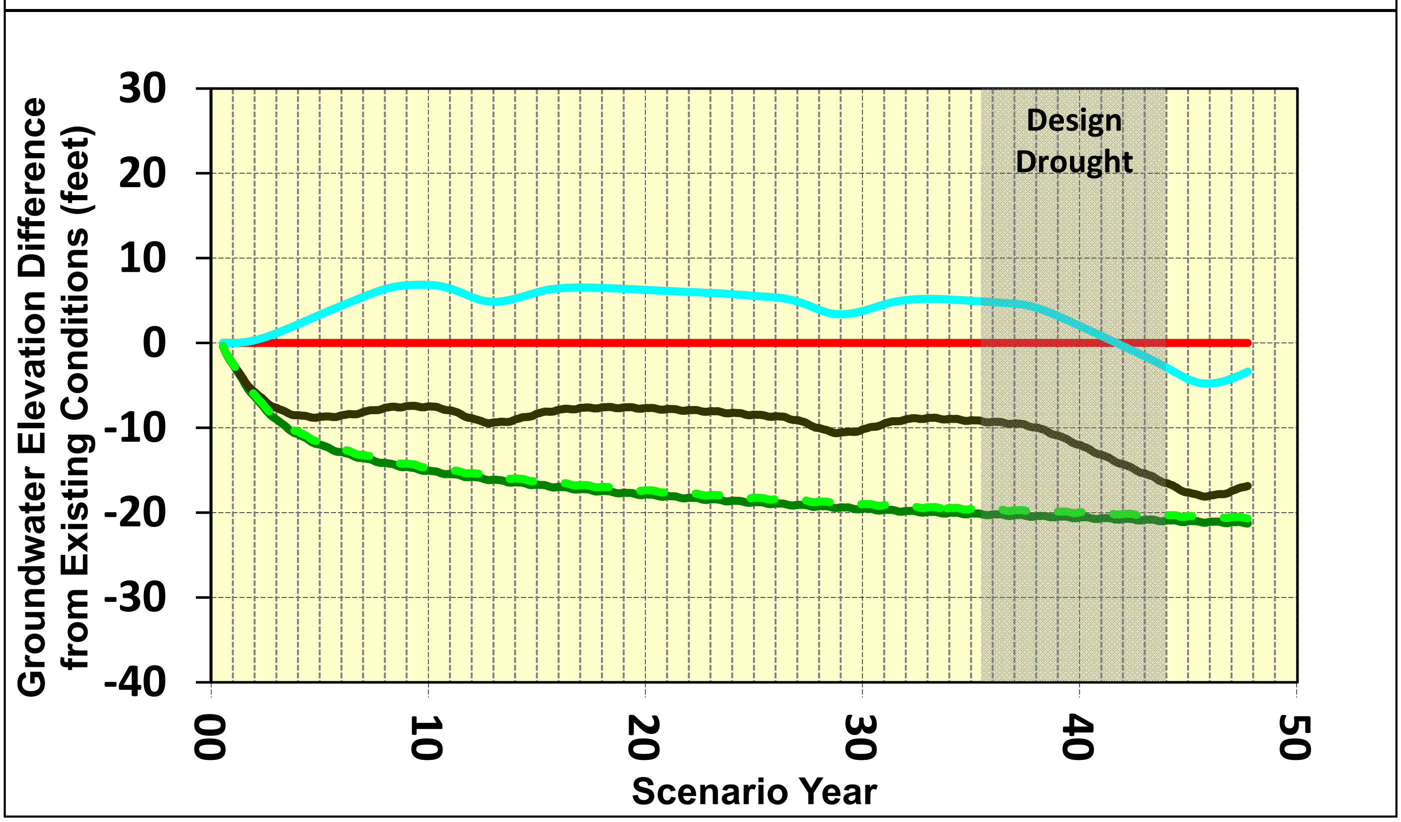
Figure 10.4-6a





Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
- **Scenario 1**
- **Scenario 2**
- **Scenario 3a**
- **Scenario 3b**
- **Scenario 4**

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Model Layer 4 Hydrographs for LMMW-4S

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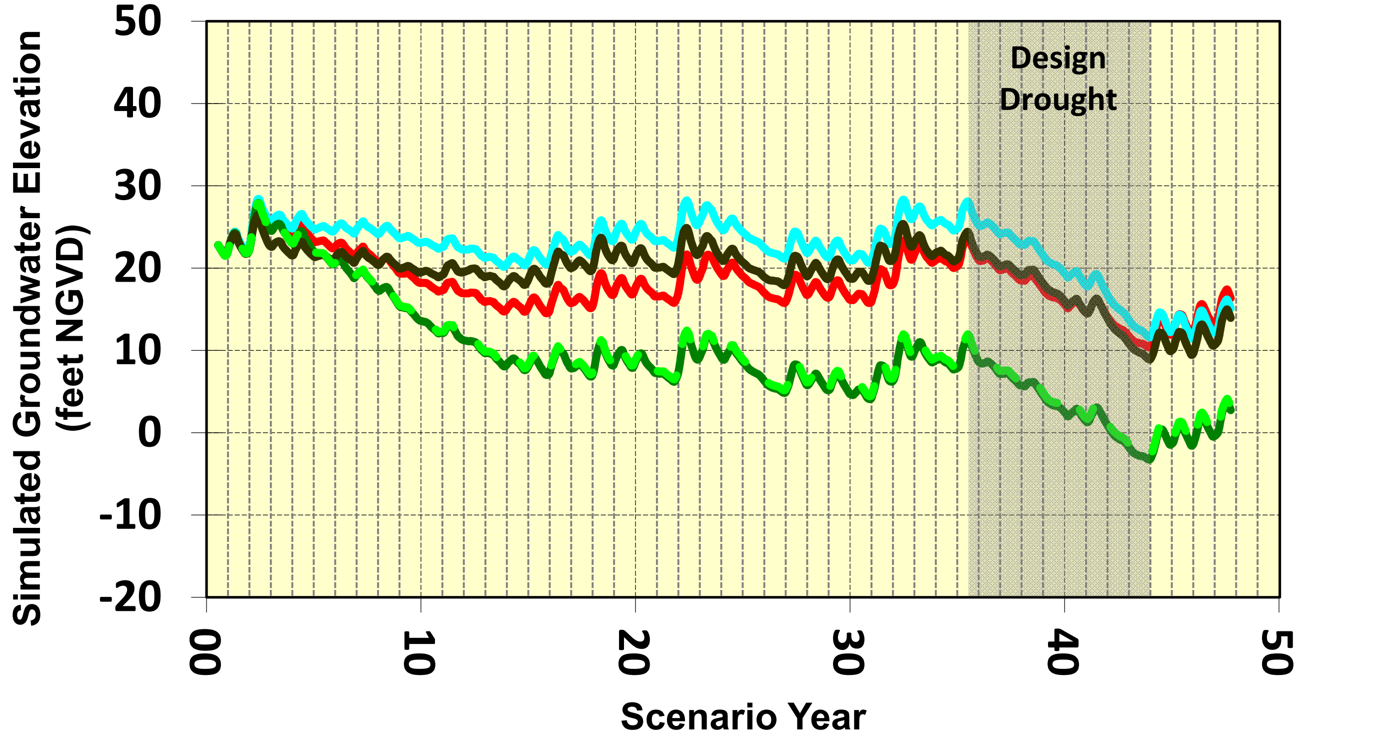
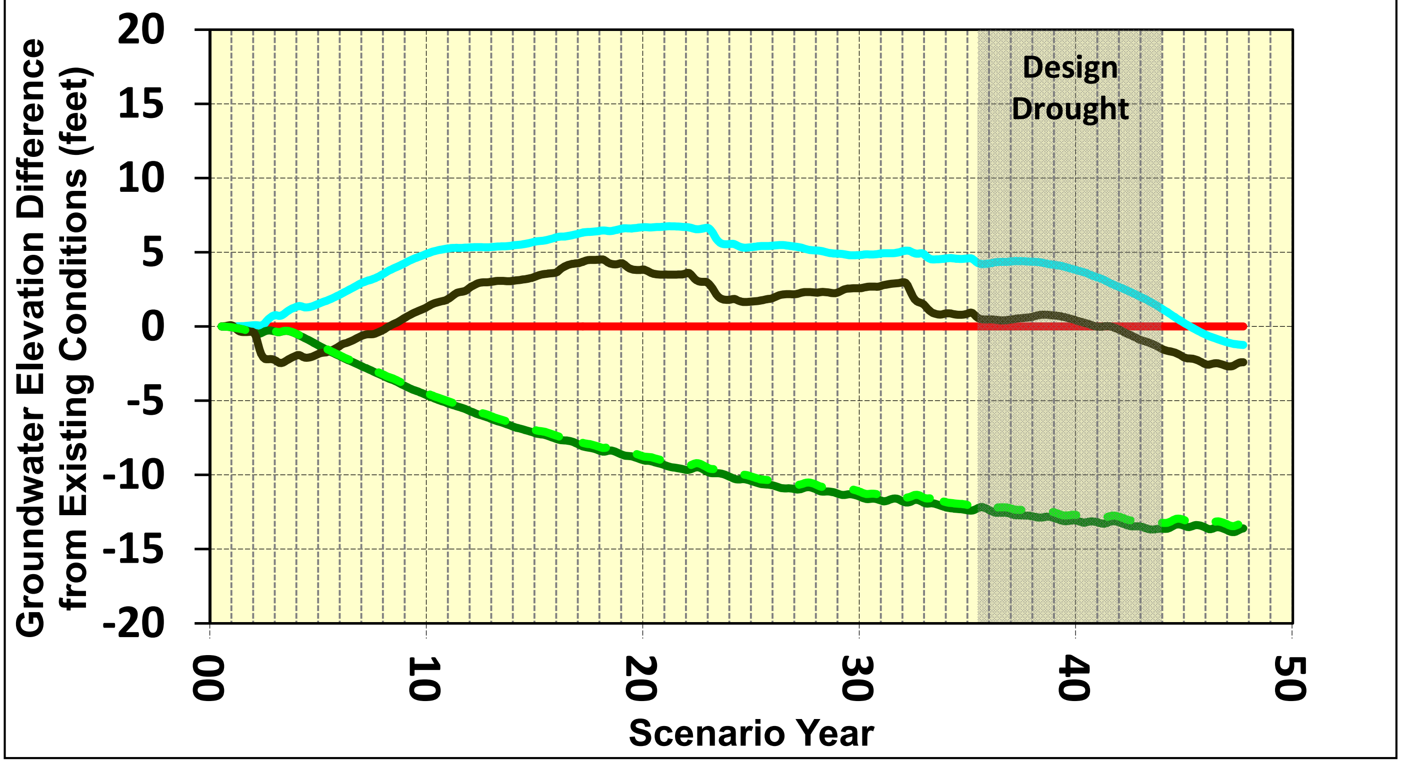
Figure 10.4-6b





Note: Mean sea level is equivalent to zero feet NGVD.

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Model Layer 1 Hydrographs for Harding Park MW

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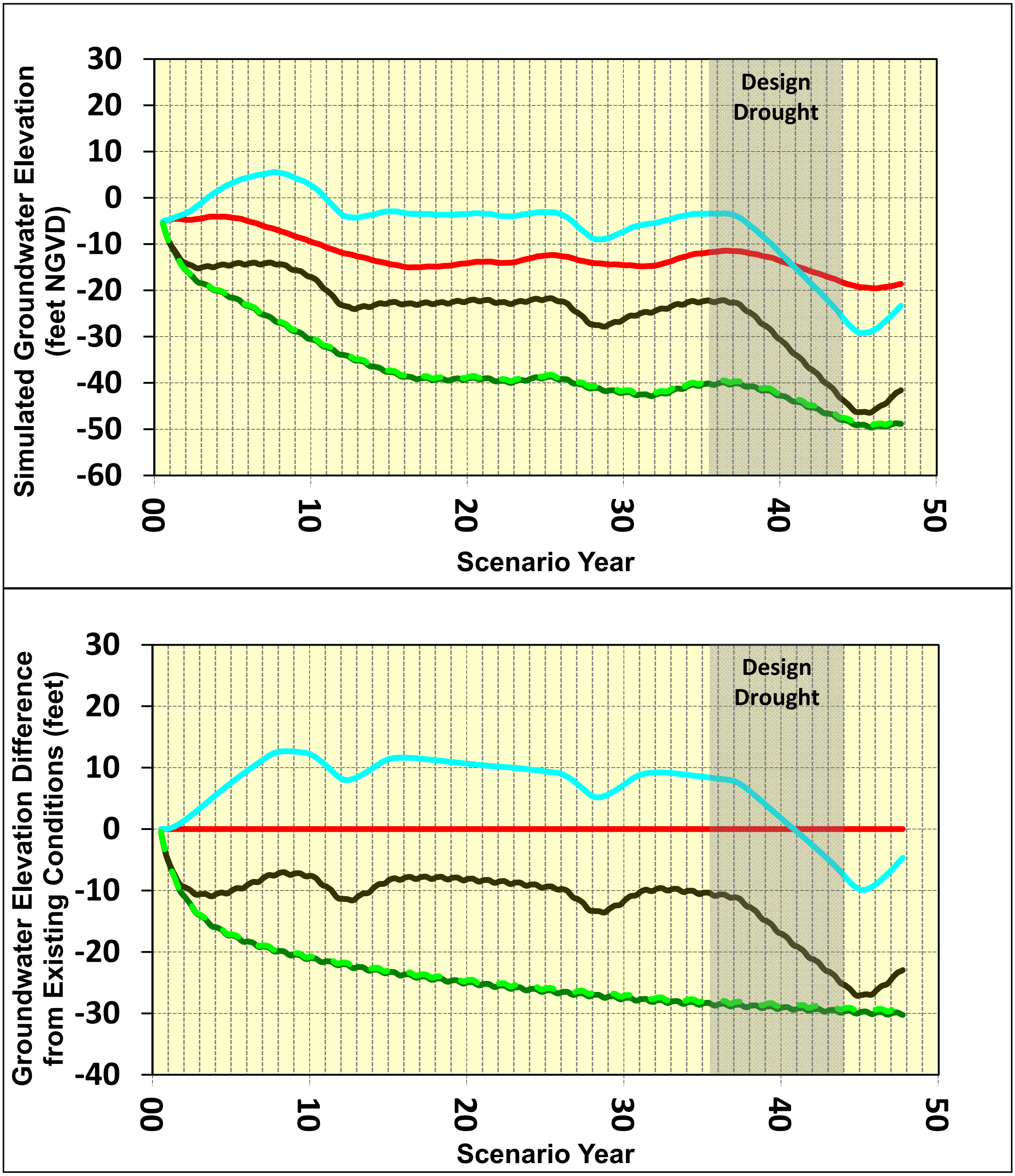
Figure 10.4-7a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 4 Hydrographs for Harding Park MW

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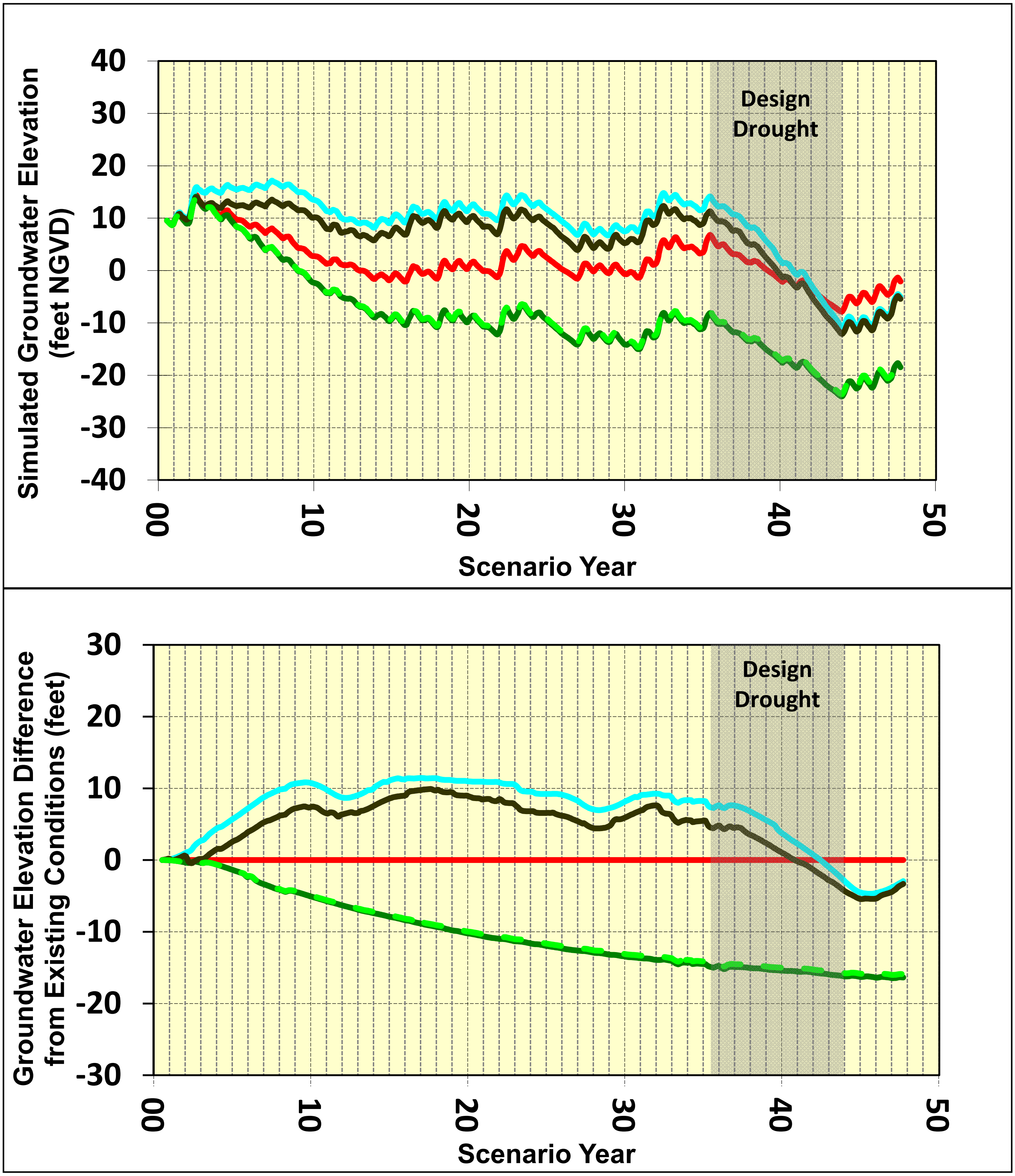
Figure 10.4-7b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

- Scenario 1
- Scenario 2
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- Scenario 3b
- Scenario 4

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Model Layer 1 Hydrographs for Olympic MW

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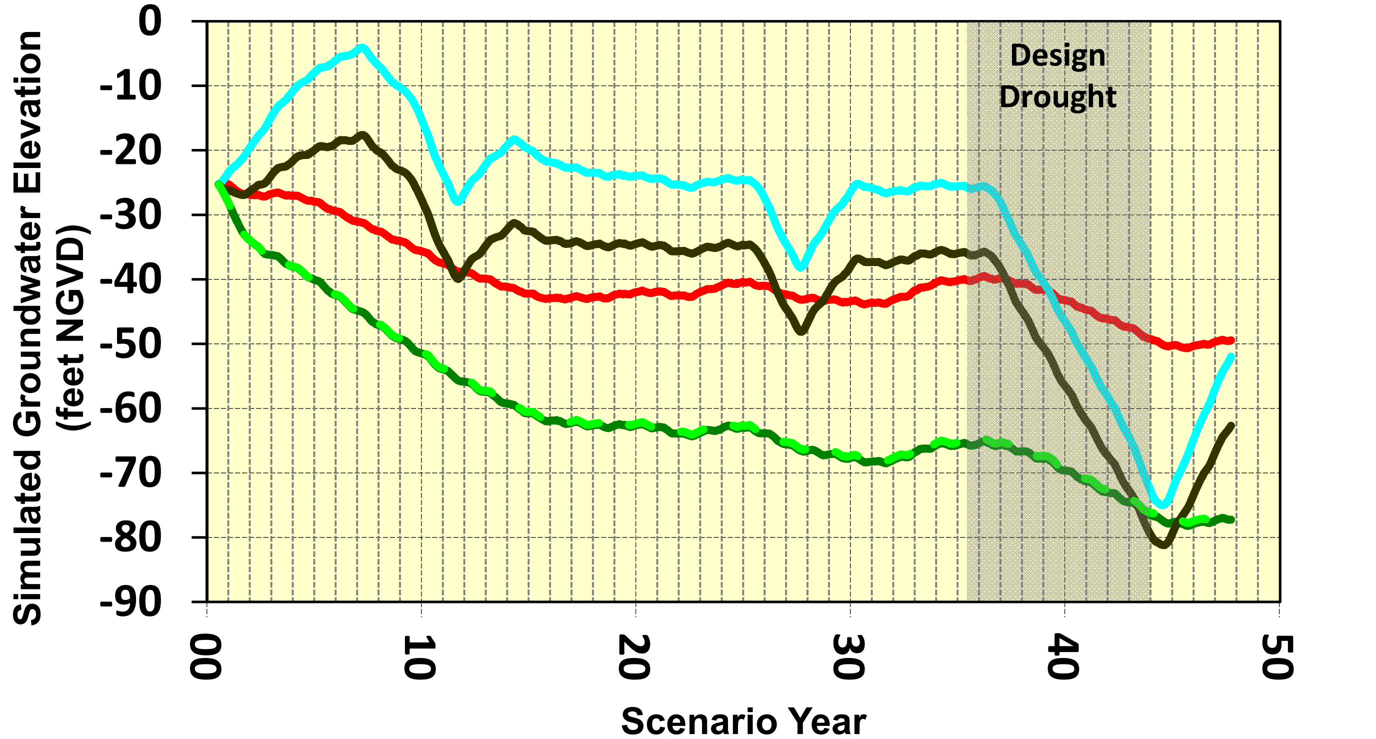
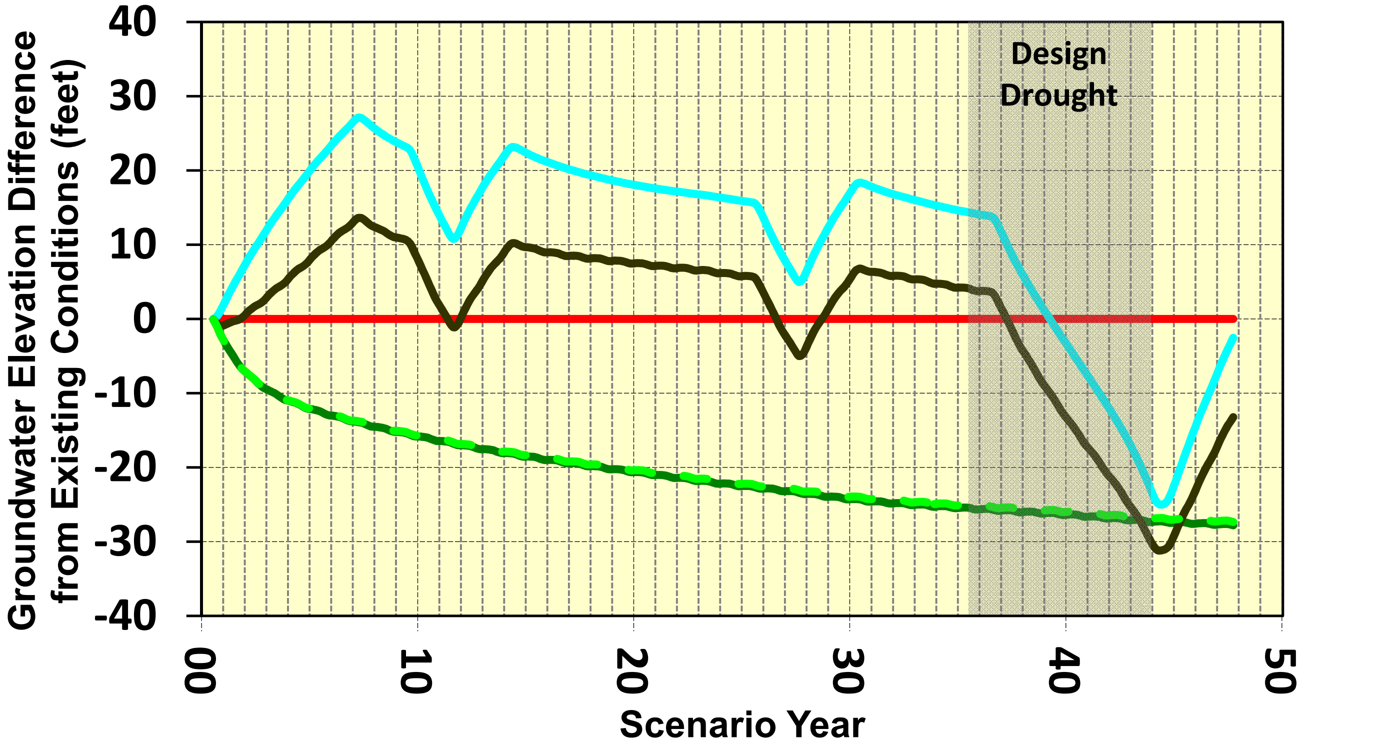
Figure 10.4-8a





Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 4 Hydrographs for Olympic MW

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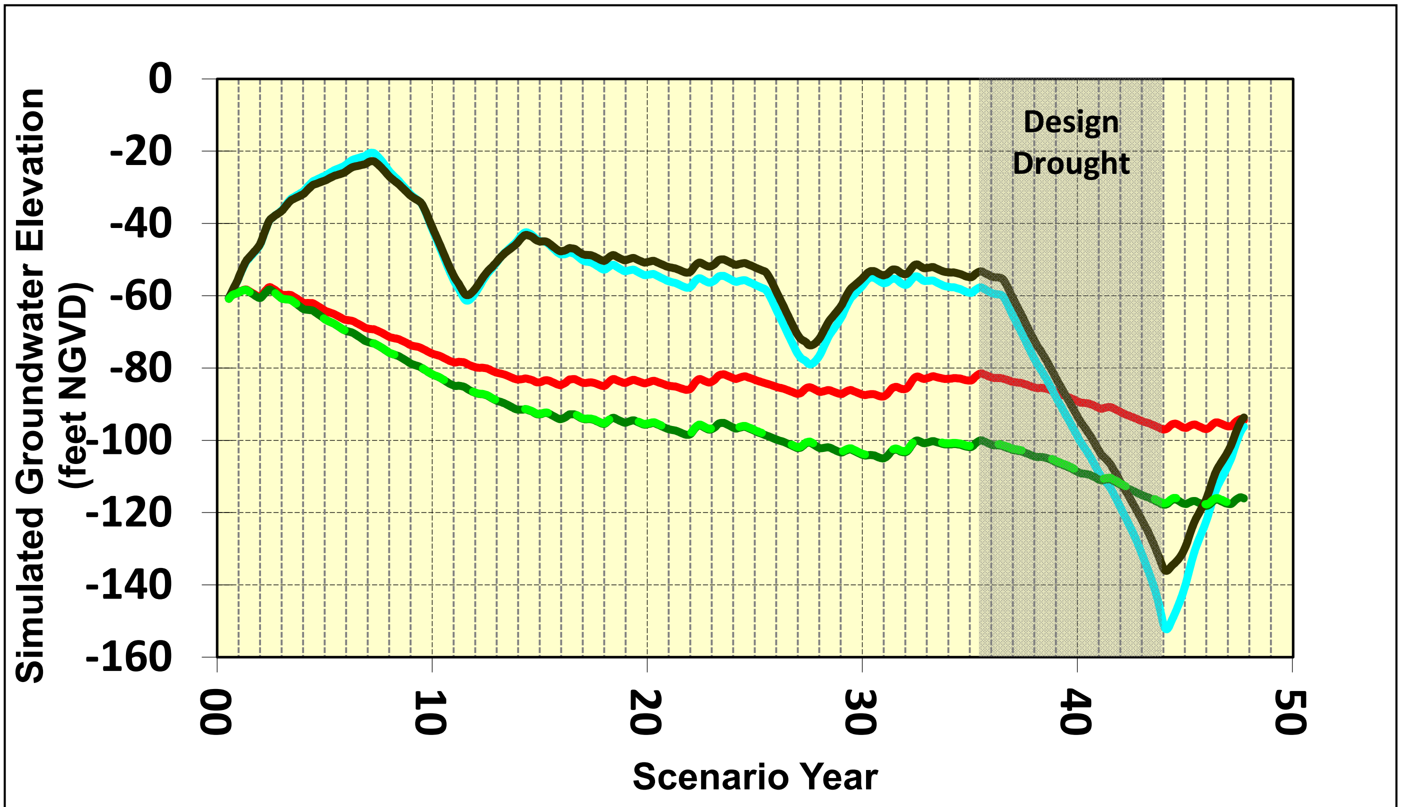
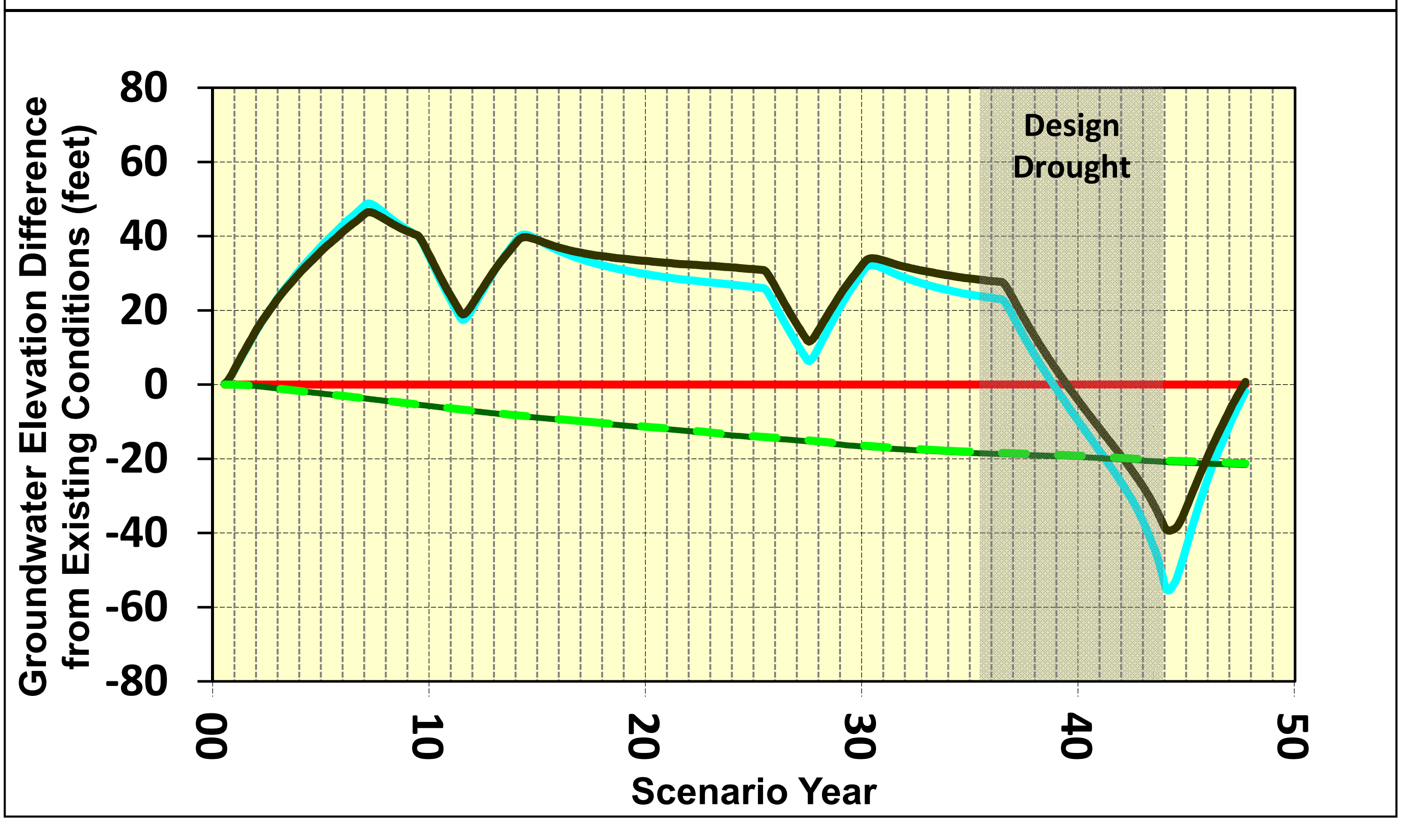
Figure 10.4-8b





Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 1 Hydrographs for DC-3

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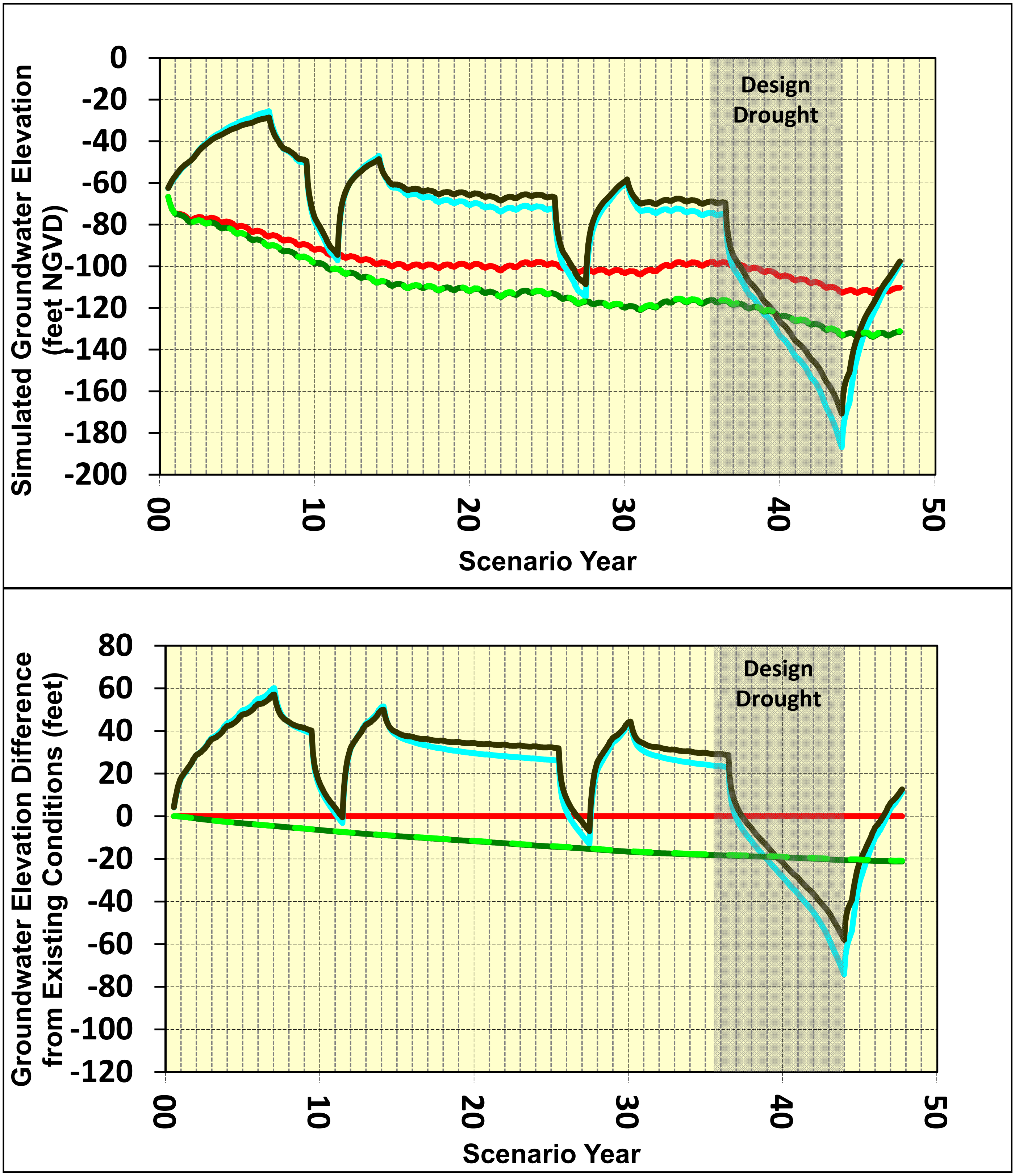
Figure 10.4-9a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 4 Hydrographs for DC-3

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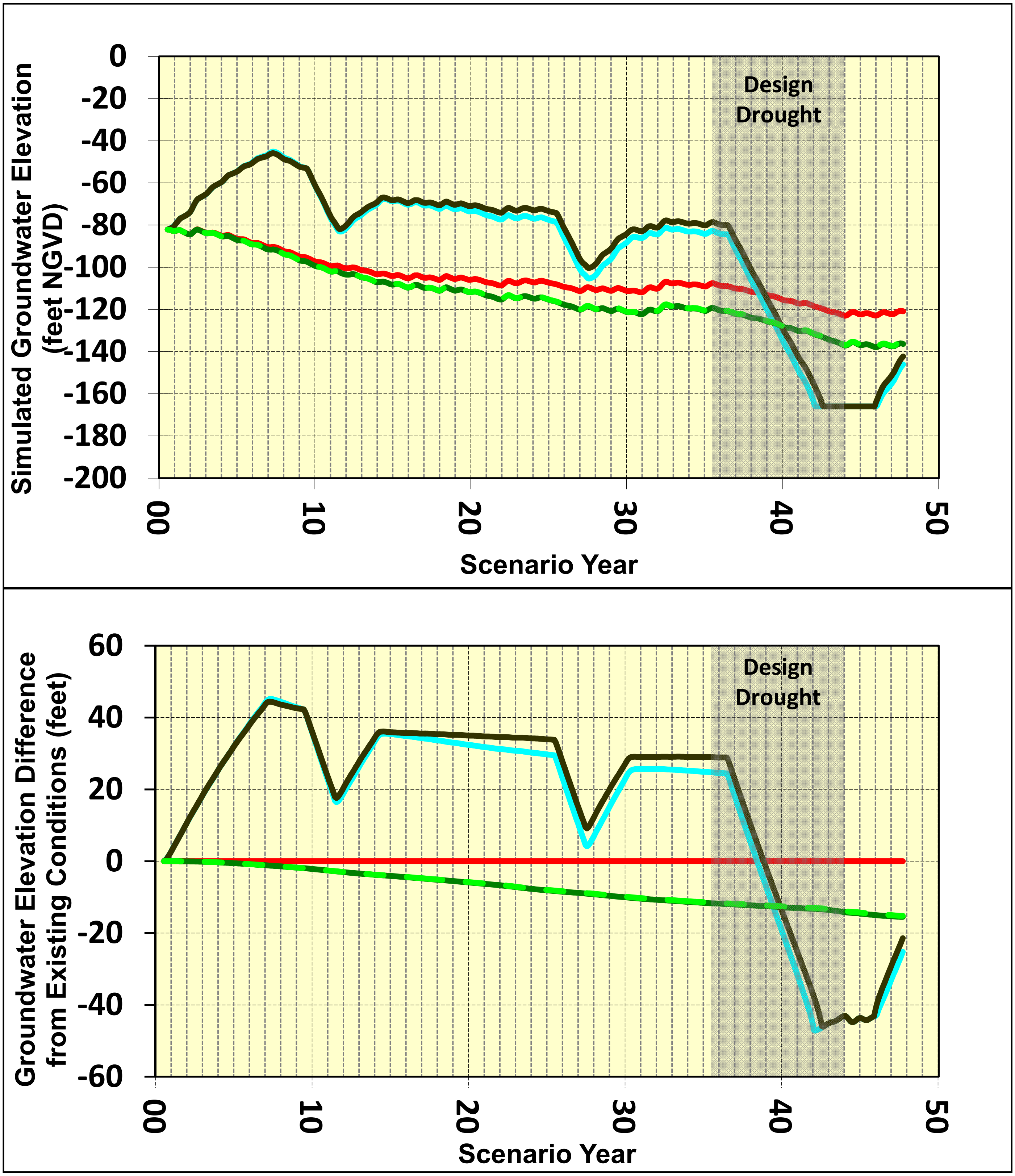
Figure 10.4-9b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 1 Hydrographs for DC-A-St

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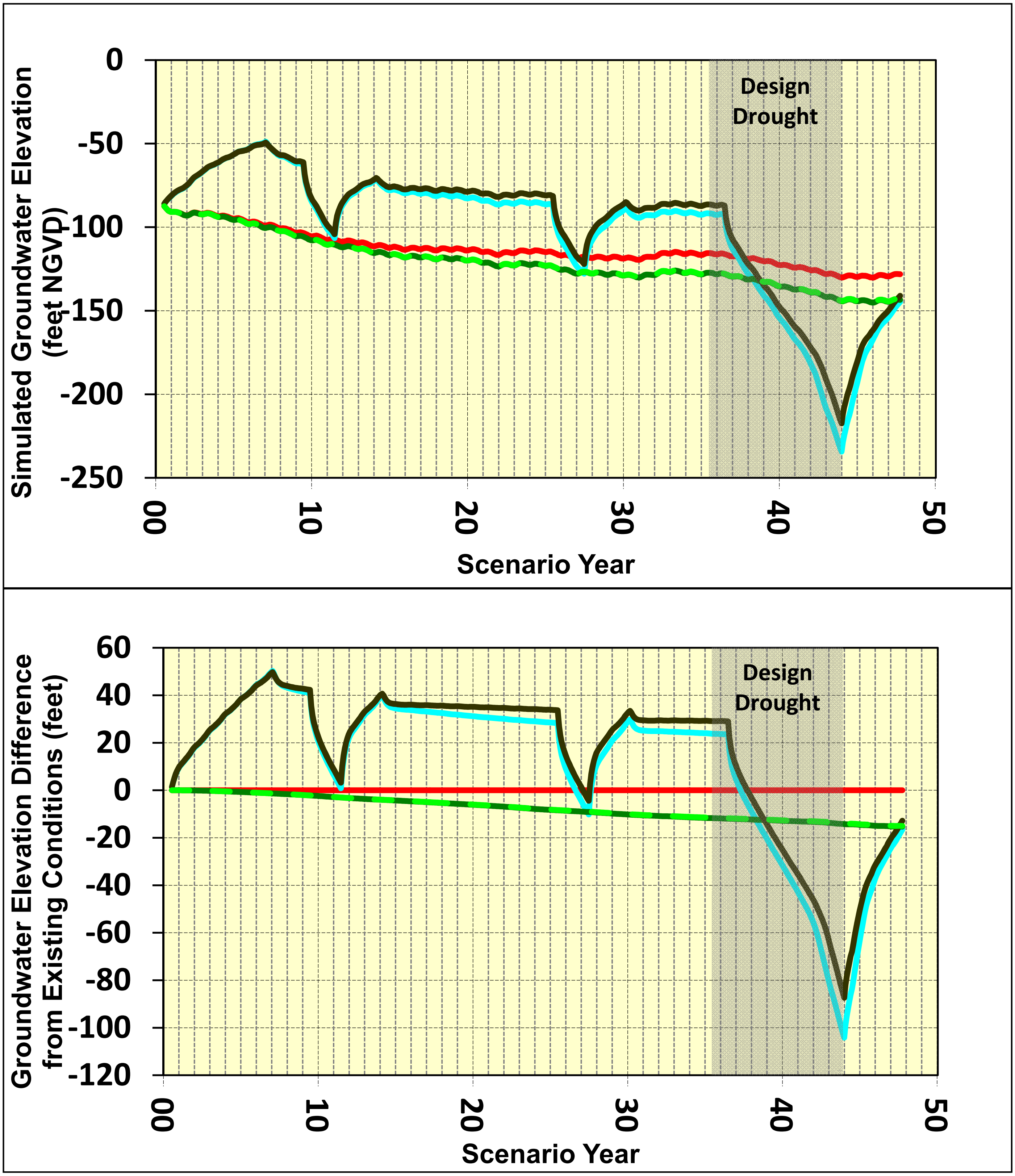
Figure 10.4-10a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 4 Hydrographs for DC-A-St

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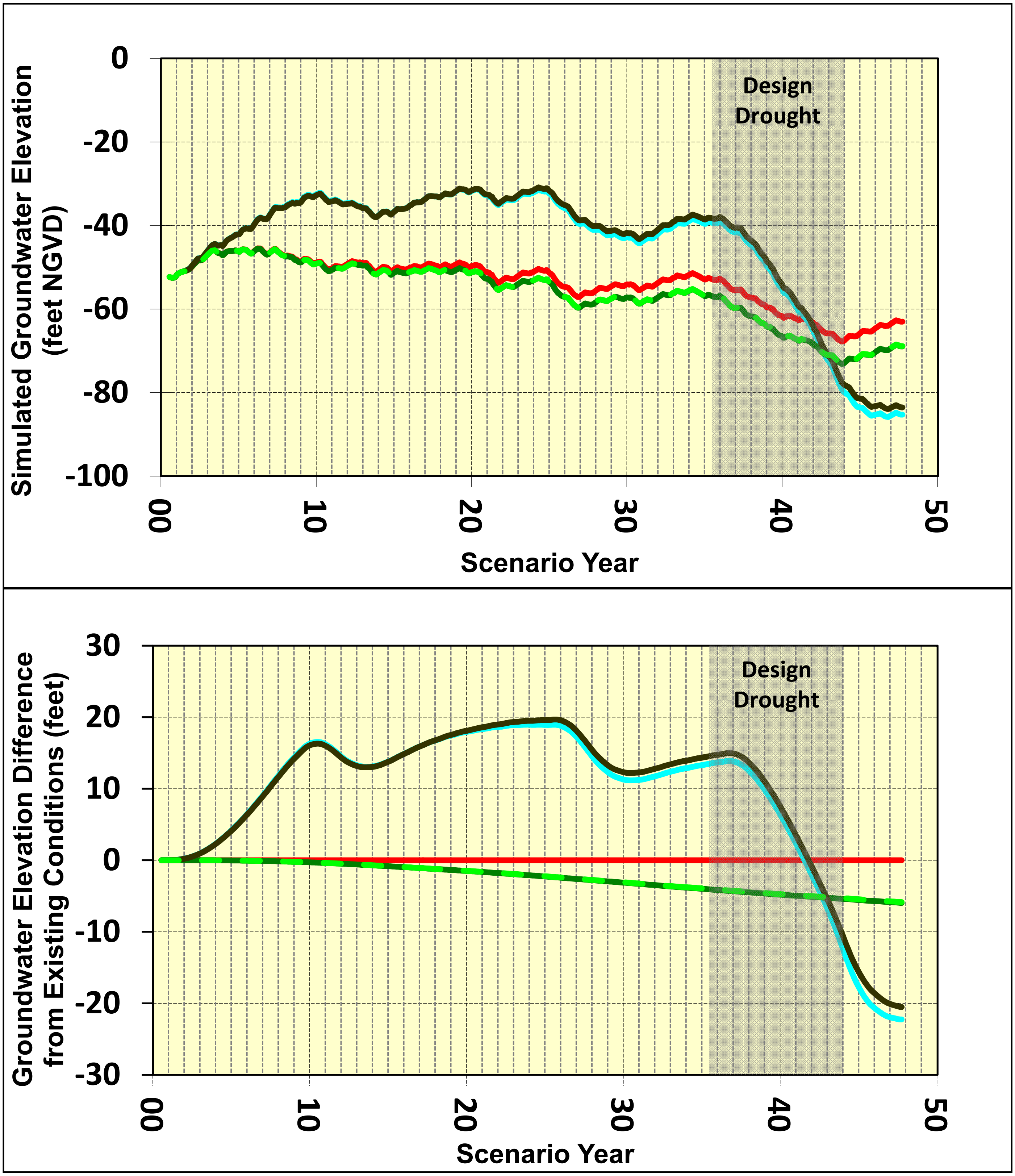
Figure 10.4-10b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

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Model Layer 1 Hydrographs for Cypress Lawn 2

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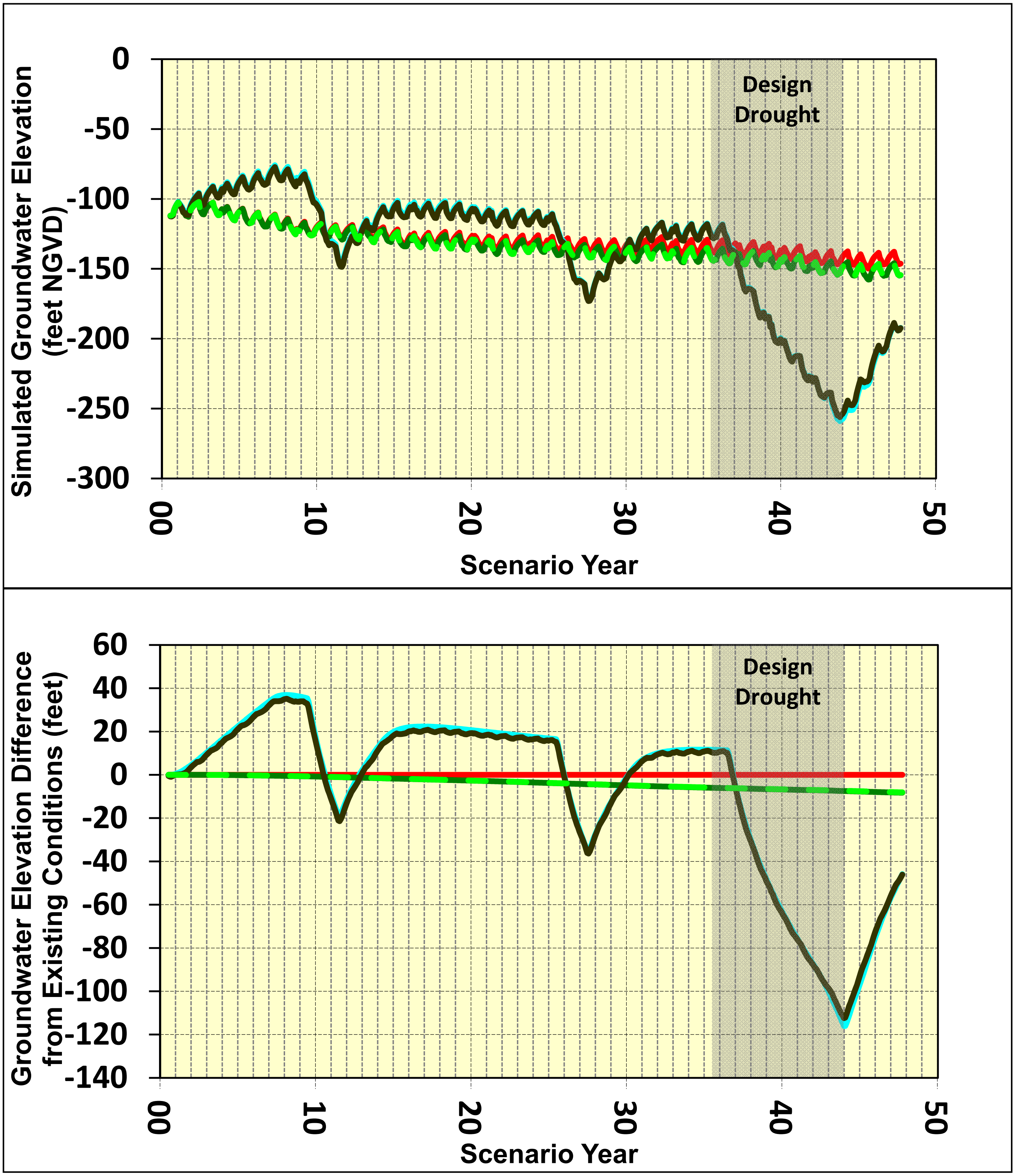
Figure 10.4-11a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 4 Hydrographs for Cypress Lawn 2

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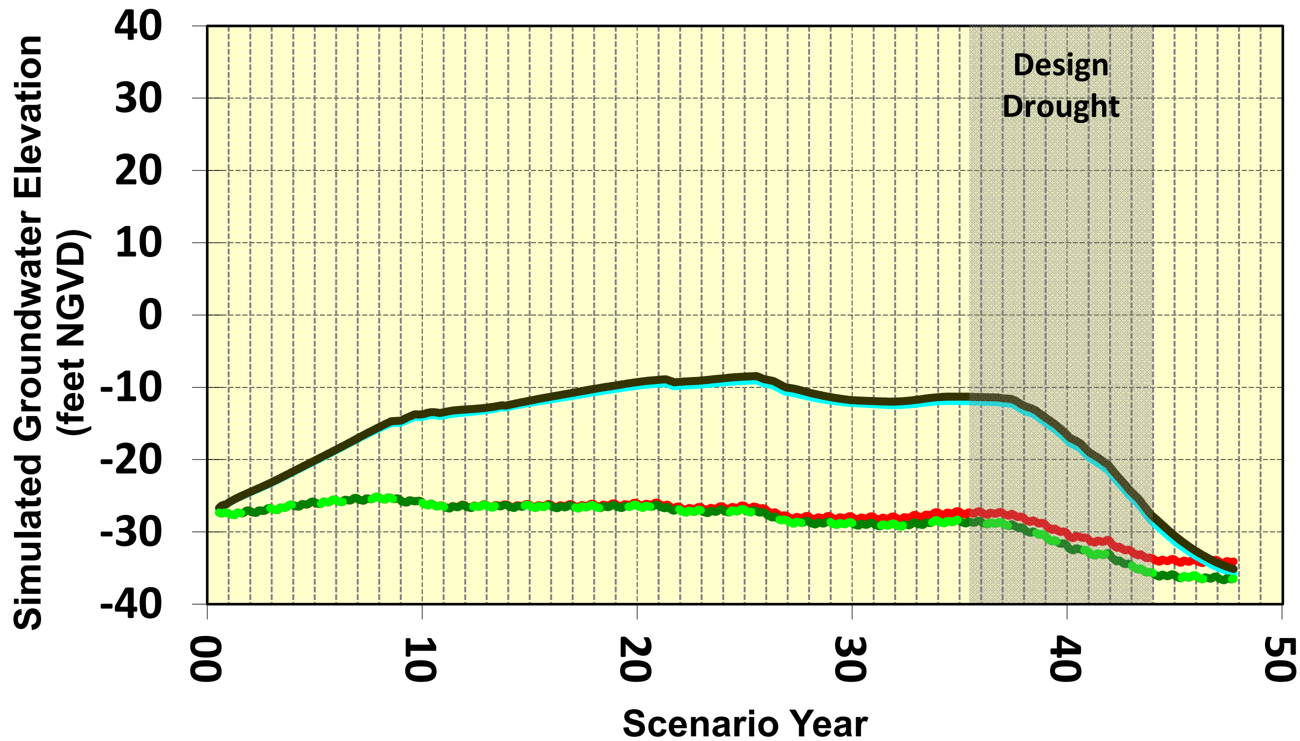
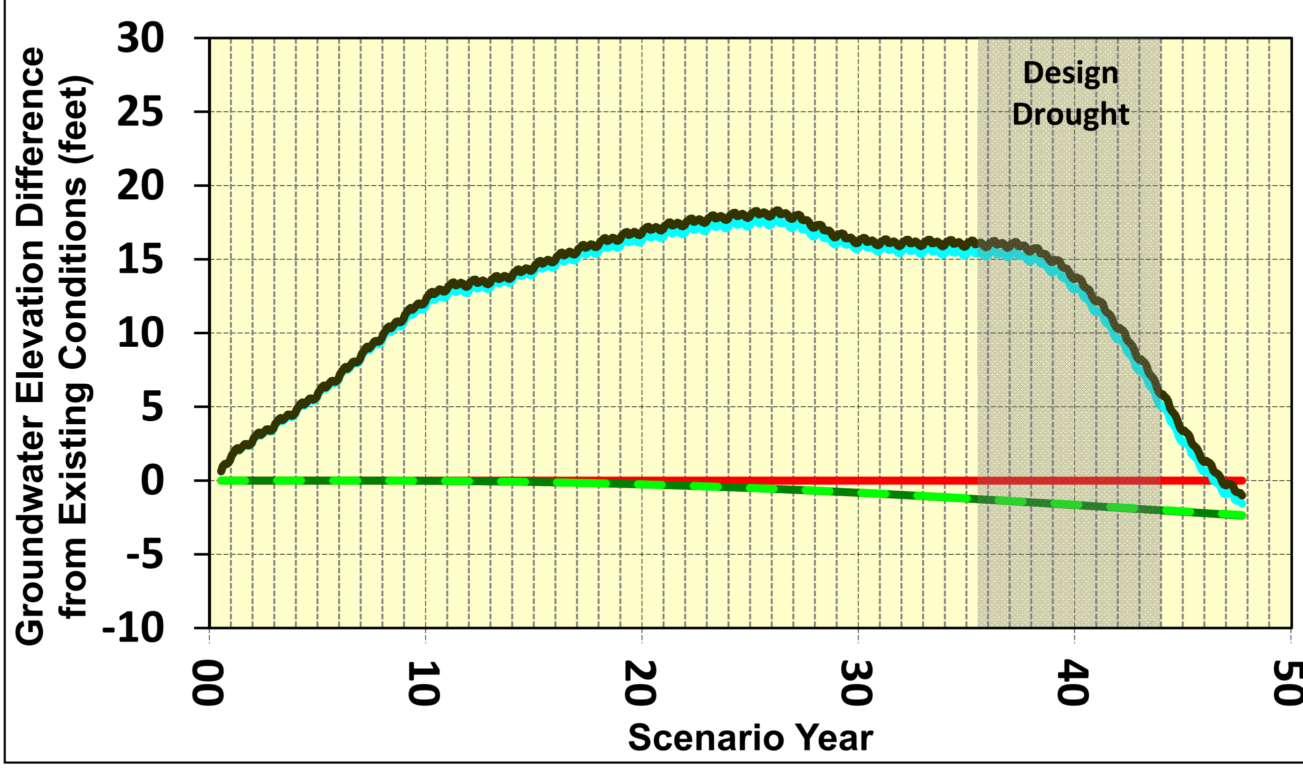
Figure 10.4-11b





Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 1 Hydrographs for SSF-02

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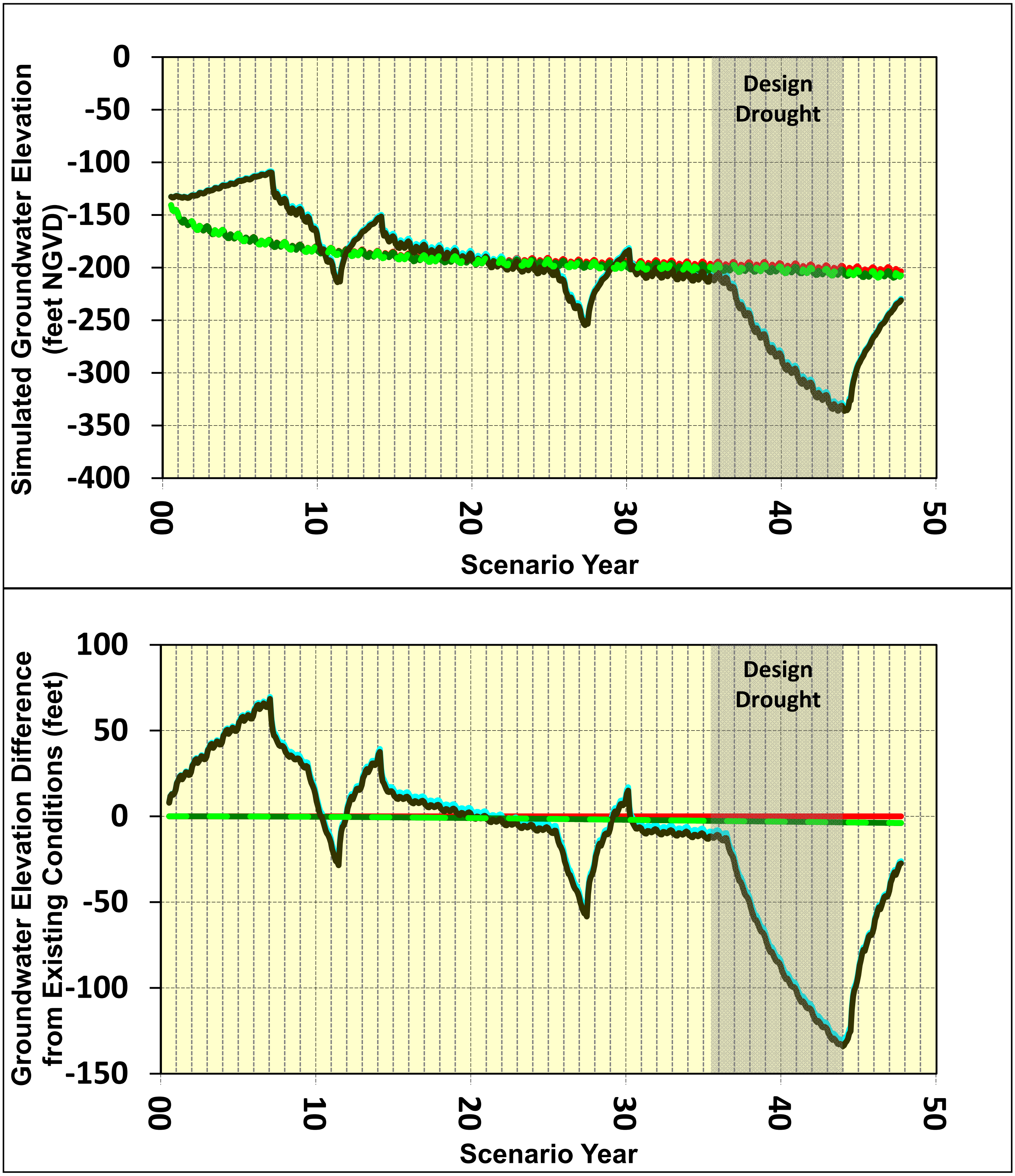
Figure 10.4-12a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 4 Hydrographs for SSF-02

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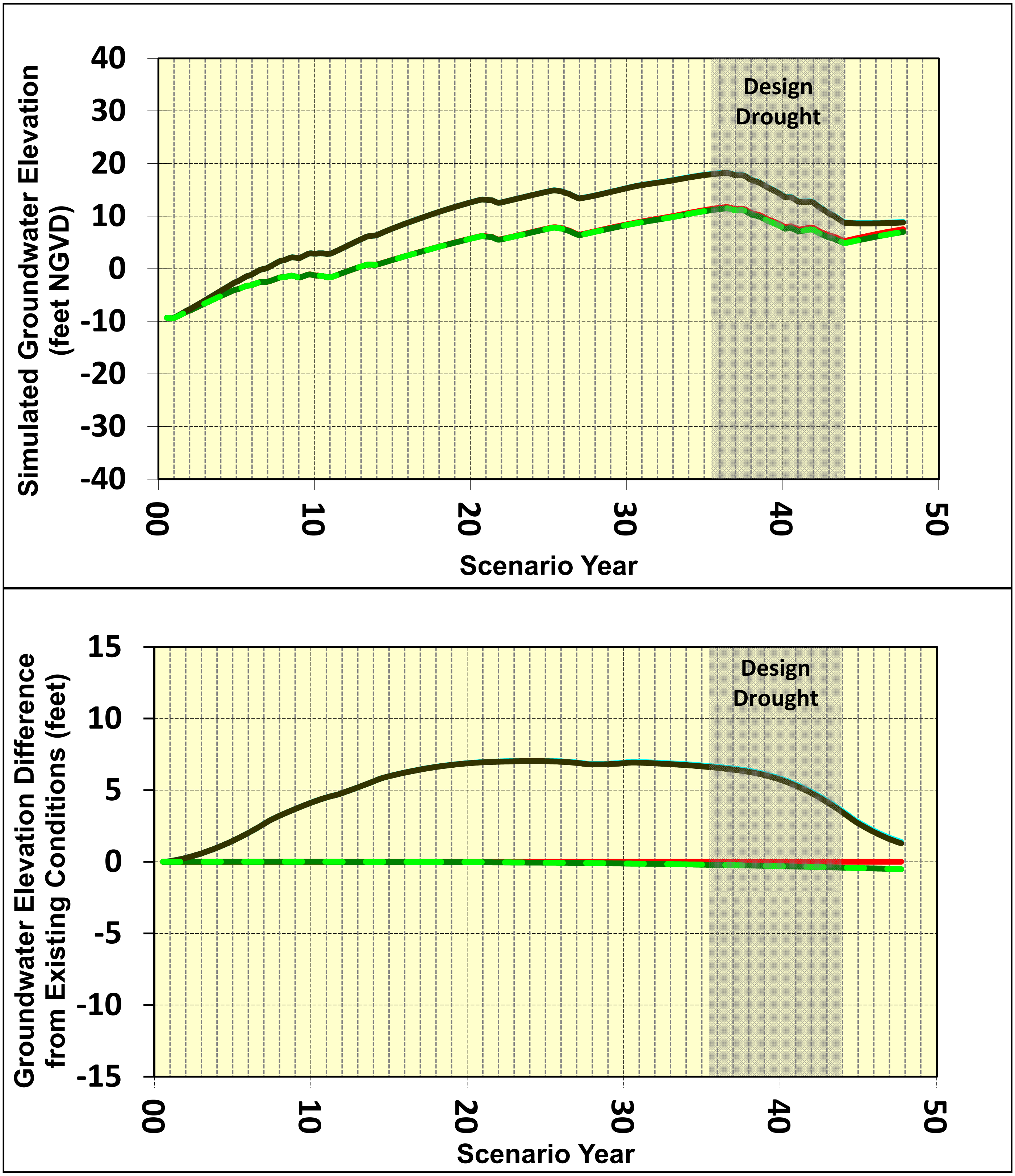
Figure 10.4-12b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

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Model Layer 1 Hydrographs for SB-12

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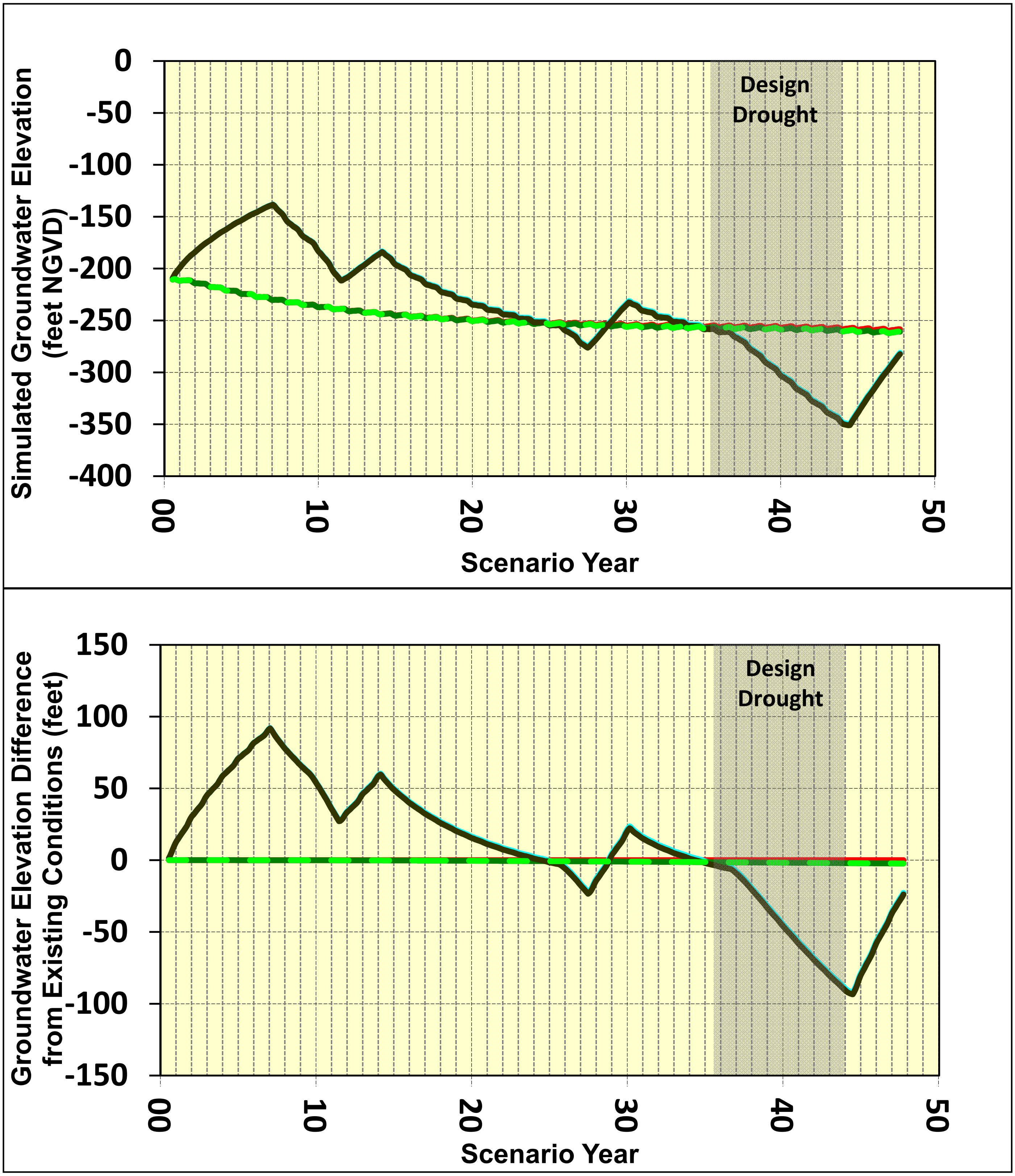
Figure 10.4-13a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

Scenario 1 — Scenario 2
Scenario 3a — Scenario 3b — Scenario 4

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Model Layer 4 Hydrographs for SB-12

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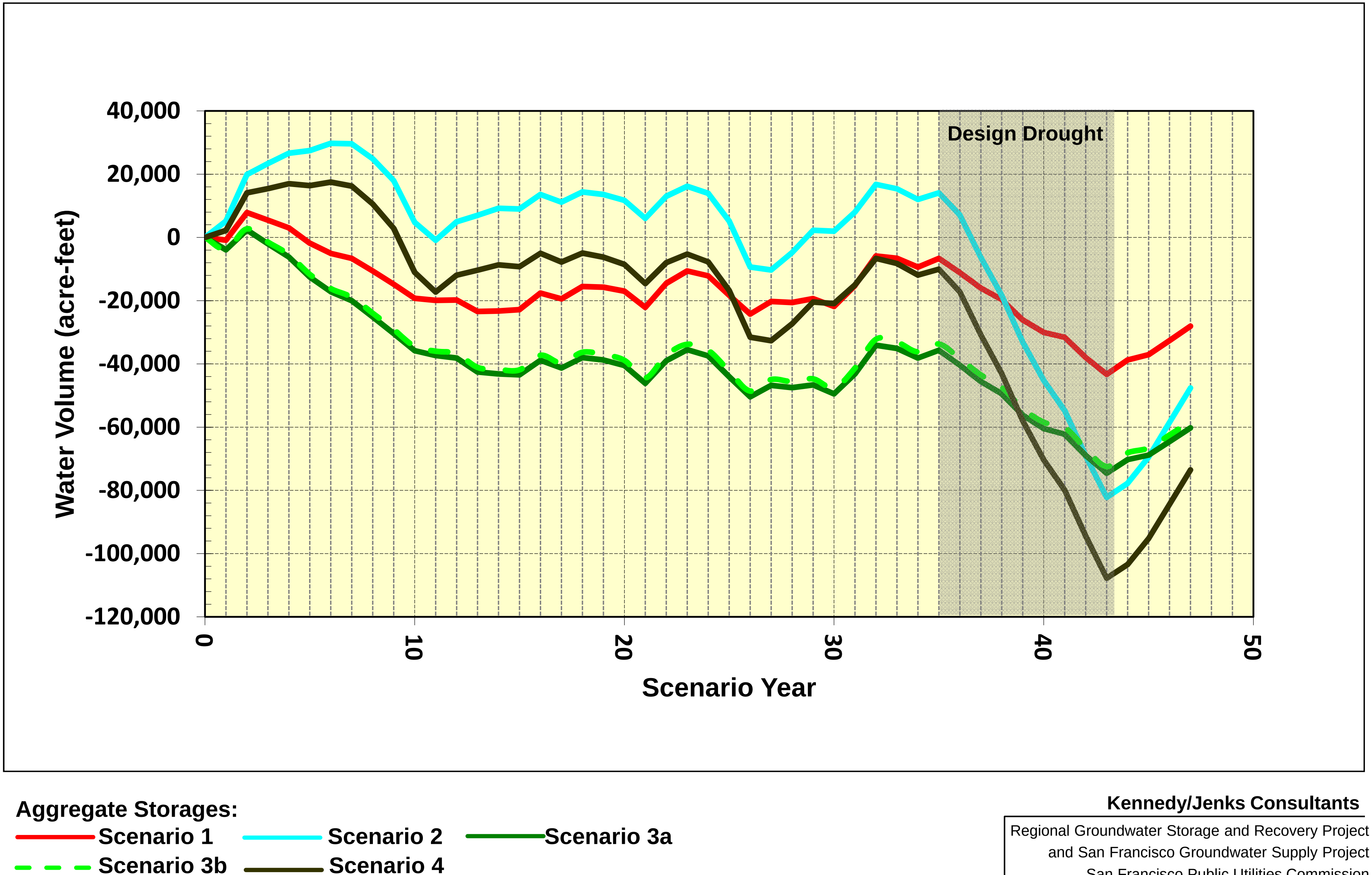
Figure 10.4-13b



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Model-Simulated Aggregate Change in Groundwater Storage

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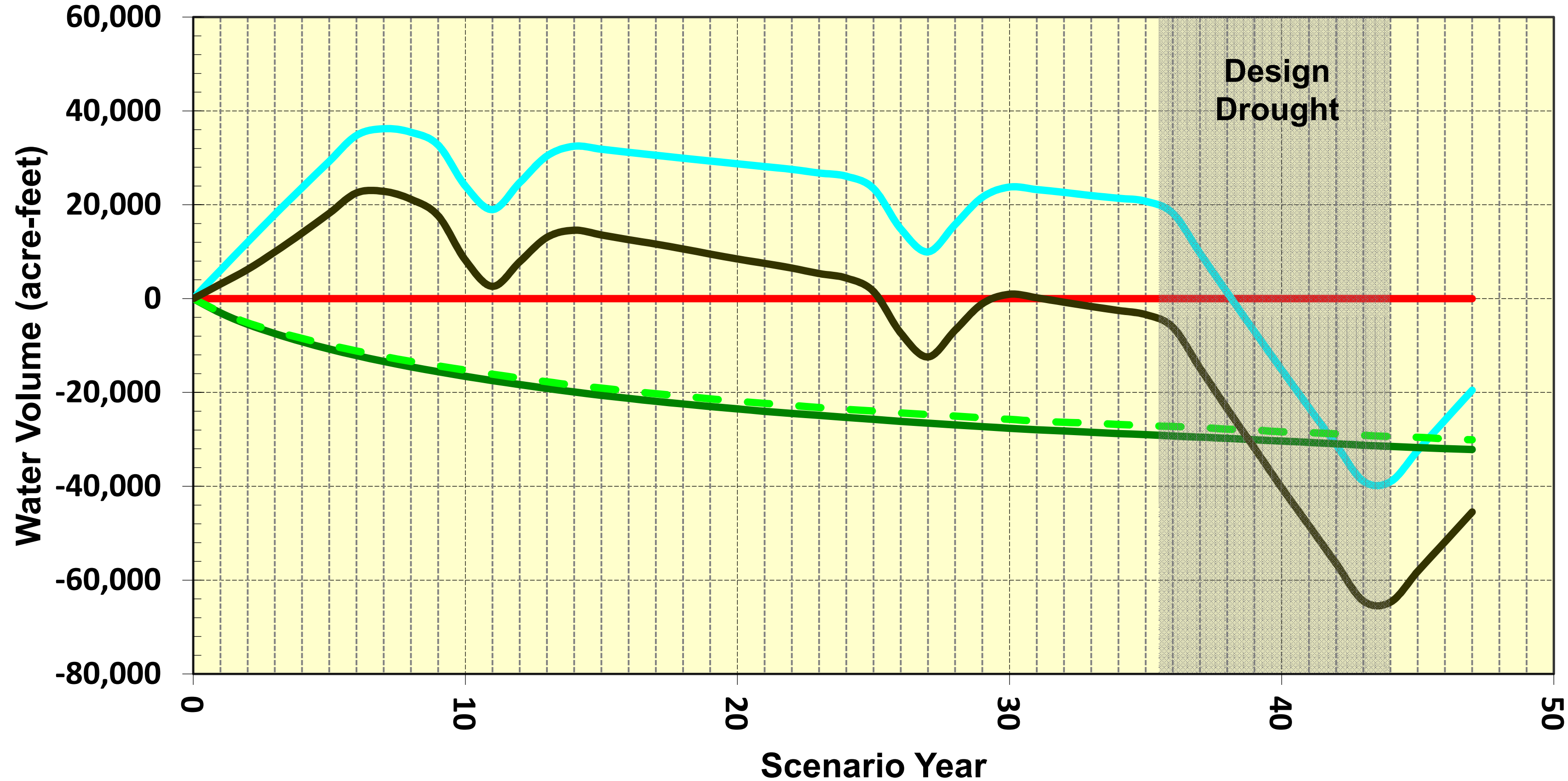
Figure 10.4-14



Aggregate Storages:

Scenario 1 | Scenario 2 | Scenario 3a
Scenario 3b | Scenario 4

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Model-Simulated Cumulative Change in Groundwater Storage Relative to Existing Conditions

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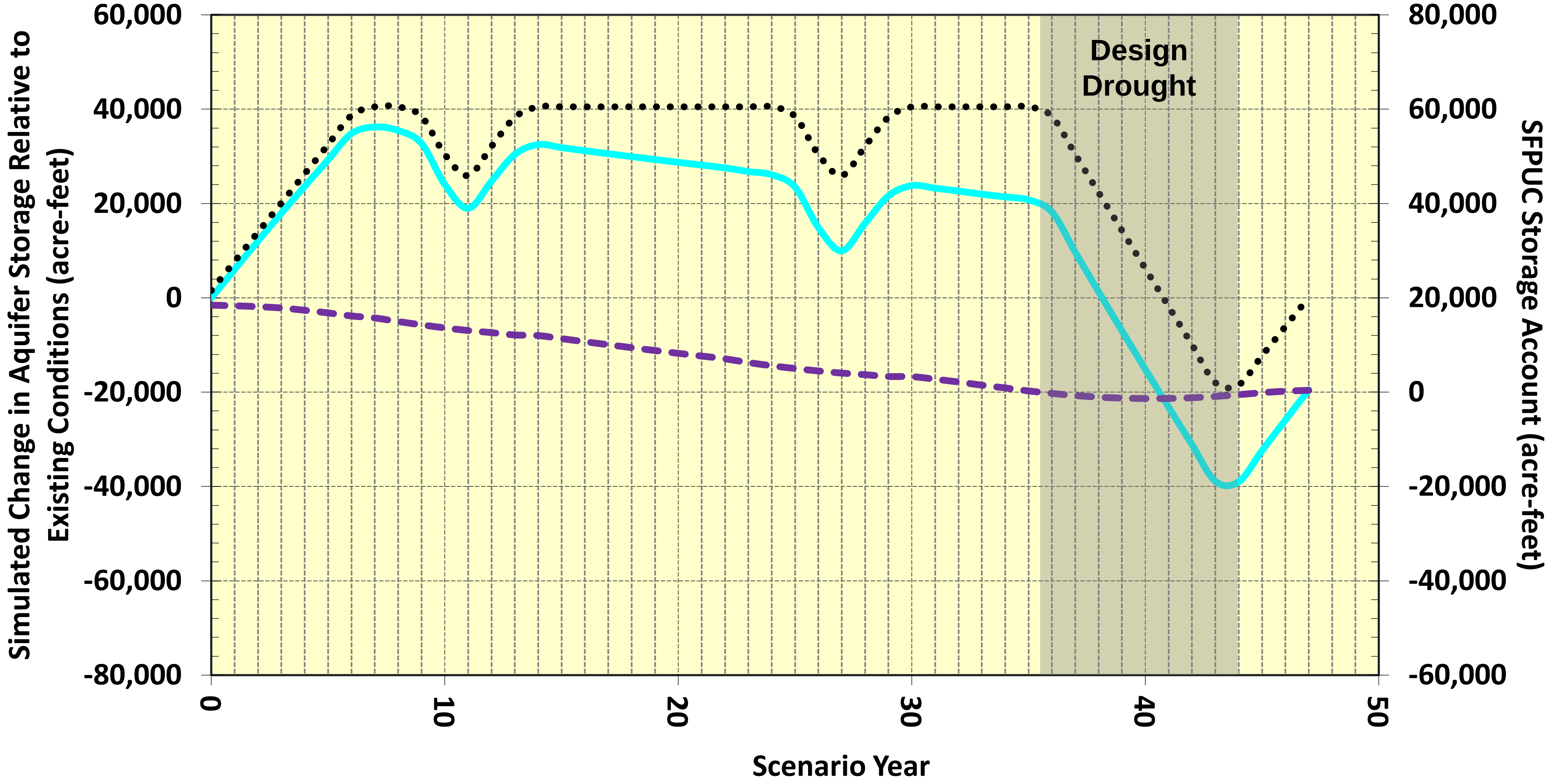
Figure 10.4-15



Note: SFPUC Storage Account axis is offset by 20,000 acre-feet relative to the Aquifer Storage axis to account for the 20,000 acre-feet in the SFPUC Storage Account at the start of the Scenario 2 simulation.

Legend:

- **Water in SFPUC Storage Account (right-hand axis)** (dotted black line)
- **Scenario 2 Simulated Aquifer Storage Relative to Scenario 1 (Existing Conditions)** (solid cyan line)
- **Difference between SFPUC Storage Account and Scenario 2 Aquifer Storage** (dashed purple line)

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Comparison of SFPUC Storage Account to Groundwater Storage Relative to Existing Conditions

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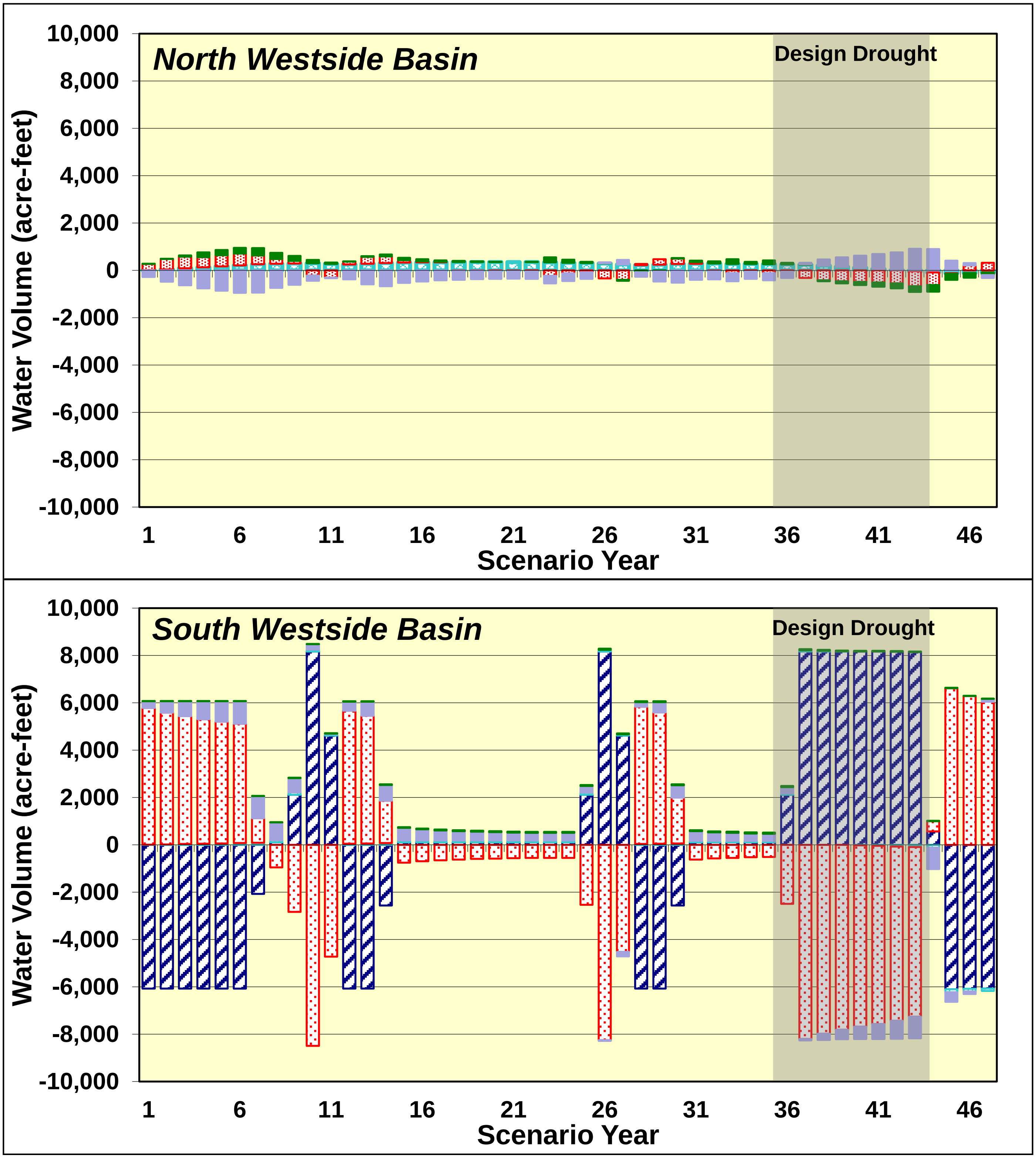
Figure 10.4-16



Note: For pumping, a positive value is an increase in pumping and a negative value is a decrease in pumping relative to Scenario 1.
For groundwater flow, a positive value is outflow from the basin, and a negative value is inflow into the basin.

Components of Analysis of Water Sources to Accommodate Pumping :

- Pumping – change in pumping relative to Scenario 1
- Ocean – change in outflow to the ocean relative to Scenario 1
- Surface Water – change in outflow to surface water relative to Scenario 1
- Aquifer Storage – change in aquifer storage relative to Scenario 1
- Groundwater flow – relative groundwater flow from adjoining basin

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Scenario 2 – Analysis of Water Sources to Accommodate Changes in Pumping Relative to Scenario 1

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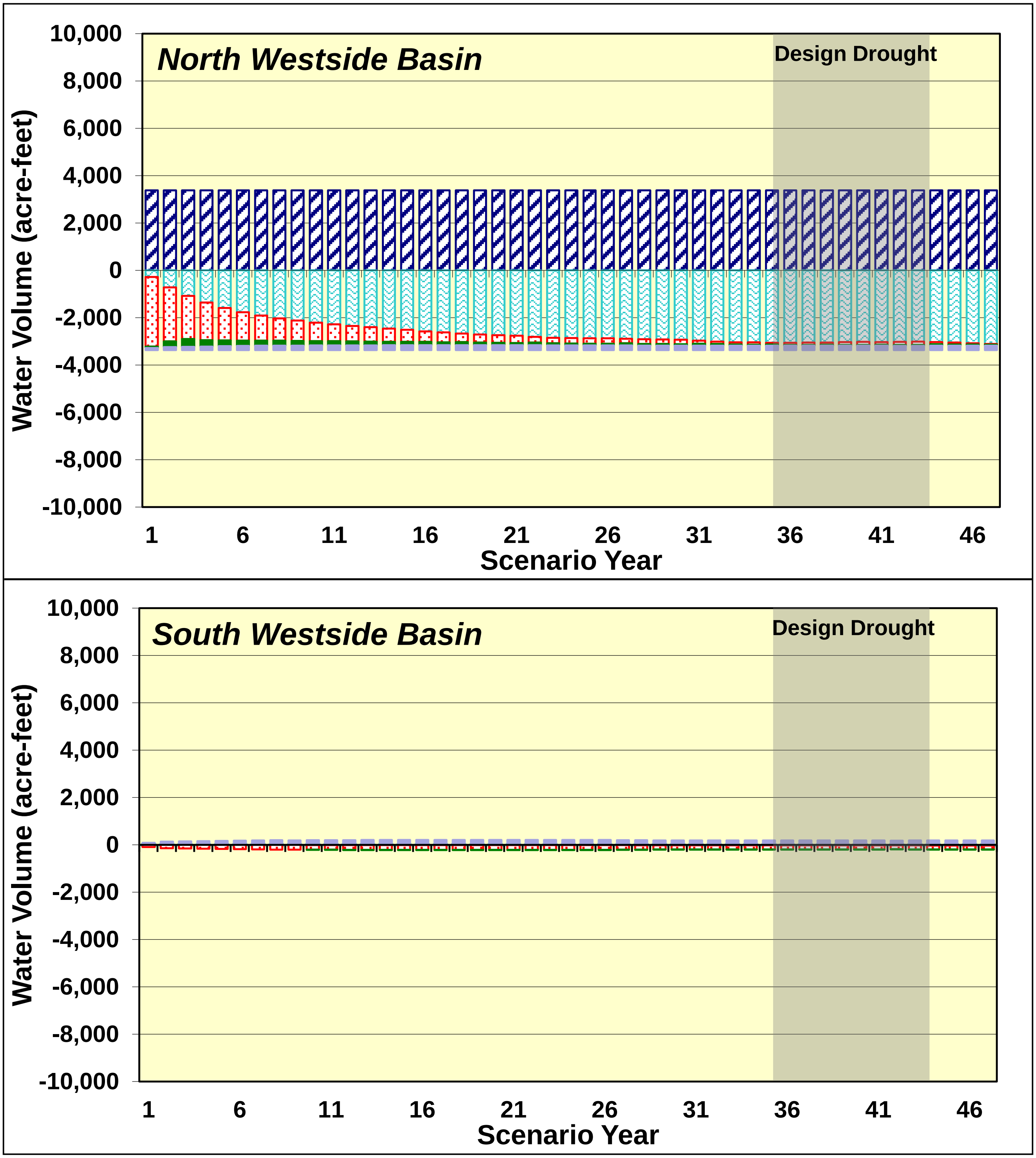
Figure 10.4-17



Note: For pumping, a positive value is an increase in pumping and a negative value is a decrease in pumping relative to Scenario 1.
For groundwater flow, a positive value is outflow from the basin, and a negative value is inflow into the basin.

Components of Analysis of Water Sources to Accommodate Pumping :

- Pumping – change in pumping relative to Scenario 1
- Ocean – change in outflow to the ocean relative to Scenario 1
- Surface Water – change in outflow to surface water relative to Scenario 1
- Aquifer Storage – change in aquifer storage relative to Scenario 1
- Groundwater flow – relative groundwater flow from adjoining basin

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Scenario 3a – Analysis of Water Sources to Accommodate Changes in Pumping Relative to Scenario 1

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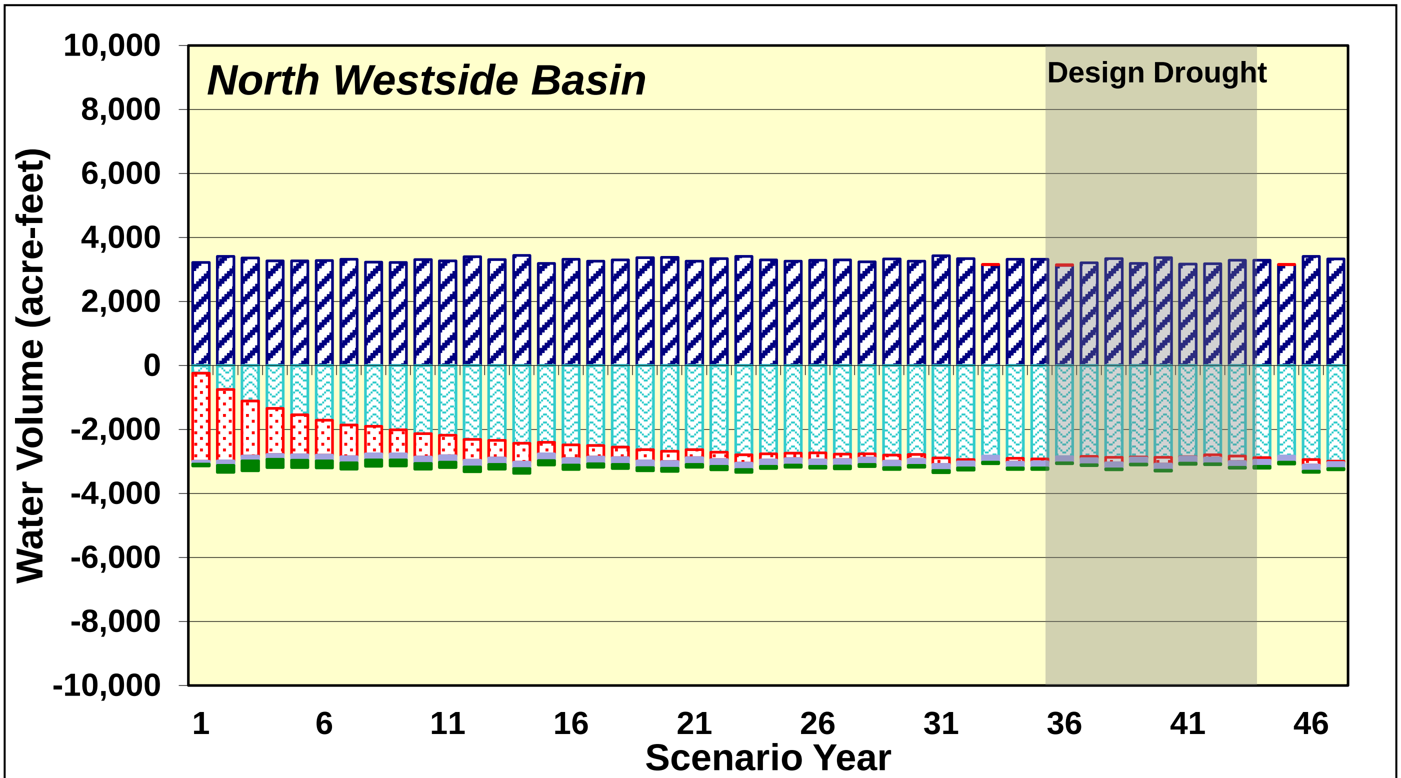
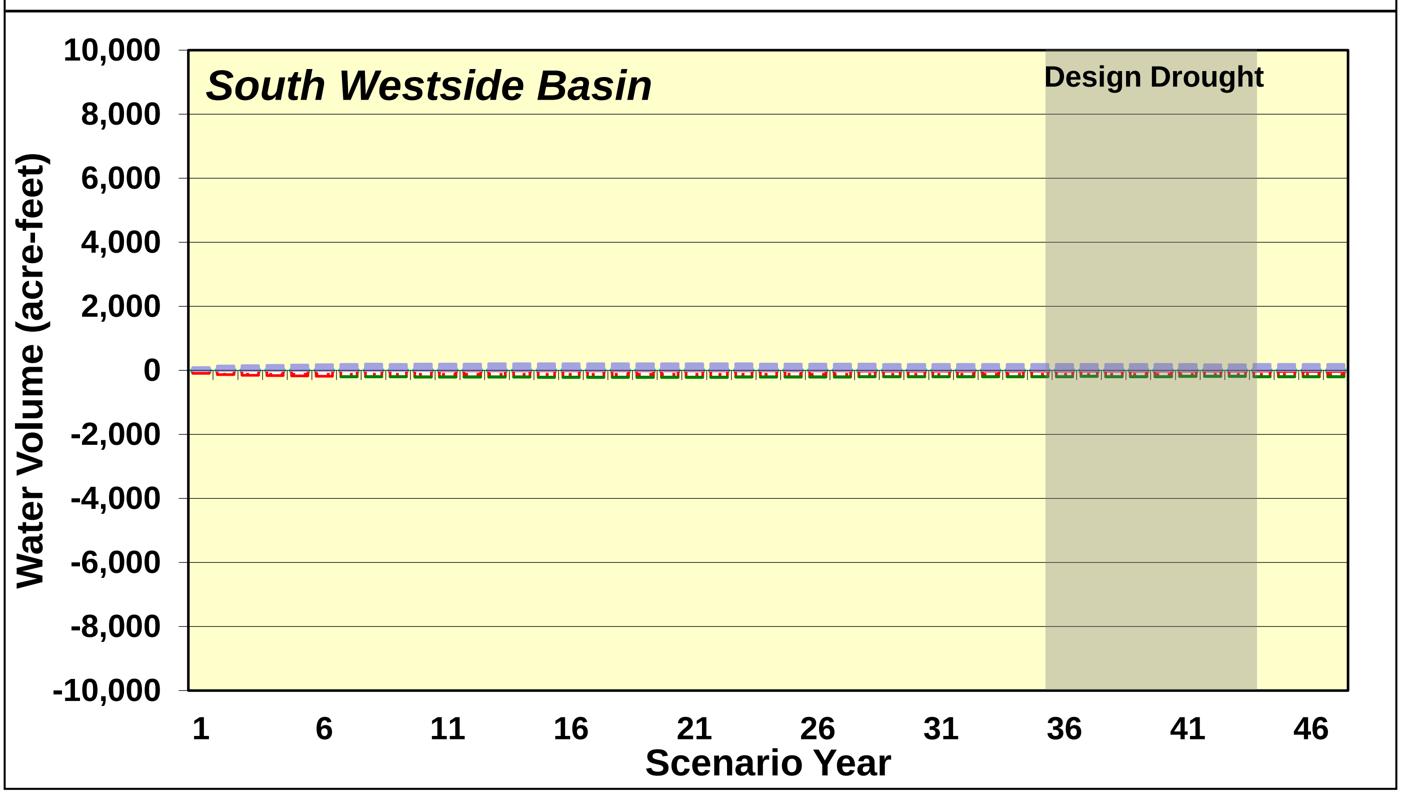
Figure 10.4-18





Note: For pumping, a positive value is an increase in pumping and a negative value is a decrease in pumping relative to Scenario 1. For groundwater flow, a positive value is outflow from the basin, and a negative value is inflow into the basin.

Components of Analysis of Water Sources to Accommodate Pumping :

- Pumping – change in pumping relative to Scenario 1
- Ocean – change in outflow to the ocean relative to Scenario 1
- Surface Water – change in outflow to surface water relative to Scenario 1
- Aquifer Storage – change in aquifer storage relative to Scenario 1
- Groundwater flow – relative groundwater flow from adjoining basin

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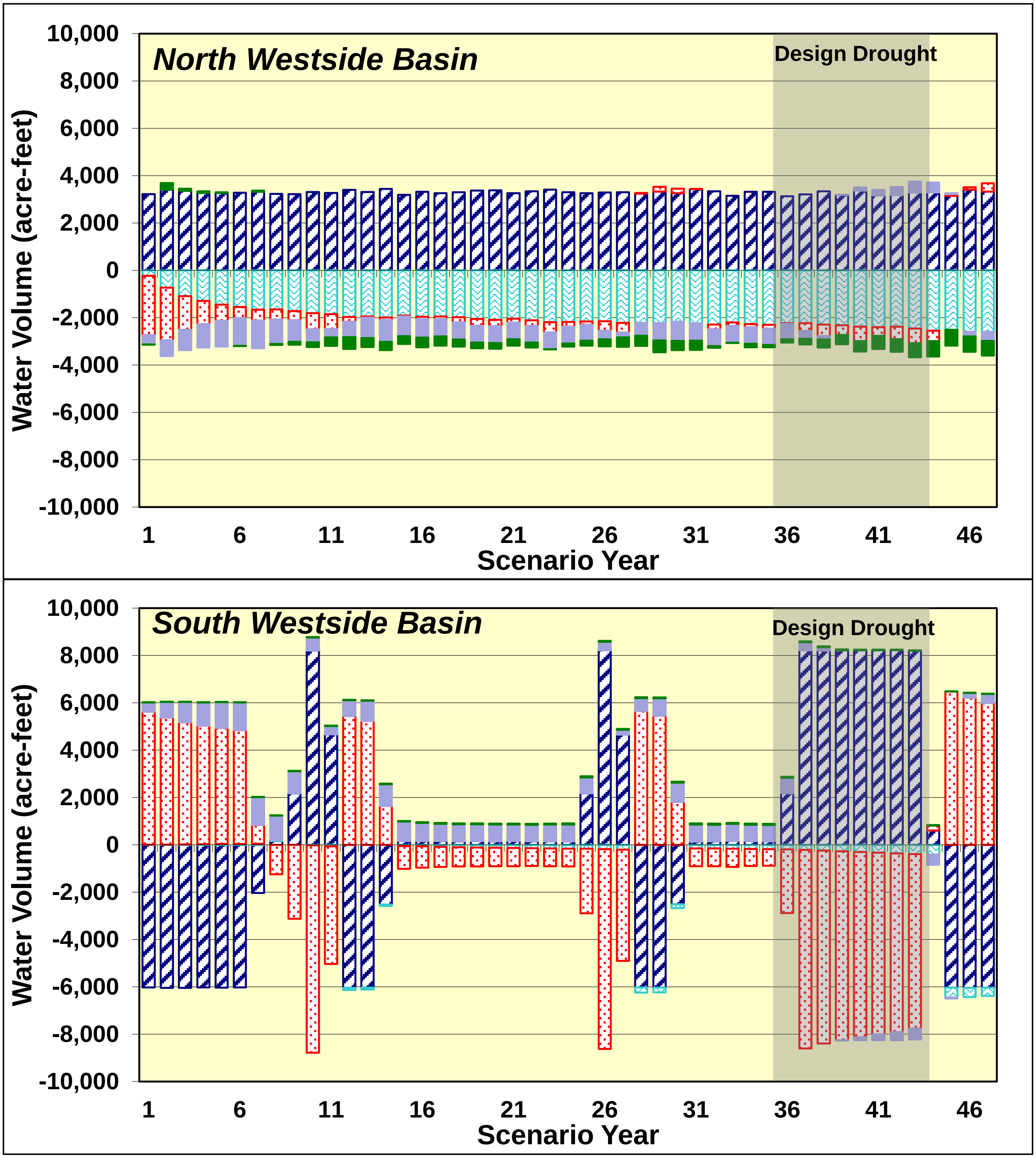
Scenario 3b – Analysis of Water Sources to Accommodate Changes in Pumping Relative to Scenario 1

K/J 0864001
April 2012
Figure 10.4-19



Note: For pumping, a positive value is an increase in pumping and a negative value is a decrease in pumping relative to Scenario 1. For groundwater flow, a positive value is outflow from the basin, and a negative value is inflow into the basin.

Components of Analysis of Water Sources to Accommodate Pumping :

- **Pumping – change in pumping relative to Scenario 1**
- **Ocean – change in outflow to the ocean relative to Scenario 1**
- **Surface Water – change in outflow to surface water relative to Scenario 1**
- **Aquifer Storage – change in aquifer storage relative to Scenario 1**
- **Groundwater flow – relative groundwater flow from adjoining basin**

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Scenario 4 – Analysis of Water Sources to Accommodate Changes in Pumping Relative to Scenario 1

K/J 0864001
April 2012
Figure 10.4-20

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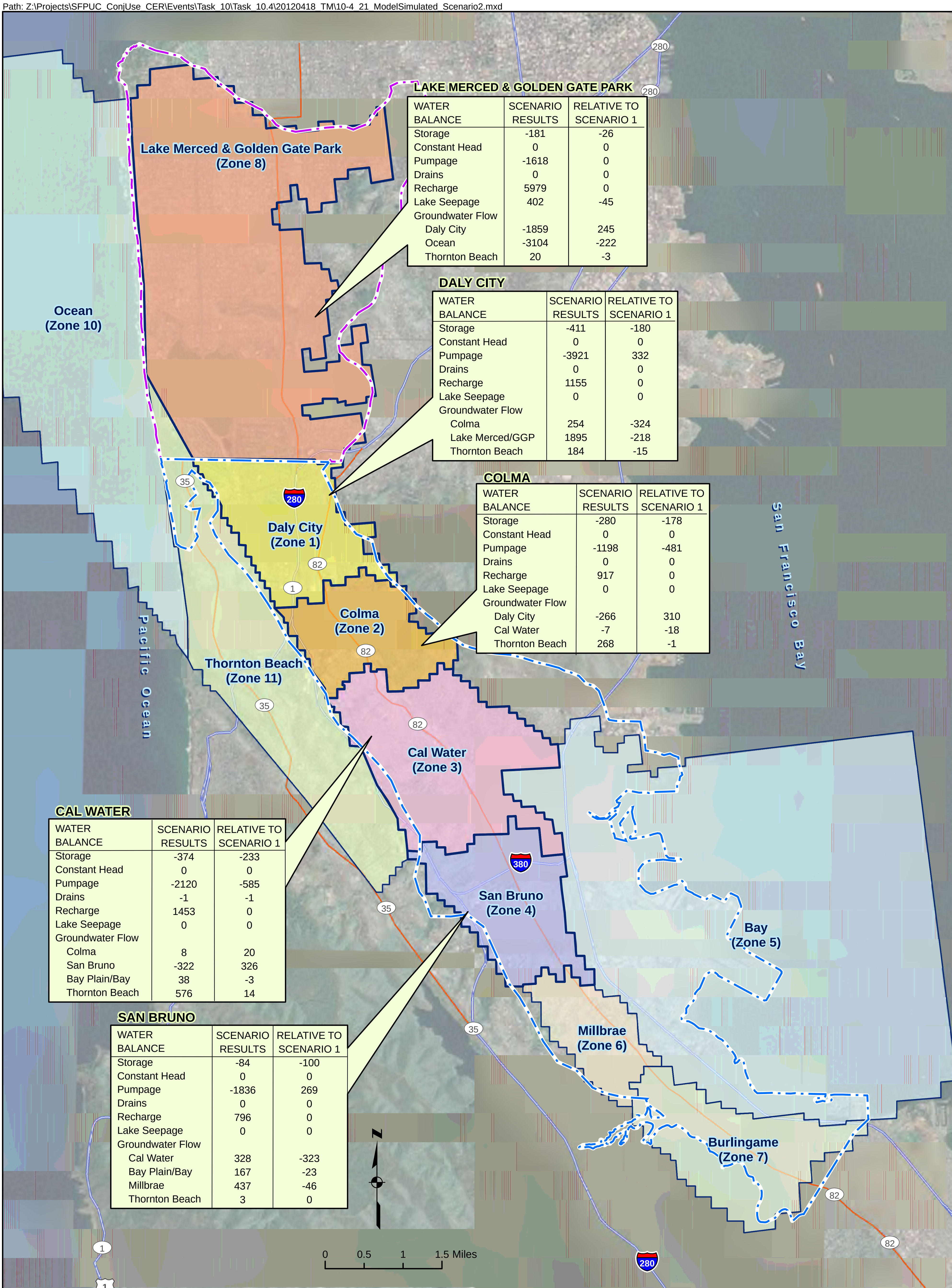

LAKE MERCED & GOLDEN GATE PARK

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-181	-26
Constant Head	0	0
Pumpage	-1618	0
Drains	0	0
Recharge	5979	0
Lake Seepage	402	-45
Groundwater Flow		
Daly City	-1859	245
Ocean	-3104	-222
Thornton Beach	20	-3

DALY CITY

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-411	-180
Constant Head	0	0
Pumpage	-3921	332
Drains	0	0
Recharge	1155	0
Lake Seepage	0	0
Groundwater Flow		
Colma	254	-324
Lake Merced/GGP	1895	-218
Thornton Beach	184	-15

COLMA

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-280	-178
Constant Head	0	0
Pumpage	-1198	-481
Drains	0	0
Recharge	917	0
Lake Seepage	0	0
Groundwater Flow		
Daly City	-266	310
Cal Water	-7	-18
Thornton Beach	268	-1

CAL WATER

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-374	-233
Constant Head	0	0
Pumpage	-2120	-585
Drains	-1	-1
Recharge	1453	0
Lake Seepage	0	0
Groundwater Flow		
Colma	8	20
San Bruno	-322	326
Bay Plain/Bay	38	-3
Thornton Beach	576	14

SAN BRUNO

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-84	-100
Constant Head	0	0
Pumpage	-1836	269
Drains	0	0
Recharge	796	0
Lake Seepage	0	0
Groundwater Flow		
Cal Water	328	-323
Bay Plain/Bay	167	-23
Millbrae	437	-46
Thornton Beach	3	0

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Legend

- South Westside Groundwater Basin
- North Westside Groundwater Basin

Model Sub-areas

- Lake Merced and Golden Gate Park
- Daly City
- Colma
- Cal Water
- San Bruno
- Millbrae
- Burlingame
- Ocean
- Thornton Beach
- Bay

Note:
Values are in units of acre-feet per year based on the annual average values over the simulated period.

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
ENGINEERING MANAGEMENT BUREAU

MODEL SIMULATED AVERAGE ANNUAL WATER BALANCE FOR SPECIFIC WESTSIDE BASIN MODEL SUBAREAS SCENARIO 2

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Figure
10.4-21

Date
April 2012

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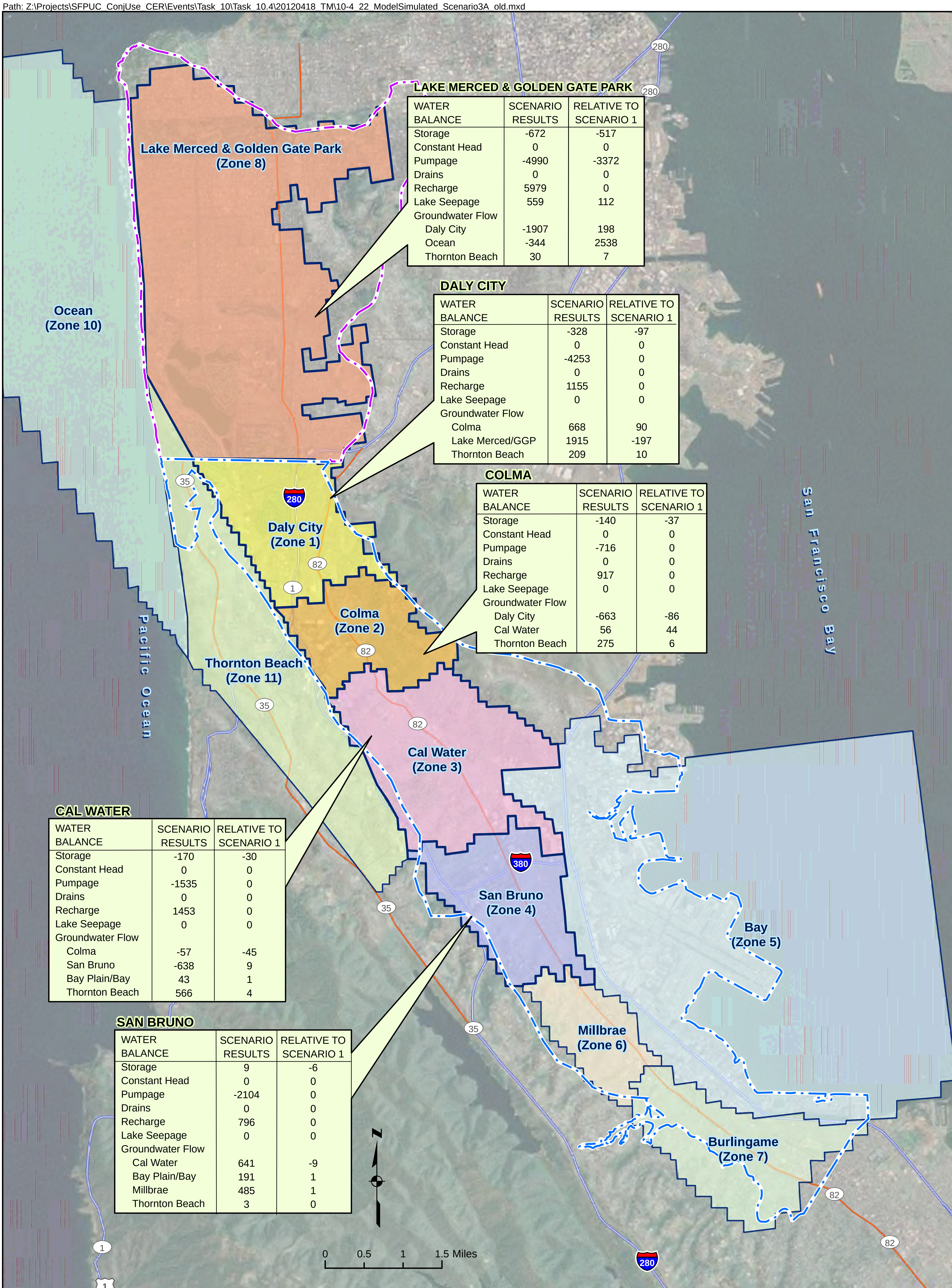

LAKE MERCED & GOLDEN GATE PARK

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-672	-517
Constant Head	0	0
Pumpage	-4990	-3372
Drains	0	0
Recharge	5979	0
Lake Seepage	559	112
Groundwater Flow		
Daly City	-1907	198
Ocean	-344	2538
Thornton Beach	30	7

DALY CITY

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-328	-97
Constant Head	0	0
Pumpage	-4253	0
Drains	0	0
Recharge	1155	0
Lake Seepage	0	0
Groundwater Flow		
Colma	668	90
Lake Merced/GGP	1915	-197
Thornton Beach	209	10

COLMA

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-140	-37
Constant Head	0	0
Pumpage	-716	0
Drains	0	0
Recharge	917	0
Lake Seepage	0	0
Groundwater Flow		
Daly City	-663	-86
Cal Water	56	44
Thornton Beach	275	6

CAL WATER

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-170	-30
Constant Head	0	0
Pumpage	-1535	0
Drains	0	0
Recharge	1453	0
Lake Seepage	0	0
Groundwater Flow		
Colma	-57	-45
San Bruno	-638	9
Bay Plain/Bay	43	1
Thornton Beach	566	4

SAN BRUNO

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	9	-6
Constant Head	0	0
Pumpage	-2104	0
Drains	0	0
Recharge	796	0
Lake Seepage	0	0
Groundwater Flow		
Cal Water	641	-9
Bay Plain/Bay	191	1
Millbrae	485	1
Thornton Beach	3	0

Legend

- South Westside Groundwater Basin
- North Westside Groundwater Basin

Model Sub-areas

- Lake Merced and Golden Gate Park
- Daly City
- Colma
- Cal Water
- San Bruno
- Millbrae
- Burlingame
- Ocean
- Thornton Beach
- Bay

Note:
Values are in units of acre-feet per year based on the annual average values over the simulated period.

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MODEL SIMULATED AVERAGE ANNUAL WATER BALANCE FOR SPECIFIC WESTSIDE BASIN MODEL SUBAREAS SCENARIO 3A

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Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Figure 10.4-22

Date April 2012

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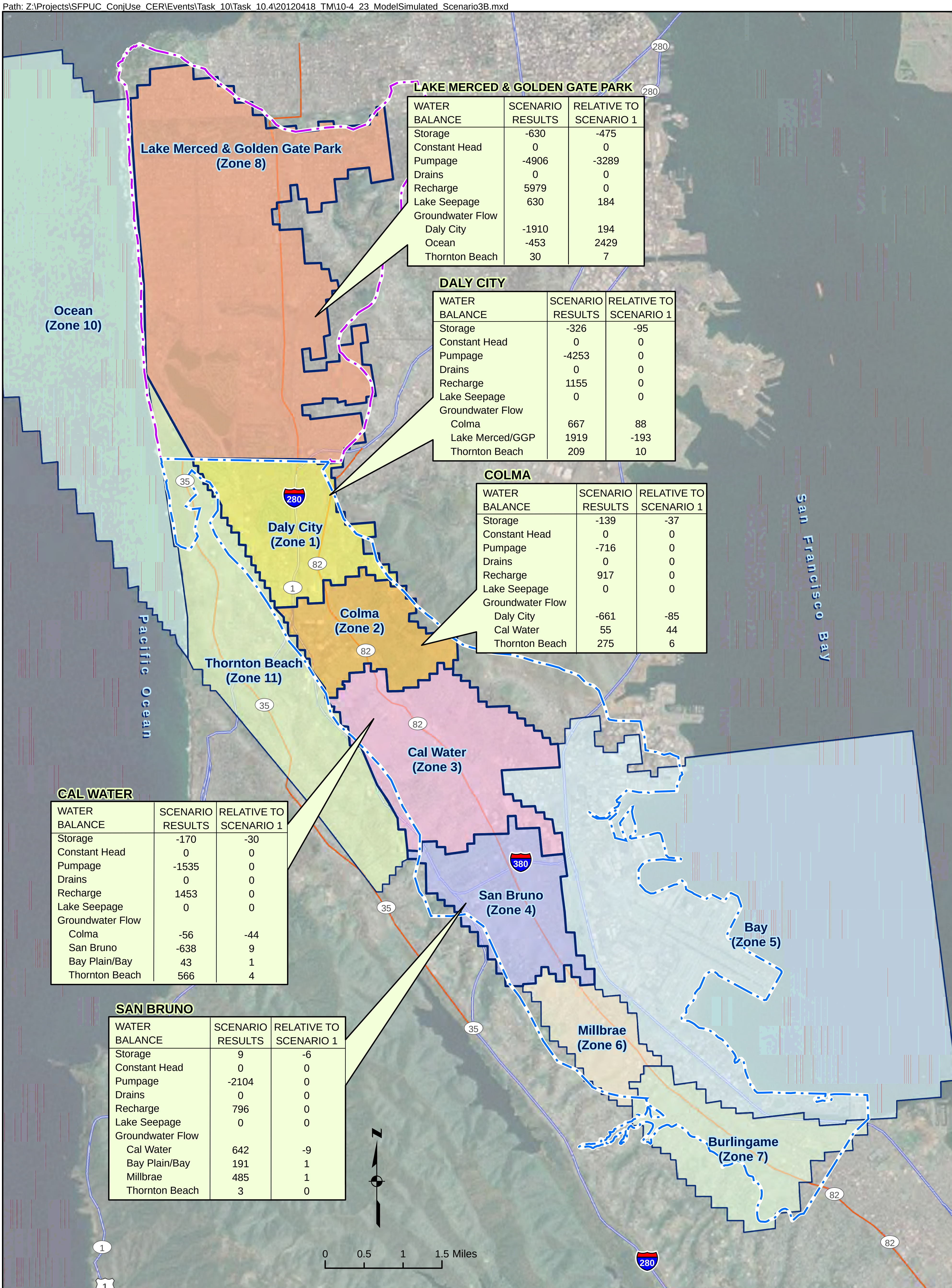

LAKE MERCED & GOLDEN GATE PARK

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-630	-475
Constant Head	0	0
Pumpage	-4906	-3289
Drains	0	0
Recharge	5979	0
Lake Seepage	630	184
Groundwater Flow		
Daly City	-1910	194
Ocean	-453	2429
Thornton Beach	30	7

DALY CITY

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-326	-95
Constant Head	0	0
Pumpage	-4253	0
Drains	0	0
Recharge	1155	0
Lake Seepage	0	0
Groundwater Flow		
Colma	667	88
Lake Merced/GGP	1919	-193
Thornton Beach	209	10

COLMA

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-139	-37
Constant Head	0	0
Pumpage	-716	0
Drains	0	0
Recharge	917	0
Lake Seepage	0	0
Groundwater Flow		
Daly City	-661	-85
Cal Water	55	44
Thornton Beach	275	6

CAL WATER

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-170	-30
Constant Head	0	0
Pumpage	-1535	0
Drains	0	0
Recharge	1453	0
Lake Seepage	0	0
Groundwater Flow		
Colma	-56	-44
San Bruno	-638	9
Bay Plain/Bay	43	1
Thornton Beach	566	4

SAN BRUNO

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	9	-6
Constant Head	0	0
Pumpage	-2104	0
Drains	0	0
Recharge	796	0
Lake Seepage	0	0
Groundwater Flow		
Cal Water	642	-9
Bay Plain/Bay	191	1
Millbrae	485	1
Thornton Beach	3	0

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Legend

- South Westside Groundwater Basin
- North Westside Groundwater Basin

Model Sub-areas

- Lake Merced and Golden Gate Park
- Daly City
- Colma
- Cal Water
- San Bruno
- Millbrae
- Burlingame
- Ocean
- Thornton Beach
- Bay

Note:
Values are in units of acre-feet per year based on the annual average values over the simulated period.

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MODEL SIMULATED AVERAGE ANNUAL WATER BALANCE FOR SPECIFIC WESTSIDE BASIN MODEL SUBAREAS SCENARIO 3B

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Figure **10.4-23**

Date April 2012

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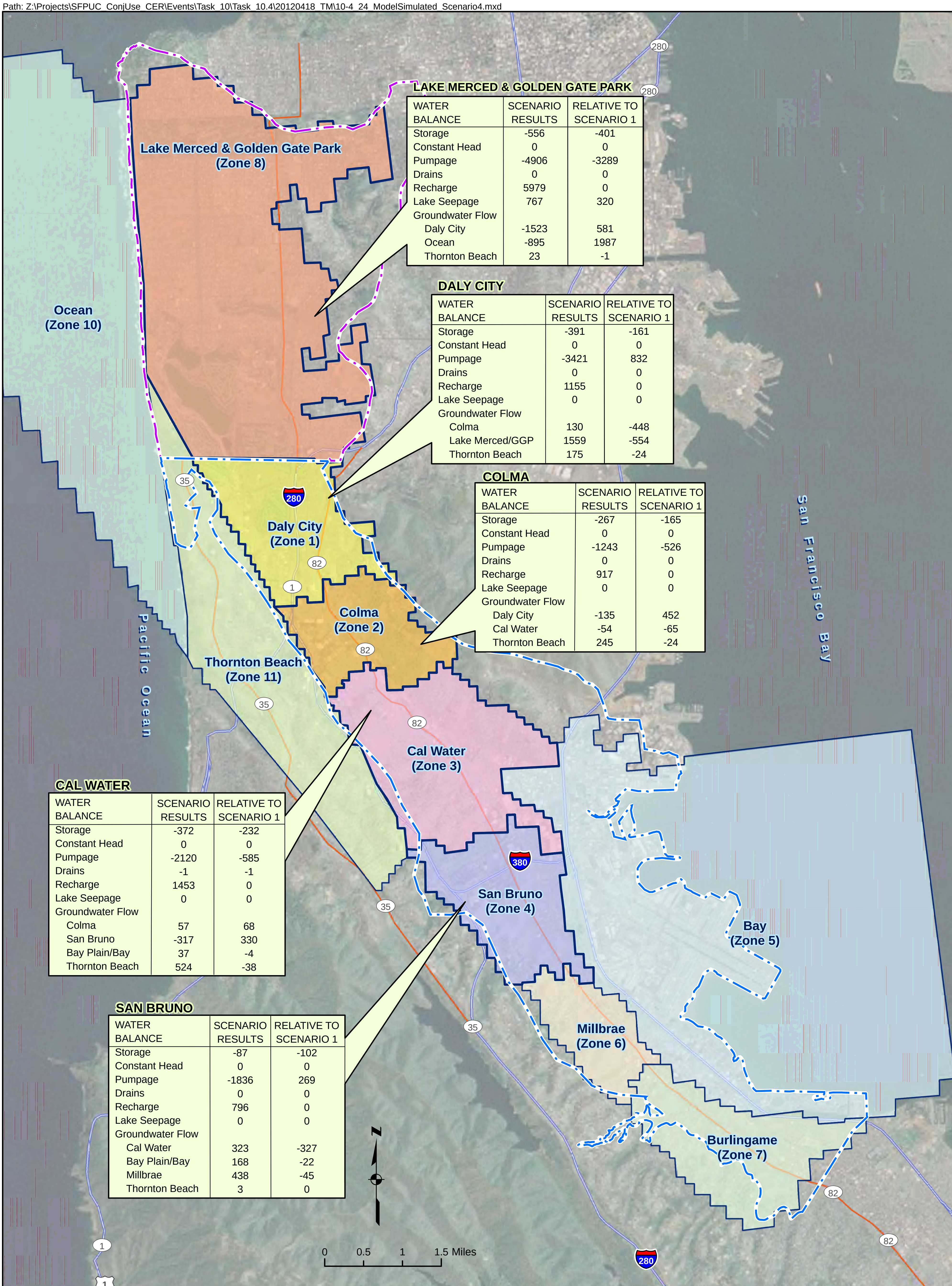

LAKE MERCED & GOLDEN GATE PARK

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-556	-401
Constant Head	0	0
Pumpage	-4906	-3289
Drains	0	0
Recharge	5979	0
Lake Seepage	767	320
Groundwater Flow		
Daly City	-1523	581
Ocean	-895	1987
Thornton Beach	23	-1

DALY CITY

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-391	-161
Constant Head	0	0
Pumpage	-3421	832
Drains	0	0
Recharge	1155	0
Lake Seepage	0	0
Groundwater Flow		
Colma	130	-448
Lake Merced/GGP	1559	-554
Thornton Beach	175	-24

COLMA

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-267	-165
Constant Head	0	0
Pumpage	-1243	-526
Drains	0	0
Recharge	917	0
Lake Seepage	0	0
Groundwater Flow		
Daly City	-135	452
Cal Water	-54	-65
Thornton Beach	245	-24

CAL WATER

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-372	-232
Constant Head	0	0
Pumpage	-2120	-585
Drains	-1	-1
Recharge	1453	0
Lake Seepage	0	0
Groundwater Flow		
Colma	57	68
San Bruno	-317	330
Bay Plain/Bay	37	-4
Thornton Beach	524	-38

SAN BRUNO

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-87	-102
Constant Head	0	0
Pumpage	-1836	269
Drains	0	0
Recharge	796	0
Lake Seepage	0	0
Groundwater Flow		
Cal Water	323	-327
Bay Plain/Bay	168	-22
Millbrae	438	-45
Thornton Beach	3	0

Legend

- South Westside Groundwater Basin
- North Westside Groundwater Basin

Model Sub-areas

- Lake Merced and Golden Gate Park
- Daly City
- Colma
- Cal Water
- San Bruno
- Millbrae
- Burlingame
- Ocean
- Thornton Beach
- Bay

Note:
Values are in units of acre-feet per year based on the annual average values over the simulated period.

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
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MODEL SIMULATED AVERAGE ANNUAL WATER BALANCE FOR SPECIFIC WESTSIDE BASIN MODEL SUBAREAS SCENARIO 4

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San Francisco, CA 94107

Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Figure **10.4-24**

Date April 2012

Tables

Tables

Table 10.4-1: Summary of Model Scenario Pumping Assumptions

		Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4
Model Scenarios		**Existing Conditions**	**GSR**	**SFGW**	**SFGW**	**Cumulative**
Establish Initial Conditions		Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence
	June 2009 Condition	√	√	√	√	√
Model Scenario Simulation Period						
	47.25 years (including Design Drought) Hydrologic Sequence: July 1996 to September 2003 -> October 1958 to November 1992 -> December 1975 to June 1978 -> July 2003 - September 2006		√	√	√	√
Pumping Assumptions for Municipal Use						
PA Municipal Wells (mgd)						
	"Take" Periods	6.84	6.90	6.84	6.84	6.90
	"Put" Periods	6.84	1.38	6.84	6.84	1.38
	"Hold" Periods	6.84	6.90	6.84	6.84	6.90
GSR Project Proposed Municipal Wells (mgd)						
	"Take" Periods	0.0	7.23	0.0	0.0	7.23
	"Put" Periods	0.0	0.04	0.0	0.0	0.04
	"Hold" Periods	0.0	0.04	0.0	0.0	0.04
SFGW Project Proposed Municipal Wells (mgd)						
	Year-Round Pumping	0.0	0.0	3.0	4.0	4.0
Total Municipal Pumping (PA + GSR + SFGW)						
	"Take" Periods	***6.84***	***14.13***	***9.84***	***10.84***	***18.13***
	"Put" Periods	***6.84***	***1.42***	***9.84***	***10.84***	***5.42***
	"Hold" Periods	***6.84***	***6.94***	***9.84***	***10.84***	***10.94***
Irrigation and Other Non-Potable Pumping Assumptions (mgd)(1)						
Golden Gate Park	Elk Glen (GGP)	0.081	0.081	0.081	0.000	0.000
	South Windmill (GGP)	0.498	0.498	0.498	0.000	0.000
	North Lake (GGP)	0.563	0.563	0.563	0.000	0.000
	Sub-Total	***1.142***	***1.142***	***1.142***	***0.000***	***0.000***
Golf Courses	Burlingame Golf Club	0.150	0.150	0.150	0.150	0.150
	California Golf No. 02	0.192	0.192	0.192	0.192	0.192
	Green Hills No. 05	0.099	0.099	0.099	0.099	0.099
	Lake Merced Golf No. 01	0.004	0.004	0.004	0.004	0.004
	Lake Merced Golf No. 02	0.004	0.004	0.004	0.004	0.004
	Lake Merced Golf No. 03	0.010	0.010	0.010	0.010	0.010
	Olympic Club No. 09(2)	0.002	0.002	0.002	0.002	0.002
	SF Golf West	0.035	0.035	0.035	0.035	0.035
	Sub-Total	***0.495***	***0.495***	***0.495***	***0.495***	***0.495***
Cemeteries	Cypress Lawn No. 02	0.020	0.020	0.020	0.020	0.020
	Cypress Lawn No. 03	0.144	0.144	0.144	0.144	0.144
	Eternal Home	0.013	0.013	0.013	0.013	0.013
	Hills of Eternity No. 02	0.020	0.020	0.020	0.020	0.020
	Holy Cross No. 03(3)	0.190	0.190	0.190	0.190	0.230
	Home of Peace No. 02	0.039	0.039	0.039	0.039	0.039
	Italian Cemetery	0.033	0.033	0.033	0.033	0.033
	Olivet	0.098	0.098	0.098	0.098	0.098
	Woodlawn No. 02	0.085	0.085	0.085	0.085	0.085
	Sub-Total	***0.641***	***0.641***	***0.641***	***0.641***	***0.681***
Other	Hillsborough Residents No. 1-12	0.291	0.291	0.291	0.291	0.291
	Edgewood Development Ctr.	0.009	0.009	0.009	0.009	0.009
	Zoo No.05	0.321	0.321	0.321	0.321	0.321
	Stern Grove	0.004	0.004	0.012	0.013	0.013
	Sub-Total	***0.626***	***0.626***	***0.634***	***0.635***	***0.635***
Total Irrigation and Other Non-Potable Pumping		***2.90***	***2.90***	***2.91***	***1.77***	***1.81***

Key:
afy - acre-feet per year
mgd - million gallons per day
PA - Partner Agencies
GGP - Golden Gate Park
GSR - Regional Groundwater Storage and Recovery
SFGW - San Francisco Groundwater Supply
SFPUC - San Francisco Public Utilities Commission

Notes:
(1) Pumping wells that are listed identify the wells in the model scenarios whose pumping assumptions were modified compared to the 2008 No-Project Scenario by HydroFocus (May, 2011, ver. 3.1), as a result of revised Soil Moisture Budget (SMB). Pumping rates for the three wells in the GGP, California Golf No. 02, Edgewood Development Center, Zoo No. 05, and Stern Grove wells were further modified compared to the results of revised SMB.
(2) Olympic Club No. 09 values include pumping for both Olympic Golf Club wells.
(3) Holy Cross No. 3 well irrigation pumping for Scenarios 1, 2, 3a, and 3b is based on the results of revised SMB. Based on the projected future build-out at the Holy Cross cemetery, an additional pumping of 0.04 mgd (45 afy) was estimated to occur under Scenario 4 (Cumulative).

Table 10.4-2: Scenario 1 (Existing Conditions) Westside Groundwater Basin Water Balance Summary

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	5	546	14,845	464	-4,684	-11,229	-753	-71	-877
2	5	558	24,505	456	-5,439	-10,299	-974	-72	8,739
3	5	552	13,329	475	-5,406	-10,445	-858	-73	-2,420
4	5	549	13,169	547	-4,988	-10,889	-758	-74	-2,440
5	5	549	10,129	623	-4,561	-10,804	-679	-74	-4,814
6	5	551	11,546	624	-4,317	-10,917	-653	-73	-3,234
7	5	552	12,988	614	-4,317	-10,717	-634	-72	-1,580
8	5	545	10,691	671	-4,064	-11,064	-680	-72	-3,968
9	6	549	10,235	853	-3,868	-11,113	-788	-70	-4,198
10	6	554	9,386	875	-3,717	-10,720	-767	-68	-4,451
11	7	549	13,455	807	-3,710	-10,879	-807	-68	-647
12	8	556	13,751	820	-3,780	-10,420	-772	-74	89
13	9	553	10,162	915	-3,568	-10,761	-841	-76	-3,609
14	10	558	13,533	1,086	-3,585	-10,315	-1,067	-75	145
15	11	549	14,876	1,040	-3,666	-11,154	-1,139	-81	437
16	12	556	19,804	925	-4,070	-10,766	-1,142	-84	5,234
17	10	549	12,678	995	-3,989	-10,883	-1,095	-88	-1,823
18	10	554	18,568	828	-4,225	-10,663	-1,102	-92	3,879
19	9	553	14,531	755	-4,322	-10,710	-932	-96	-212
20	9	556	13,363	791	-4,272	-10,673	-920	-100	-1,245
21	9	548	9,310	896	-3,869	-11,010	-912	-93	-5,120
22	10	554	22,751	765	-4,542	-10,729	-1,125	-94	7,591
23	9	556	19,036	745	-4,914	-10,402	-1,014	-101	3,915
24	9	549	13,397	837	-4,599	-10,670	-949	-105	-1,530
25	9	549	8,479	893	-4,123	-10,963	-904	-107	-6,167
26	11	550	8,071	921	-3,694	-10,827	-871	-96	-5,935
27	12	552	18,354	870	-3,946	-10,732	-1,017	-96	3,997
28	12	549	14,398	788	-4,057	-11,007	-911	-104	-331
29	12	553	15,609	801	-4,065	-10,650	-921	-109	1,231
30	13	550	11,960	905	-3,871	-10,961	-964	-112	-2,479
31	13	556	20,974	840	-4,352	-10,230	-1,076	-115	6,611
32	12	556	24,922	717	-5,079	-10,564	-1,106	-118	9,340
33	12	545	15,668	661	-5,124	-11,398	-951	-121	-709
34	11	554	12,389	855	-4,732	-10,800	-955	-124	-2,802
35	11	553	18,045	708	-4,839	-10,663	-951	-128	2,737
36	11	545	11,034	780	-4,601	-11,255	-871	-129	-4,486
37	11	545	9,932	915	-4,215	-11,035	-919	-121	-4,886
38	11	554	10,605	904	-4,058	-10,620	-900	-114	-3,618
39	12	549	7,905	926	-3,789	-11,119	-846	-106	-6,468
40	15	556	9,935	1,119	-3,588	-10,839	-1,052	-100	-3,953
41	17	549	12,714	1,156	-3,608	-11,081	-1,163	-100	-1,516
42	22	550	7,618	1,146	-3,322	-11,202	-1,120	-96	-6,403
43	28	549	7,975	1,171	-3,057	-10,827	-1,087	-87	-5,335
44	31	552	18,357	1,090	-3,379	-10,805	-1,216	-87	4,544
45	29	545	16,490	1,030	-3,669	-11,371	-1,263	-95	1,697
46	27	556	18,714	1,050	-4,069	-10,412	-1,305	-98	4,464
47	23	545	19,422	1,095	-4,385	-10,681	-1,383	-101	4,535
Average (afy)	**12**	**551**	**14,034**	**846**	**-4,172**	**-10,814**	**-960**	**-94**	**-597**
Maximum (afy)	**31**	**558**	**24,922**	**1,171**	**-3,057**	**-10,230**	**-634**	**-68**	**9,340**
Minimum (afy)	**5**	**545**	**7,618**	**456**	**-5,439**	**-11,398**	**-1,383**	**-129**	**-6,468**

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.

Table 10.4-3: Scenario 2 Westside Groundwater Basin Water Balance Summary, Relative to Existing Conditions

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	0	0	0	-13	-13	6,072	-1	0	6,045
2	0	0	0	-51	-59	6,072	44	0	6,005
3	0	0	0	-74	-121	6,072	23	-1	5,900
4	0	0	0	-152	-178	6,072	-40	-1	5,701
5	0	0	0	-204	-228	6,072	-18	-3	5,619
6	-1	0	0	-230	-284	6,072	-14	-4	5,540
7	-1	0	0	-262	-340	2,070	-46	-6	1,414
8	-1	0	0	-306	-371	-108	40	-10	-755
9	-2	0	0	-427	-384	-2,123	219	-14	-2,731
10	-2	0	0	-383	-380	-8,169	238	-17	-8,713
11	-3	0	0	-295	-334	-4,619	233	-19	-5,036
12	-2	0	0	-244	-301	6,072	239	-20	5,743
13	-4	0	0	-348	-332	6,072	319	-22	5,686
14	-7	0	0	-560	-378	2,557	485	-23	2,073
15	-8	0	0	-592	-404	-108	491	-28	-650
16	-8	0	0	-506	-411	-108	414	-33	-652
17	-6	0	0	-534	-417	-108	471	-36	-630
18	-6	0	0	-402	-422	-108	350	-38	-626
19	-5	0	0	-269	-427	-108	242	-40	-606
20	-5	0	0	-261	-429	-108	249	-42	-596
21	-5	0	0	-301	-427	-108	301	-41	-581
22	-6	0	0	-294	-428	-108	285	-41	-592
23	-5	0	0	-303	-418	-108	94	-43	-783
24	-5	0	0	-320	-394	-108	187	-43	-684
25	-5	0	0	-299	-382	-2,123	241	-44	-2,611
26	-6	0	0	-278	-359	-8,169	266	-43	-8,589
27	-6	0	0	-272	-298	-4,618	312	-41	-4,924
28	-5	0	0	-171	-253	6,072	248	-41	5,851
29	-6	0	0	-212	-275	6,072	254	-40	5,792
30	-8	0	0	-337	-313	2,557	322	-41	2,181
31	-8	0	0	-351	-336	-108	299	-42	-546
32	-6	0	0	-293	-339	-108	198	-43	-592
33	-6	0	0	-231	-329	-108	40	-45	-680
34	-6	0	0	-297	-321	-108	198	-47	-580
35	-5	0	0	-208	-316	-108	48	-48	-637
36	-5	0	0	-207	-306	-2,123	134	-47	-2,554
37	-5	0	0	-267	-288	-8,169	248	-42	-8,523
38	-4	0	0	-215	-231	-8,169	256	-39	-8,402
39	-3	0	0	-136	-160	-8,169	233	-35	-8,270
40	0	0	0	-81	-90	-8,169	210	-31	-8,160
41	6	0	0	-108	-23	-8,169	280	-28	-8,041
42	14	0	0	24	44	-8,162	187	-25	-7,918
43	25	0	0	327	109	-8,150	-85	-20	-7,794
44	34	0	0	390	178	-567	-114	-16	-96
45	31	0	0	392	217	6,100	-121	-13	6,606
46	20	0	0	306	205	6,076	-103	-9	6,496
47	11	0	0	186	177	6,073	-70	-6	6,371
Average (afy)	**0**	**0**	**0**	**-206**	**-246**	**-112**	**176**	**-28**	**-416**
Maximum (afy)	**34**	**0**	**0**	**392**	**217**	**6,100**	**491**	**0**	**6,606**
Minimum (afy)	**-8**	**0**	**0**	**-592**	**-429**	**-8,169**	**-121**	**-48**	**-8,713**

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.

Table 10.4-4 Scenario 3a Westside Groundwater Basin Water Balance Summary, Relative to Existing Conditions

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	0	0	0	21	270	-3,375	42	0	-3,042
2	2	0	0	61	708	-3,375	168	0	-2,436
3	6	0	0	126	1,067	-3,375	197	0	-1,979
4	21	0	0	113	1,338	-3,375	154	0	-1,748
5	48	0	0	96	1,538	-3,375	145	0	-1,548
6	87	0	0	194	1,678	-3,375	25	0	-1,390
7	122	0	0	267	1,791	-3,375	-58	0	-1,252
8	177	0	0	203	1,852	-3,375	2	0	-1,141
9	238	0	0	182	1,890	-3,375	16	0	-1,049
10	295	0	0	230	1,915	-3,375	-47	0	-981
11	342	0	0	224	1,945	-3,375	-47	0	-911
12	328	0	0	210	2,028	-3,375	-46	0	-855
13	400	0	0	120	2,010	-3,375	32	0	-812
14	420	0	0	-84	2,046	-3,375	232	0	-761
15	451	0	0	-99	2,072	-3,375	243	0	-709
16	385	0	0	-2	2,198	-3,375	144	0	-650
17	360	0	0	-44	2,269	-3,375	165	0	-624
18	351	0	0	99	2,328	-3,375	30	0	-566
19	305	0	0	189	2,417	-3,375	-79	0	-543
20	318	0	0	188	2,437	-3,375	-87	0	-518
21	423	0	0	136	2,348	-3,375	-46	0	-513
22	336	0	0	180	2,485	-3,375	-68	0	-441
23	244	0	0	200	2,615	-3,375	-111	0	-426
24	264	0	0	174	2,614	-3,375	-98	0	-421
25	370	0	0	164	2,514	-3,375	-96	0	-422
26	534	0	0	150	2,351	-3,375	-84	0	-425
27	510	0	0	127	2,396	-3,375	-43	0	-383
28	457	0	0	173	2,468	-3,375	-103	0	-379
29	451	0	0	163	2,491	-3,375	-92	0	-362
30	516	0	0	75	2,436	-3,374	-15	1	-361
31	412	0	0	119	2,574	-3,375	-41	1	-310
32	279	0	0	215	2,752	-3,374	-140	1	-269
33	246	0	0	277	2,810	-3,374	-232	1	-273
34	282	0	0	184	2,784	-3,374	-142	1	-267
35	291	0	0	306	2,792	-3,375	-257	1	-241
36	326	0	0	256	2,756	-3,374	-224	1	-259
37	415	0	0	152	2,658	-3,375	-116	1	-265
38	484	0	0	154	2,585	-3,374	-116	1	-267
39	601	0	0	131	2,456	-3,375	-102	1	-287
40	714	0	0	-82	2,333	-3,374	116	1	-292
41	740	0	0	-155	2,311	-3,375	200	1	-277
42	927	0	0	-173	2,118	-3,375	205	1	-296
43	1,095	0	0	-183	1,941	-3,374	215	1	-305
44	925	0	0	-147	2,128	-3,375	210	1	-257
45	777	0	0	-139	2,301	-3,375	194	2	-241
46	609	0	0	-146	2,497	-3,375	192	2	-221
47	485	0	0	-157	2,651	-3,374	199	2	-194
Average (afy)	**391**	**0**	**0**	**95**	**2,191**	**-3,375**	**13**	**1**	**-684**
Maximum (afy)	**1,095**	**0**	**0**	**306**	**2,810**	**-3,374**	**243**	**2**	**-194**
Minimum (afy)	**0**	**0**	**0**	**-183**	**270**	**-3,375**	**-257**	**0**	**-3,042**

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.

Table 10.4-5: Scenario 3b Westside Groundwater Basin Water Balance Summary, Relative to Existing Conditions

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	0	80	0	20	230	-3,223	40	0	-2,852
2	1	70	0	76	736	-3,412	213	0	-2,316
3	4	74	0	189	1,090	-3,364	248	0	-1,759
4	17	77	0	158	1,301	-3,271	167	0	-1,551
5	39	77	0	124	1,479	-3,270	149	0	-1,402
6	69	77	0	133	1,615	-3,274	113	0	-1,268
7	96	73	0	282	1,748	-3,317	-60	0	-1,178
8	127	81	0	219	1,752	-3,233	-4	0	-1,057
9	170	77	0	98	1,828	-3,219	107	0	-938
10	215	74	0	241	1,900	-3,312	-51	0	-934
11	248	77	0	238	1,919	-3,270	-56	0	-844
12	259	70	0	223	2,043	-3,395	-55	0	-855
13	305	73	0	134	2,028	-3,312	22	0	-750
14	346	70	0	-72	2,077	-3,436	222	0	-794
15	330	77	0	-87	2,065	-3,186	233	0	-568
16	297	70	0	9	2,177	-3,321	134	0	-634
17	268	77	0	-31	2,234	-3,261	155	0	-558
18	268	73	0	110	2,285	-3,294	20	0	-538
19	245	73	0	200	2,385	-3,368	-89	0	-554
20	252	70	0	201	2,433	-3,375	-97	0	-518
21	306	77	0	148	2,330	-3,255	-57	0	-450
22	274	73	0	190	2,442	-3,334	-78	0	-433
23	207	70	0	210	2,585	-3,411	-120	0	-459
24	210	77	0	186	2,554	-3,302	-109	0	-384
25	267	77	0	176	2,484	-3,255	-107	0	-357
26	394	77	0	162	2,344	-3,293	-96	0	-410
27	397	74	0	138	2,387	-3,301	-53	0	-359
28	330	77	0	183	2,442	-3,234	-113	0	-315
29	337	73	0	173	2,476	-3,328	-103	0	-372
30	371	77	0	86	2,418	-3,254	-26	0	-327
31	337	70	0	129	2,561	-3,425	-52	1	-380
32	240	70	0	225	2,717	-3,340	-151	1	-238
33	188	81	0	288	2,662	-3,146	-242	1	-168
34	213	73	0	196	2,697	-3,320	-154	1	-293
35	227	73	0	317	2,707	-3,321	-268	1	-264
36	230	81	0	268	2,638	-3,133	-235	1	-150
37	282	80	0	164	2,574	-3,214	-128	1	-241
38	336	74	0	166	2,544	-3,335	-128	1	-342
39	434	77	0	143	2,448	-3,188	-114	1	-198
40	558	70	0	-71	2,335	-3,373	105	1	-375
41	566	77	0	-145	2,310	-3,170	188	1	-172
42	701	77	0	-162	2,115	-3,181	194	1	-254
43	909	77	0	-171	1,943	-3,292	203	1	-330
44	771	74	0	-137	2,132	-3,286	198	1	-247
45	581	81	0	-129	2,279	-3,154	182	2	-158
46	480	70	0	-136	2,482	-3,413	180	2	-334
47	393	74	0	-146	2,620	-3,331	187	2	-202
Average (afy)	**300**	**75**	**0**	**105**	**2,161**	**-3,292**	**11**	**0**	**-640**
Maximum (afy)	**909**	**81**	**0**	**317**	**2,717**	**-3,133**	**248**	**2**	**-150**
Minimum (afy)	**0**	**70**	**0**	**-171**	**230**	**-3,436**	**-268**	**0**	**-2,852**

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.

Table 10.4-6 Scenario 4 Westside Groundwater Basin Water Balance Summary, Relative to Existing Conditions

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	0	80	0	-4	218	2,793	16	0	3,104
2	0	70	0	-93	704	2,629	-181	0	3,128
3	0	74	0	-139	1,066	2,674	54	-1	3,729
4	4	77	0	-153	1,255	2,754	83	-1	4,019
5	12	77	0	-163	1,395	2,759	136	-3	4,213
6	26	77	0	-153	1,484	2,750	159	-4	4,338
7	36	73	0	-192	1,568	-1,290	142	-6	331
8	52	81	0	-205	1,551	-3,394	241	-10	-1,685
9	79	77	0	-295	1,625	-5,396	414	-14	-3,509
10	116	74	0	-188	1,708	-11,525	383	-17	-9,450
11	163	77	0	-10	1,753	-7,936	374	-19	-5,598
12	183	70	0	50	1,881	2,642	447	-21	5,252
13	196	73	0	6	1,840	2,716	379	-22	5,188
14	203	70	0	-240	1,845	-914	582	-24	1,521
15	178	77	0	-288	1,788	-3,349	622	-29	-1,002
16	154	70	0	-260	1,867	-3,476	674	-34	-1,004
17	129	77	0	-329	1,904	-3,416	720	-37	-951
18	128	73	0	-244	1,947	-3,444	543	-39	-1,037
19	108	73	0	-187	2,047	-3,523	433	-41	-1,090
20	110	70	0	-198	2,106	-3,529	432	-42	-1,052
21	142	77	0	-165	2,033	-3,416	435	-42	-936
22	126	73	0	-219	2,125	-3,488	431	-42	-993
23	82	70	0	-301	2,261	-3,556	311	-44	-1,177
24	81	77	0	-282	2,254	-3,453	412	-44	-956
25	115	77	0	-208	2,215	-5,429	413	-45	-2,862
26	202	77	0	14	2,131	-11,510	286	-44	-8,843
27	235	74	0	30	2,189	-7,962	370	-42	-5,107
28	204	77	0	167	2,238	2,789	265	-42	5,698
29	188	73	0	112	2,242	2,702	378	-41	5,655
30	182	77	0	15	2,151	-747	375	-41	2,013
31	157	70	0	-120	2,235	-3,564	509	-43	-756
32	99	70	0	-243	2,343	-3,488	323	-44	-940
33	68	81	0	-233	2,298	-3,315	239	-46	-908
34	78	73	0	-264	2,367	-3,475	408	-47	-860
35	88	73	0	-171	2,391	-3,472	266	-48	-873
36	89	81	0	-192	2,343	-5,311	335	-47	-2,702
37	126	80	0	-142	2,317	-11,435	378	-43	-8,717
38	186	74	0	84	2,339	-11,546	260	-39	-8,643
39	265	77	0	156	2,332	-11,411	232	-35	-8,385
40	372	70	0	0	2,307	-11,594	430	-31	-8,446
41	398	77	0	61	2,330	-11,389	494	-28	-8,057
42	489	77	0	174	2,247	-11,405	359	-25	-8,083
43	653	77	0	219	2,190	-11,495	369	-20	-8,007
44	598	74	0	243	2,360	-3,898	402	-16	-237
45	450	81	0	246	2,482	2,877	419	-13	6,542
46	357	70	0	178	2,624	2,623	474	-9	6,316
47	277	74	0	95	2,679	2,699	526	-6	6,343
Average (afy)	**174**	**75**	**0**	**-86**	**1,991**	**-3,450**	**356**	**-28**	**-968**
Maximum (afy)	**653**	**81**	**0**	**246**	**2,679**	**2,877**	**720**	**0**	**6,542**
Minimum (afy)	**0**	**70**	**0**	**-329**	**218**	**-11,594**	**-181**	**-48**	**-9,450**

Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with the sign convention used by MODFLOW. For example, positive values for "Seepage from Lake Merced" represent flows from Lake Merced to the groundwater basin (aquifer). Negative values for "Seepage to Lake Merced" represent groundwater flow from the aquifer into Lake Merced.

Table 10.4-7: Annual Average Water Balances for Selected Subareas, Absolute and Relative to Existing Conditions, All Scenarios

Subarea	Component	Scenario 1 Simulated (afy)	Scenario 2 Simulated (afy)	Scenario 2 Relative (afy)	Scenario 3a Simulated (afy)	Scenario 3a Relative (afy)	Scenario 3b Simulated (afy)	Scenario 3b Relative (afy)	Scenario 4 Simulated (afy)	Scenario 4 Relative (afy)
Daly City	Storage	-230	-411	-180	-328	-97	-326	-95	-391	-161
	Constant Head	0	0	0	0	0	0	0	0	0
	Pumpage	-4,253	-3,921	332	-4,253	0	-4,253	0	-3,421	832
	Drains	0	0	0	0	0	0	0	0	0
	Recharge	1,155	1,155	0	1,155	0	1,155	0	1,155	0
	Lake Seepage	0	0	0	0	0	0	0	0	0
	Groundwater Flow									
	Colma	578	254	-324	668	90	667	88	130	-448
	Lake Merced/GGF	2,112	1,895	-218	1,915	-197	1,919	-193	1,559	-554
	Thornton Beach	199	184	-15	209	10	209	10	175	-24
Colma	Storage	-103	-280	-178	-140	-37	-139	-37	-267	-165
	Constant Head	0	0	0	0	0	0	0	0	0
	Pumpage	-716	-1,198	-481	-716	0	-716	0	-1,243	-526
	Drains	0	0	0	0	0	0	0	0	0
	Recharge	917	917	0	917	0	917	0	917	0
	Lake Seepage	0	0	0	0	0	0	0	0	0
	Groundwater Flow									
	Daly City	-577	-266	310	-663	-86	-661	-85	-135	442
	Cal Water	11	-7	-18	56	44	55	44	-54	-65
	Thornton Beach	269	268	-1	275	6	275	6	245	-24
Cal Water	Storage	-140	-374	-233	-170	-30	-170	-30	-372	-232
	Constant Head	0	0	0	0	0	0	0	0	0
	Pumpage	-1,535	-2,120	-585	-1,535	0	-1,535	0	-2,120	-585
	Drains	0	-1	-1	0	0	0	0	-1	-1
	Recharge	1,453	1,453	0	1,453	0	1,453	0	1,453	0
	Lake Seepage	0	0	0	0	0	0	0	0	0
	Groundwater Flow									
	Colma	-12	8	20	-57	-45	-56	-44	57	68
	San Bruno	-647	-322	326	-638	9	-638	9	-317	330
	Bay Plain/Bay	41	38	-3	43	1	43	1	37	-4
	Thornton Beach	562	576	14	566	4	566	4	524	-38
San Bruno	Storage	15	-84	-100	9	-6	9	-6	-87	-102
	Constant Head	0	0	0	0	0	0	0	0	0
	Pumpage	-2,104	-1,836	269	-2,104	0	-2,104	0	-1,836	269
	Drains	0	0	0	0	0	0	0	0	0
	Recharge	796	796	0	796	0	796	0	796	0
	Lake Seepage	0	0	0	0	0	0	0	0	0
	Groundwater Flow									
	Cal Water	650	328	-323	641	-9	642	-9	323	-327
	Bay Plain/Bay	190	167	-23	191	1	191	1	168	-22
	Millbrae	484	437	-46	485	1	485	1	438	-45
	Thornton Beach	3	3	0	3	0	3	0	3	0
Lake Merced/GGP	Storage	-155	-181	-26	-672	-517	-630	-475	-556	-401
	Constant Head	0	0	0	0	0	0	0	0	0
	Pumpage	-1,618	-1,618	0	-4,990	-3,372	-4,906	-3,289	-4,906	-3,289
	Drains	0	0	0	0	0	0	0	0	0
	Recharge	5,979	5,979	0	5,979	0	5,979	0	5,979	0
	Lake Seepage	446	402	-45	559	112	630	184	767	320
	Groundwater Flow									
	Daly City	-2,104	-1,859	245	-1,907	198	-1,910	194	-1,523	581
	Ocean	-2,882	-3,104	-222	-344	2,538	-453	2,429	-895	1,987
	Thornton Beach	23	20	-3	30	7	30	7	23	-1

Notes: (1) Water balance components represent annual average values on a water year basis, from October to September. The first three months of the simulation period, which represent July through September conditions, are omitted from the annual averages because they represent only a partial water year. The volumes presented represent the 47 complete water years for the simulation period.
(2) Relative values represent average annual net volumetric changes for a given scenario relative to Scenario 1.
(3) Negative storage values represent losses of storage from the aquifer, while positive storage values represent gains in storage in the aquifer.
(4) Recharge is the model-simulated combined recharge from deep percolation of rainfall, irrigation, and leaky pipes and sewers, as well as recharge from lakes and ponds in Golden Gate Park (for Lake Merced/GGP subarea).
(5) Positive Lake Seepage simulated values for the Lake Merced/GGP subarea represent groundwater flow from Lake Merced to the groundwater basin; and negative Lake Merced Seepage simulated values represent groundwater flow out of the groundwater basin into Lake Merced.
(6) Positive simulated values for Groundwater Flow components represent groundwater flow entering the subarea (i.e., inflow); and negative simulated values for Groundwater Flow components represent groundwater flow leaving the subarea (i.e., outflow).

Table 10.4-8: Comparison of Historic and Model-Simulated Groundwater Elevations

Historic Groundwater Level Elevations		Model-Simulated Groundwater Elevations				
Well Location (Period of Record)		**Model Equivalent Location**	**Scenario 1 - Existing Conditions**	**Scenario 2 - GSR Only**	**Scenario 3a - SFGW Only**	**Scenario 4 - Cumulative (GSR & SFGW)**
Shallow Aquifer	**Approx. Elev. Range (ft) (NGVD 29)**	Model Layer 1	**Approx. Elev. Range (ft) (NGVD 29)**			
South Windmill MW-57 (2006-2009)	-4 to 15	SWM-GS-M	6 to 15	6 to 15	-3 to 14	-3 to 11
Taraval MW-145 (2004-2009)	6 to 10	Taraval MW	4 to 9	4 to 9	-1 to 6	0 to 6
LMMW-3S (1996-2009)	2 to 14	LMMW-3S	2 to 20	2 to 21	-13 to 20	1 to 18
LMMW-4S (2003-2009)	11 to 15	LMMW-4S	10 to 25	11 to 25	-4 to 22	5 to 21
Primary Production Aquifer		Model Layer 4				
West Sunset Playground Well (1996-2009)	13 to 24	W-Sunset-PG	-2 to 4	-3 to 4	-14 to 3	-12 to 3
LMMW-2D (1996-2009)	6 to 14	LMMW-2D	-17 to -3	-25 to 6	-44 to -4	-40 to -4
DC-1 Westlake (2002-2009)	-121 to -68	Westlake-DC-1	-120 to -72	-198 to -28	-140 to -72	-181 to -30
MW-CUP-23-515 (08/09-10/09)	-167 to -135	CUP-23	-159 to -111	-289 to -86	-165 to -111	-289 to -87
Cal Water SS1-02 (2002-2009)	-172 to -108	SSF1-02	-206 to -141	-333 to -108	-210 to -141	-336 to -109
MW-CUP-36-1-585 (11/08-10/09)	-175 to -161	CUP-36	-194 to -134	-320 to -107	-198 to -134	-322 to -107
SB-12 Elm Avenue (2004-2009)	-198 to -181	SB-12	-260 to -210	-350 to -138	-262 to -210	-351 to -138

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Project No. 04.B0103128

TECHNICAL MEMORANDUM

To: Mr. Greg Bartow and Mr. Jeff Gilman
San Francisco Public Utilities Commission

From: Peter Leffler, C.Hg.; Ron Bajuniemi, P.E., G.E.

Subject: **Subsidence Analysis for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project**

INTRODUCTION

This Technical Memorandum (TM) was prepared to document work performed by Fugro and as part of contract CS-879A with Kennedy/Jenks Consultants (Kennedy/Jenks) for the San Francisco Public Utilities Commission (SFPUC) pursuant to the amended Task Order authorizations CUW30103-TO-1.12 of the Regional Groundwater Storage and Recovery (GSR) Project and CUW30102-TO-2.7 of the San Francisco Groundwater Supply (SFGW) Project. These projects are funded by the SFPUC's Water System Improvement Program (WSIP).

The San Francisco Public Utilities Commission (SFPUC) is conducting environmental review for the proposed Groundwater Storage and Recovery (GSR) project in the South Westside Groundwater Basin in northern San Mateo County and the San Francisco Groundwater Supply (SFGW) project in the North Westside Groundwater Basin in the City and County of San Francisco. The proposed GSR project involves a partnership between SFPUC and the City of Daly City, California Water Service Company (Cal Water), and the City of San Bruno. The study area encompasses a portion of San Mateo County located between Millbrae and Daly City. Each of the Partner Agencies (Daly City, Cal Water, and San Bruno) has historically obtained municipal water supplies from a combination of groundwater and SFPUC surface water. In the proposed project, the SFPUC would provide a greater allocation of surface water to Partner Agencies during average and wet years in order to allow Partner Agencies to reduce groundwater pumping. The project would create in-lieu groundwater recharge, which would be tapped during drought cycles via new wells installed by the SFPUC between Millbrae and Daly City.

The proposed SFGW project involves groundwater extraction of 3 to 4 million gallons per day (MGD) from four to six new wells installed in the vicinity of Lake Merced, the Sunset District, and Golden Gate Park. The study area encompasses the western portion of San Francisco between the San Francisco/San Mateo county line and Golden Gate Park. The scope of the proposed project (3 or 4 MGD) would depend upon whether or not recycled water would replace a portion of irrigation pumping in Golden Gate Park. If the recycled water project is implemented, two existing irrigation wells at the west end of Golden Gate Park would be converted to municipal supply wells, and four additional municipal supply wells would be brought online to pump a total of 4 MGD from six wells. If the recycled water project is not implemented, the two Golden Gate Park irrigation wells would continue irrigation pumping, and only the four new municipal supply wells would be used to pump 3 MGD for the SFGW project.

Purpose of Study

The proposed GSR project in northern San Mateo County would only extract groundwater up to the amount stored via in-lieu recharge. However, due to potential for localized effects (i.e., greater drawdown in the vicinity of proposed GSR wells), this study is being conducted to evaluate potential for subsidence that may be caused by localized areas of water level drawdowns that may exceed historic lows and exceed future expected groundwater levels without the proposed project(s).

This study addresses the following technical issues:

- The geologic setting of the area (presence of semi-consolidated, fine-grained deposits) with regard to the potential for subsidence.
- Compilation of historical survey and monument data for the study area that could document the existence of and nature of historical subsidence in the area. If data allow – evaluate if subsidence has occurred or is occurring, where it is occurring, and the causes.
- The historical range of water level variations in the principal aquifer units in the study area related to groundwater withdrawal.
- Evaluation of the potential for subsidence related to several proposed scenarios of in-lieu recharge and groundwater extraction in the Westside Basin.

For the purpose of this study, the area evaluated includes the Westside Groundwater Basin in San Francisco and northern San Mateo counties as generally defined by Luhdorff & Scalmanini (2010) and the “model domain” used by Kennedy/Jenks (2012). The area of study is shown on Figure 1, which also shows the approximate location of survey benchmarks with vertical elevation control data from the National Geodetic Survey (NGS).

Background and Previous Studies

A previous study conducted by CH2M Hill (1996) evaluated subsidence associated with potential development of new municipal groundwater supply wells in the Golden Gate Park, Sunset District, North Lake Merced, and South Lake Merced areas. The results estimated total subsidence of up to one foot in the Golden Gate Park area, 0.8 foot in the Sunset District, and 1.4 feet for continuous 5-year pumping rates of 1,400 gpm (approximately 2 MGD) in each respective area. The study did not identify any clay layers of significance in the South Lake Merced area; hence, it was assumed no subsidence would occur in this area. The CH2M Hill study effectively assumes all project pumping comes from one well.

The CH2M Hill study states that subsidence generally occurs in confined aquifers with compressible clay layers, whereas the Westside Basin is generally described as unconfined to semi-confined. Although not explicitly stated in terms of soil compressibility values used in the CH2M Hill subsidence model, it appears that compressible clay values were used based upon data from Santa Clara Valley and Central Valley. Nonetheless, the CH2M Hill study assumes the Westside Basin in San Francisco is confined with compressible clay layers.

The study based the head changes on analytical calculations of drawdown from a well pumping at various discharge rates, with the maximum rate being 1,400 gpm. This calculation resulted in drawdowns (and head changes for subsidence calculations) in excess of 200 feet, and essentially assumes that historic lows are exceeded by greater than 200 feet. The transmissivity value used in the drawdown calculations (13,280 gpd/ft) is too low for the higher pumping rates (e.g., 1,000 and 1,400 gpm) used in the study, and results in excessive drawdown being used in the calculations. Typical pumping rates associated with a T value of 13,280 would be less than 800 gpm. Review of study results for a more realistic individual well pumping rate (relative to a T value of 13,280 gpd/ft) range from 0 to 0.6 feet for a 500 gpm well.

Clay properties used in the calculations were not explicitly stated in the CH2M Hill study; however, two figures provided in the study indicated that clays were assumed to have high compressibility as derived from unconsolidated Santa Clara Valley and Central Valley clay deposits. The semi-consolidated nature of the Westside Basin Merced Formation means its clay units are much less compressible than more recently deposited alluvial clays in Santa Clara Valley and the Central Valley. Furthermore, the CH2M Hill study assumes that all clay layers have the same head change, whereas the current study is based on the different head changes that occur at different depths in clay layers.

The current study that is the subject of this TM uses more realistic soil compressibility parameters and drawdown estimates (especially relative to preconsolidation stresses), as compared to the CH2M Hill study, and thus the results of the current study are more realistic and applicable. It should be further noted that all the areas addressed in the CH2M Hill Subsidence Study currently have or historically have had significant groundwater pumping that will require substantially lower water levels in the future to have any potential of subsidence. For example, the Lake Merced area has historically had significant pumping at nearby golf course irrigation wells that was largely replaced by recycled water in 2005. The Sunset region had an extensive well field in the 1930s and likely much lower water levels at that time compared to today. Irrigation wells have operated historically and continue presently in Golden Gate Park.

A calibrated transient numerical groundwater flow model of the Westside Groundwater Basin, developed by HydroFocus (2011) and applied by Kennedy/Jenks (2012), predicts the extent and magnitude of water level declines in five model layers under various scenarios of in-lieu recharge and groundwater extraction. The Technical Memo completed for Task 10-1 provides a discussion of the HydroFocus model and how it was applied for Task 10 studies (Kennedy/Jenks, 2012). The maximum model-predicted drawdowns in the South Westside Basin related to the GSR project occur at the end of the Design Drought. The maximum model predicted drawdowns in the North Westside Basin related to the SFGW project generally occur at the end of the model run (47 years), which also happens to generally coincide with the Design Drought sequence. The magnitude and extent of the predicted water level declines would theoretically control the extent of potential subsidence and are appropriate to use in the analysis, subject to the discussion provided below. These predicted water level fluctuations are provided in Appendix A – Groundwater Model Results.

Luhdorff and Scalmanini completed a study that documents the hydrogeologic setting of the Westside Basin (TM1: Hydrologic Setting of Westside Basin; Luhdorff and Scalmanini, 2010). The geologic setting of the Westside Basin has been characterized as containing semi-consolidated, unconfined to confined aquifers with variable percentages of interbedded fine-grained deposits depending on location in the basin. Several geologic cross-sections included in this study were utilized in evaluation of well locations selected for subsidence calculations.

Water level declines that would be created from the GSR project or SFGW project may have the potential to cause aquitard (i.e., clay layer) compaction, leading to ground subsidence. This study was conducted to evaluate the potential for ground subsidence related to the proposed GSR and SFGW projects, as well as other reasonable foreseeable future projects ("cumulative scenario").

SUBSIDENCE CONCEPTUAL MODEL

Theory and Cause of Subsidence Related to Fluid Withdrawal

Causes of subsidence and the mechanics of aquifer system responses to fluid withdrawals have been the subject of considerable research in California, largely due to the pioneering efforts of Dr. Joseph Poland. AEG Special Publication No. 8 (Borchers, 1998) provides a wealth of information on subsidence in California caused by groundwater withdrawal. The forces acting on a clay layer at depth include the weight/mass of the overlying sediments and water acting in a downward direction (total stress), balanced by the intergranular skeleton (effective stress) and pore pressures (pore fluid stress) acting in an upward direction (Galloway, et.al., 1999). As the upward forces must balance the downward forces, a decrease in the pore pressure increases the effective stress borne by the soil skeleton. In the case of unconsolidated and semi-consolidated clays, an increase in the effective stress may cause compaction of the clay layers and subsidence at the land surface. Coarse-grained layers would tend to experience some compaction as well, but generally at one to two orders of magnitude less than clay layers. Furthermore, the slight compaction of coarse-grained layers is often elastic and can be reversed when pumping stops or is decreased.

As pore pressures are reduced in a sequence of interbedded aquifers and aquitards due to pumping, compaction of the sequence can only occur as rapidly as excess pore pressures dissipate or reach equilibrium. In aquitard deposits (clay and silt beds) such as those that exist in the Westside Groundwater Basin, the time required for pore pressures to reach equilibrium (i.e., maximum consolidation) can be a slow process requiring several months or even years. Our analysis assumes that the drawdown condition is maintained long enough for residual excess pore pressures to fully dissipate (i.e., steady-state conditions) resulting in the maximum consolidation of the aquitards.

Aquitard values of specific storage (elastic and inelastic) and/or properties of compressibility are required to calculate the theoretical compaction of fine-grained deposits. Knowledge of such values is limited and often imprecise, and hence so are predictions of ultimate aquitard consolidation. Site-specific laboratory test results were not available for this study. We assumed typical soil compressibility values and estimates of the stress history of the Merced Formation, as discussed in other sections of this TM.

Unconsolidated confined aquifers (and aquitards) even at great depth are sensitive to changes in effective stress; small stress changes may cause permanent, widespread compaction. Semi-consolidated aquifers and aquitards (such as exist in the Westside groundwater basin) are generally less susceptible to subsidence due to greater pre-existing consolidation of the sediments. Nonetheless some potential for subsidence may exist for semi-consolidated aquifers/aquitards depending on the magnitude of the changes in hydraulic head (pore pressures) and soil properties.

Groundwater level declines, such as predicted in the numerical model, are an estimate of effective stress changes that would occur in the aquifer system. Aquifer/aquitard compaction may be either recoverable (elastic) or irrecoverable (inelastic) based on the degree of effective stress change and the characteristics of the deposits (compressibility, stress history). During the first cycle of groundwater withdrawal, much of the pumped water comes from the unrecoverable compaction of the aquifer system. In the study area, substantial historical groundwater extractions have occurred by such entities as the San Francisco Water Department in the Sunset area of San Francisco (in the 1930s), San Francisco Zoo, Golden Gate Park, Daly City, Cal-Water Service in the South San Francisco area, the City of San Bruno, various golf courses, and the Colma cemeteries. In cases where well field yields and transient drawdowns were relatively large, such "first cycle of pumped water" may already have occurred, with resultant subsidence. During subsequent cycles of water level declines or to the extent the proposed SFPUC groundwater withdrawals result in water level declines greater than the historical range, the aquifer system preconsolidation stresses again would be exceeded, resulting in renewed potential for layer compaction and land subsidence.

Conceptual Analysis Evaluation

It should be noted that historic subsidence in the Westside Groundwater Basin study area has not occurred (or at least it has not been documented) as it has further south in the area from Redwood City to San Jose. The fact that extensive historic groundwater extraction has resulted in associated declines in groundwater levels, but without any apparent substantial subsidence, suggests that the semi-consolidated Merced Formation sediments have limited compressibility. Therefore, based on a conceptual understanding of the mechanisms required for land subsidence and the apparent lack of historic subsidence in the study area, the potential for future subsidence even with additional lowering of groundwater levels below historic lows is likely limited due to low compressibility of semi-consolidated Merced Formation sediments.

DATA COLLECTION AND REVIEW

Geologic/Hydrogeologic Setting and Selection of Representative Well Locations

The hydrogeologic investigations of the study area conducted by Luhdorff & Scalmanini (2010), Kennedy/Jenks (2009 and 2010), and others provide detailed information on the geologic setting and aquifer/aquitard variability and characteristics. Luhdorff & Scalmanini has prepared geologic cross-sections for the Westside Groundwater Basin extending from Golden Gate Park in the north to Millbrae in the south. Clay and sandy clay layers are present at variable depths in most areas of the basin. Two prominent clay layers present in the Lake Merced area include the X clay and the W clay. The W clay is regionally continuous and extends south through Daly City and Colma. Other clay layers are present in South San Francisco and San Bruno as well.

North Westside Basin

The north-south geologic cross-section prepared by Luhdorff & Scalmanini (2010) extends from Golden Gate Park in the north through Millbrae on the south. This cross-section shows the general location of the predominant clay layers in the groundwater basin. In particular, prominent clay layers identified around the Lake Merced and Sunset areas in San Francisco include the -100 foot clay, X Clay, and W Clay. The two representative locations selected from among the SFGW Project wells were the South Sunset Playground (South Sunset well) and Lake Merced Pump Station (LMPS well). Wells from these two areas were selected over a site in Golden Gate Park due to the greater prevalence of clay layers in the Sunset/Lake Merced areas compared to Golden Gate Park.

The LMPS well has substantial clay layers present both above (333 to 390 feet below ground surface (bgs)) and below (454 to 542 feet bgs) the proposed pumped zone. The more confined nature of the LMPS well might be expected to result in greater head declines, and its location in the southern portion of San Francisco would experience some contribution to head losses from the GSR project in addition to the primary groundwater level declines related to the SFGW project. Therefore, the LMPS location may be considered more susceptible to project-related subsidence effects than a location in Golden Gate Park.

The South Sunset Well has a shallow sandy clay layer within the upper 100 feet, several intermediate depth clay layers between 290 and 390 feet, and a deeper clay layer below 500 feet. In addition, review of the geophysical and geologic logs show that clayey sand (and sand with clay) layers present at 320-335, 340-348, 430-447, 450-476, and 514-570 feet bgs display similar characteristics to layers logged as clay and sandy clay on the geologic log. Therefore, clayey sand and sand with clay layers in the geologic log were treated as clay layers for the subsidence analysis. The South Sunset well is located between the LMPS well on the south and West Sunset well to the north, both of which should add some mutual interference drawdown to the South Sunset well location (which would tend to result in a more conservative analysis).

South Westside Basin

Geologic cross-sections and well data were reviewed for the South Westside Groundwater Basin to select two representative locations for analysis of subsidence. In general, the selected locations should emphasize basin areas with greater thicknesses of clay layers and anticipated lower groundwater elevations since these characteristics create more potential for subsidence. Review of geologic cross-sections indicates clay layers are less prevalent in the north (Daly City area) and more prevalent in the central to southern portion of the basin (in the Colma area and further south). The Colma and South San Francisco areas were selected over the San Bruno/Millbrae areas further south due to the concentration of proposed GSR wells in the Colma and South San Francisco areas compared to the San Bruno/Millbrae areas.

In terms of the South Westside Groundwater Basin, the shallow (-100 foot clay) and intermediate (X Clay) layers appear to pinch out in the Daly City area – thus reducing the potential for subsidence. An intermediate depth clay layer occurs again in the Colma area along with continuing presence of the deeper W Clay. Due to the comprehensive nature of boring data collected as part of the GSR monitoring well installation program (geologists log, geophysical log, drillers log) (Kennedy/Jenks, 2009 and 2010), the SFPUC nested well data were reviewed to select representative locations.

Consistent with the overall geology shown in the Luhdorff & Scalmanini cross-sections, CUP- 6, 7, and 10A (locations shown in Figure 2) in the Daly City area generally had greater prevalence of sand over clay compared to areas further south and were not selected. CUP-18, 19, 22A, and 23 (locations shown in Figure 2) were reviewed as a group, and CUP-19 was selected to be representative the Colma area. CUP-19 appears to have clay layers that are representative of other well locations in the Colma area. The proposed CUP-19 well site has both intermediate depth and deep clay layers. In addition, CUP-19 provides a location that should be representative of the extensive Take pumping proposed for this area. The combination of clay layers and the amount of proposed pumping in this area make CUP-19 a good selection for calculation of subsidence potential.

Further to the south along the Luhdorff & Scalmanini axial cross-section in South San Francisco it is apparent that the deeper W clay pinches out; however, a much thicker intermediate clay layer is present along with a shallow clay layer. A thinner deep clay layer also is present at the location of proposed CUP 41-4. Therefore, the fourth site selected for subsidence analysis was the proposed CUP-41-4 well location based on the presence of the clay layers discussed above. In addition, CUP-41-4 was selected over a location in San Bruno due to the greater influence of Take-year pumping on groundwater levels around CUP-41-4 compared to sites in the City of San Bruno. The location/thickness of clay layers and the potential head declines are thought to create more potential for project-related subsidence effects at CUP-41-4 than in San Bruno. Although the San Bruno area has a lot of clay at shallow to intermediate depths, there is less groundwater extraction from proposed GSR wells in the area and thus head changes would be smaller than other areas.

Survey Data

Sources of information on the location of survey monuments and the history of vertical measurements of elevation changes within the study area are limited. Review of the National Geodetic Survey's (NGS) database (http://www.ngs.noaa.gov/cgi-bin/datasheet.prl) indicates that benchmark data are available for 57 stations within the study area. For the most part, all survey data from these benchmarks represent one or two time measurements performed by the National Geodetic Survey (NGS) and others. Printouts of the station reports that are typical of the limited history for vertical elevation measurements in the area are provided in Appendix B - NGS Survey Data.

Although the available survey data do not allow for any conclusions to be reached with regard to historic subsidence due to lack of enough measurements at any given location, the data are provided in this study for documentation purposes and possible use as baseline data to compare against future measurements.

Review of Historic Groundwater Level Data

Historical water level data for the study area were obtained from SFPUC and Partner Agencies. As previously discussed, compaction of interbedded aquifer and aquitard materials can occur only as rapidly as pore pressures in the materials are reduced as a result of lower water levels. Past groundwater extractions in the area have resulted in sustained lowered water levels (and increase in effective stress) in the various aquifers. Land subsidence due to such groundwater withdrawal in the area would be expected to have already occurred if the area were susceptible; however, no historic subsidence has been documented.

Groundwater level elevation hydrographs for 11 wells (which are limited to South Westside Basin locations due to the general lack of groundwater level data prior to the 1980s in the North Westside Basin) of various depths with the longest historic records in the study area are provided in Appendix C – Groundwater Hydrographs. Table 1 provides a summary of historical groundwater level data from the wells included in Appendix C and several additional wells from the North and South Westside Basins with shorter periods of record. A few wells in the South Westside Basin have water level records extending back to the 1940s or 50s and provide a limited representation of static water level variations since that time. A map showing the distribution of wells in the study area for which hydrographs have been prepared is included in Figure 2. The data contained in Appendix C and summarized in Table 1 indicate the hydrograph records are quite variable in terms of the number and temporal span of water level measurements. To the extent that data on the perforated interval is available, it is provided in Table 1.

Although essentially no wells in the North Westside Basin have water level data extending back to the 1940s to 1970s, it is known that an extensive well field was developed in the Sunset District from 1930 to 1935. The historic Sunset Well Field consisted of 21 wells along 43rd and 44th Avenue between Kirkham and Taraval streets. The average depth of the wells was 250 feet and the total pumping capacity of the wells was about 6.5 MGD (4,500 gpm). The wells were operated from October 1930 to October 1935. Documented monthly pumping totals from May to October 1931 showing water production of 165 to 186 million gallons per month from the Sunset Well Field (3,850 to 4,200 gpm) (San Francisco Water Department, 1931).

Given that historic groundwater pumping from this well field is estimated at up to 6.5 MGD, it is likely that substantial groundwater level decline occurred that would have caused a proportional amount of subsidence in the area (again assuming clays have substantial compressibility), if the area were susceptible. However, given the lack of documentation of historic lows during the 1930-35 time period, this era of groundwater extraction in San Francisco was not used as a basis for historic lows in the Sunset District. Golden Gate Park also has an extensive history of pumping groundwater for irrigation, but little water level data prior to the late 1980s are available; thus, possible pre-1980s groundwater levels lower than recent historic lows are discounted.

Groundwater level data for wells located in San Francisco are generally limited to the time period from the late 1980s until present, and most available historic data are from the last 10 years. Thus, it is unlikely that historic lows have been captured in the available measured groundwater level data. Nonetheless, groundwater level data that are available from selected wells extending from Golden Gate Park in the north to Lake Merced in the south of San Francisco were reviewed with respect to lowest recorded groundwater levels. The shallow aquifer at the North and South Windmill wells has historic low groundwater level measurements ranging from -6 to 7 feet NGVD 29, whereas the deeper zone has a historic low of -26 feet NGVD 29. Since the time it was installed in 1993, the lowest measured historical groundwater level at the West Sunset Well was 14 feet NGVD 29 in 1995. Groundwater level data collected in the last few years show low groundwater levels of -9 feet NGVD 29 and -99 feet NGVD 29 in the primary and deep aquifers at Lake Merced Pump Station nested monitoring wells. The deepest recorded level at the Olympic Club Well 1 was -47 feet NGVD 29.

Inspection of the hydrographs with long histories of water level data extending back to the 1950's or earlier in the South Westside Basin (DC-1, DC-8, DC-9, SS1-14, SS1-17, SS1-18) generally shows water levels declining until the early 1970s. Since the early 1970s water levels have tended to fluctuate around an average level without much of a net rise or decline until the In-Lieu Recharge Demonstration Study was implemented in 2002. Since 2002 the hydrographs with water level data available from 2000 to 2009 (DC-1, DC-8, SS1-02, and SB-12) show substantial rises in water level (although SB-12 subsequently declined back to its 2002 level after normal pumping resumed from 2005 to 2008). Based on these water level variations, subsidence due to historic groundwater extractions would be expected to have already occurred in proportion to historic lows to the extent that fine-grained aquitard layers may be present within the associated depth intervals and to the extent that semi-consolidated clays of the Merced Formation are compressible.

Screen interval data are only available for one of the three Daly City wells (DC-1, DC-8, and DC-9) with long-term water level records. However, the range of historic lows (-142 to -154 feet NGVD 29) and available screen data indicate these water levels are likely most representative of the shallow to intermediate depth aquifer zones.

Cal-Water wells SS1-14 through SS1-18 are more representative of shallow aquifer zones based on screen intervals, and SS1-21 is representative primarily of the deeper more confined aquifer that has been the primary municipal aquifer pumped in recent years. Historic lows in the Cal-Water area represented by shallow-screened wells ranged from -150 to -169 feet NGVD 29, whereas the one well screened in the deeper confined aquifer has a historic low of -229 feet NGVD 29. Of the two other Cal-Water wells (SS1-19 and SS1-20) with more intermediate depth upper screen zones, SS1-19 has a historic low more consistent with shallow screened wells whereas SS1-20 has a historic low more consistent with the deeper screened well. Overall, historic low water levels in Cal-Water wells are generally consistent with the observations from nested monitoring wells in the basin that show lower groundwater elevations with increasing screen depths. This vertical downward gradient is likely a function of most existing municipal and irrigation wells being screened in and pumping from the deeper aquifers (i.e., screened at depths below 350 feet).

Historical groundwater level data for San Bruno wells prior to 1996 are very limited and no data are available during the last major drought period (1988-1992). Thus, it is difficult to evaluate representative historic lows from measured data in the San Bruno area. Measured historic lows in recent years ranged from -144 to -213 feet NGVD 29 and occurred in the 1999-2001 timeframe.

With respect to groundwater level declines indicated by historic data, WRIME has evaluated the issue of historical subsidence as part of their work in preparing a draft groundwater management plan for the South Westside Basin (WRIME, October 2011). WRIME states the following with respect to subsidence south of the study area, "There are no available records of historical subsidence in the South Westside Basin. Significant studies have been performed to the south in the Santa Clara Valley, due to extensive subsidence in that area. Those studies show that the extent of subsidence in the area is focused on Santa Clara, where land subsided 8 ft from 1934 to 1967. To the north, subsidence is more limited, with less than 1 foot of subsidence in the Palo Alto area and approximately an inch of subsidence in the Redwood City area (Poland and Ireland, 1988). Studies have not been performed farther north, likely due to a lack of evidence of active subsidence." WRIME further states the following with regard to the study area itself, "There has been no evidence of historical land subsidence, even though water levels have declined significantly from pre-development levels. Land subsidence is most rapid immediately after the initial dewatering of sediments. Thus, land subsidence is not anticipated from sediments that have been historically dewatered. Should water levels decline in the future, it is unlikely that subsidence would occur as these materials are similar to those historically dewatered and would likely exhibit the same limited compressibility."

GROUNDWATER MODEL RESULTS

Introduction

The numerical groundwater flow model for the Westside Basin was developed over a period of time from 2003 to 2011 by HydroFocus and Gus Yates, who were retained by Daly City (2007, 2009, and 2011). It was a collaborative effort sponsored by Daly City with review by the SFPUC, Cal Water, San Bruno and their respective consultants. The Project EIR efforts being conducted by the SFPUC for the SFGW and GSR projects have utilized the calibrated Westside Basin Groundwater-Flow Model as one of the tools for evaluating potential project effects. Kennedy/Jenks Consultants have been the lead in applying the existing model to future project scenarios for the respective EIR efforts (with review and input by Luhdorff & Scalmanini and Fugro). The following sections describe groundwater levels derived from model results of the HydroFocus (2011) calibration run (historic results), and groundwater levels predicted by the model over various future project scenario runs performed by Kennedy/Jenks (2012).

Historic Results from 1959-2009

The historic model results over the 1959 to 2009 time frame are used to supplement the available record of actual historic groundwater level measurements described in the previous section of this report. Historic low groundwater levels from model results for selected wells are provided in Tables 2 through 5. The limited availability of historic groundwater level measurements and screening over multiple layers of many wells with historic data make the use of model-estimated historic groundwater levels very important in the subsidence analysis. The model results provide a predicted continuous (monthly) record of groundwater levels by discrete depth zones (model layers). Review of the historic model results allows for selection of a more representative historic low due to the continuous record (limited historic measurements likely missed the historic low from a timing standpoint) and output of groundwater levels by model layer (many wells with historic measurements are screened across multiple aquifers or model layers). Because the historic model-predicted groundwater levels are calibrated to the limited available measured data, model-based historic lows should provide a reasonable approximation of actual historic lows. At a minimum the groundwater model provides the best means available to derive historic lows.

Model-derived historic lows for the area around CUP-19 for two well locations (Cypress 2 and Holy Cross 2) for the various model layers ranged from -53 to -61 feet NGVD 29 in model layer 1 to -170 to -179 in model layer 5. The proposed municipal well at CUP-19 is planned to be screened in model layers 3, 4, and 5, where model historic lows at nearby wells range from -111 to -179 feet NGVD 29 (Table 2). The measured historic low for Holy Cross 1 was -162 feet NGVD 29 in June 2000 based upon a limited number of measurements since 1986.

Model-derived historic lows for the area around CUP-41-4 for three well locations (California Golf Club 6, SSF-02, and SB-12) for the various model layers ranged from -71 to -84 feet NGVD 29 in model layer 1 to -226 feet NGVD 29 in model layer 4. The proposed municipal well at CUP-41-4 is planned to be screened in model layers 4 and 5, where model historic lows from nearby wells range from -171 to -226 feet NGVD 29 (Table 3). Measured historic lows for SSF-02 and SB-12 are -131 and -210 feet NGVD 29, respectively.

Model-derived historic lows for the area around Lake Merced Pump Station Well at three nearby well locations (Olympic, Harding Park, Higuera) for the various model layers ranged from -8 to 13 feet NGVD 29 in model layer 1 to -70 to -146 feet NGVD 29 in model layer 5. The Lake Merced Pump Station Well is screened in model layer 4, where model historic lows at nearby wells range from -22 to -68 feet NGVD 29 (Table 4). Measured historic lows for the Olympic Club Well 1 and Olympic Club MW range from -56 to -5 feet NGVD 29.

Model-derived historic lows for the area around the South Sunset Well at three well locations (LMMW-4, LMMW-5, and Santiago) for the various model layers ranged from 9 to 26 feet NGVD 29 in Model Layer 1 to -31 feet NGVD 29 in Model Layer 5. The South Sunset Well is screened in model layers 1 through 4, where model historic lows at three surrounding well locations range from -11 to 26 feet NGVD 29 (Table 5). The West Sunset Well had a measured historic low of 14 feet NGVD 29 based on limited data.

Future Results from 2009-2056

The model scenarios run to simulate future project conditions were used to assess the likelihood of historic low groundwater levels being exceeded and, if exceeded, the approximate magnitude and duration by which historic lows may be exceeded. The results of this analysis provide key input data to the subsidence calculations presented later in this report.

The future groundwater model scenarios are described in detail by Kennedy/Jenks (2012). The subsidence analysis evaluated scenarios 1, 2, 3a, 3b, and 4, which are described below. All scenarios are 47.25-year runs based in part on historical hydrology but also including a Design Drought. The Design Drought ends with the 1976-77 drought added onto the end of the 1987-92 drought, to simulate a 7.5-year drought. Scenario 1 includes existing pumping conditions and no proposed SFPUC projects, and begins with June 2009 basin groundwater levels.

Scenario 2 is based on implementation of the proposed GSR project. Scenarios 3a and 3b simulate implementation of the proposed SFGW project with total pumping of 3 MGD (3a) and 4 MGD (3b). Scenario 3a includes 3 MGD of SFGW project pumping via four wells located in central Golden Gate Park, the Sunset District, and at the Lake Merced Pump Station, while maintaining irrigation pumping at the western Golden Gate Park irrigation wells. Scenario 3b includes 4 MGD of SFGW project pumping from six wells in Golden Gate Park, the Sunset

District, and the Lake Merced Pump Station. Scenarios 3a and 3b start with June 2009 groundwater levels (consistent with scenario 1).

Scenario 4 represents a cumulative scenario and includes simulation of both the proposed GSR and SFGW projects together. In addition, scenario 4 includes other reasonably foreseeable future projects such as implementation of supplemental water to help maintain Lake Merced surface water levels, and expansion of the Holy Cross Cemetery with an associated increase in irrigation pumping.

CUP-19

The Cypress 2 Well in the groundwater model was used as the basis for historic lows in groundwater levels for comparison to future model-predicted groundwater levels at CUP-19. The results are tabulated in Table 2 (and Appendix D). Under the existing conditions model scenario (1), historic lows would be exceeded by 3 to 18 feet in model layers 1 through 3 and by 24 feet in model layer 5. Under model scenario 2, historic lows are estimated to be exceeded by 49 to 118 feet for model layers 1 through 4 and by 173 feet for model layer 5.

However, the best comparison to evaluate actual project effects is to compare model scenario 2 (and 4) to model scenario 1, which represents that incremental head drop caused by the project. Comparison of scenario 2 to 1 shows incremental head decreases of 31 to 125 feet for model layers 1 through 4 and 149 feet for model layer 5. Scenario 4 heads were 3 to 7 feet higher than heads for scenario 2, possibly related to slight differences between scenarios 2 and 4 with respect to locations of municipal (existing vs. replacement) well(s) along with the general lack of impact from scenario 3 at this location.

CUP-41-4

There were no adjacent wells to CUP-41-4 in the historical groundwater model run to use for assessment of model-predicted historical groundwater levels. Therefore, an average of three wells (CGC-6, SSSF-02, and SB-12) was used as a basis for comparison to future model-predicted groundwater levels at CUP-41-4. The results are tabulated in Table 3 (and Appendix D). Groundwater elevations under the existing conditions model run (model scenario 1) were higher than historic lows in model layers 1 through 3. Historic lows were exceeded by 10 to 23 feet in model layers 4 and 5. Under model scenario 2, historic lows were not exceeded in model layers 1 and 2, but were exceeded by 50 to 174 feet for model layers 3 through 5.

As stated above, actual project effects are best evaluated by comparing model scenario 2 (and 4) to model scenario 1, which represents the incremental head drop caused by the project. Comparison of scenario 2 to 1 shows incremental head decreases of 0 to 153 feet for model layers 1 through 4 and 151 feet for model layer 5. Scenario 4 shows negligible differences as compared to results of scenario 2 at CUP-41-4, likely due to the substantial distance between the proposed CUP-41-4 well and the proposed SFGW project wells.

Lake Merced Pump Station (LMPS) Well

There are three wells in close proximity to the LMPS Well in the historical groundwater model run that were used for assessment of model-predicted historical groundwater levels (Olympic, Harding Park, and Higuera). Higuera was used as the basis for comparison to future model-predicted groundwater levels at the LMPS Well due to its close proximity. The results are tabulated in Table 4 (and Appendix D). Under the existing conditions model run (1), historic lows would be exceeded by 3 to 4 feet in model layers 1 and 2, but not exceeded in layers 3 through 5. Under model scenario 2, historic lows are estimated to be exceeded by 4 to 10 feet for model layers 1 through 4 and by 58 feet for model layer 5. Under model scenarios 3a and 3b, historic lows are estimated to be exceeded by 18 to 57 feet in model layers 1 through 4 and by 5 feet in model layer 5.

Scenario 4 exceeds historic lows by 6 to 56 feet in model layers 1 through 5. Scenario 4 groundwater elevation lows were higher than scenario 3 lows for model layers 1 through 3. This is likely due to incorporation of supplemental water for Lake Merced in Scenario 4, which was not included in Scenario 3 (a and b).

Again, actual project effects are best evaluated by comparing model scenario 2 (and 3a, 3b, 4) to model scenario 1, which represents the incremental head drop caused by the project. Comparison of scenario 2 to 1 shows incremental head decreases of 0 to 15 feet for model layers 1 through 4 and 63 feet for model layer 5. Comparison of scenario 3a/3b to 1 shows incremental head decreases of 10 to 21 feet for model layers 1, 2, 3, and 5, and a 62 feet incremental head decrease for model layer 4. Comparison of scenario 4 to 1 shows incremental head decreases of 2 to 16 feet for model layers 1 through 3 and 59 to 61 feet for model layers 4 and 5.

South Sunset Well

There are three wells surrounding the South Sunset Well in the historical groundwater model run that were used for assessment of model-predicted historical groundwater levels. The average of three wells (LMMW-4, LMMW-5, and Santiago) was used as a basis for comparison to future model-predicted groundwater levels at South Sunset Well. The results are tabulated in Table 5 (and Appendix D). Under the existing conditions model run (1), historic lows were exceeded only by 1 to 2 feet. Under model scenario 3a, historic lows are estimated to be exceeded by 22 to 33 feet for model layers 1 through 4 and by 7 feet for model layer 5. The amount by which historic lows would be exceeded under scenario 3b is 21 to 31 feet for model layers 1 through 4 and by 7 feet for layer 5. The amounts by which historic lows are exceeded under scenario 4 are slightly less than under scenarios 3a and 3b (16 to 26 feet for model layers 1 through 4 and 14 feet in model layer 5); the likely reason for this prediction is that Lake Merced supplemental water was included in scenario 4 but not in scenarios 3a/3b (see Kennedy/Jenks, 2012).

Actual project effects are best evaluated by comparing model scenario 3a (and 3b, 4) to model scenario 1, which represents that incremental head drop caused by the project. Comparison of scenario 3a to scenario 1 shows incremental head decreases of 21 to 32 feet for model layers 1 through 4 (6 feet for model layer 5). The amount by which scenario 1 lows would be exceeded under scenario 3b is 1 to 2 feet less than under scenario 3a. Comparison of scenario 4 to scenario 1 shows incremental head decreases of 15 to 25 feet for model layers 1 through 4 and 13 feet for layer 5.

SUBSIDENCE CALCULATIONS

As discussed above, substantial land subsidence is not known to have occurred in the study area even with documented historic declines in groundwater levels over 200 feet below the ground surface. Nonetheless, based on the data analysis described above, it is apparent that withdrawals of groundwater under the two proposed projects being considered by the SFPUC has some potential to create land subsidence due to compaction of fine-grained deposits within and adjacent to the pumped aquifer. The groundwater model results predict relatively substantial drawdowns and exceedence of historic low groundwater levels in the pumped aquifer over a broad geographic area under the various proposed project scenarios.

Potential subsidence was estimated using an analytical equation for various proposed scenarios using representative subsurface profiles at the four well locations described above (CUP-19, CUP-41-4, LMPS, and South Sunset). The detailed assumptions and results of the subsidence calculations are presented in Appendix E. Initial groundwater levels were derived from historic model runs (with some validation by measured water levels) and from model scenario 1 (existing conditions with no proposed projects). Final groundwater levels at each of the four well locations were taken as the lowest predicted future groundwater elevations under each respective scenario. Subsidence estimates are provided for the area in the general vicinity of the pumping well analyzed in each of the four cases, but can be considered to be a representative but conservative estimate of broader areas around the wells.

The amount of subsidence was estimated using the following equation:

$$S = C_{ec} \times H \times \log(\sigma'_f/\sigma'_i)$$

Where:

- S = subsidence
- C_{ec} = compression ratio (or C_{er} – recompression ratio)
- H = layer thickness
- σ'_i = initial effective stress
- $\sigma'f$ = final effective stress

Site-specific field/lab compressibility data for the Merced Formation were not available. Therefore, the compression ratios used in the subsidence estimates were from areas of known land subsidence based on our interpretation of available geologic/geophysical logs, published information from the Santa Clara Valley subsidence studies (Poland, 1971; Poland and Ireland, 1988), and our engineering judgment. This approach is conservative because the compression ratios used are based on younger and less consolidated sediments with known land subsidence compared to Merced Formation sediments.

The USGS (Poland, 1971) reported virgin compression ratios of approximately 0.17 to 0.2 for clays in the Santa Clara Valley. For clay layers, we assumed a virgin compression ratio of 0.18 and a re-compression ratio of 0.03 (approximately one-sixth of the compression ratio). We also assigned compression ratios of 0.01 to 0.005 for sand layers in virgin compression and re-compression, respectively (Pestana and Whittle, 1995; Mitchell and Soga, 2005). It should be noted that Santa Clara Valley clay deposits are considered to be of a more recent age and unconsolidated nature compared to the older semi-consolidated Pliocene to Pleistocene age Merced Formation clay layers. Thus, it would be expected that Santa Clara Valley clay compression ratios should be greater than Merced Formation clay compression ratios (resulting in a more conservative analysis).

Many factors affect the compressibility of geologic materials. The primary factors are: the previous loading history caused by deposition and subsequent erosion of sediments, and fluctuations in groundwater levels. Secondary factors include: desiccation due to wetting and drying cycles, freezing and thawing cycles, chemical changes caused by precipitation and/or oxidation, and cementation or interparticle bonding. Due to the geologic age of the Plio-Pleistocene Merced Formation, we assumed that the soils would be in recompression under the proposed pumping conditions. This assumption is considered valid because the proposed pumping conditions would result in a maximum increase in effective stress of no more than 30%.

Pore pressures were computed for individual layers using initial groundwater levels (either historic low or scenario 1 low) and final groundwater levels (lowest groundwater elevation for the given project scenario) for each scenario. Our analysis assumes that the lowest groundwater elevation in each scenario is maintained long enough for residual excess pore pressures to fully dissipate (i.e., steady-state conditions) resulting in the maximum consolidation of the aquitards. Effective stresses were estimated by subtracting pore pressures from total stresses. The increase in effective stress due to the proposed groundwater pumping was generally less that 30 percent of the current effective stress condition.

Subsidence estimates are summarized in Table 6. Appendix E includes spreadsheets showing the assumptions and results of the calculations performed. Overall, the estimates of subsidence range from 1.5 to 3.5 inches when comparing to historical low groundwater elevations, depending on the location and scenario. The subsidence estimates for the project scenarios compared to scenario 1 ranged from 1.0 to 3.5 inches. The settlement estimates include compression of both aquitard (clay) and aquifer (sand). Permanent (inelastic) subsidence (assumed to be equal to estimated compaction of clay layers) would likely be on the order of two-thirds the estimates presented Table 6. Thus, based on the parameters and assumptions used for this analysis, the estimated potential permanent subsidence attributable to the proposed project(s) is less than 3 inches.

In the South Westside Basin, subsidence estimates are about 3 inches compared to historical lows for the two locations evaluated (CUP-19 and CUP-41-4). In terms of potential project impacts (i.e., comparison to Scenario 1), the estimated subsidence at CUP-41-4 is about 3.5 inches compared to about 2.9 inches at CUP-19. The fact that subsidence estimated at CUP-41-4 is slightly greater compared to Scenario 1 than compared to historical lows is likely related to model predictions of rising groundwater levels in the future (scenario 1) in some model layers at this location. Also, the similar to slightly greater overall subsidence estimates at CUP-41-4 compared to CUP-19 despite a lower GSR pumping rate at CUP-41-4 (220 gpm vs. 400 gpm) are likely related to a greater total thickness of clay at the CUP-41-4 location. This slight difference in potential project impacts also occurs despite the greater concentration of GSR project wells in the Colma vicinity (around CUP-19) as compared to the South San Francisco/San Bruno area (around CUP-41-4). In general, it is expected that calculation of potential subsidence based upon groundwater levels at GSR well locations will result in equal or greater amounts of predicted subsidence as compared to locations in between GSR well locations due to cones of depressions that typically occur around pumping wells.

In the North Westside Basin, subsidence estimates for scenarios 3a, 3b, and 4 range from about 1.7 to 3.4 inches compared to historical lows (and 1.5 inches for scenario 2 at LMPS). The subsidence estimates at the Lake Merced Pump Station Well are slightly greater than for the South Sunset Well for a given scenario due to overall greater groundwater level fluctuations at the LMPS Well. The greater groundwater level fluctuations at the LMPS Well may be attributable in part to the more confined nature of the primary production zone at this location, and possibly its closer proximity to the GSR project (relative to scenario 4). In terms of potential project impacts (i.e., comparison to Scenario 1), the estimated subsidence at South Sunset Well (1.5 to 1.9 inches) is similar to but slightly less than the range estimated for LMPS Well (2.8 to 3.0 inches) for scenarios 3a, 3b, and 4. In general, it is expected that calculation of potential subsidence based upon groundwater levels at SFGW project well locations will result in equal or greater amounts of predicted subsidence as compared to locations in between SFGW project well locations due to cones of depressions that typically occur around pumping wells.

DISCUSSION OF RESULTS

It is important to recognize that there can be a substantial time lag between the drop in head (effective stress) created by pumping and the slow drainage and compaction of the aquitard deposits. The proposed (and modeled) scenario for the SFPUC GSR project assumes that GSR pumping during the major (design) drought period extends for a relatively long duration (7.5 years of continuous pumping). The subsidence estimates are based on the lowest model-estimated future groundwater elevations at any time during this drought period (or at any other time during the model simulation), and from that perspective, represent conservative estimates in that lag times are not considered. The calculations described above assume steady-state conditions (i.e., their ultimate compaction if excess pore pressures fully dissipate). Because of the transient nature of the proposed groundwater conditions (especially for the GSR project), the calculations of potential subsidence that have been presented are likely overestimated with respect to (lack of) time lag considerations.

The greatest uncertainty in the subsidence analysis is likely the clay properties with respect to compression ratios. As noted above, the subsidence estimates are based on assumed compression ratios from review of geologic/geophysical logs, literature review, and engineering judgment. From the standpoint of the sensitivity of this assumption, it is worth noting that even if clay compression ratios were assumed to fall on the virgin compression curve as opposed to the recompression curve (resulting in an approximately 6 times greater compression ratio for clay layers), estimated total subsidence would not exceed 16 inches compared to the estimated range of 1.0 to 3.5 inches given above. The subsidence estimates described in this study of less than 4 inches are consistent with the lack of historic subsidence despite past groundwater pumping and dewatering of sediments.

Several other factors that may make the subsidence calculations conservative include:

1. Use of groundwater levels from proposed project production wells,
2. Selection of representative well locations intended to emphasize areas of greater presence of clay and/or greater drawdowns, and

3. Not factoring in probable lower historical groundwater levels in the North Westside Basin related to operation of the Sunset well field in the 1930s and extensive historic pumping for Golden Gate Park irrigation, due to lack of available historic groundwater level data for these areas and time periods.

In terms of use of production well water levels, the typical pattern of cones of depression around pumping wells would be expected to result in greater drawdowns at these locations compared to locations in between production wells. Thus, estimated subsidence would be expected to be somewhat less than presented in this TM at locations in between proposed production wells. As described in this TM, hydrogeologic cross-sections, boring logs, and geophysical logs were reviewed in conjunction with overall distribution of proposed project wells to select four representative well locations for subsidence calculations. It is anticipated that this methodology for well selection would tend to emphasize locations with equal or greater potential for subsidence compared to other proposed well locations. Historical documents and data indicate that substantial groundwater pumping (on the order of 5 MGD) occurred at a well field in the Sunset District from 1930 to 1935; thus, it is likely that historic low groundwater levels in this area were lower than those used in the current study. If historic groundwater elevations were lower in the 1930s the amount of potential subsidence calculated in this study would be lower. Similarly, historic groundwater pumping in Golden Gate Park likely generated lower historic lows than were captured in the available historic groundwater level data records used in the current study.

With respect to Item 1 above regarding the use of groundwater levels at proposed production wells, these estimated subsidence results are still expected to be generally representative (while being somewhat greater as described above) of areas in between the selected wells in both the North and South Westside Basins. The reason for this is that these in-between areas will experience overlapping drawdowns (similar to mutual interference) from multiple wells such that there will be some amount of regional groundwater level decline related to the proposed project(s).

SUMMARY AND CONCLUSIONS

The proposed GSR and SFGW projects have a potential to cause subsidence if a sufficient thickness of compressible clay layers is present and pore pressures of those clay layers are decreased below historic low groundwater elevations. Given data and/or assumptions about soil properties and changes in groundwater levels caused by the proposed project(s), the estimated amount of subsidence due to the proposed project(s) can be calculated. This study included:

1. Review of available data on the geologic setting with regard to subsidence potential, and selection of four representative well locations;
2. Evaluation and assignment of soil compressibility properties for Merced Formation clay and sand layers;
3. Review of historic measured groundwater level data to obtain historic low groundwater elevations;

4. Review of Westside Basin Groundwater-Flow Model historic and future model scenario results to obtain estimates of historic low and anticipated future groundwater elevations both with and without the proposed SFPUC projects; and
5. Application of an analytical equation to calculate the amount of subsidence that is estimated to occur under various scenarios related to the proposed SFPUC projects.

Based upon review of the South Westside Basin geologic setting and locations of proposed pumping wells for the GSR project, the two locations selected for subsidence calculations were CUP-19 (to be representative of the Colma area) and CUP-41-4 (to be representative of the South San Francisco area). Based upon review of the North Westside Basin geologic setting and locations of proposed pumping wells for the SFGW project, the two locations selected for subsidence calculations were the South Sunset Well (to be representative of the Sunset District) and LMPS Well (to be representative of the Lake Merced area). These two well locations were selected over a Golden Gate Park location due largely to the presence of more clay layers at the South Sunset and LMPS well locations. Permanent (inelastic) subsidence (assumed to be equal to estimated compaction of clay layers) would likely be on the order of two-thirds the estimates presented Table 6. Thus, based on the parameters and assumptions used for this analysis, the estimated potential permanent subsidence attributable to the proposed project(s) is less than 3 inches.The total subsidence (compaction of clay and sand layers) estimate for the proposed project(s) is less than 4 inches.

Site-specific soil compressibility data were not available for this study. Based upon review of literature for the Santa Clara Valley and Central Valley, soil compressibility data from Santa Clara Valley were used to estimate clay compressibility values for the Merced Formation. Other literature sources were used to estimate sand layer compressibility values. Due to the fact that the Merced Formation is older than Santa Clara Valley sediments responsible for subsidence in that area and due to the more semi-consolidated nature of Merced Formation sediments (compared to the younger more unconsolidated Santa Clara Valley sediments), assignment of clay compressibility values from Santa Clara Valley soil data should be more conservative (i.e., tend to result in higher estimates of subsidence). The clay layer compressibility ratios were 0.18 for virgin compression and 0.03 for recompression, whereas sand layer compressibility ratios were 0.01 for virgin compression and 0.005 for recompression. Given the geologic age of the Merced Formation (Plio-Pleistocene) and the potential magnitude of increase in effective stress, it was assumed that clay layers would be in recompression.

The number of wells with a good record of historic groundwater levels is very limited. Essentially no wells in the North Westside Basin have groundwater level records extending back prior to the late 1980s. In the South Westside Basin, a few wells in Daly City and South San Francisco had historic groundwater levels extending back to the 1950s or earlier. In general, groundwater levels in the South Westside Basin declined over time from the 1940s/1950s through the 1970s due to increased groundwater pumping for municipal and irrigation purposes. Beginning in the 1970s the Partner Agencies (Daly City, Cal Water, San Bruno) were able to obtain increased amounts of surface water from the SFPUC so that their groundwater pumping could be somewhat reduced and stabilized. The increased use of surface water slowed the rate of groundwater level decline and generally helped stabilize groundwater levels from the 1970s through about 2002. Implementation of the In-Lieu Recharge Demonstration Study beginning in 2002 has led to general increases in groundwater levels in the South Westside Basin.

Due to the sparse measured historic groundwater level data, the groundwater model results were used to help estimate both historic low groundwater elevations and anticipated future low groundwater elevations related to several potential scenarios for implementation of the GSR and SFGW projects. Comparisons (and subsidence calculations) were made between future model-predicted lows with the proposed project(s) and historic lows, and between future model-predicted lows with the proposed project(s) compared to future model-predicted lows without the proposed projects. The calculations performed for this study provided estimates of subsidence that are less than 4 inches for the various scenarios at the four well locations.

Finally, several factors should be noted that likely make the subsidence calculations presented in this TM conservative including: using the lowest predicted groundwater levels without regard to lag time to reach equilibrium in aquitards, use of a conservative consolidation factor, the use of groundwater levels from proposed project production wells, selection of representative well locations intended to emphasize areas of greater presence of clay and/or greater drawdowns, and not factoring in probable lower historical groundwater levels in the North Westside Basin related to operation of the Sunset well field in the 1930s and extensive historic pumping for Golden Gate Park irrigation, due to lack of available historic groundwater level data for these areas and time periods. Consideration of these factors would likely result in lower estimates of potential subsidence.

Attachments: Tables 1 through 6
Figures 1 and 2
Appendices A through E

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Appendices

Table 1. Summary of Historical Groundwater Level Data

Well I.D.	Screen Interval (feet, bgs) [1]	Period of Record	Measured Historic Low Date	Measured Historic Low GW Elevation (feet, NAVD88) [2]
N.Windmill (Windmill NE)		1987-1992	May 1988	7.6 NGVD [3]
Windmill NW		1987-1992; 2001-	May 1990	11.5 NGVD
S.Windmill (SWM-GS-S) (also known as S. Windmill MW-57)	30-50	1989-1993; 2001-2002; 2006-	July 2009	-3
S. Windmill (SWM-GS-M) (also known as S. Windmill MW-140)	118-138	1989-1993; 2001-2002; 2006-	June 2008	-19
S. Windmill (SWM-GS-D)	372-387	1989-1990; 2001-2002	Oct. 1989	-26 NGVD
W. Sunset Playground	150-330	1995-1996;2000-2009	1995	14 NGVD
LMPS-440	410-430	2005-2009	Sept. 2008	-6
LMPS-575	555-565	2004-2009	Sept. 2008	-96
LMMW-3D	180-200	2002-2009	June 2002	-33
Olympic MW	36-46	1990-1993	Sept. 1992	-2
Olympic Club 1		1959, 1971, 1988-1993	Jan. 1988	-53
San Francisco Golf Club No. 1		1951; 1990-1992	Sept. 1991	-36 NGVD
San Francisco Golf Club No. 2		1985; 1989-1990, 1993	May 1990	-74 NGVD
DC-1	190-370	1954-2009	August 1988	-151
DC-8	N/A; TD=479	1958-2009	April 1996	-139
DC-9	N/A, TD=476	1958-2003	July 1996	-150
Holy Cross - 1	368-458; 478-668	1986; 1989-1991; 1998-2001; 2010	June 2000	-162 NGVD
SS1-02	N/A; TD=249	1950-2009	September 1982	-131
SS1-14	69-560	1952-1997	July 1985	-147

Well I.D.	Screen Interval (feet, bgs) [1]	Period of Record	Measured Historic Low Date	Measured Historic Low GW Elevation (feet, NAVD88) [2]
SS1-15	128-535	1965-1997	October 1975	-166
SS1-17	150-460	1939-2003	October 1982 October 1987	-158
SS1-18	160-557	1942-2003	August 1980	-147
SS1-19	216-528	1954-2003	January 1963	-143
SS1-20	220-580	1973-2008	August 1977	-209
SS1-21	370-580	1977-1997	August 1990	-226
Linear Park MW-440	360-370; 420-430	2007-2009	July 2009	-175
Linear Park MW-520	500-510	2007-2009	July 2009	-180
SB-12	146-482	1971; 1996-2009	April 2001	-210
SB-13	185-500	1998-2005	November 2000	-210
SB-14	TD=434	1998-2005	December 2001	279 (DTW)
SB-15	300-500	1998-2005	December 1999	-141

NOTES:

1 – bgs below ground surface

2 – Groundwater elevations are referenced to North American Vertical Datum 1988 (NAVD88) unless otherwise indicated

3 – NGVD29 National Geodetic Vertical Datum 1929

4 – TD total depth

Table 2. CUP-19 Groundwater Level Data Analysis

Table 2a. Lowest Model-Predicted Groundwater Elevations (Feet, NGVD 29)

	Model Historic Lows			Scenario 1		Scenario 2		Scenario 4	
Model Layer	Cypress 2	Holy Cross 2	Historic Low Average	CUP-19	CUP-23	CUP-19	CUP-23	CUP-19	CUP-23
1	-61	-53	-57	-79	-51	-110	-63	-107	-62
2	-73	-63	-68	-87	-60	-122	-75	-118	-74
3	-112	-111	-112	-115	-113	-207	-190	-200	-189
4	-143	-156	-150	-136	-159	-261	-289	-255	-289
5	-170	-179	-175	-194	-190	-343	-317	-338	-318

Table 2b. Difference Between Model Scenario Lows and Model Historic Lows (Feet)

	Model Historic Lows			Scenario 1		Scenario 2		Scenario 4	
Model Layer	Cypress 2	Holy Cross 2	Average	CUP-19	CUP-23	CUP-19	CUP-23	CUP-19	CUP-23
1				-18	2	-49	-10	-46	-9
2				-14	3	-49	-12	-45	-11
3				-3	-2	-95	-79	-88	-78
4				7	-3	-118	-133	-112	-133
5				-24	-11	-173	-138	-168	-139

Table 2c. Difference Between Project Model Scenario Lows and Existing Conditions Model Scenario 1 Lows (Feet)

	Model Historic Lows			Scenario 1		Scenario 2		Scenario 4	
Model Layer	Cypress 2	Holy Cross 2	Average	CUP-19	CUP-23	CUP-19	CUP-23	CUP-19	CUP-23
1						-31	-12	-28	-11
2						-35	-15	-31	-14
3						-92	-77	-85	-76
4						-125	-130	-119	-130
5						-149	-127	-144	-128

Table 2d. Top and Bottom Elevations of Model Layers and Clay Layers and Thickness of Clay Layers in each Model Layer at CUP-19

	CUP-19			Clay Layers		Clay Thickness		
Model Layer	Top Elev	Bot Elev	Model Layer Thickness (Feet)	Top Elev	Bot Elev	Interval (Feet)	Layer Total (Feet)	Scenario 2 compared to historic lows
1	114	-162	276	-156		6	6	6 feet has pore pressure drop of 49 feet
2	-162	-231	69		-181	19	19	19 feet has pore pressure head drop of 49 feet
3	-231	-300	69			0	0	
4	-300	-474	174	-366	-396	30		
				-411	-421	10		
				-471		3	43	43 feet has pore pressure head drop of 116 feet
5	-474	-700	226		-481	7	7	7 feet has pore pressure head drop of 173 feet

Note: Top Elev and Bot Elev are Top Elevation and Bottom Elevation in Feet, NGVD.

Table 3. CUP-41-4 Groundwater Level Data Analysis

Table 3a. Lowest Model-Predicted Groundwater Elevations (Feet, NGVD 29)

	Model Historic Lows				Scenario 1		Scenario 2		Scenario 4	
Model Layer	CGC-6	SSF-02	SB-12	Historic Low Average	CUP 41-4	SB-12	CUP 41-4	SB-12	CUP 41-4	SB-12
1	-71	-84	-84	-80	-26	-9	-26	-9	-26	-9
2	-82	-110	-108	-100	-47	-27	-58	-27	-58	-27
3	-115	-127	-140	-127	-121	-118	-177	-157	-177	-157
4	-171	-185	-226	-194	-204	-260	-357	-350	-358	-350
5	-176	-189	NA	-183	-205	NA	-356	NA	-358	NA

Table 3b Difference Between Model Scenario Lows and Model Historic Lows (Feet)

	Model Historic Lows				Scenario 1		Scenario 2		Scenario 4	
Model Layer	CGC-6	SSF-02	SB-12	Average	CUP 41-4	SB-12	CUP 41-4	SB-12	CUP 41-4	SB-12
1					54	75	54	75	54	75
2					53	81	42	81	42	81
3					6	22	-50	-17	-50	-17
4					-10	-34	-163	-124	-164	-124
5					-23	NA	-174	NA	-176	NA

Table 3c. Difference Between Project Model Scenario Lows and Existing Conditions Model Scenario 1 Lows (Feet)

	Model Historic Lows				Scenario 1		Scenario 2		Scenario 4	
Model Layer	CGC-6	SSF-02	SB-12	Average	CUP 41-4	SB-12	CUP 41-4	SB-12	CUP 41-4	SB-12
1							0	0	0	0
2							-11	0	-11	0
3							-56	-39	-56	-39
4							-153	-90	-154	-90
5							-151	NA	-153	NA

Table 3d. Top and Bottom Elevations of Model Layers and Clay Layers and Thickness of Clay Layers in each Model Layer at CUP-41-4

	CUP 41-4			Clay Layers		Clay Thickness		
Model Layer	Top Elev	Bot Elev	Model Layer Thickness (Feet)	Top Elev	Bot Elev	Interval (Feet)	Layer Total (Feet)	Scenario 2 compared to Scenario 1
1	24	-164	188	24	7	17		
				-67	-73	6		
				-130	-134	4	27	27 feet has no change in pore pressure
2	-164	-232	68	-174	-176	2		
				-220		12	14	14 feet has pore pressure head decrease of 11 feet
3	-232	-300	68		-284	52		
				-295		5	57	57 feet has pore pressure head drop of 56 feet
4	-300	-460	160		-316	16		
				-364	-376	12		
				-446	-460	14	42	42 feet has pore pressure head drop of 153 feet
5	-460	-556	96			0	0	

Note: Top Elev and Bot Elev are Top Elevation and Bottom Elevation in Feet, NGVD.

Table 4. Lake Merced Pump Station Well Groundwater Level Data Analysis

Table 4a. Lowest Model-Predicted Groundwater Elevations (Feet, NGVD 29)

	Model Historic Lows				1	2	3a	3b	4
Model Layer	Olympic	Harding Park	Higuera	Historic Low Average	LMPS	LMPS	LMPS	LMPS	LMPS
1	-8	11	13	5	9	9	-5	-5	7
2	-17	10	10	1	7	6	-8	-8	4
3	-40	-7	-16	-21	-15	-25	-36	-35	-31
4	-68	-22	-35	-42	-30	-45	-92	-92	-91
5	-146	-70	-97	-104	-92	-155	-102	-102	-151

Table 4b. Difference Between Model Scenario Lows and Model Historic Lows (Feet)

	Model Historic Lows				1	2	3a	3b	4
Model Layer	Olympic	Harding Park	Higuera	Average	LMPS	LMPS	LMPS	LMPS	LMPS
1					-4	-4	-18	-18	-6
2					-3	-4	-18	-18	-6
3					1	-9	-20	-19	-15
4					5	-10	-57	-57	-56
5					5	-58	-5	-5	-54

Table 4c. Difference Between Project Model Scenario Lows and Existing Conditions Model Scenario 1 Lows (Feet)

	Model Historic Lows				1	2	3a	3b	4
Model Layer	Olympic	Harding Park	Higuera	Average	LMPS	LMPS	LMPS	LMPS	LMPS
1						0	-14	-14	-2
2						-1	-15	-15	-3
3						-10	-21	-20	-16
4						-15	-62	-62	-61
5						-63	-10	-10	-59

Table 4d. Top and Bottom Elevations of Model Layers and Clay Layers and Thickness of Clay Layers in each Model Layer at LMPS Well

	LMPS			Clay Layers		Clay Thickness		
Model Layer	Top Elev	Bot Elev	Model Layer Thickness (Feet)	Top Elev	Bot Elev	Interval (Feet)	Layer Total (Feet)	Scenario 4 compared to Scenario 1
1	43	-28	71			0	0	
2	-28	-150	122			0	0	
3	-150	-300	150	-290	-300	10	10	10 feet has pore pressure head drop of 10 feet
4	-300	-496	196	-300	-347	47		
				-411	-496	85	132	132 feet has pore pressure head drop of 49 feet
5	-496	-572	76	-496	-499	3	3	3 feet has pore pressure had drop of 47 feet

Note: Top Elev and Bot Elev are Topo Elevation and Bottom Elevation in Feet, NGVD.

Table 5. South Sunset Well Groundwater Level Data Analysis

Table 5a. Lowest Model-Predicted Groundwater Elevations (Feet, NGVD 29)

	Model Historic Lows				Scenario 1		Scenario 3a		Scenario 3b		Scenario 4	
Model Layer	LMMW-4S	LMMW-5S	Santiago-S	Historic Low Average	South Sunset	West Sunset	South Sunset	West Sunset	South Sunset	West Sunset	South Sunset	West Sunset
1	9	26	11	15	14	14	-7	-24	-6	-21	-1	-19
2	8	23	10	14	13	13	-19	-23	-17	-21	-12	-19
3	-1	6	2	2	0	4	-28	-16	-27	-15	-23	-12
4	-11	NA	-5	-8	-10	-2	-37	-14	-36	-14	-34	-12
5	-31	NA	-8	-20	-20	-5	-26	-12	-26	-12	-33	-13

Table 5b. Difference Between Model Scenario Lows and Model Historic Lows (Feet)

	Model Historic Lows				Scenario 1		Scenario 3a		Scenario 3b		Scenario 4	
Model Layer	LMMW-4S	LMMW-5S	Santiago-S	Average	South Sunset	West Sunset	South Sunset	West Sunset	South Sunset	West Sunset	South Sunset	West Sunset
1					-1	3	-22	-35	-21	-32	-16	-30
2					-1	3	-33	-33	-31	-31	-26	-29
3					-2	2	-30	-18	-29	-17	-25	-14
4					-2	3	-29	-9	-28	-9	-26	-7
5					-1	3	-7	-4	-7	-4	-14	-5

Table 5c. Difference Between Project Model Scenario Lows and Existing Conditions Model Scenario 1 Lows (Feet)

	Model Historic Lows				Scenario 1		Scenario 3a		Scenario 3b		Scenario 4	
Model Layer	LMMW-4S	LMMW-5S	Santiago-S	Average	South Sunset	West Sunset	South Sunset	West Sunset	South Sunset	West Sunset	South Sunset	West Sunset
1							-21	-38	-20	-35	-15	-33
2							-32	-36	-30	-34	-25	-32
3							-28	-20	-27	-19	-23	-16
4							-27	-12	-26	-12	-24	-10
5							-6	-7	-6	-7	-13	-8

Table 5d. Top and Bottom Elevations of Model Layers and Clay Layers and Thickness of Clay Layers in each Model Layer at South Sunset Well

	South Sunset			Clay Layers		Clay Thickness		
Model Layer	Top Elev	Bot Elev	Model Layer Thickness (Feet)	Top Elev	Bot Elev	Interval (Feet)	Layer Total (Feet)	Scenario 3a compared to historic lows
1	83	-152	235	41	9	32		6 feet dewatered
				-127	-129	2	34	2 feet has pore pressure head drop of 22 feet
2	-152	-226	74	-207	-217	10	10	10 feet has pore pressure head drop of 33 feet
3	-226	-300	74	-237	-252	15		
				-257	-265	8		
				-279	-287	8	31	31 feet has pore pressure head drop of 30 feet
4	-300	-454	154	-300	-304	4		
				-347	-393	46		
				-417	-454	37	87	87 feet has pore pressure head drop of 29 feet
5	-454	-463	9	-454	-487	33	33	33 feet has pore pressure head drop of 7 feet

Note: Top Elev and Bot Elev are Top Elevation and Bottom Elevation in Feet, NGVD.

Table 6. Summary of Subsidence Estimates

Well CUP-19	Subsidence (inches)		
Scenario	Sand Layers	Clay Layers	Total
2 to HL	1.54	1.55	3.09
4 to HL	1.48	1.47	2.95
2 to 1	1.43	1.46	2.89
4 to 1	1.36	1.38	2.74

Well CUP-41-4	Subsidence (inches)		
Scenario	Sand Layers	Clay Layers	Total
2 to HL	0.87	1.90	2.77
4 to HL	0.88	1.90	2.78
2 to 1	1.17	2.27	3.44
4 to 1	1.17	2.28	3.45

LMPS Well	Subsidence (inches)		
Scenario	Sand Layers	Clay Layers	Total
2 to HL	0.59	0.95	1.54
3a to HL	0.99	2.54	3.53
3b to HL	0.98	2.54	3.52
4 to HL	0.83	2.52	3.35
2 to 1	0.34	0.61	0.95
3a to 1	0.75	2.21	2.96
3b to 1	0.74	2.20	2.94
4 to 1	0.59	2.18	2.77

South Sunset Well	Subsidence (inches)		
Scenario	Sand Layers	Clay Layers	Total
3a to HL	0.76	1.23	1.99
3b to HL	0.73	1.19	1.92
4 to HL	0.60	1.07	1.67
3a to 1	0.72	1.15	1.87
3b to 1	0.69	1.10	1.79
4 to 1	0.56	0.99	1.55

Note: HL is Historical Low Groundwater Elevation

FIGURES

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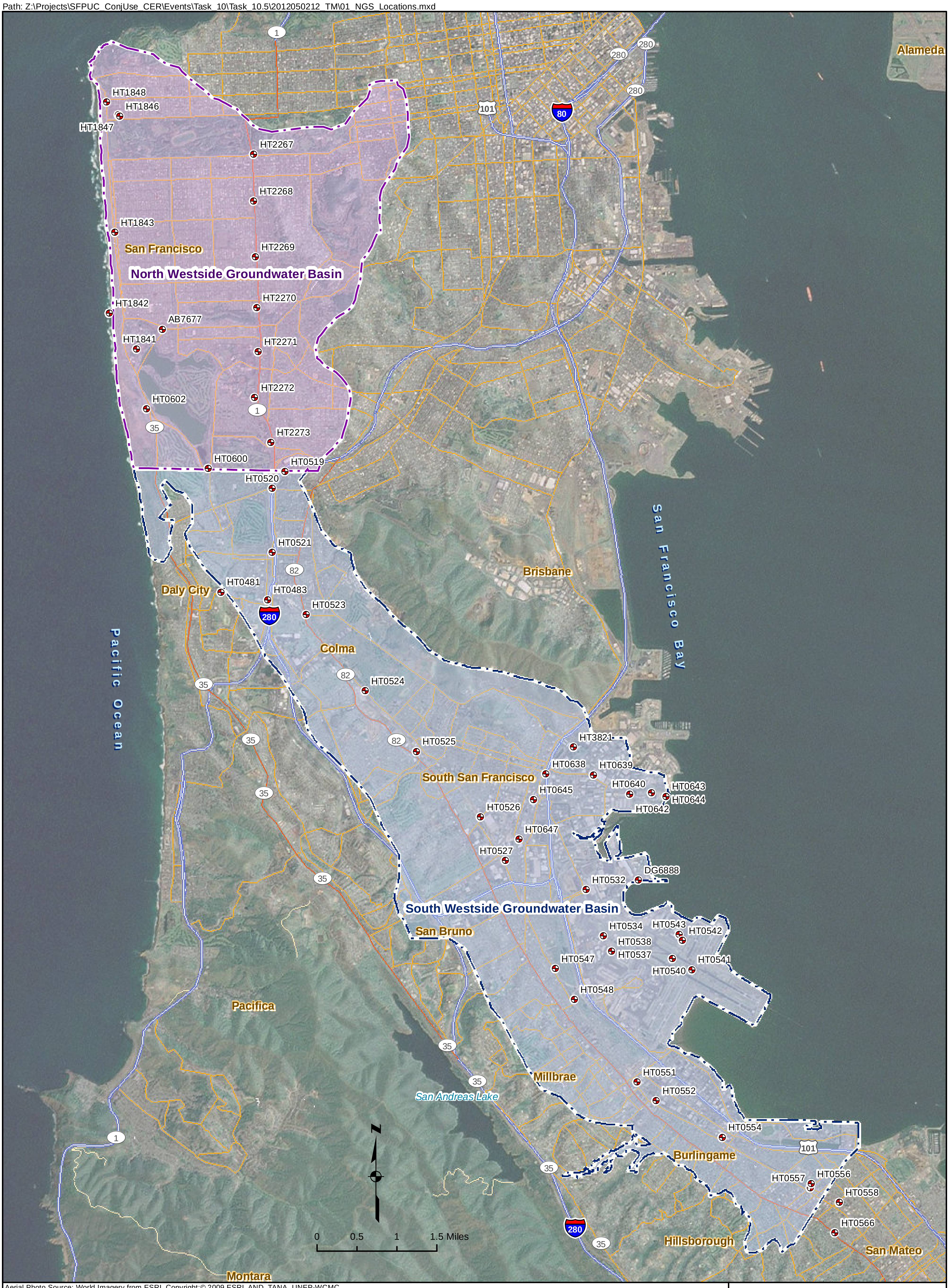

Aerial Photo Source: World Imagery from ESRI. Copyright:© 2009 ESRI, AND, TANA, UNEP-WCMC

Note:
See Appendix B for more information on the NGS monuments,

Legend

National Geodetic Survey Monument Locations (NAD83)

North Westside Groundwater Basin

South Westside Groundwater Basin

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
ENGINEERING MANAGEMENT BUREAU

STUDY AREA MAP AND NATIONAL GEODETIC SURVEY MONUMENT LOCATIONS

Kennedy/Jenks Consultants
303 Second Street, Suite 300 South
San Francisco, CA 94107

Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Figure
1

Date
May 2012

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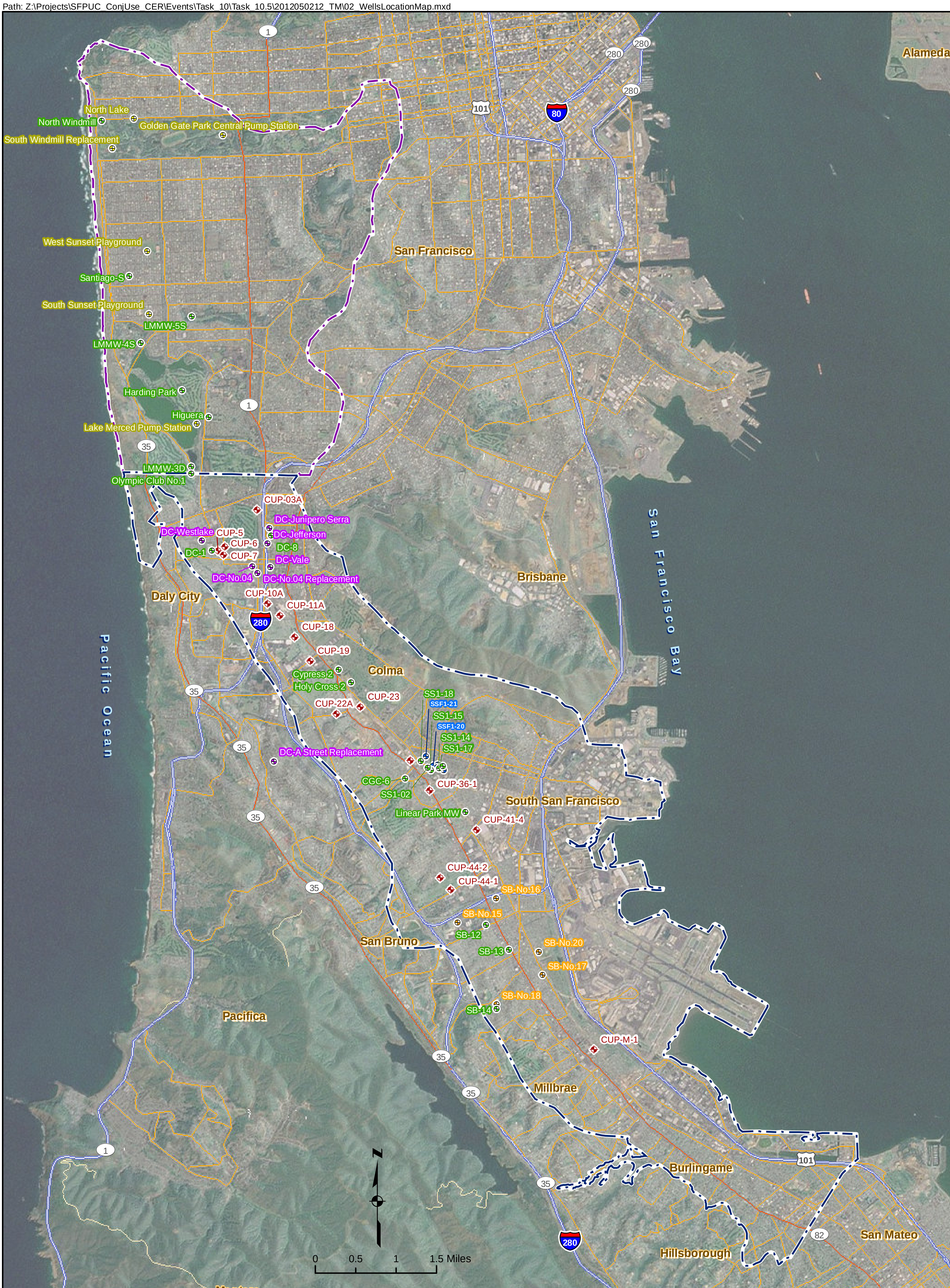


Aerial Photo Source: World Imagery from ESRI. Copyright:© 2009 ESRI, AND, TANA, UNEP-WCMC

Legend

- Selected Groundwater Model Wells
- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- Cal Water Municipal Wells
- Daly City Municipal Wells
- San Bruno Municipal Wells
- North Westside Groundwater Basin
- South Westside Groundwater Basin

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
ENGINEERING MANAGEMENT BUREAU

WELL LOCATION MAP

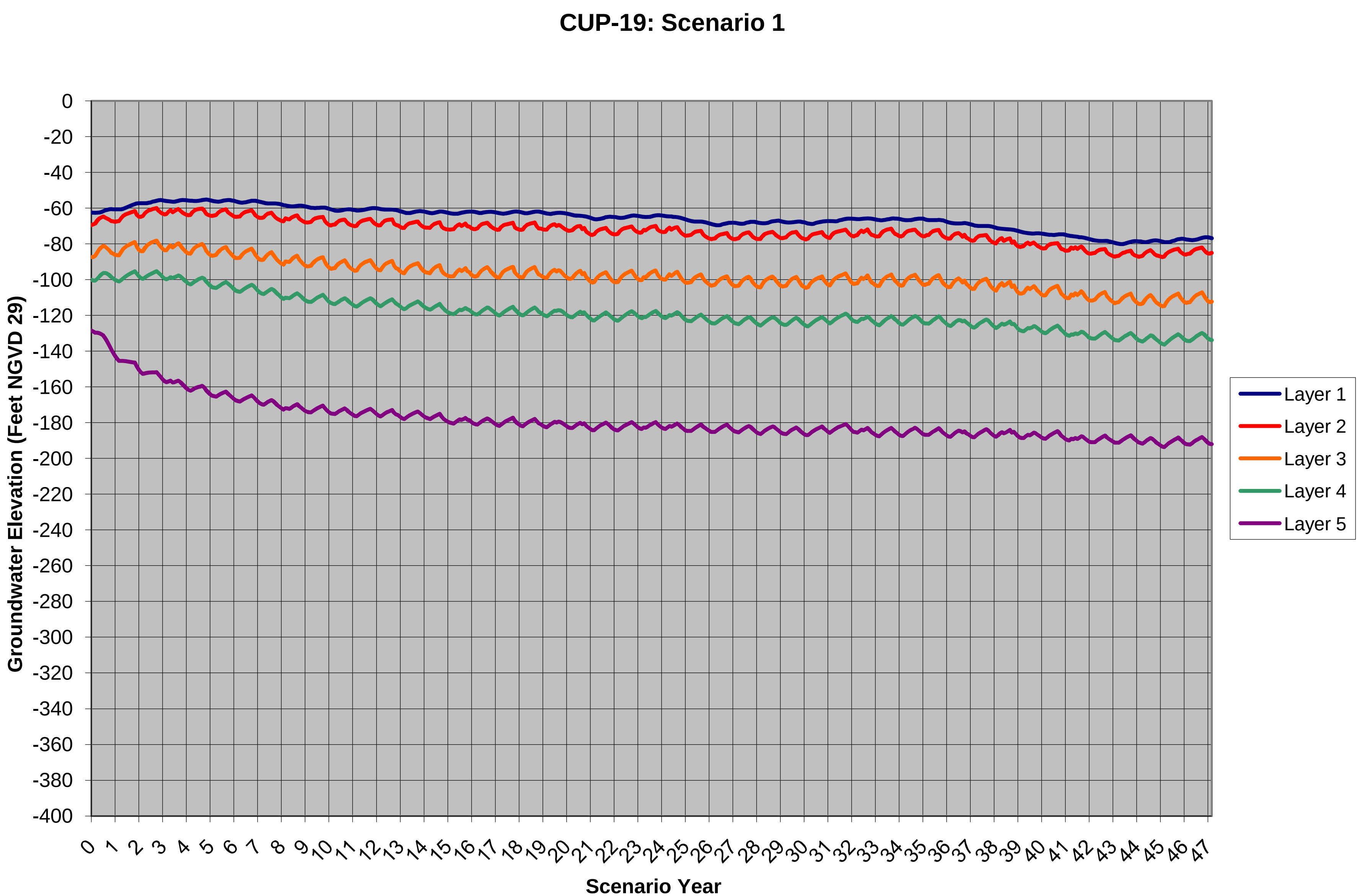
Kennedy/Jenks Consultants
303 Second Street, Suite 300 South
San Francisco, CA 94107

Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Figure **2**

Date May 2012

APPENDIX A



CUP-19: Scenario 1
Groundwater Elevation (Feet NGVD 29)
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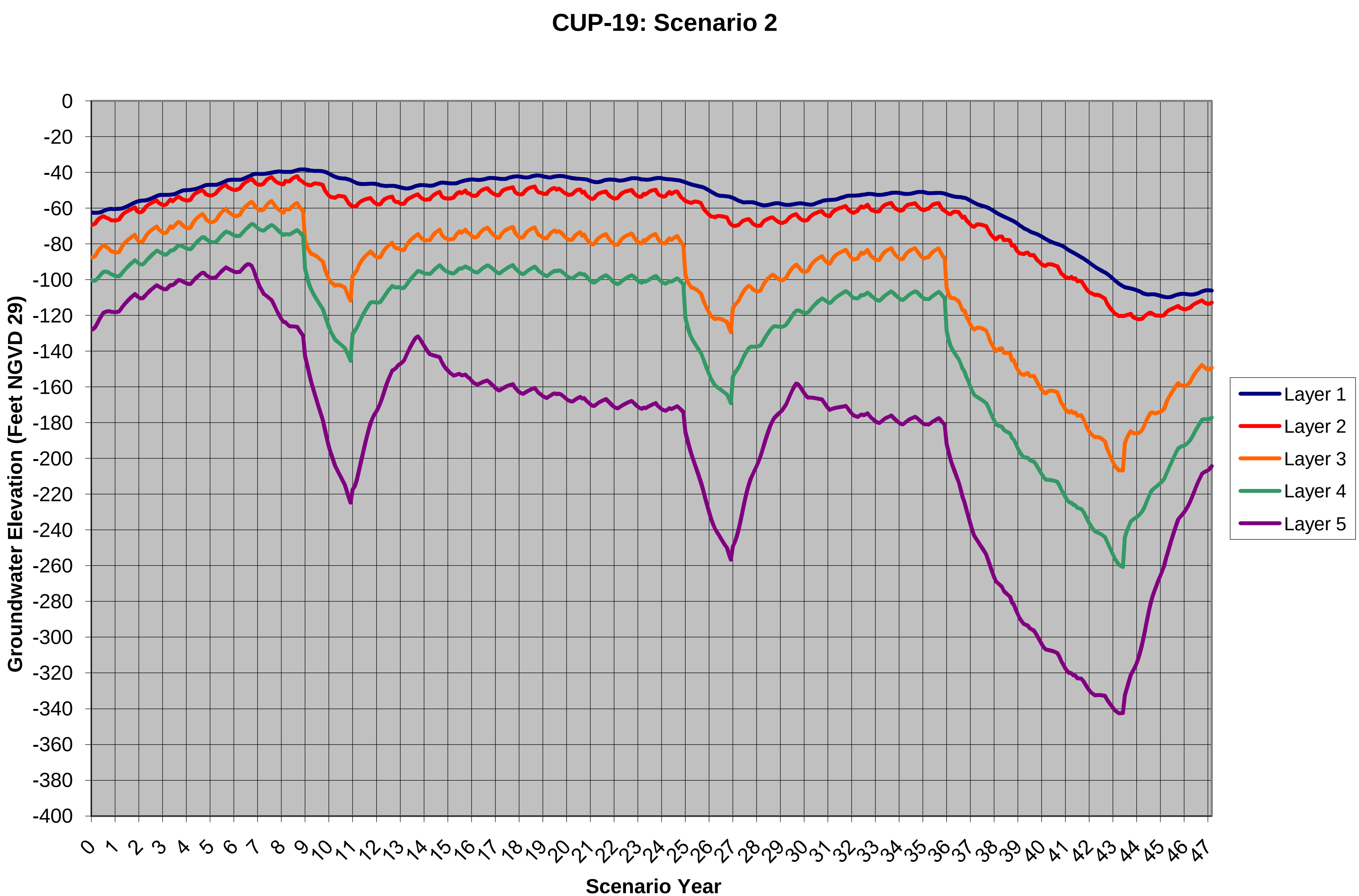
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300
-320
-340
-360
-380
-400
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



CUP-19: Scenario 2
Groundwater Elevation (Feet NGVD 29)
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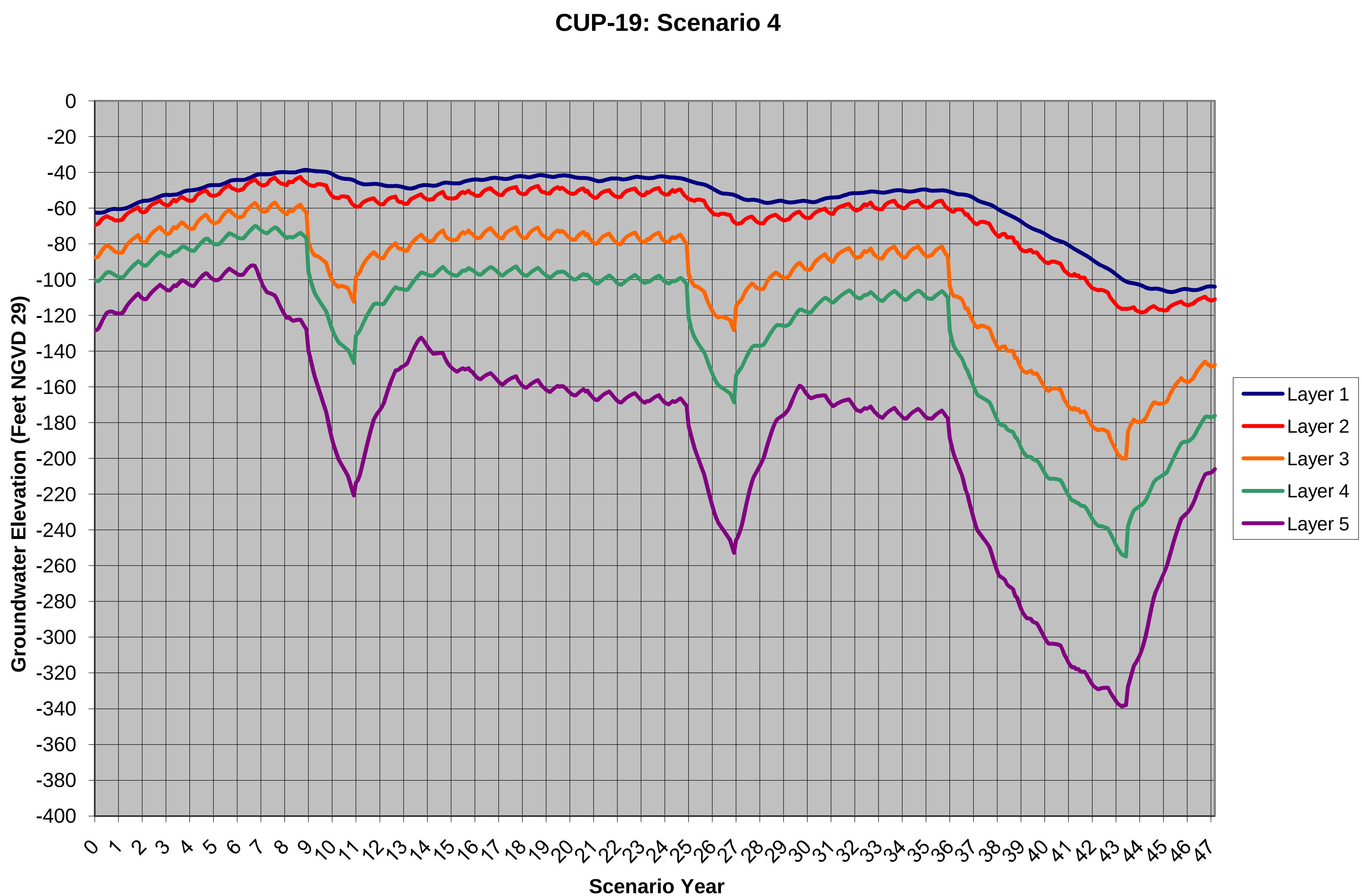
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300
-320
-340
-360
-380
-400
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



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Groundwater Elevation (Feet NGVD 29)
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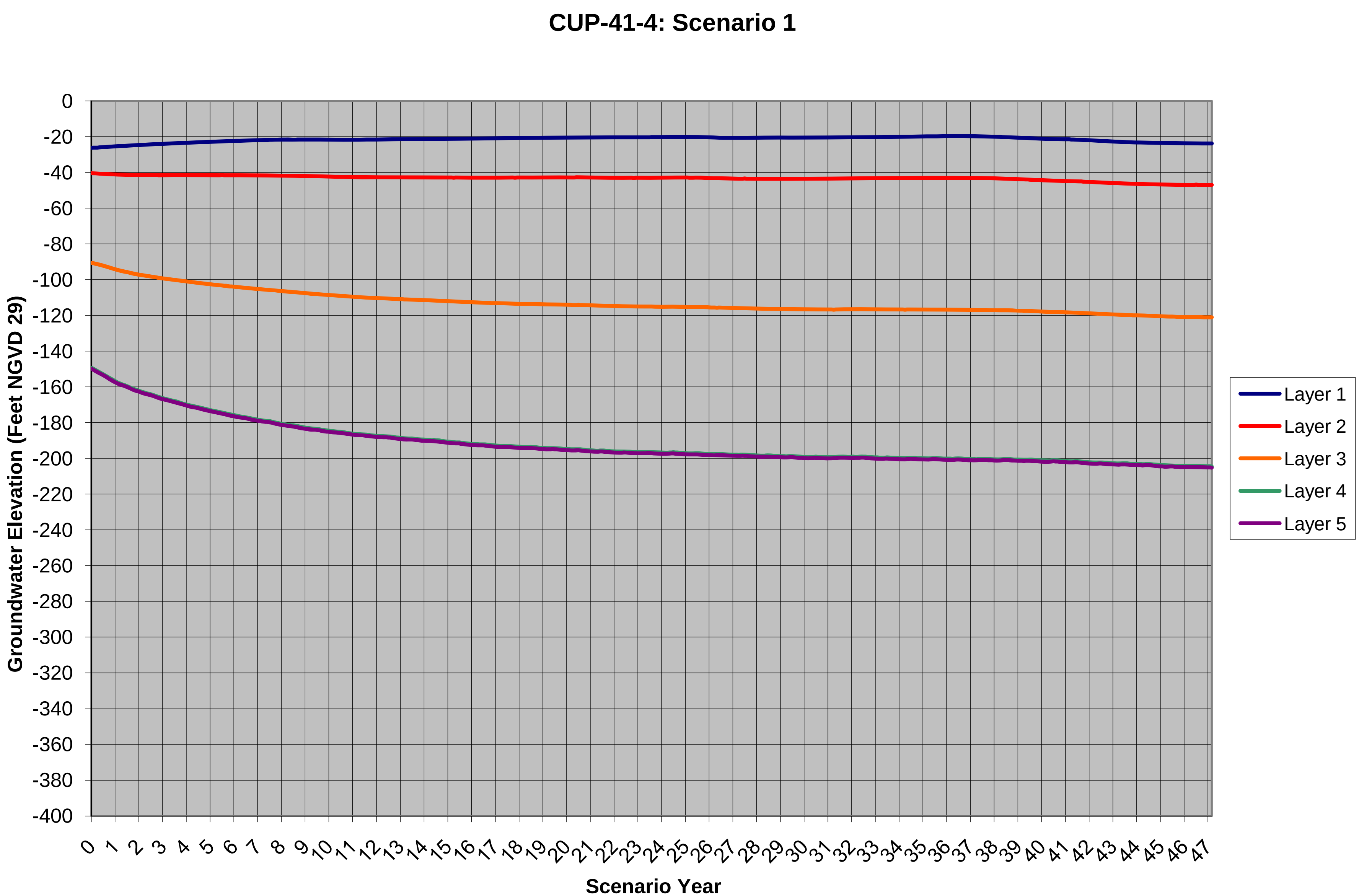
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300
-320
-340
-360
-380
-400
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5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Groundwater Elevation (Feet NGVD 29)
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-60
-80
-100
-120
-140
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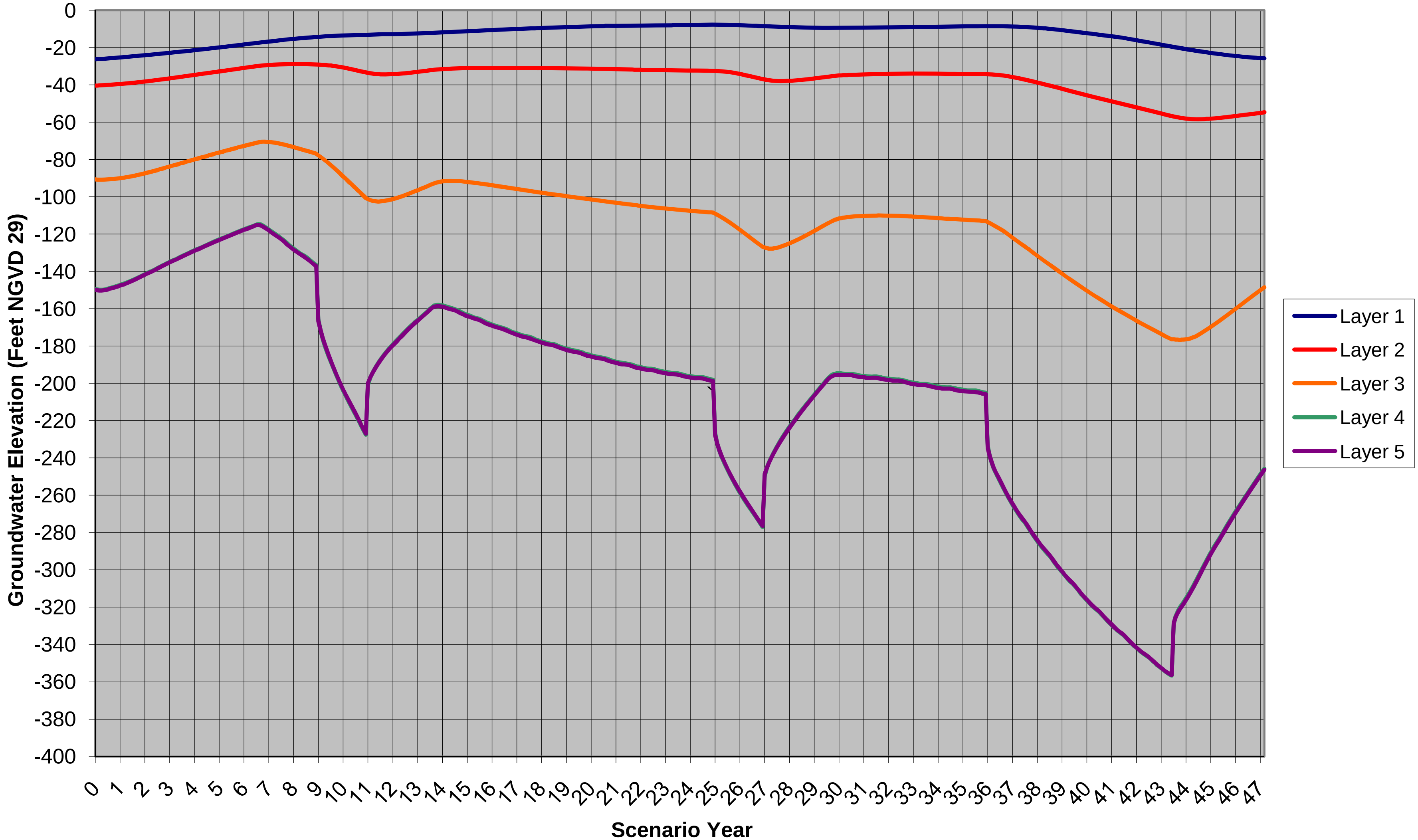
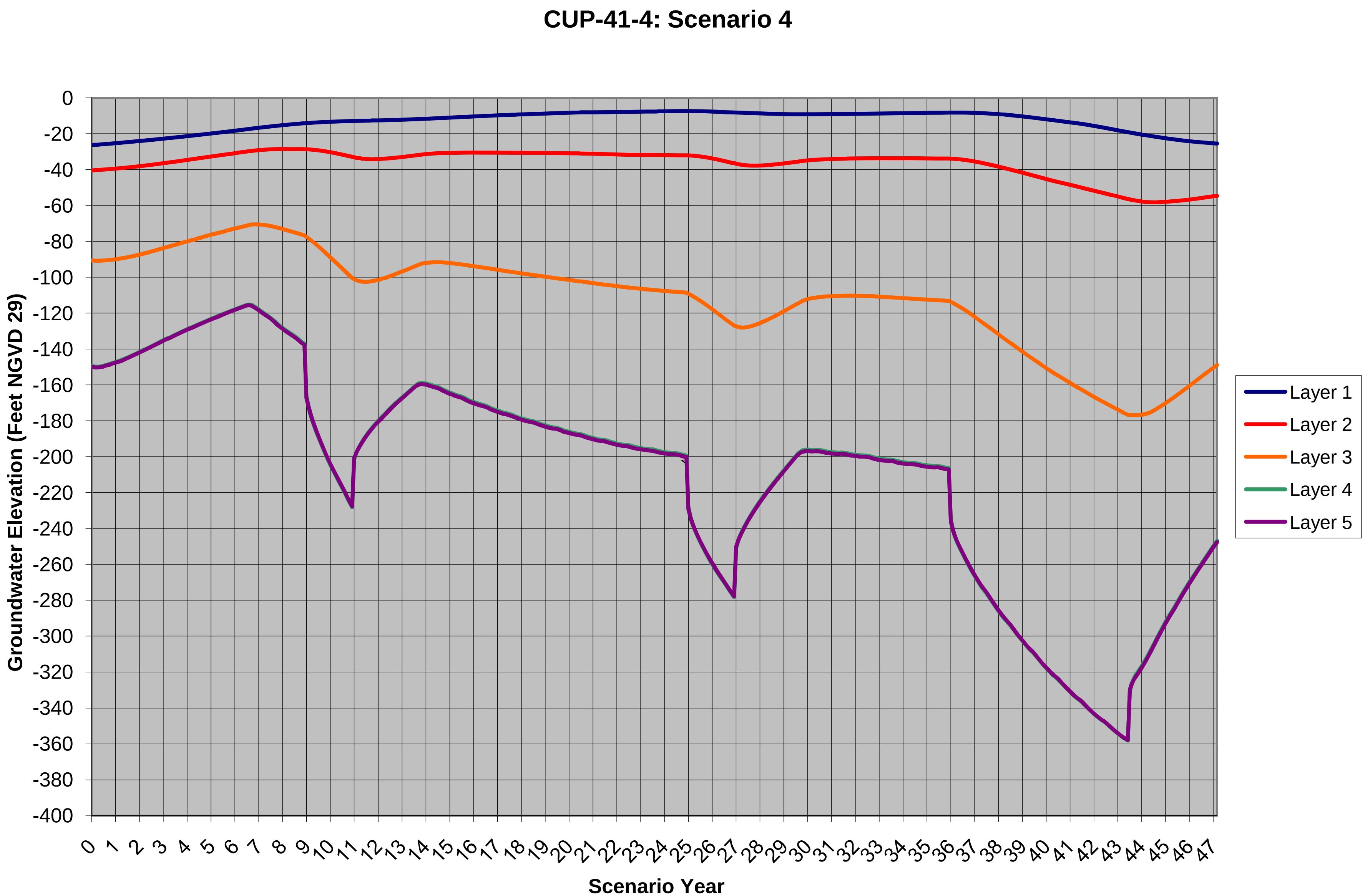
-180
-200
-220
-240
-260
-280
-300
-320
-340
-360
-380
-400
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

CUP-41-4: Scenario 2

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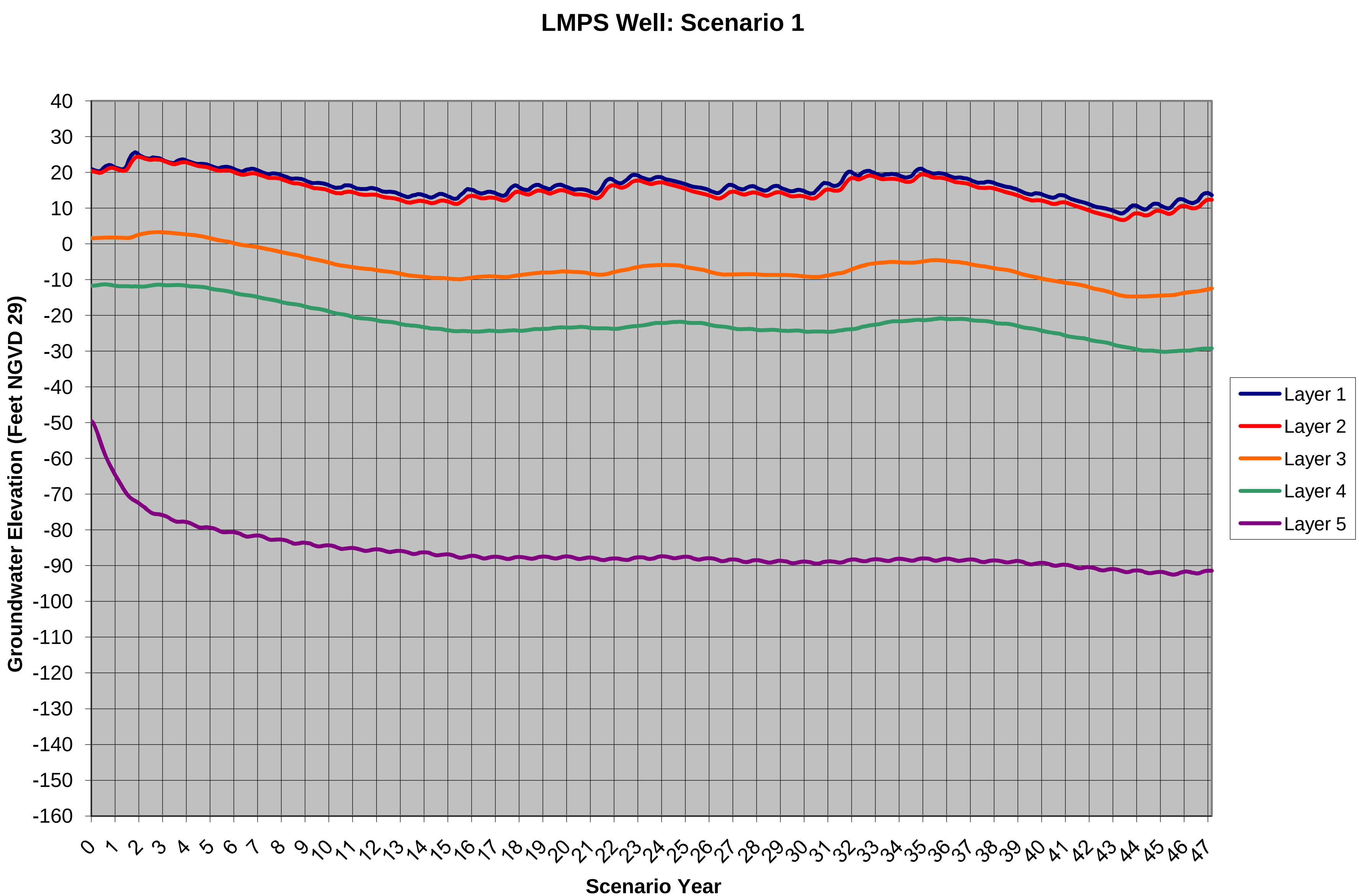
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300
-320
-340
-360
-380
-400
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


LMPS Well: Scenario 1
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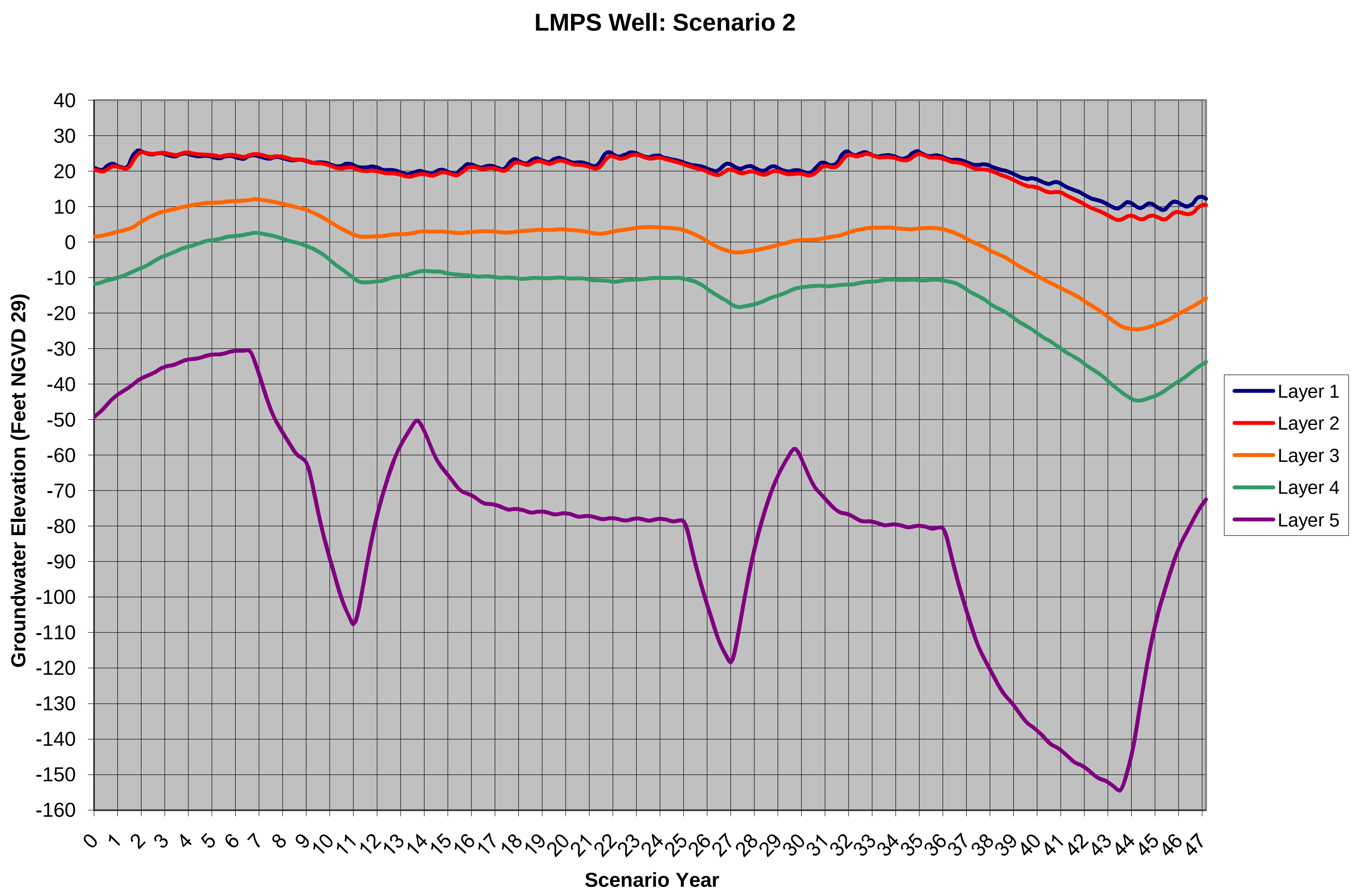
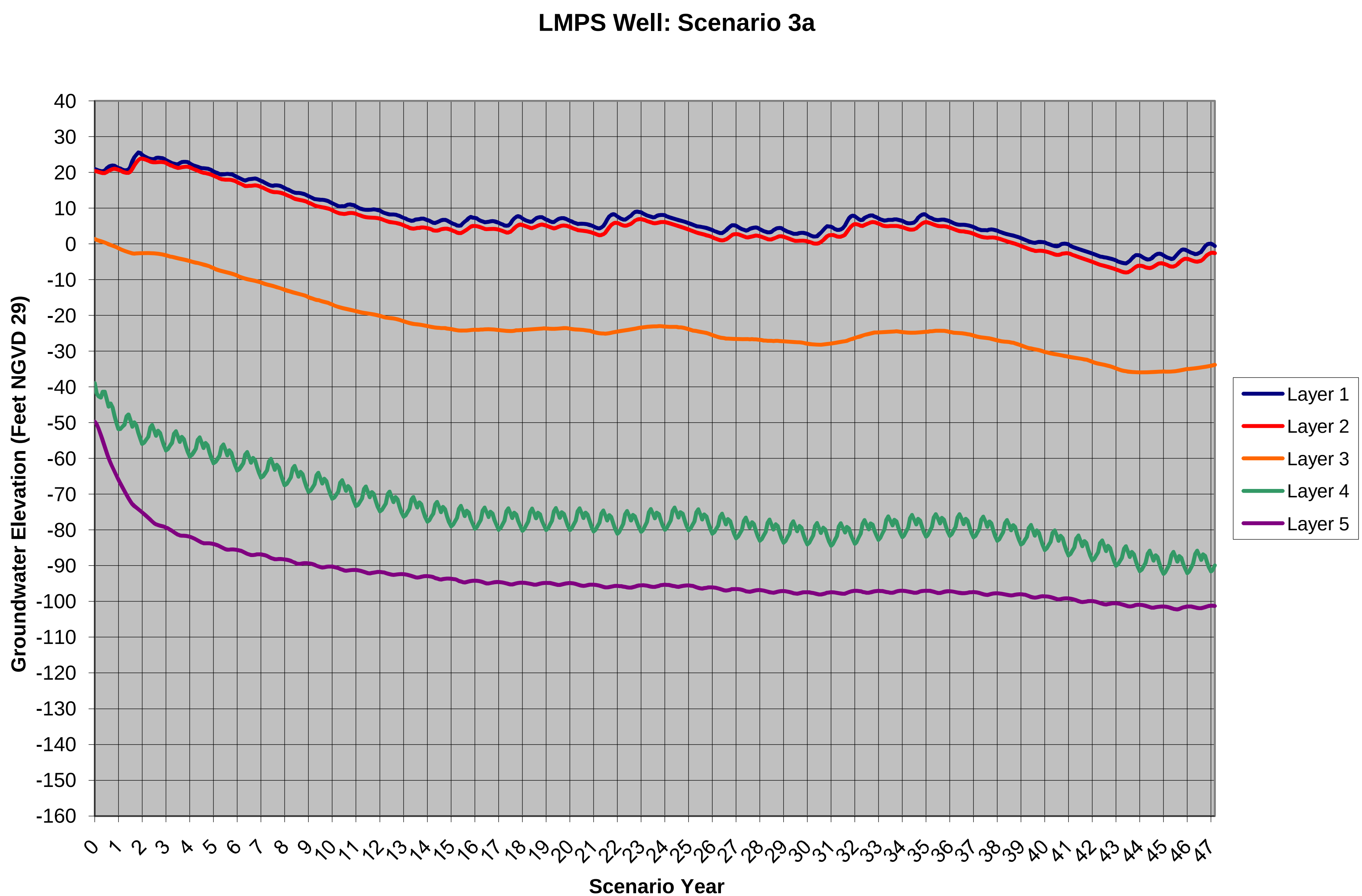
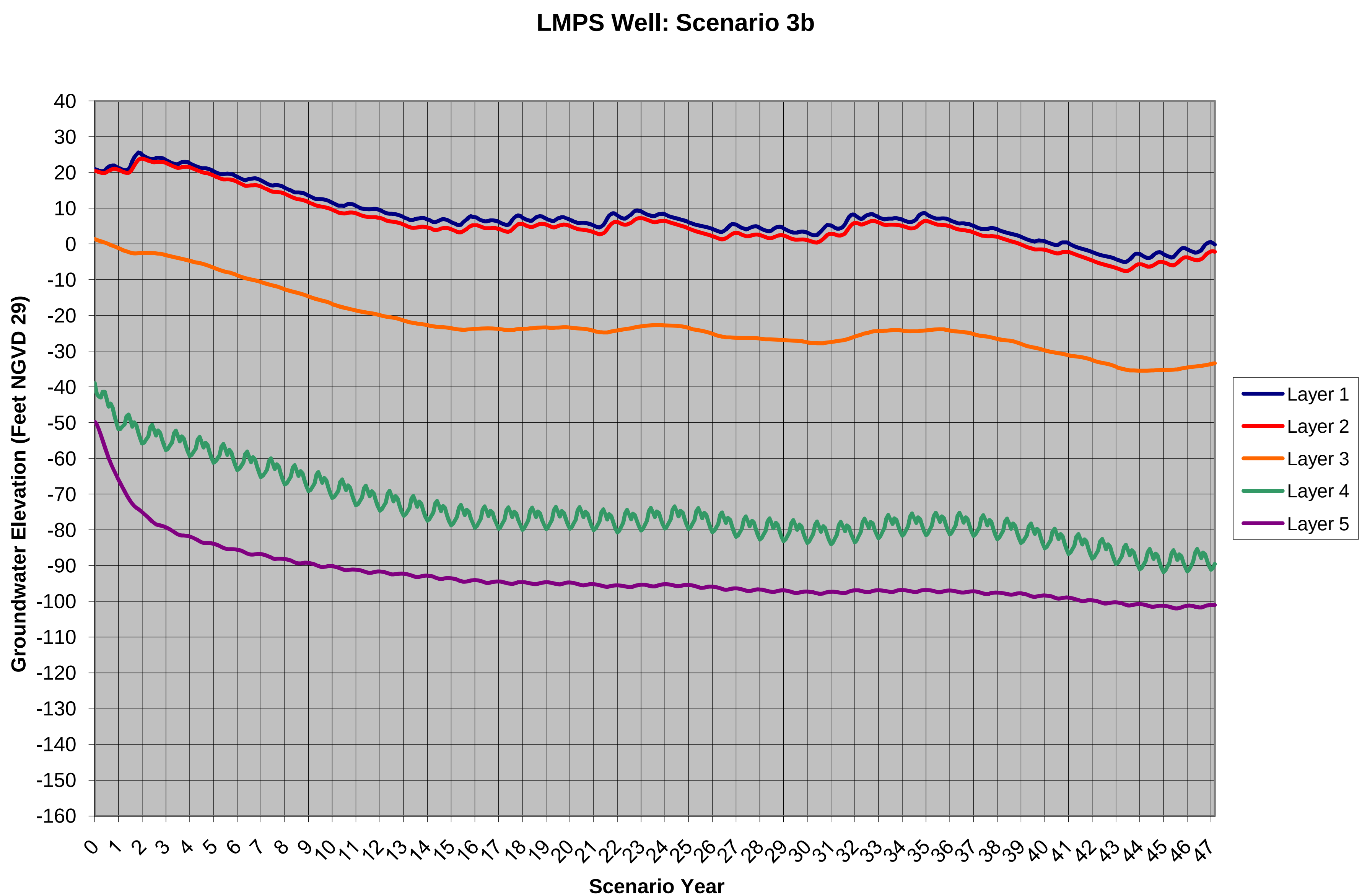
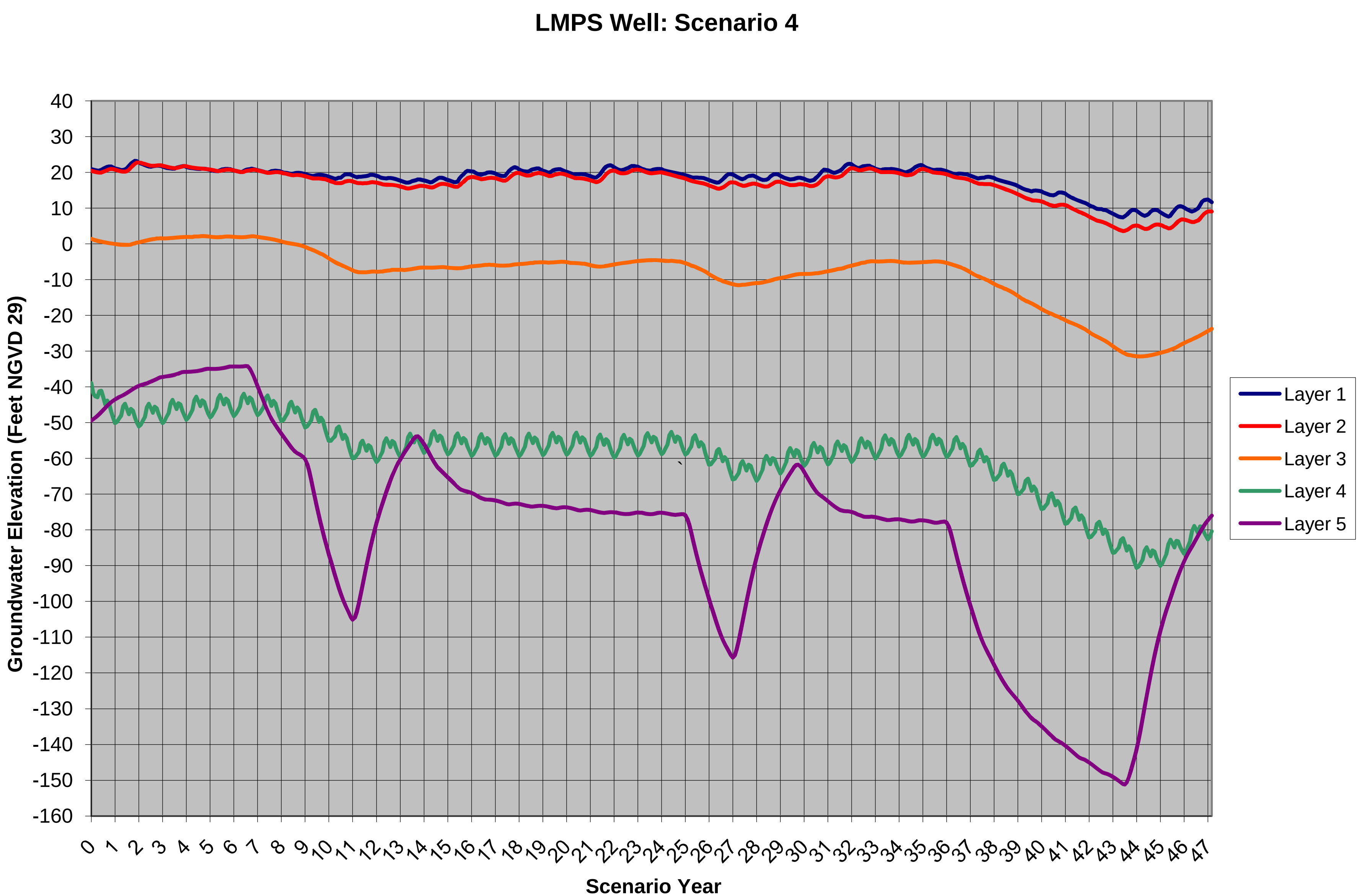
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


LMPS Well: Scenario 2
Groundwater Elevation (Feet NGVD 29)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

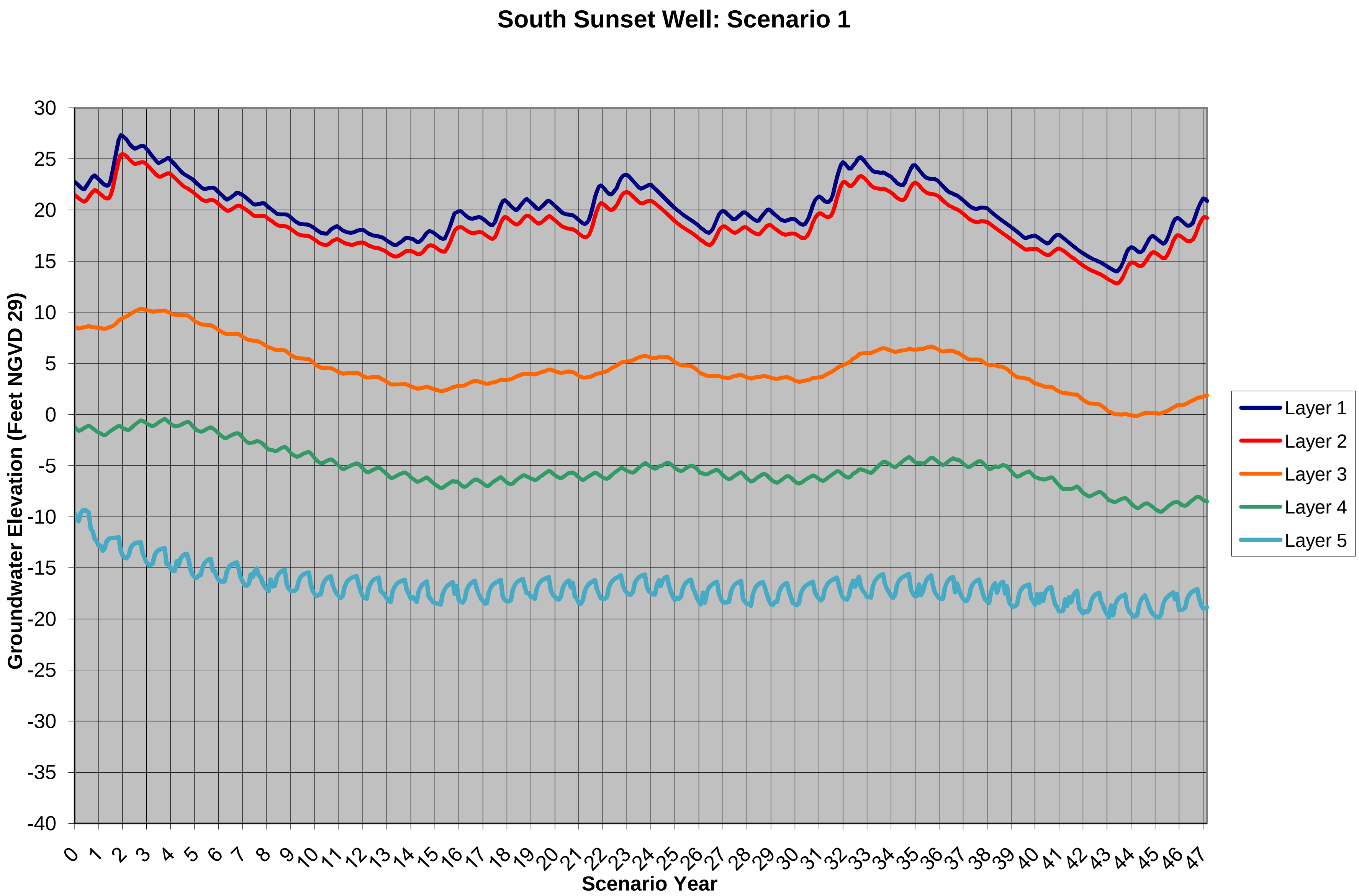

LMPS Well: Scenario 3a
Groundwater Elevation (Feet NGVD 29)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



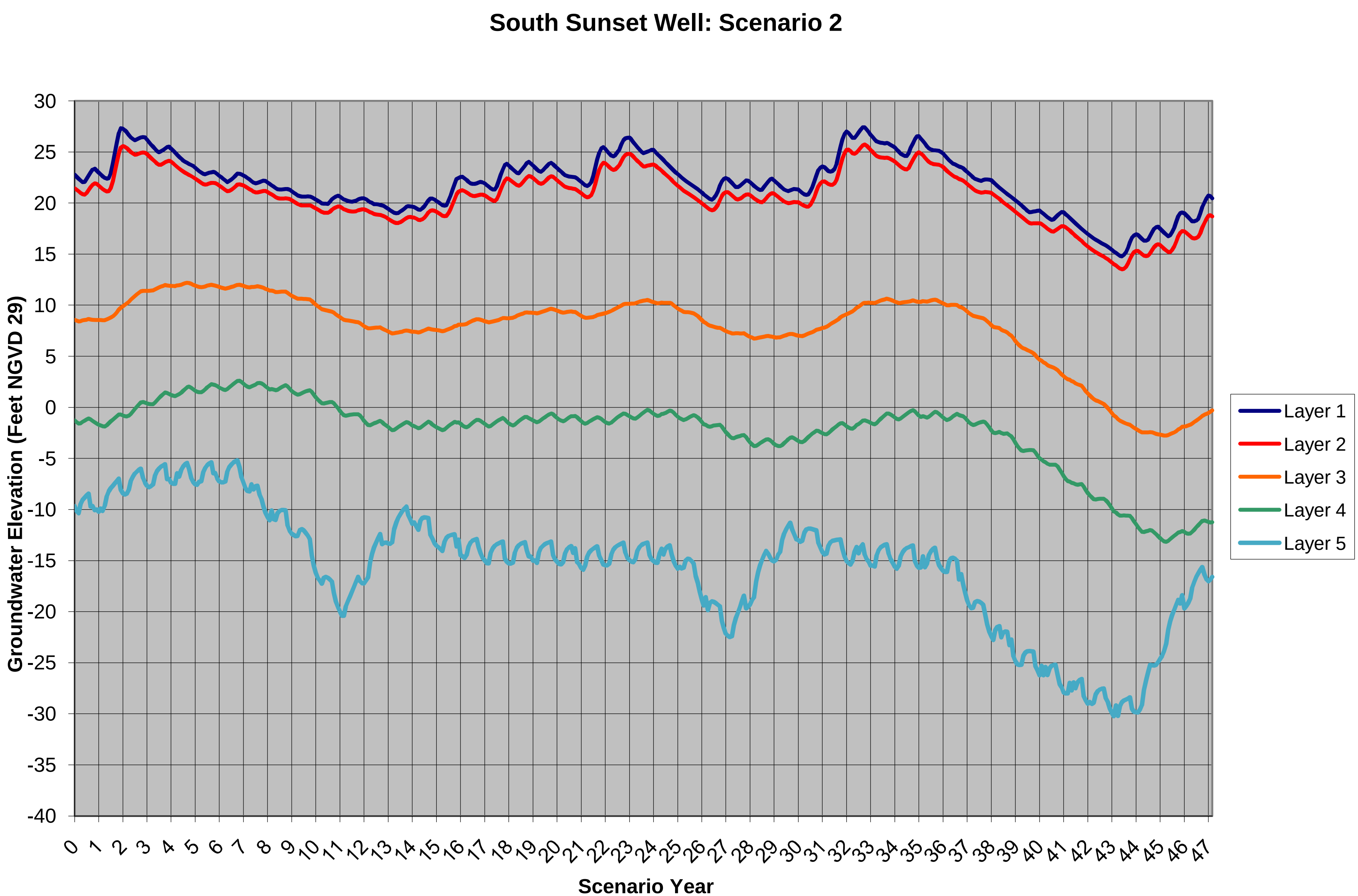
LMPS Well: Scenario 3b
Groundwater Elevation (Feet NGVD 29)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



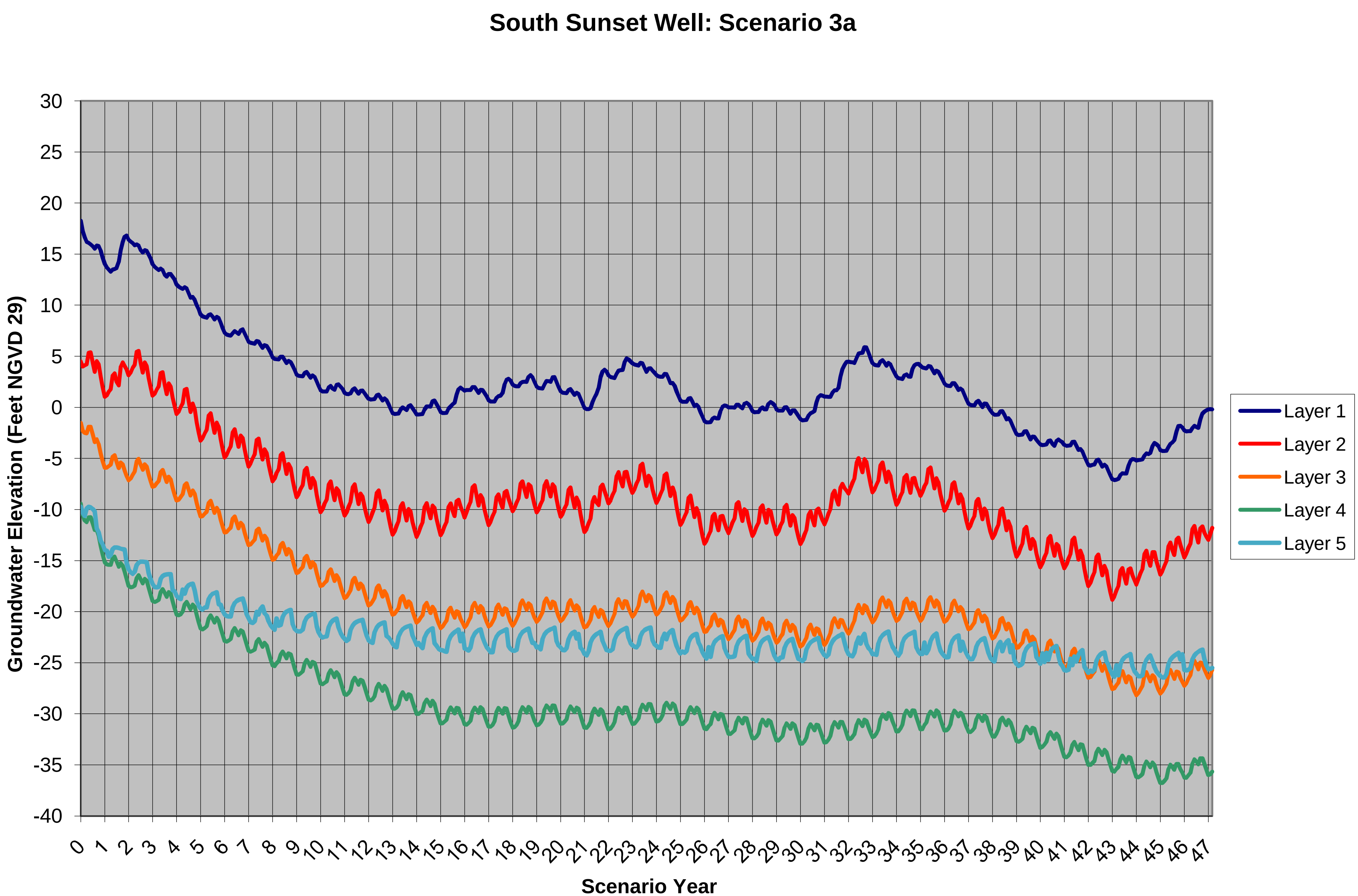
LMPS Well: Scenario 4
Groundwater Elevation (Feet NGVD 29)
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



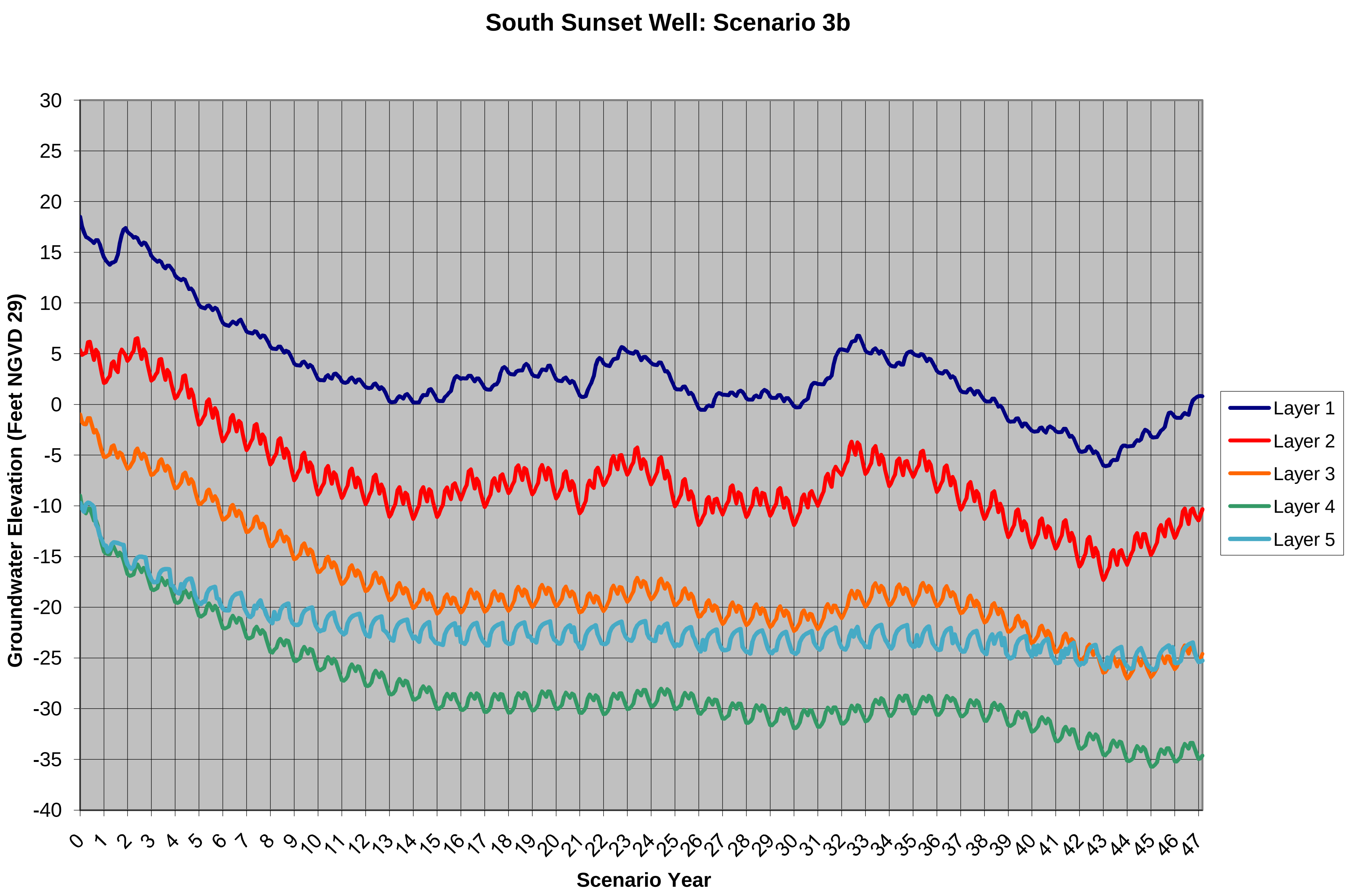
South Sunset Well: Scenario 1
Groundwater Elevation (Feet NGVD 29)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

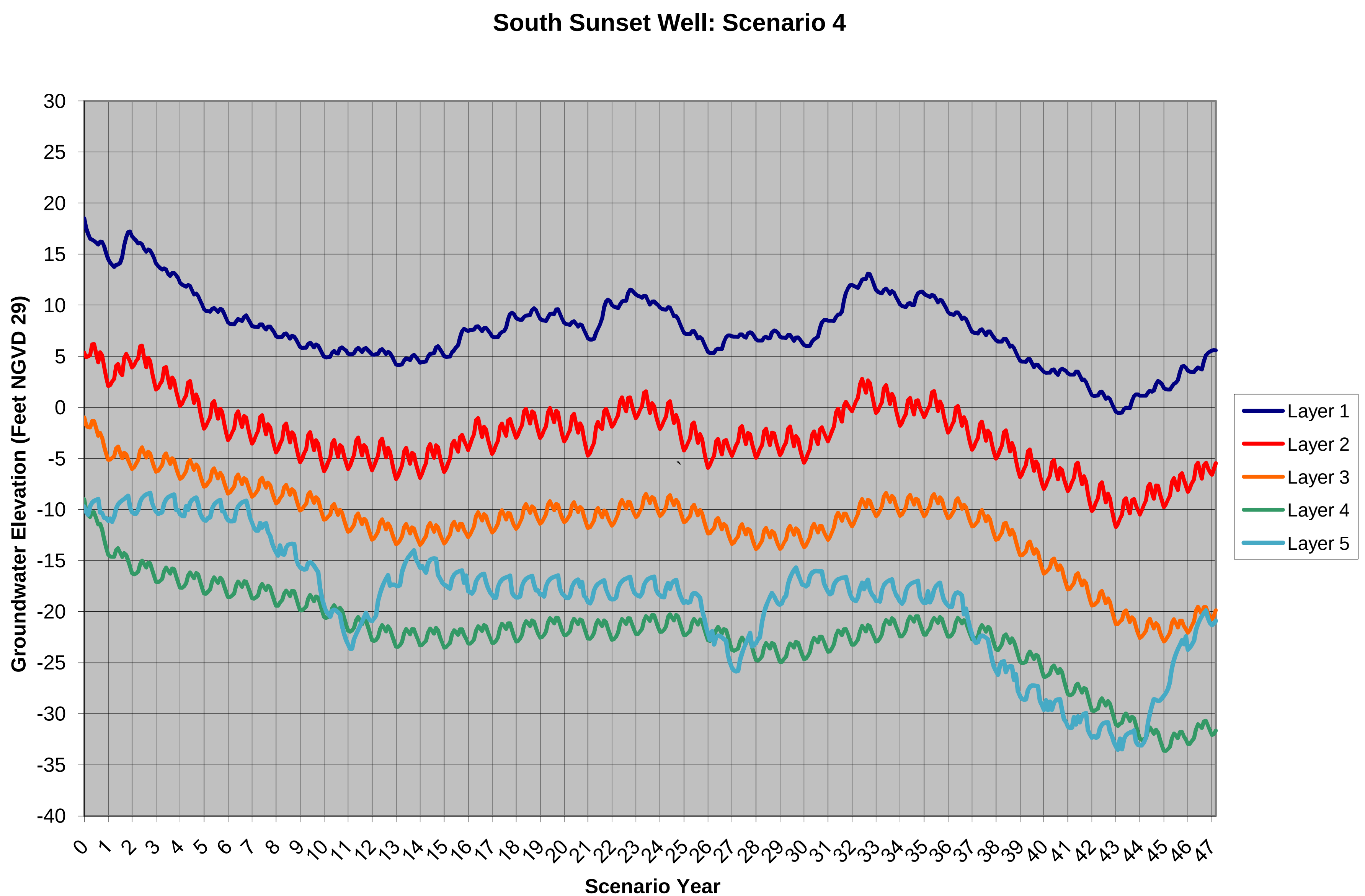


South Sunset Well: Scenario 2
Groundwater Elevation (Feet NGVD 29)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



South Sunset Well: Scenario 3a
Groundwater Elevation (Feet NGVD 29)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


South Sunset Well: Scenario 3b
Groundwater Elevation (Feet NGVD 29)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


South Sunset Well: Scenario 4
Groundwater Elevation (Feet NGVD 29)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

APPENDIX B

NGS Monuments within Study Area

PID[1]	Latitude (N)[2]			Longitude (W)		
AB7677	37	44	0.33344	122	29	49.03035
HT0600	37	42	30	122	29	9
HT0602	37	43	8.00	122	30	1.00
HT2271	37	43	47.00	122	28	30
HT1841	37	43	47.00	122	30	10
HT1842	37	44	10.00	122	30	33
HT1843	37	45	3.00	122	30	30
HT2267	37	45	56.00	122	28	37
HT2268	37	45	25.32	122	28	36.35587
HT2269	37	44	49.00	122	28	34
HT1848	37	46	28.00	122	30	39
HT1847	37	46	20.00	122	30	29
HT1846	37	46	19.00	122	30	28
HT2270	37	44	15.72	122	28	31.9305
HT2272	37	43	17.00	122	28	32
HT2273	37	42	48.00	122	28	18
HT0519	37	42	29.00	122	28	6
HT0521	37	41	36.00	122	28	15
HT0520	37	42	18.00	122	28	16
HT0481	37	41	9.43	122	28	56.41929
HT0483	37	41	5.00	122	28	18
HT0523	37	40	56.00	122	27	46
HT0540	37	37	16.00	122	22	39
HT0541	37	37	9.00	122	22	23
HT0544	37	37	32.00	122	22	34
HT0557	37	34	48.00	122	20	42
HT0641	37	39	4.00	122	22	59
HT0642	37	39	2.00	122	22	47
HT0532	37	38	0.00	122	23	51
HT0554	37	35	20.00	122	21	55
HT0543	37	37	32.00	122	22	34
HT3821	37	39	33.00	122	24	4
HT0542	37	37	28.00	122	22	31
HT0638	37	39	15.00	122	24	26
HT0639	37	39	15.00	122	23	47
HT0645	37	38	58.00	122	24	36
HT0647	37	38	32.00	122	24	47
HT0527	37	38	18.00	122	24	58
HT0537	37	37	20.00	122	23	29
HT0552	37	35	43	122	22	50
DG6888	37	38	6.88788	122	23	8.17798
HT0525	37	39	28	122	26	13
HT0644	37	39	2	122	22	47
HT0640	37	39	3	122	23	17
HT0643	37	39	2	122	22	47
HT0526	37	38	46	122	25	19
HT0556	37	34	50.73	122	20	41.37
HT0558	37	34	39	122	20	18
HT0524	37	40	7	122	26	56

[1]Point ID
[2]Latitude and Longitude in NAD83 coordinates

HT2430	37	36	42.8427	122	32	32.93442
HT0528	37	37	44	12	24	39
HT0551	37	35	55	122	23	6
HT0566	37	34	19	122	20	21
HT0538	37	37	20	122	23	29
HT0547	37	37	8	122	24	15
HT0534	37	37	30	122	23	36
HT0548	37	36	48	122	23	59

DSDATA.TXT

```
"@(#)dsdata.txt 1.20 - 2009/04/14 15:05:54"
**********************************************************************
*                        dsdata.txt                                  *
**********************************************************************

OVERVIEW:

Information about survey monuments on record with the National Geodetic
Survey (NGS) is published in a Digital Survey DATA (DSDATA) format.
The format consists of fixed field records in an 80 column ASCII text file.
The authoritative source for digital survey data format is the NGS bluebook.
This document is an extract of the bluebook for public convenience.

An individual DSDATA record of a monument is called a datasheet.  Datasheets
are sorted alphanumerically by station designation within a DSDATA file.

The last line of a correctly retrieved DSDATA file is:
***retrieval complete.

The first line of each datasheet is:
1        NATIONAL GEODETIC SURVEY,   Retrieval Date =
followed by the date the data was extracted from the NGS database.

The second line of each datasheet begins with the PID in column 2,
then is followed by a row of asterisks that begins in column 9.

Most other data items are identified by the data identifier text in cc 10-22.
Data identifier text text is characterised by a hyphen(-) in column 22.

The following data items are exceptions that require the use of cc 10-22,
and are identified by the following codes, all which start in column 8.
Note that projection data items are identified by codes in cc 8-11:

  Identifier     Data Item

      *          Current Survey Control

      .          Data Determination Text

      ;SPC       SPC Data

      ;UTM       UTM Data

      :          Primary Azimuth Object

      |          Box Score (Reference Objects)

      _          Mark Setting Information

      +          Mark Setting Information Continued
```

```
SUMMARY OF DATA ITEMS:

                                *** 
 DATA ITEM: Special Control Station Header
 DISPLAYED: Only when station is one of those types listed under EXAMPLES.
 COMMENTS :
 EXAMPLES :________________________________________________________________
 AA3495  CORS         -  This is a GPS Continuously Operating Reference Station.
 HV8128  FBN          -  This is a Federal Base Network Control Station.
 HV9260  CBN          -  This is a Cooperative Base Network Control Station.
 RF0849  PACS         -  This is a Primary Airport Control Station.
 RF0850  SACS         -  This is a Secondary Airport Control Station.
 CJ0500  TIDAL BM     -  This is a Tidal Bench Mark

                                *** 
 DATA ITEM: Designation
 DISPLAYED: Always
 COMMENTS : Usually the DESIGNATION does not match exactly with the STAMPING.
 EXAMPLES :________________________________________________________________
 AA3495  DESIGNATION -  GAITHERSBURG CORS L1 PHASE CENTER
 RF0849  DESIGNATION -  CARIPORT
 CA0570  DESIGNATION -  MP 77-5015
 AA8531  DESIGNATION -  66-26

                                *** 
 DATA ITEM: CORS Identifier
 DISPLAYED: When Station is a Continuously Operational Reference Station
 COMMENTS :
 EXAMPLES :________________________________________________________________
 AW5607  CORS_ID      -  HOUS
 ER0702  CORS_ID      -  PIE1
 AA3495  CORS_ID      -  GAIT

                                *** 
 DATA ITEM: Station Permanent Identifier (PID)
 DISPLAYED: Always
 COMMENTS : The PID is also found on the left side of each datasheet record.
            The PID is always 2 upper case letters followed by 4 numbers.
 EXAMPLES :________________________________________________________________
 AA3495  PID          -  AA3495
 RF0849  PID          -  RF0849
 TV0007  PID          -  TV0007

                                *** 
 DATA ITEM: STATE/COUNTY
 DISPLAYED: Always, but County may be blank.
 COMMENTS : Bououghs may be used for Alaska; Parishes are used for Louisiana
 EXAMPLES :________________________________________________________________
 FV1057  STATE/COUNTY-  CA/SAN LUIS OBISPO
 BW0029  STATE/COUNTY-  LA/POINTE COUPEE
 TT0026  STATE/COUNTY-  AK/
 TT4608  STATE/COUNTY-  AK/MATANUSKA-SUSITNA

                                *** 
 DATA ITEM: USGS Quad
 DISPLAYED: Always, but may be blank
 COMMENTS : This is the name of the USGS 7.5 minute series map sheet which
            shows the area of the station.  The station may or may not appear
            as a map feature.  NGS sometimes publishes data according to the
            USGS quadrangle (quad) system, for which the USGS quad sheet
            name is used as a reference.
 EXAMPLES :________________________________________________________________
 AA3495  USGS QUAD   -  GAITHERSBURG (1986)
 FA3038  USGS QUAD   -  ELLENDALE (1973)
 TV1290  USGS QUAD   -
 FV1057  USGS QUAD   -  CYPRESS MOUNTAIN (1979)
```

```
                         ***
DATA ITEM: Current Survey Control
DISPLAYED: Always, but the HEIGHT may be blank if the station
           is a horizontal control station only.
COMMENTS : Current Survey Control is identified by a '*' in cc8
           and comes under the heading "*CURRENT SURVEY CONTROL"

           The horizontal datum in use is the North American Datum of 1983 (NAD 83).
           This datum also defines ellipsoid vertical height. The orthometric vertical
           datum in use in the conterminous United States and Alaska is the North American
           Vertical Datum of 1988 (NAVD 88).  The orthometric vertical datum in Hawaii is
           referenced as Local Tidal.  This tag also applies to all orthometric heights in
           the United States territories that were determined prior to the establishment
           of the vertical datums listed below

           American Samoa: American Samoa Vertical Datum of 2002 (ASVD 02)
           Guam: Guam Vertical Datum of 2004 (GUVD 04)
           Northern Marianas: Northern Marianas Vertical Datum of 2003 (NMVD 03)
           Puerto Rico: Puerto Rico Vertical Datum of 2002 (PRVD 02)
           U.S. Virgin Islands: Virgin Islands Vertical Datum of 2009 (VIVD 09)

           NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
           Care should be taken not to "mix" current datum(s) with
           past datum(s) within a project.

           NAD83 (1986) indicates positions on the NAD83 datum for the
           North American Adjustment, completed in 1986.
           NAD83 (nnnn) indicates positions on the NAD83 datum for the
           North American Adjustment, but readjusted to a State High
           Accuracy Reference Network (HARN) on the date shown in (nnnn).
           NAD83 (CORS) indicates positions which are part of the CORS
           network.

           There are various Horizontal Control sources, as specified below:

           ADJUSTED = Least squares adjustment.
                      (Rounded to 5 decimal places.)

           HD_HELD1 = Differentially corrected hand held GPS observations.
                      (Rounded to 2 decimal places.)

           HD_HELD2 = Autonomous hand held GPS observations.
                      (Rounded to 1 decimal places.)

           SCALED   = Scaled from a topographic map.
                      (Rounded to 0 decimal places.)


           NAVD 88 orthometric heights are displayed where available.
           If there was a height for the station on the National Geodetic
           Vertical Datum of 1929 (NGVD 29), then that height will be
           displayed under SUPERSEDED SURVEY CONTROL.

           There are various Vertical Control sources, as specified below:

           ADJUSTED = Direct Digital Output from Least Squares Adjustment
                      of Precise Leveling.
                      (Rounded to 3 decimal places.)

           ADJ UNCH = Manually Entered (and NOT verified) Output of
                      Least Squares Adjustment of Precise Leveling.
                      (Rounded to 3 decimal places.)

           POSTED   = Pre-1991 Precise Leveling Adjusted to
                      the NAVD 88 Network After Completion of
```

```
                 the NAVD 88 General Adjustment of 1991.
                 (Rounded to 3 decimal places.)

      READJUST = Precise Leveling Readjusted as Required
                 by Crustal Motion or Other Cause.
                 (Rounded to 2 decimal places.)

      N HEIGHT = Computed from Precise Leveling Connected
                 at Only One Published Bench Mark.
                 (Rounded to 2 decimal places.)

      RESET    = Reset Computation of Precise Leveling.
                 (Rounded to 2 decimal places.)

      COMPUTED = Computed from Precise Leveling Using
                 Non-rigorous Adjustment Technique.
                   (Rounded to 2 decimal places.)

      GPSCONLV = Leveled Orthometric Height tied to GPS
                 HT_MOD Orthometric Height.
                 (Rounded to 2 decimal places.)

      LEVELING = Precise Leveling Performed by Horizontal
                 Field Party.
                  (Rounded to 2 decimal places.)

      H LEVEL  = Level between control points not connected
                 to bench mark.
                  (Rounded to 1 decimal places.)

      GPS OBS  = Computed from GPS Observations.
                 (Rounded to 1 decimal places.)

      VERT ANG = Computed from Vertical Angle Observations.
                 (Rounded to 1 decimal place;
                  If No Check, to 0 decimal places.)

      SCALED   = Scaled from a Topographic Map.
                 (Rounded to 0 decimal places.)

      U HEIGHT = Unvalidated height from precise leveling
                 connected at only one NSRS point.
                 (Rounded to 2 decimal places.)

      VERTCON  = The NAVD 88 height was computed by applying the
                 VERTCON shift value to the NGVD 29 height.
                 (Rounded to 0 decimal places.)


      NOTE:    NAVD 88 and NGVD 29 heights in meters are
               converted to U.S. Survey Feet by using the
               conversion factor:
                 U.S. Survey Feet = (39.37 / 12.00) x meters
               Height in feet is rounded to 1 less decimal
               place than the corresponding height in meters.

 EXAMPLES :________________________________________________________________
 AA0000                    *CURRENT SURVEY CONTROL
 AA0000
```

NGS has adopted a realization of NAD83 called NAD83(NSRS2007) for the distribution of coordinates at approximately 70,000 passive geodetic control monuments. This realization approximates (but is not, and can never be, equivalent to) the more rigorously defined NAD 83 (CORS96) realization in which Continuously Operating Reference Sstations (CORS) coordinates are distributed.

NAD 83 (NSRS2007) was created by adjusting GPS data collected during various campaign-style geodetic surveys performed between the mid-1980's and 2005. For this adjustment, NAD 83 (CORS96) positional coordinates for approximately 700 CORS were held fixed (predominately at the 2002.0 epoch for the stable north American plate, but 2007.0 in Alaska and western CONUS) to obtain consistent positional coordinates for the approximately 70,000 passive marks, as described by Vorhauer [2007]. Derived NAD 83(NSRS2007) positional coordinates should be consistent with corresponding NAD 83(CORS96) positional coordinates to within the accuracy of the GPS data used in the adjustment and the accuracy of the corrections applied to these data for systematic errors, such as refraction. In particular, there were no corrections made to the observations for vertical crustal motion when converting from the epoch of the GPS survey into the epoch of the adjustment, while the NAD 83(CORS96) coordinates do reflect motion in all three directions at CORS sites.
For this reason alone, there can never be total equivalency between NAD 83(NSRS2007) and NAD 83(CORS96).

Note: NGS has not computed NAD83 (NSRS2007) velocities for any of the apprroximately 70,000 passive marks involved in this adjustment. Also, the positional coordinates of a passive mark will make reference to an "epoch date". Epoch dates are the date for which the positional coordinates were adjusted, and are therefore considered "valid" (within the tolerance of not applying vertical crustal motion). because a mark's positional coordinates will change due to the dynamic nature of the earth's crust, the coordinates of a mark on epochs different than the listed "epoch date" can only be accurately known if a 3-dimensional velocity has been computed and applied to that mark.

Loading of the National Readjustment data commenced on September 14, 2007. Before this the format of the position and elevation lines appeared as follows:

```
 AA3495* NAD 83(CORS)-  39 08 02.34046(N)    077 13 15.51884(W)     ADJUSTED
 AA3495* NAVD 88     -       140.76   (meters)     461.8    (feet)  GPS OBS
```

After the readjustment, the position and elevation lines on a datasheet will appear in a slightly modified format to accomodate the larger datum tag field (i.e. NSRS2007) as shown in the below examples.

```
______________________________________________________________
 DF9012* NAD 83(NSRS2007)-  42 56 15.39233(N) 071 26 19.03487(W)    ADJUSTED
 AA3495* NAD 83(CORS)    -  39 08 02.34046(N) 077 13 15.51884(W)    ADJUSTED
 RF0849* NAD 83(NSRS2007)-  46 52 08.05186(N) 068 00 53.02328(W)    ADJUSTED
 TA0047* NAD 83(1986)    -  48 04 54.20   (N) 090 45 48.42   (W)    HD_HELD1
 AC3384* NAD 83(1986)    -  25 57 14.7    (N) 081 43 29.2    (W)    HD_HELD2
 HV0454* NAD 83(1986)    -  38 20 52.     (N) 076 13 39.     (W)    SCALED
 DX3756* NAD 83(NSRS2007)-  33 38 08.42412(N) 117 05 10.37961(W)    ADJUSTED
 FQ0856* NAD 83(1986)    -  35 47 36.     (N) 111 52 56.     (W)    SCALED
 DB0356* NAVD 88         -       -11.886  (meters)  -39.00  (feet)  READJUSTED
 DC2131* NAVD 88         -      1096.93   (meters) 3598.8   (feet)  N HEIGHT
 AI5086* NAVD 88         -       123.68   (meters)  405.8   (feet)  GPS OBS
 GP0162* NAVD 88         -      1456.97   (meters) 4780.1   (feet)  RESET
 DE3069* NAVD 88         -        38.25   (meters)  125.5   (feet)  GPS OBS
 GP0641* NAVD 88         -      1831.8    (meters) 6010.    (feet)  GPS OBS
 BW0768* NAVD 88         -        59.70   (+/-2cm)  195.9   (feet)  VERTCON
 BW2469* NAVD 88         -       125.     (meters)  410.    (feet)  SCALED
 FG1799* NAVD 88         -
 TV0377* LOCAL TIDAL     -          7.2    (meters)   24.    (feet)  VERT ANG
```

***

DATA ITEM: Epoch Date
DISPLAYED: When Horizontal Position Requires
COMMENTS : The epoch date is used for stations in regions of episodic and/or continuous horizontal crustal motion where the position changes in time. The epoch date indicates the time the published horizontal coordinates are valid.

All stations with an adjusted horizontal position that falls within

```
          a designated crustal motion region will have an epoch date displayed
          on the datasheet.  Stations outside of these regions will not have
          an epoch date.  As the crustal motion effect tapers to zero before
          reaching a region's boundary, stations immediately inside that
          boundary and having an epoch date will normally have consistant
          positions with stations outside that boundary with no epoch date.

          To aid users with changing coordinates through epochs, NGS has
          developed software package HTDP to model changes in California
          and parts of Alaska.  HTDP is available from the NGS Information
          Services Branch.
EXAMPLES :________________________________________________________________
AA3495  EPOCH DATE  -        1996.00
EV3471  EPOCH DATE  -        1991.35

                                   ***
DATA ITEM: X, Y, Z
DISPLAYED: When adjusted Horizontal Position and Ellipsoid Height are available.
COMMENTS : These values represent earth-centered earth-fixed coordinates,
           where the X axis follows zero degrees longitude, the Z axis follows
           positive 90 degrees latitude and the Y axis completes a right hand
           system.
EXAMPLES :________________________________________________________________
AA3495  X           -   1,095,790.787 (meters)                      COMP
AA3495  Y           -  -4,831,328.133 (meters)                      COMP
AA3495  Z           -   4,003,934.481 (meters)                      COMP

                                   ***
DATA ITEM: Laplace Correction
DISPLAYED: For stations that have an adjusted position and that are
           within areas that have a geoid model with a derived
           vertical deflection model.
COMMENTS : The Laplace correction is the quantity which, when added to an
           astronomic azimuth, yields a geodetic azimuth.

           The simplified Laplace equation, which assumes horizontal lines
           of sight (cotangent of zenith angle ~ zero) and which assumes a
           clockwise reference frame during model development is:

           LAPLACE CORR = (a - A)
                        = (eta) * tan(geodetic latitude)
           where:
           a    =  Geodetic azimuth
           A    =  Astronomic azimuth
           eta  =  Deflection of the vertical in the prime-vertical plane,
                   an east-west component.

           The reader is cautioned that the Laplace equation has also been
           derived by others using a counterclockwise reference frame,
           which leads to subtracting the Laplace correction from the
           astronomic azimuth to yield a geodetic azimuth:
                 Laplace corr = (A - a).
           However, NGS uses a clockwise reference frame.
EXAMPLES :________________________________________________________________
RF0849  LAPLACE CORR-          3.14  (seconds)                      USDV2009
EV3471  LAPLACE CORR-          0.60  (seconds)                      USDV2009
TV1290  LAPLACE CORR-          0.12  (seconds)                      USDV2009
EZ4149  LAPLACE CORR-         -3.23  (seconds)                      USDV2009

                                   ***
DATA ITEM: Ellipsoid Height
DISPLAYED: When available
COMMENTS : The ellipsoid height is the elevation of the station above the
           reference ellipsoid for horizontal datum, currently the NAD83
           ellipsoid.  The ellipsoid is a reference surface for how the
           world appears, with respect to physical location.
```

```
           As a very close approximation:

                    h = H + N
           where
              h  =  ellipsoid height
              H  =  orthometric height
              N  =  geoid height

           In theory this equation is not exact because the ellipsoid height
           is normal to the ellipsoid, orthometric height is normal to the
           geoid, and these two surfaces are not necessarily parallel.
           In practice these three data item quantities will not usually
           satisfy the above equation since they were derived from seperate
           sources.  The above equation assumes a model where the geoid
           is above the ellipsoid, and terrain above the geoid.
           The date (mm/dd/yy) attached to the ellipsoid height is the date
           when the ellipsoid height was adjusted.  If the day is unknown
           then it is filled with "??".
EXAMPLES :_________________________________________________________________
AA3495  ELLIP HEIGHT-         109.047 (meters)          (03/??/02) GPS OBS
HV8128  ELLIP HEIGHT-         -24.700 (meters)          (02/12/02) GPS OBS
FT1606  ELLIP HEIGHT-         974.023 (meters)          (03/??/02) GPS OBS

                                ***
DATA ITEM: Geoid Height
DISPLAYED: For areas covered by the 'GEOID' software.
COMMENTS : The geoid height is the elevation of the geoid above the horizontal
           datum's reference ellipsoid.  The geoid is a specific equi-
           geopotential surface (geop), that best fits global mean sea level.
           The geoid is a reference surface for how the world acts,
           with respect to the geopotential force of gravity.
           The majority of the conterminous United States shows a negative
           geoid height, indicating that the geoid is below the ellipsoid.
EXAMPLES :_________________________________________________________________
RF0849  GEOID HEIGHT-         -23.39  (meters)                    GEOID96
TU0165  GEOID HEIGHT-         -28.00  (meters)                    GEOID96
TV0007  GEOID HEIGHT-         -40.70  (meters)                    GEOID96

                                ***

DATA ITEM: Dynamic Height
DISPLAYED: For stations with an NAVD88 height and Modeled Gravity.
COMMENTS : The dynamic height of a benchmark is the height at
           a reference latitude of the geopotential surface through the
           benchmark.  This value is of interest because two stations with
           different orthometric heights may have similar geopotential,
           due to undulations of the geopotential reference surface (geoid).
           The source of a dynamic height is always computed.
           The reference latitude for the United States is North 45 degrees.

           Dynamic heights were computed from geopotential heights
           (geopotential numbers) which were obtained for all bench marks
           in the general adjustment of the North American Vertical
           Datum of 1988 (NAVD88).  A dynamic height referenced to the
           International Great Lakes Datum of 1985 is then obtained by
           dividing the adjusted NAVD88 geopotential height of a
           bench mark by the normal gravity value (G) computed on the
           Geodetic Reference System of 1980 (GRS 80) ellipsoid
           at 45 degrees latitude (G = 980.6199 gal).

           A related unit for measuring geopotential is the geopotential
           number (C), which was adopted by the IAG in 1955.
           The geopotential number equals the dynamic height multiplied by
           the normal gravity at the reference latitude:
                         C = H(dynamic) * gamma(ref).
           The geopotential number (C) is measured in geopotential units
```

(g.p.u.), where:
1 g.p.u. = 1 kgal meter = 1000 gal meter.

Since local gravity near sea level is approximately 0.98 kgal, the magnitude of geopotential numbers (C) are approximately that of orthometric height in meters, which leads to better intuitive understanding.

EXAMPLES :

```
DB0356  DYNAMIC HT  -        -11.870 (meters)    -38.94   (feet)  COMP
HV0454  DYNAMIC HT  -          1.026 (meters)      3.37   (feet)  COMP
DC0409  DYNAMIC HT  -       1055.66  (meters)   3463.4    (feet)  COMP
```

***

DATA ITEM: Modeled Gravity
DISPLAYED: When available.
COMMENTS : The interpolated gravity value which was used in the NAVD 88 general adjustment.

EXAMPLES :

```
HV8128  MODELED GRAV-     980,028.4   (mgal)                        NAVD 88
EV3471  MODELED GRAV-     979,412.1   (mgal)                        NAVD 88
CA0570  MODELED GRAV-     979,272.6   (mgal)                        NAVD 88
```

***

DATA ITEM: Survey Control Order and Class
DISPLAYED: For Adjusted Control Only
COMMENTS : The Order will be 'HORZ ORDER', 'VERT ORDER' or 'ELLIP ORDER' depending on whether it refers to Horizontal control, Vertical Orthometric control or Vertical Ellipsoid control.

ORDER AND CLASS: HORIZONTAL
****

With the conclusion of the national readjustment, we will no longer publish horizontal order and class. Instead we will publish network and local accuracies.

For publication purposes, the network accuracy of a control point is a value that represents the uncertainty of its coordinates with respect to the geodetic datum at the 95 percent confidence level. Since the datum is considered to be best expressed by the Continuous Operating Reference Stations (CORS), which are held fixed during the adjustment. Local and Network accuracy values at CORS sites are considered to be infinitesimal (approach zero). The Local Accuracy of a control point is a value that represents the uncertainly of its coordinates relative to other directly connected, adjacent control points at the 95-percent confidence level. This value represents the relative positional error which surveyors can expect between survey marks in a locality. It also represents an approximate average of the indicudual local accuracy values between this control point and other observed control points used to establish its coordinates although, in general, all of the immediately surrounding stations will not necessarily have been used in teh survey which established the original coordinates.

These accuracies have been implemented with the publication of the National Readjustment.

Note: CORS stations that are NOT part of the National CORS program in NGS (e.g. California CORS) will show both network and local accuracies. This is because they are in a separate program from that National CORS and thereby are not constricted to the rules of the National CORS on NGS datasheets.

ORDER AND CLASS: ORTHOMETRIC VERTICAL
****

Vertical station order and class for first-, second-, and third-order stations are defined in the Federal Geodetic Control Committee publication "Standards and Specifications for Geodetic Control Networks". In addition:

Normal bench marks with unknown order will display a '?'. Vertical control which were determined only for the purpose of supplying a height for Horizontal Distance Reductions are assigned an order of 'THIRD'. If these types of heights do not have supporting observations then the Order is displayed as 'THIRD ?'.

Class 0 is used for special cases of orthometric vertical control as follows:

Vertical Order/Class		Tolerance Factor
FIRST	CLASS 0	2.0 mm or less
SECOND	CLASS 0	8.4 mm or less
THIRD	CLASS 0	12.0 mm or less

"Posted bench marks" are vertical control points in the NGS data base which were excluded from the NAVD 88 general adjustment. Some of the bench marks were excluded due to large adjustment residuals, possibly caused by vertical movement of the bench marks during the time interval between different leveling epochs. Adjusted NAVD 88 are computed for posted bench marks by supplemental adjustments.

A range of mean distribution rate corrections is listed for each posted bench mark in the data portion of the publication. A summary table of the mean distribution rates and their codes is listed below. The mean distribution rate corrections which were applied to the original leveling observations is a good indication of the usefulness of the posted bench marks' adjusted NAVD 88 heights.

Distribution Rate Code	Distribution Rate Correction
"a"	0.0 thru 1.0 mm/km
"b"	1.1 thru 2.0 "
"c"	2.1 thru 3.0 "
"d"	3.1 thru 4.0 "
"e"	4.1 thru 8.0 "
"f"	greater than 8.0 mm/km

POSTED BENCH MARKS SHOULD BE USED WITH CAUTION. As is the case for all leveling projects, the manditory FGCS check leveling two-mark or three-mark tie procedure will usually detect any isolated movement (or other problem) at an individual bench mark. Of course, regional movement affecting all the marks equally is not detected by the two- or three-mark tie procedure.

GPS CONSTRAINED LEVELED HEIGHT. The height was determined by differential leveling referenced to only one NSRS GPS Height Mod determined height. Therefore this height should be used with CAUTION.

ORDER AND CLASS: ELLIPSOID VERTICAL
****

The following ellipsoid height order and class relative accuracy standards have not yet been adopted by the Federal Geodetic Control Subcommittee, but are currently in use by NGS:

```
         Ellipsoid Height                     Maximum Height
          Classification                    Difference Accuracy
        ------------------                  -------------------
        FIRST      CLASS 1                   0.5 (mm)/sqrt(km)
        FIRST      CLASS 2                   0.7
        SECOND     CLASS 1                   1.0
        SECOND     CLASS 2                   1.3
        THIRD      CLASS 1                   2.0
        THIRD      CLASS 2                   3.0
        FOURTH     CLASS 1                   6.0
        FOURTH     CLASS 2                  15.0
        FIFTH      CLASS 1                  30.0
        FIFTH      CLASS 2                  60.0

    The ellipsoid height difference accuracy (b) is computed from a
    a minimally constrained correctly weighted least squares adjustment
    by:
         b = s / sqrt(d)

    where
         b = height difference accuracy
         s = propagated standard deviation of ellipsoid height
             difference in millimeters between control points
             obtained from the least squares adjustment.
         d = horizontal distance between control points in kilometers

EXAMPLES :________________________________________________________________
AA3495  HORZ ORDER  -  SPECIAL (CORS)
HV8128  HORZ ORDER  -  A
HV9260  HORZ ORDER  -  B
AA0169  HORZ ORDER  -  FIRST
FG1796  HORZ ORDER  -  SECOND
FG1797  HORZ ORDER  -  THIRD

HV8128  VERT ORDER  -  FIRST     CLASS II
HU0680  VERT ORDER  -  SECOND    CLASS 0
FG0846  VERT ORDER  -  THIRD (See Below)
GP0162  VERT ORDER  -  THIRD
HH0701  VERT ORDER  -  THIRD     CLASS 0
LX7164  VERT ORDER  -  THIRD ?
FG0744  VERT ORDER  -  ?
FQ0849  VERT ORDER  -  * POSTED, Code a , SEE BELOW
GP0241  VERT ORDER  -  * POSTED, Code b , SEE BELOW
FR0070  VERT ORDER  -  * POSTED, Code c , SEE BELOW
TF1074  VERT ORDER  -  * POSTED, Code d , SEE BELOW
TF1144  VERT ORDER  -  * POSTED, Code e , SEE BELOW
TF0916  VERT ORDER  -  * POSTED, Code f , SEE BELOW
FR0371  VERT ORDER  -  * POSTED, Code NC , SEE BELOW
EV3471  VERT ORDER  -  * READJUSTED, Code A , SEE BELOW
AA3495  ELLP ORDER  -  SPECIAL (CORS)

TV1290  ELLP ORDER  -  FIRST     CLASS II
RF0849  ELLP ORDER  -  THIRD     CLASS I
HV8128  ELLP ORDER  -  FOURTH    CLASS I

                             ***
DATA ITEM: Text regarding Horizontal Control
DISPLAYED: As required when explaining source of data values.
COMMENTS :
EXAMPLES :________________________________________________________________
AA0000.The horizontal coordinates were established by classical geodetic methods
AA0000.and adjusted by the National Geodetic Survey in June, 1995.

AA0000.The horizontal coordinates were established by classical geodetic methods
AA0000.and adjusted by the National Geodetic Survey.
```

```
AA0000.The horizontal coordinates were established by GPS observations
AA0000.and adjusted by the National Geodetic Survey in June, 1995.

AA0000.The horizontal coordinates were established by GPS observations
AA0000.and adjusted by the National Geodetic Survey.

AA0000.The horizontal coordinates were established by VLBI observations
AA0000.and local terrestrial surveys and adjusted by the National Geodetic
AA0000.Survey in June, 1995.

AA0000.The horizontal coordinates were established by VLBI observations
AA0000.and local terrestrial surveys and adjusted by the National Geodetic
AA0000.Survey.

AA0000.The horizontal coordinates were scaled from a topographic map and have
AA0000.an estimated accuracy of +/- 6 seconds.

AA0000.No horizontal observational check was made to the station.

AA0000.This is a SPECIAL STATUS position.  See SPECIAL STATUS under the
AA0000.DATUM ITEM on the data sheet items page.

AA0000.The horizontal coordinates are valid at the epoch date displayed above.
AA0000.The epoch date for horizontal control is a decimal equivalence
AA0000.of Year/Month/Day.

                                ***
 DATA ITEM: Text regarding Vertical Control
 DISPLAYED: As required when explaining source of data values.
 COMMENTS :
 EXAMPLES :________________________________________________________________
AA0000.The orthometric height was determined by differential leveling
AA0000.and adjusted by the National Geodetic Survey in June, 1990.

AA0000.The orthometric height was determined by differential leveling
AA0000.and adjusted by the National Geodetic Survey.

AA0000.The orthometric height was computed from unverified reset data.

AA0000.The orthometric height was key entered from printed documents
AA0000.and not key verified.

AA0000.The approximate orthometric height was determined by applying
AA0000.unadjusted height differences to other nearby adjusted values.

AA0000.The orthometric height was determined by differential leveling.
AA0000.The vertical network tie was performed by a horz. field party for horz.
AA0000.obs reductions. Reset procedures were used to establish the elevation.

AA0000.The orthometric height was determined by vertical angle observations.

AA0000.The orthometric height was determined by GPS observations.

AA0000.The orthometric height was scaled from a topographic map.
AA0000.The NAVD 88 height was computed by applying the VERTCON shift value to
AA0000.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)

AA0000.No vertical observational check was made to the station.

AA0000.* This is a POSTED BENCH MARK height.  Code A indicates a distribution
AA0000.rate of 0.0 thru 1.0 mm/km.

AA0000.* This is a READJUSTED BENCH MARK height.  Code NC indicates the bench
AA0000.mark was located on a no-check spur therefore a value was not computed.

AA0000.The height was derived from older observations constrained to new
```

```
AA0000.heights in a crustal motion area.  The height is approximate in
AA0000.relation to other heights in its vicinity.

AA0000.The height was determined by precise leveling from only one NGRS
AA0000.bench mark.  This was not adequate "tie leveling" to NGRS and was
AA0000.allowed ONLY to validate the GPS-derived height.

AA0000.WARNING-GPS observations at this control monument resulted in a GPS
AA0000.derived orthometric height which differed from the leveled height by
AA0000.more than one decimeter (0.1 meter).

AA0000.WARNING-Repeat measurements at this control monument indicate possible
AA0000.vertical movement.

CJ0500.This mark is designated as VM 4064 in the Oceanographic Products
CJ0500.and Services Division Tidal Bench Mark database.
       NOTE: If a web browser is used to retrieve an NGS bench mark that is
       also a tidal bench mark, the words "Oceanographic Products" will be
       highlighted and will provide a link to the series of descriptions and
       tide height references in the Oceanographic Products and Services
       Division (OPSD) Tidal Bench Mark database that includes the bench mark.
       The specific bench mark is uniquely identified by a corresponding
       tide station number and state, which are provided at an intermediate
       web page, where a link to the OPSD Home Page is also available
       for further tidal bench mark information.

                                 ***
 DATA ITEM: Text regarding Other Data Control
 DISPLAYED: As required when explaining source of data values.
 COMMENTS :
 EXAMPLES :________________________________________________________________
 AA0000.The XYZ, and position/ellipsoidal ht. are equivalent.
 AA0000.The X, Y, and Z were computed from the position and the ellipsoidal ht.
 AA0000.The Laplace correction was computed from DEFLEC93 derived deflections.
 AA0000.The ellipsoidal height was determined by GPS observations
 AA0000.and is referenced to NAD 83.
 AA0000.The geoid height was determined by GEOID93.
 AA0000.The dynamic height is computed by dividing the NAVD 88
 AA0000.geopotential number by the normal gravity value computed on the
 AA0000.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 AA0000.degrees latitude (G = 980.6199 gals).
 AA0000.The modeled gravity was interpolated from observed gravity values.
 AA3495.No superseded survey control is available for this station.
 AA0000.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 AA0000.See file format.dat to determine how the superseded data were derived.
 AA0170.The vertical order pertains to the superseded datum.

                                 ***
 DATA ITEM: Grid Coordinate Systems:
            State Plane Coordinate System of 1983 (SPC)
            Universal Transverse Mercator (UTM)
 DISPLAYED: SPC coordinates are shown where zones where available.
            UTM zones are available worldwide, but coordinates are shown only
            for those stations with horizontal control.
 COMMENTS : UTM units are always in meters(MT).  In addition to meters,
            SPC units may also be expressed in U.S. Survey Foot(sFT), or
            International Foot(iFT), where:

            U.S. Survey Foot   :=  39.37 inches = 1 meter, exactly
            International Foot :=        1 inch = 2.54 centimeters, exactly

            All azimuths are referenced clockwise from north.
            Stations near zone limits may report positions for each zone.
            Scale Factor multiplied by ellipsoid distance equals grid distance.
            Convergence is also known as the mapping angle.
            Convergence plus grid azimuth yields geodetic azimuth.
```

```
          The second-term correction known as the Arc-to-Chord correction
          has not been included in the convergence.

          Scaled SPC values that are provided for stations which do not
          have adjusted horizontal control have no digits to the right
          of the decimal.  Scaled SPC do not report a Scale Factor or
          Convergence, but report an Estimated Accuracy.

          A Grid Coordinate record contains:
                     |   Northing |   Easting  |Units|  Scale   | Convergence
                     |            |            |     |  Factor  | (d mm ss.s)
         Type,Zone-
EXAMPLES :________________________________________________________________
RF0849;SPC ME E     -   355,965.757   336,994.238   MT  0.99991682 +0 21 14.9
HV8128;SPC MD       -   257,462.59  1,245,959.54   sFT  0.99998804 -0 08 43.1
CK3919;SPC SC       -   342,482.46  2,008,965.76   iFT  0.99991459 +0 00 58.2
FB2124;SPC TN       -   186,810.      805,260.      MT  (+/- 180 meters Scaled)
RF0849;UTM  19      - 5,191,067.175   575,088.597   MT  0.99966930 +0 43 08.7
FT1606;UTM  11      - 3,919,831.845   510,241.833   MT  0.99960129 +0 03 55.4
FV1057;UTM  10      - 3,937,617.155   689,693.779   MT  1.00004345 +1 13 03.9

                              ***

DATA ITEM: Grid Azimuth for Primary Reference Object
DISPLAYED: When Box Score is available.
COMMENTS : The grid azimuth applies to the specified map projection only.
EXAMPLES :________________________________________________________________
RF0849:SPC ME E     -   CARIPORT AZ MK                           338 16 51.1
RF0849:UTM  19      -   CARIPORT AZ MK                           337 54 57.3

                              ***

DATA ITEM: Box Score
DISPLAYED: When available for Old Horizontal Control marks.
COMMENTS : Distance may be blank;  PID may be blank.
           There may be unadjusted marks not shown that are
           in the vicinity of the Old Horizontal Control mark.
           Contact NGS regarding their information.
EXAMPLES :________________________________________________________________
MC0588|---------------------------------------------------------------------|
MC0588| PID    Reference Object                     Distance      Geod. Az  |
MC0588|                                                           dddmmss.s |
MC0588| MC1379 WESTON MUNICIPAL TANK               APPROX.14.8 KM 0024913.8 |
MC0588| MC0587 FRANK RM 1                           36.576 METERS 10109     |
MC0588|        HOYTVILLE N BALT GRAIN ELEV         APPROX. 3.0 KM 1400111.8 |
MC0588| MC1373 MC COMB MUNICIPAL TANK              APPROX.11.7 KM 1753525.4 |
MC0588| MC0586 FRANK AZ MK                                        1800257.9 |
MC0588| MC0592 FRANK AZ MK 2                                      2563259.8 |
MC0588| MC1376 DESHLER MUNICIPAL TANK              APPROX. 7.9 KM 2694631.8 |
MC0588| MC0589 FRANK RM 2                           34.759 METERS 34452     |
MC0588|---------------------------------------------------------------------|

                              ***

DATA ITEM: Superseded Survey Control
DISPLAYED: When available.
COMMENTS : Superceded control are previously published data control values
           that are obsolete but reprinted for continuity of records.
           Format is similar to 'Current Survey Control',
           but is not marked with '*' in cc 8.
           AD means ADJUSTED, referring to horizontal position.
           GP means GPS_OBS,  referring to GPS derived ellipsoidal height.
           This is followed by an epoch date (if available).
           This is followed by Order (if available, Horizontal or Vertical),
           then is followed by Class (if available, Vertical only).

           A horizontal Order of 'c' is used for CORS stations.
           Superseded elevations have no epoch date but the
           Order and Class are displayed for bench mark heights.
```

The determination text used for superseded elevations
is identical to that used for the current survey control.

EXAMPLES :____

```
AA0000                       SUPERSEDED SURVEY CONTROL
AA0000
AB6382  NAD 83(CORS)-  31 52 26.11223(N)   102 18 54.55641(W) AD(1996.00) c
FV1057  NAD 83(1992)-  35 33 50.72286(N)   120 54 24.79262(W) AD(1991.35) 1
HW3152  NAD 83(1986)-  38 26 14.08939(N)   079 49 54.57180(W) AD(       ) 3
HW3152  NAD 27      -  38 26 13.66570(N)   079 49 55.35309(W) AD(       ) 3
TV1290  PR          -  18 28 33.07855(N)   066 48 04.76640(W) AD(       ) 2
TU3368  OLD HI      -  21 12 45.75000(N)   156 58 20.86500(W) AD(       ) 3
RF0849  ELLIP HT    -       164.56   (m)           (04/19/96) GP(1995.00) 3 1
HV9260  ELLIP HT    -       131.19   (m)           (06/29/94) GP(       ) 4 1
HV0454  NGVD 29     -         1.266  (m)           4.15    (f) ADJUSTED    1 2
GW1440  NGVD 29     -       304.876  (m)        1000.25    (f) ADJ UNCH    2 0
AA4380  NGVD 29     -       175.86   (m)         577.0     (f) LEVELING    3
FE2754  NGVD 29     -        84.07   (m)         275.8     (f) N HEIGHT    3
FV1057  NGVD 29     -       564.37   (m)        1851.6     (f) RESET       3
CA0570  NGVD 29     -       545.10   (m)        1788.4     (f) COMPUTED    1 2
AA8531  NGVD 29     -        75.8    (m)         249.      (f) GPS OBS
UV2087  NGVD 29     -         6.8    (m)          22.      (f) VERT ANG
LX3119.No superseded survey control is available for this station.
```

***

DATA ITEM: U.S. NATIONAL GRID SPATIAL ADDRESS
DISPLAYED: When available.
COMMENTS : The U.S. National Grid System is an alpha-numeric reference system that overlays the UTM coordinate system. It is a Federal Geographic Data Committee (FGDC) standard developed to improve public safety, commerce, as well as aid the casual GPS user.
The USNG provides an easy to use geoaddress system for identifying and determining locations with the help of a USNG gridded map and/or a USNG enabled GPS system.

To learn how to read USNG coordinates see:
http://www.fgdc.gov/usng/how-to-read-usng/index_html
and follow the link "US National Grid (USNG)"
in the second paragraph.

For further information about the U.S. National Grid System, see the Federal Geographic Data Committee's Standard for the United States Nation Grid at:
http://www.fgdc.gov/usng
and select paper fgdc_std_011_2001_usng.pdf

EXAMPLES :____

```
KF0798_U.S. NATIONAL GRID SPATIAL ADDRESS: 14SPJ8660324404(NAD 83)
HV0454_U.S. NATIONAL GRID SPATIAL ADDRESS: 18SUH927451(NAD 83)
```

***

DATA ITEM: Mark Setting Information
DISPLAYED: When available.
COMMENTS : _ is used as an identifier for the data record.
+ is used as an identifier for a record continuation.

EXAMPLES :____

```
RF0849_MARKER: DH = HORIZONTAL CONTROL DISK
RF0849_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT (ROUND)
RF0849_STAMPING: CARIPORT 1985
RF0849_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
RF0849+STABILITY: SURFACE MOTION

RF0849_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
RF0849+SATELLITE: SATELLITE OBSERVATIONS - October 15, 1995

PU1648_SATELLITE: THE SITE LOCATION WAS REPORTED AS NOT SUITABLE FOR
PU1648+SATELLITE: SATELLITE OBSERVATIONS - August 19, 1991
```

```
                          ***
DATA ITEM: Recovery History Records
DISPLAYED: Always.
COMMENTS : Landmarks will say 'FIRST OBSERVERED' rather than 'MONUMENTED'
           The Month/Day are displayed if available.
           Refer to the bluebook for recovery agency acronyms.
EXAMPLES :________________________________________________________________
MC0588  HISTORY     - Date     Condition        Recov. By
MC0588  HISTORY     - 1943     MONUMENTED       CGS
MC0588  HISTORY     - 1968     GOOD             NGS
MC0588  HISTORY     - 1968     GOOD             CGS
MC0588  HISTORY     - 1984     MARK NOT FOUND   USPSQD
MC0588  HISTORY     - 19940826 GOOD             OH-063

                          ***
DATA ITEM: Description and Recovery text
DISPLAYED: When available.
COMMENTS : Displayed chronologically.  The description format has evolved
           through time.  The authoritative reference for descriptions is
           the NGS bluebook, chapter three.  A current format is as follows.
           The phrases "DESCRIBED BY... " and "RECOVERY BY..." are inserted
           by NGS during processing.
           The first paragraph gives the general location of the station and
           the landowner and/or the person to contact for station access.
           The second paragraph gives a "to-reach". The to-reach begins at a
           well-known location that will remain through time, such as the
           junction of state, federal or interstate highways.   Legs along the
           the route are given as right or left turn, compass direction
           followed, road name if any, distance traveled in kilometers (miles),
           and leg terminating feature. The to-reach ends with the phrase,
           "TO THE STATION ON THE RIGHT/LEFT."
           The third paragraph first details the survey mark that is observed,
           then the monument in which the mark is set, then ties are given
           FROM features in the vicinity of the station TO the station, with
           horizontal distances reported to the closest 0.1 m (0.1 ft).
           A vertical tie is encouraged to assist with recovery of stations
           that may become buried.
           A fourth paragraph may be added to include notes, such as
           obstructions to GPS visibility or hazards of station occupation.
EXAMPLES :________________________________________________________________
HU0680                          STATION DESCRIPTION
HU0680
HU0680 DESCRIBED BY COAST AND GEODETIC SURVEY 1942
HU0680 1.5 MI SE FROM SALEM.
HU0680 THIS MARK IS ABOUT 1.5 MILES SOUTHEAST OF THE JUNCTION WITH
HU0680 HIGHWAY U.S. 50 ALONG A GRAVEL ROAD FROM SALEM, DORCHESTER COUNTY,
HU0680 0.25 MILE NORTHEAST ALONG A DIRT ROAD TO THE FARM HOUSE, ABOUT
HU0680 100 FEET NORTH OF THE STATION, 20 FEET NORTHEAST OF THE NORTHEAST
HU0680 CORNER OF THE HOUSE, 1 FOOT WEST OF A WIRE FENCE ROW, AND IS A
HU0680 STANDARD REFERENCE DISK SET IN THE TOP OF A CONCRETE POST.
HU0680
HU0680                          STATION RECOVERY (1988)
HU0680
HU0680 RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1988
HU0680 THE MARK IS LOCATED ABOUT 1.9 KM (1.20 MI) SOUTH OF THE SMALL COMUNITY
HU0680 OF SALEM.  OWNERSHIP--EDGAR S. GORE, RD 1 BOX 85, VIENNA, MD. 21869.
HU0680 PHONE (301) 228-2862.
HU0680 TO REACH THE STATION FROM THE POST OFFICE IN LINKWOOD, GO SOUTHEAST ON
HU0680 U.S. HIGHWAY 50 FOR 3.55 KM (2.20 MI) TO A SIDE ROAD RIGHT.  TURN
HU0680 RIGHT AND GO SOUTHEAST ON SALEM ROAD FOR 0.85 KM (0.55 MI) TO A SIDE
HU0680 ROAD RIGHT.  TURN RIGHT AND GO SOUTH ON RAVENWOOD ROAD FOR 1.90 KM
HU0680 (1.20 MI) TO A SIDE ROAD LEFT.  TURN LEFT AND GO EAST ON A DIRT
HU0680 DRIVEWAY FOR 0.42 KM (0.25 MI) TO THE MARK ON THE LEFT.
HU0680 THE MARK IS A CGS TRIANGULATION DISK SET IN THE TOP OF A 0.3 M (1.0 FT)
HU0680 SQUARE CONCRETE POST PROJECTING 0.13 M (0.4 FT) ABOVE THE GROUND.  THE
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HU0680 STATION IS LOCATED 15.7 M (51.5 FT) SOUTHWEST FROM THE SOUTHWEST EDGE
HU0690 OF A CULTIVATED FIELD, 8.1 M (26.6 FT) SOUTH-SOUTHEAST FROM A 0.25 M
HU0690 (0.8 FT) CHERRY TREE, 7.7 M (25.3 FT) NORTHEAST FROM THE NORTHEAST
HU0690 CORNER OF A TWO STORY HOUSE AND 7.0 M (23.0 FT) NORTH FROM THE NORTH
HU0690 CORNER OF A BLOCK BUILDING.

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The NGS Data Sheet

See file dsdata.txt for more information about the datasheet.

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DATABASE =  ,PROGRAM = datasheet, VERSION = 7.85
1         National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0566 ***********************************************************************
 HT0566  DESIGNATION -  XX 109
 HT0566  PID         -  HT0566
 HT0566  STATE/COUNTY-  CA/SAN MATEO
 HT0566  USGS QUAD   -  SAN MATEO (1997)
 HT0566
 HT0566                         *CURRENT SURVEY CONTROL
 HT0566  ___________________________________________________________________
 HT0566* NAD 83(1986)-  37 34 19.     (N)    122 20 21.     (W)     SCALED
 HT0566* NAVD 88     -        15.10   (+/-2cm)      49.5    (feet)  VERTCON
 HT0566  ___________________________________________________________________
 HT0566  GEOID HEIGHT-         -32.59  (meters)                     GEOID09
 HT0566  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0566
 HT0566.The horizontal coordinates were scaled from a topographic map and have
 HT0566.an estimated accuracy of +/- 6 seconds.
 HT0566
 HT0566.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0566.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0566.The vertical order pertains to the NGVD 29 superseded value.
 HT0566
 HT0566.The geoid height was determined by GEOID09.
 HT0566
 HT0566;                    North         East    Units  Estimated Accuracy
 HT0566;SPC CA 3     -   620,560.    1,837,550.      MT  (+/- 180 meters Scaled)
 HT0566
 HT0566                          SUPERSEDED SURVEY CONTROL
 HT0566
 HT0566  NGVD 29 (??/??/92)   14.262  (m)           46.79   (f) ADJ UNCH    1 2
 HT0566
 HT0566.Superseded values are not recommended for survey control.
 HT0566.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0566.See file dsdata.txt to determine how the superseded data were derived.
 HT0566
 HT0566_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG583585(NAD 83)
 HT0566_MARKER: DB = BENCH MARK DISK
 HT0566_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT0566_SP_SET: CONCRETE BLOCK
 HT0566_STAMPING: XX 109 1932
 HT0566_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT0566
 HT0566  HISTORY     - Date     Condition        Report By
 HT0566  HISTORY     - 1932     MONUMENTED       CGS
 HT0566  HISTORY     - 1951     GOOD             NGS
 HT0566  HISTORY     - 1967     GOOD             NGS
 HT0566
 HT0566                          STATION DESCRIPTION
 HT0566
 HT0566'DESCRIBED BY NATIONAL GEODETIC SURVEY 1951
 HT0566'AT SAN MATEO.
 HT0566'AT SAN MATEO, IN A SMALL PARK IN A TRIANGLE FORMED BY THE
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 HT0566'JUNCTION OF U.S. HIGHWAY 101 (NORTH EL CAMINO REAL) AND CLARK
 HT0566'DRIVE, 81.9 FEET SOUTHWEST OF SOUTHWEST CURB OF EL CAMINO
 HT0566'REAL, 47.6 FEET EAST OF EAST CURB ON WESTERN LEG OF TRIANGLE, AT THE
 HT0566'APPROXIMATE CENTER OF THE NORTHEAST SIDE OF A SMALL TRIANGULAR CLUMP
 HT0566'OF BUSHES ABOUT 2 FEET HIGHER THAN THE HIGHWAY, IN TOP OF A
 HT0566'3-FOOT BY 3-FOOT CONCRETE BLOCK FLUSH WITH THE GROUND.
 HT0566
 HT0566                          STATION RECOVERY (1967)
 HT0566
 HT0566'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1967
 HT0566'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0558 ***********************************************************************
 HT0558  DESIGNATION -  W 109
 HT0558  PID         -  HT0558
 HT0558  STATE/COUNTY-  CA/SAN MATEO
 HT0558  USGS QUAD   -  SAN MATEO (1997)
 HT0558
 HT0558                         *CURRENT SURVEY CONTROL
 HT0558  ___________________________________________________________________
 HT0558* NAD 83(1986)-  37 34 39.     (N)    122 20 18.     (W)     SCALED
 HT0558* NAVD 88     -         9.83   (+/-2cm)       32.3    (feet)  VERTCON
 HT0558  ___________________________________________________________________
 HT0558  GEOID HEIGHT-         -32.59  (meters)                      GEOID09
 HT0558  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0558
 HT0558.The horizontal coordinates were scaled from a topographic map and have
 HT0558.an estimated accuracy of +/- 6 seconds.
 HT0558
 HT0558.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0558.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0558.The vertical order pertains to the NGVD 29 superseded value.
 HT0558
 HT0558.The geoid height was determined by GEOID09.
 HT0558
 HT0558;                      North         East     Units  Estimated Accuracy
 HT0558;SPC CA 3     -   621,180.    1,837,630.      MT  (+/- 180 meters Scaled)
 HT0558
 HT0558                          SUPERSEDED SURVEY CONTROL
 HT0558
 HT0558  NGVD 29 (??/??/92)    9.000  (m)           29.53    (f) ADJ UNCH    1 2
 HT0558
 HT0558.Superseded values are not recommended for survey control.
 HT0558.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0558.See file dsdata.txt to determine how the superseded data were derived.
 HT0558
 HT0558_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG584591(NAD 83)
 HT0558_MARKER: DB = BENCH MARK DISK
 HT0558_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
 HT0558_SP_SET: CONCRETE POST
 HT0558_STAMPING: W 109 1932
 HT0558_MARK LOGO: CGS
 HT0558_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
 HT0558+STABILITY: SURFACE MOTION
 HT0558
 HT0558  HISTORY     - Date     Condition        Report By
 HT0558  HISTORY     - 1932     MONUMENTED       CGS
 HT0558  HISTORY     - 1952     GOOD             NGS
 HT0558  HISTORY     - 1967     GOOD             NGS
 HT0558  HISTORY     - 1986     GOOD             NGS
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 HT0558
 HT0558                          STATION DESCRIPTION
 HT0558
 HT0558'DESCRIBED BY NATIONAL GEODETIC SURVEY 1952
 HT0558'0.4 MI SE FROM BURLINGAME.
 HT0558'0.4 MILE SOUTHEAST ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD
 HT0558'FROM THE STATION AT BURLINGAME, AT THE PENINSULAR AVENUE CROSSING,
 HT0558'76.7 FEET NORTHEAST OF THE NORTHEAST RAIL OF THE MAIN TRACK,
 HT0558'21.6 FEET SOUTHWEST OF THE WEST CORNER OF A WIRE FENCE AROUND
 HT0558'THE STANDARD OIL COMPANY YARD, 15.3 FEET SOUTHEAST OF THE
 HT0558'SOUTHEAST CURB OF THE AVENUE, 6 1/2 FEET NORTH OF A LARGE
 HT0558'EUCALYPTUS TREE, 1.3 FEET SOUTHWEST OF A WITNESS POST, ABOUT
 HT0558'LEVEL WITH THE TRACK, AND SET IN THE TOP OF A CONCRETE POST
 HT0558'PROJECTING 0.6 FOOT ABOVE THE GROUND.
 HT0558
 HT0558                          STATION RECOVERY (1967)
 HT0558
 HT0558'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1967
 HT0558'RECOVERED IN GOOD CONDITION.
 HT0558
 HT0558                          STATION RECOVERY (1986)
 HT0558
 HT0558'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0558'RECOVERED IN GOOD CONDITION. THE DESCRIPTION IS ADEQUATE EXCEPT ADD
 HT0558'2.0 METERS (6.5 FT) NORTHWEST OF A LARGE TRIPLE TRUNKED EUCALYPTUS
 HT0558'TREE.
 HT0558'THE MARK IS 0.3 METERS  NW FROM  A WITNESS POST
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0557 ***********************************************************************
 HT0557  DESIGNATION -  B 814
 HT0557  PID         -  HT0557
 HT0557  STATE/COUNTY-  CA/SAN MATEO
 HT0557  USGS QUAD   -  SAN MATEO (1997)
 HT0557
 HT0557                         *CURRENT SURVEY CONTROL
 HT0557  ___________________________________________________________________
 HT0557* NAD 83(1986)-  37 34 48.     (N)    122 20 42.     (W)     SCALED
 HT0557* NAVD 88     -        10.10   (+/-2cm)      33.1    (feet)  VERTCON
 HT0557  ___________________________________________________________________
 HT0557  GEOID HEIGHT-         -32.59  (meters)                     GEOID09
 HT0557  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0557
 HT0557.The horizontal coordinates were scaled from a topographic map and have
 HT0557.an estimated accuracy of +/- 6 seconds.
 HT0557
 HT0557.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0557.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0557.The vertical order pertains to the NGVD 29 superseded value.
 HT0557
 HT0557.The geoid height was determined by GEOID09.
 HT0557
 HT0557;                   North         East    Units  Estimated Accuracy
 HT0557;SPC CA 3     -   621,470.    1,837,050.      MT  (+/- 180 meters Scaled)
 HT0557
 HT0557                          SUPERSEDED SURVEY CONTROL
 HT0557
 HT0557  NGVD 29 (??/??/92)    9.266  (m)           30.40   (f) ADJ UNCH    1 2
 HT0557
 HT0557.Superseded values are not recommended for survey control.
 HT0557.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
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 HT0557.See file dsdata.txt to determine how the superseded data were derived.
 HT0557
 HT0557_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG578594(NAD 83)
 HT0557_MARKER: DB = BENCH MARK DISK
 HT0557_SETTING: 34 = SET IN THE FOOTINGS OF SMALL/MEDIUM STRUCTURES
 HT0557_SP_SET: RAILROAD DEPOT FOUNDATION
 HT0557_STAMPING: B 814 1952
 HT0557_MARK LOGO: CGS
 HT0557_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
 HT0557+STABILITY: SURFACE MOTION
 HT0557
 HT0557  HISTORY     - Date     Condition        Report By
 HT0557  HISTORY     - 1952     MONUMENTED       CGS
 HT0557  HISTORY     - 1956     GOOD             NGS
 HT0557  HISTORY     - 1965     GOOD             NGS
 HT0557  HISTORY     - 1986     GOOD             NGS
 HT0557
 HT0557                          STATION DESCRIPTION
 HT0557
 HT0557'DESCRIBED BY NATIONAL GEODETIC SURVEY 1956
 HT0557'AT BURLINGAME.
 HT0557'AT BURLINGAME, SET VERTICALLY IN THE NORTHEAST FACE OF THE
 HT0557'CONCRETE FOUNDATION OF THE SOUTHERN PACIFIC COMPANY RAILROAD
 HT0557'STATION, 47.6 FEET SOUTHWEST OF THE SOUTHWEST RAIL, 2.1 FEET
 HT0557'NORTHWEST OF THE EAST CORNER OF THE BUILDING, AND 0.3 FOOT ABOVE
 HT0557'THE SIDEWALK.
 HT0557
 HT0557                          STATION RECOVERY (1965)
 HT0557
 HT0557'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1965
 HT0557'RECOVERED IN GOOD CONDITION.
 HT0557
 HT0557                          STATION RECOVERY (1986)
 HT0557
 HT0557'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0557'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0556 ***********************************************************************
 HT0556  DESIGNATION -  VV 109
 HT0556  PID         -  HT0556
 HT0556  STATE/COUNTY-  CA/SAN MATEO
 HT0556  USGS QUAD   -  SAN MATEO (1997)
 HT0556
 HT0556                         *CURRENT SURVEY CONTROL
 HT0556  ___________________________________________________________________
 HT0556* NAD 83(1986)-  37 34 50.73   (N)    122 20 41.37   (W)     HD_HELD1
 HT0556* NAVD 88     -         9.39   (+/-2cm)      30.8    (feet)  VERTCON
 HT0556  ___________________________________________________________________
 HT0556  GEOID HEIGHT-        -32.59  (meters)                      GEOID09
 HT0556  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0556
 HT0556.The horizontal coordinates were established by differentially corrected
 HT0556.hand held GPS obs and have an estimated accuracy of +/- 3 meters.
 HT0556
 HT0556.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0556.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0556.The vertical order pertains to the NGVD 29 superseded value.
 HT0556
 HT0556.Photographs are available for this station.
 HT0556
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 HT0556.The geoid height was determined by GEOID09.
 HT0556
 HT0556;                     North         East     Units  Estimated Accuracy
 HT0556;SPC CA 3     -   621,549.2   1,837,067.8     MT  (+/- 3 meters HH1 GPS)
 HT0556
 HT0556                          SUPERSEDED SURVEY CONTROL
 HT0556
 HT0556  NGVD 29 (??/??/92)    8.565  (m)           28.10   (f) ADJ UNCH    1 2
 HT0556
 HT0556.Superseded values are not recommended for survey control.
 HT0556.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0556.See file dsdata.txt to determine how the superseded data were derived.
 HT0556
 HT0556_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG5784859502(NAD 83)
 HT0556_MARKER: DB = BENCH MARK DISK
 HT0556_SETTING: 35 = SET IN A MAT FOUNDATION OR CONCRETE SLAB OTHER THAN
 HT0556+WITH SETTING: PAVEMENT
 HT0556_SP_SET: FLAGPOLE BASE
 HT0556_STAMPING: VV 109 1932
 HT0556_MARK LOGO: CGS
 HT0556_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
 HT0556+STABILITY: SURFACE MOTION
 HT0556
 HT0556  HISTORY     - Date     Condition        Report By
 HT0556  HISTORY     - 1932     MONUMENTED       CGS
 HT0556  HISTORY     - 1952     GOOD             NGS
 HT0556  HISTORY     - 1965     GOOD             NGS
 HT0556  HISTORY     - 1986     GOOD             NGS
 HT0556  HISTORY     - 20090111 POOR             GEOCAC
 HT0556
 HT0556                          STATION DESCRIPTION
 HT0556
 HT0556'DESCRIBED BY NATIONAL GEODETIC SURVEY 1952
 HT0556'AT BURLINGAME.
 HT0556'AT BURLINGAME, AT WASHINGTON PARK, ABOUT 100 YARDS NORTH OF AND
 HT0556'ACROSS THE TRACKS FROM THE SOUTHERN PACIFIC COMPANY RAILROAD
 HT0556'STATION, IN THE TOP OF THE SOUTH CONCRETE BASE FOR A FLAGPOLE,
 HT0556'ABOUT 45 YARDS NORTHEAST OF THE APPROXIMATE CENTER OF THE
 HT0556'JUNCTION OF CAROLAN AND NORTH LANE AVENUES, 22.5 FEET SOUTHWEST
 HT0556'OF THE WEST CORNER OF A WIRE FENCE AROUND A TENNIS COURT, 17.3
 HT0556'FEET NORTH OF A STREET LIGHT, AND 1.6 FEET ABOVE THE GROUND.
 HT0556
 HT0556                          STATION RECOVERY (1965)
 HT0556
 HT0556'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1965
 HT0556'RECOVERED IN GOOD CONDITION.
 HT0556
 HT0556                          STATION RECOVERY (1986)
 HT0556
 HT0556'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0556'RECOVERED IN GOOD CONDITION.
 HT0556
 HT0556                          STATION RECOVERY (2009)
 HT0556
 HT0556'RECOVERY NOTE BY GEOCACHING 2009 (RM)
 HT0556'THE MARK'S SURFACE IS DAMAGED.  THE DISK'S STAMPING IS DIFFICULT TO
 HT0556'READ BUT IS
 HT0556'LEGIBLE.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0554 ***********************************************************************
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HT0554  DESIGNATION -  J 553
HT0554  PID         -  HT0554
HT0554  STATE/COUNTY-  CA/SAN MATEO
HT0554  USGS QUAD   -  SAN MATEO (1997)
HT0554
HT0554                         *CURRENT SURVEY CONTROL
HT0554  ___________________________________________________________________
HT0554* NAD 83(1986)-  37 35 20.     (N)    122 21 55.     (W)     SCALED
HT0554* NAVD 88     -         4.72   (+/-2cm)      15.5    (feet)  VERTCON
HT0554  ___________________________________________________________________
HT0554  GEOID HEIGHT-         -32.59  (meters)                     GEOID09
HT0554  VERT ORDER  -  FIRST     CLASS II (See Below)
HT0554
HT0554.The horizontal coordinates were scaled from a topographic map and have
HT0554.an estimated accuracy of +/- 6 seconds.
HT0554
HT0554.The NAVD 88 height was computed by applying the VERTCON shift value to
HT0554.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
HT0554.The vertical order pertains to the NGVD 29 superseded value.
HT0554
HT0554.The geoid height was determined by GEOID09.
HT0554
HT0554;                    North         East     Units  Estimated Accuracy
HT0554;SPC CA 3     -   622,490.    1,835,280.      MT  (+/- 180 meters Scaled)
HT0554
HT0554                          SUPERSEDED SURVEY CONTROL
HT0554
HT0554  NGVD 29 (??/??/92)    3.888  (m)           12.76   (f) ADJ UNCH    1 2
HT0554
HT0554.Superseded values are not recommended for survey control.
HT0554.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT0554.See file dsdata.txt to determine how the superseded data were derived.
HT0554
HT0554_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG560603(NAD 83)
HT0554_MARKER: DB = BENCH MARK DISK
HT0554_SETTING: 34 = SET IN THE FOOTINGS OF SMALL/MEDIUM STRUCTURES
HT0554_SP_SET: BUILDING FOUNDATION
HT0554_STAMPING: J 553 1956
HT0554_MARK LOGO: CGS
HT0554_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
HT0554+STABILITY: SURFACE MOTION
HT0554
HT0554  HISTORY     - Date     Condition        Report By
HT0554  HISTORY     - 1956     MONUMENTED       CGS
HT0554  HISTORY     - 1965     GOOD             NGS
HT0554  HISTORY     - 1986     GOOD             NGS
HT0554
HT0554                          STATION DESCRIPTION
HT0554
HT0554'DESCRIBED BY COAST AND GEODETIC SURVEY 1956
HT0554'AT BROADWAY.
HT0554'AT BROADWAY, 0.1 MILE NORTHWEST ALONG THE SOUTHERN PACIFIC
HT0554'COMPANY RAILROAD FROM THE STATION, 1.4 MILES SOUTHWEST OF
HT0554'MILLBRAE, AT THE WEST CORNER OF THE BUILDING OF THE AETNA
HT0554'MANUFACTURING COMPANY, IN THE TOP OF THE NORTHWEST SIDE OF A
HT0554'CONCRETE FOUNDATION FOR THE WEST CORNER OF THE BUILDING, 66.1
HT0554'FEET NORTHEAST OF THE NORTHEAST RAIL OF THE NORTHEAST MAIN TRACK,
HT0554'36 1/2 FEET EAST OF THE THIRD TELEPHONE POLE SOUTHEAST OF
HT0554'MILEPOST 15, 2.5 FEET ABOVE AN ASPHALT PARKING LOT, AND ABOUT
HT0554'1 FOOT HIGHER THAN THE TRACK.
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 HT0554
 HT0554                          STATION RECOVERY (1965)
 HT0554
 HT0554'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1965
 HT0554'RECOVERED IN GOOD CONDITION.
 HT0554
 HT0554                          STATION RECOVERY (1986)
 HT0554
 HT0554'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0554'RECOVERED IN GOOD CONDITION. THE DESCRIPTION IS ADEQUATE EXCEPT ADD IN
 HT0554'THE FIRST LARGE BUILDING NORTHWEST OF THE BEKINS STORAGE BUILDING.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0552 ***********************************************************************
 HT0552  DESIGNATION -  S 109
 HT0552  PID         -  HT0552
 HT0552  STATE/COUNTY-  CA/SAN MATEO
 HT0552  USGS QUAD   -  MONTARA MOUNTAIN (1997)
 HT0552
 HT0552                         *CURRENT SURVEY CONTROL
 HT0552  ___________________________________________________________________
 HT0552* NAD 83(1986)-  37 35 43.     (N)    122 22 50.     (W)     SCALED
 HT0552* NAVD 88     -         3.40   (+/-2cm)      11.2    (feet)  VERTCON
 HT0552  ___________________________________________________________________
 HT0552  GEOID HEIGHT-         -32.60  (meters)                     GEOID09
 HT0552  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0552
 HT0552.The horizontal coordinates were scaled from a topographic map and have
 HT0552.an estimated accuracy of +/- 6 seconds.
 HT0552
 HT0552.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0552.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0552.The vertical order pertains to the NGVD 29 superseded value.
 HT0552
 HT0552.The geoid height was determined by GEOID09.
 HT0552
 HT0552;                   North         East     Units  Estimated Accuracy
 HT0552;SPC CA 3     -   623,220.    1,833,950.      MT  (+/- 180 meters Scaled)
 HT0552
 HT0552                          SUPERSEDED SURVEY CONTROL
 HT0552
 HT0552  NGVD 29 (??/??/92)    2.567  (m)            8.42    (f) ADJ UNCH    1 2
 HT0552
 HT0552.Superseded values are not recommended for survey control.
 HT0552.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0552.See file dsdata.txt to determine how the superseded data were derived.
 HT0552
 HT0552_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG546610(NAD 83)
 HT0552_MARKER: DB = BENCH MARK DISK
 HT0552_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
 HT0552_SP_SET: SET IN TOP OF CONCRETE MONUMENT
 HT0552_STAMPING: S 109 1932
 HT0552_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
 HT0552+STABILITY: SURFACE MOTION
 HT0552
 HT0552  HISTORY     - Date     Condition        Report By
 HT0552  HISTORY     - 1932     MONUMENTED       CGS
 HT0552  HISTORY     - 1952     GOOD             NGS
 HT0552  HISTORY     - 1965     GOOD             NGS
 HT0552  HISTORY     - 1986     MARK NOT FOUND   NGS
 HT0552
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 HT0552                          STATION DESCRIPTION
 HT0552
 HT0552'DESCRIBED BY NATIONAL GEODETIC SURVEY 1952
 HT0552'0.4 MI SE FROM MILLBRAE.
 HT0552'0.4 MILE SOUTHEAST ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD
 HT0552'FROM THE STATION AT MILLBRAE, AT A DIRT ROAD CROSSING, 45.2 FEET
 HT0552'NORTHEAST OF THE NORTHEAST RAIL, 40 FEET NORTHWEST OF THE 3RD
 HT0552'TELEGRAPH LINE POLE SOUTHEAST OF MILEPOLE 14, 31.2 FEET SOUTH
 HT0552'OF A BOARD FENCE, 24 1/2 FEET EAST OF THE CENTER LINE OF THE
 HT0552'ROAD, 1.6 FEET WEST OF A WITNESS POST, ABOUT 1 1/2 FEET LOWER
 HT0552'THAN THE TRACK, AND SET IN THE TOP OF A CONCRETE POST PROJECTING
 HT0552'0.2 FOOT ABOVE THE GROUND.
 HT0552
 HT0552                          STATION RECOVERY (1965)
 HT0552
 HT0552'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1965
 HT0552'RECOVERED IN GOOD CONDITION.
 HT0552
 HT0552                          STATION RECOVERY (1986)
 HT0552
 HT0552'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0552'NOT RECOVERED.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0551 ***********************************************************************
 HT0551  DESIGNATION -  X 984 RESET
 HT0551  PID         -  HT0551
 HT0551  STATE/COUNTY-  CA/SAN MATEO
 HT0551  USGS QUAD   -  MONTARA MOUNTAIN (1997)
 HT0551
 HT0551                         *CURRENT SURVEY CONTROL
 HT0551  ___________________________________________________________________
 HT0551* NAD 83(1986)-  37 35 55.     (N)    122 23 06.     (W)     SCALED
 HT0551* NAVD 88     -         3.63   (+/-2cm)      11.9    (feet)  VERTCON
 HT0551  ___________________________________________________________________
 HT0551  GEOID HEIGHT-         -32.60  (meters)                     GEOID09
 HT0551  VERT ORDER  -  THIRD (See Below)
 HT0551
 HT0551.The horizontal coordinates were scaled from a topographic map and have
 HT0551.an estimated accuracy of +/- 6 seconds.
 HT0551
 HT0551.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0551.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0551.The vertical order pertains to the NGVD 29 superseded value.
 HT0551
 HT0551.The geoid height was determined by GEOID09.
 HT0551
 HT0551;                   North         East     Units  Estimated Accuracy
 HT0551;SPC CA 3     -   623,600.    1,833,560.      MT  (+/- 180 meters Scaled)
 HT0551
 HT0551                          SUPERSEDED SURVEY CONTROL
 HT0551
 HT0551  NGVD 29 (??/??/??)    2.79   (m)            9.2    (f) RESET       3
 HT0551
 HT0551.Superseded values are not recommended for survey control.
 HT0551.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0551.See file dsdata.txt to determine how the superseded data were derived.
 HT0551
 HT0551_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG542614(NAD 83)
 HT0551_MARKER: DB = BENCH MARK DISK
 HT0551_SETTING: 30 = SET IN A LIGHT STRUCTURE
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 HT0551_SP_SET: CONCRETE MANHOLE BOX
 HT0551_STAMPING: X 984 RESET 1969
 HT0551_MARK LOGO: CGS
 HT0551_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 HT0551
 HT0551  HISTORY     - Date     Condition        Report By
 HT0551  HISTORY     - 1969     MONUMENTED       CGS
 HT0551  HISTORY     - 1983     GOOD             USGS
 HT0551  HISTORY     - 1986     GOOD             NGS
 HT0551
 HT0551                          STATION DESCRIPTION
 HT0551
 HT0551'DESCRIBED BY COAST AND GEODETIC SURVEY 1969
 HT0551'AT MILLBRAE.
 HT0551'AT MILLBRAE, ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD, 0.1
 HT0551'MILE SOUTHEAST OF THE STATION, AT A POWERLINE CROSSING, SET IN
 HT0551'THE TOP OF A 6 X 14-FOOT CONCRETE BOX, 49.2 FEET SOUTHWEST OF
 HT0551'A GUYED POWERLINE POLE AT THE CENTER OF THE POWERLINE CROSSING,
 HT0551'13.0 FEET NORTHEAST OF THE NORTHEAST RAIL OF THE NORTHWEST-BOUND
 HT0551'TRACK, 11.7 FEET NORTHWEST OF THE EXTENDED CENTERLINE OF
 HT0551'MURCHISON DRIVE, 2.8 FEET WEST OF THE CENTER OF A 28-INCH
 HT0551'MANHOLE, 0.7 FOOT EAST OF THE WEST CORNER OF THE CONCRETE BOX,
 HT0551'AND ABOUT 2 FEET LOWER THAN THE TRACK.
 HT0551
 HT0551                          STATION RECOVERY (1983)
 HT0551
 HT0551'RECOVERY NOTE BY US GEOLOGICAL SURVEY 1983
 HT0551'RECOVERED IN GOOD CONDITION.
 HT0551
 HT0551                          STATION RECOVERY (1986)
 HT0551
 HT0551'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0551'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT2430 ***********************************************************************
 HT2430  SACS        -  This is a Secondary Airport Control Station.
 HT2430  DESIGNATION -  X 1383
 HT2430  PID         -  HT2430
 HT2430  STATE/COUNTY-  CA/SAN MATEO
 HT2430  USGS QUAD   -  SAN MATEO (1997)
 HT2430
 HT2430                         *CURRENT SURVEY CONTROL
 HT2430  ___________________________________________________________________
 HT2430* NAD 83(2007)-  37 36 42.84271(N)    122 22 32.93442(W)     ADJUSTED
 HT2430* NAVD 88     -         1.84   (meters)       6.0    (feet)  GPS OBS
 HT2430  ___________________________________________________________________
 HT2430  EPOCH DATE  -       2007.00
 HT2430  X           -  -2,708,842.844 (meters)                     COMP
 HT2430  Y           -  -4,272,438.470 (meters)                     COMP
 HT2430  Z           -   3,871,391.091 (meters)                     COMP
 HT2430  LAPLACE CORR-           0.59  (seconds)                    DEFLEC09
 HT2430  ELLIP HEIGHT-         -30.788 (meters)         (02/10/07) ADJUSTED
 HT2430  GEOID HEIGHT-         -32.60  (meters)                     GEOID09
 HT2430
 HT2430  ------- Accuracy Estimates (at 95% Confidence Level in cm) --------
 HT2430  Type    PID    Designation                      North   East  Ellip
 HT2430  -------------------------------------------------------------------
 HT2430  NETWORK HT2430 X 1383                            0.53   0.74   3.10
 HT2430  -------------------------------------------------------------------
 HT2430
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HT2430.This mark is at San Francisco Intl Airport (SFO)
HT2430
HT2430.The horizontal coordinates were established by GPS observations
HT2430.and adjusted by the National Geodetic Survey in February 2007.
HT2430
HT2430.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
HT2430.See National Readjustment for more information.
HT2430.The horizontal coordinates are valid at the epoch date displayed above.
HT2430.The epoch date for horizontal control is a decimal equivalence
HT2430.of Year/Month/Day.
HT2430
HT2430.The orthometric height was determined by GPS observations and a
HT2430.high-resolution geoid model.
HT2430
HT2430.GPS derived orthometric heights for airport stations designated as
HT2430.PACS or SACS are published to 2 decimal places.  This maintains
HT2430.centimeter relative accuracy between the PACS and SACS.  It does
HT2430.not indicate centimeter accuracy relative to other marks which are
HT2430.part of the NAVD 88 network.
HT2430
HT2430.The X, Y, and Z were computed from the position and the ellipsoidal ht.
HT2430
HT2430.The Laplace correction was computed from DEFLEC09 derived deflections.
HT2430
HT2430.The ellipsoidal height was determined by GPS observations
HT2430.and is referenced to NAD 83.
HT2430
HT2430.The geoid height was determined by GEOID09.
HT2430
HT2430;                   North         East     Units Scale Factor Converg.
HT2430;SPC CA 3     -   625,059.178 1,834,400.390   MT  0.99993211   -1 08 54.4
HT2430;SPC CA 3     - 2,050,714.99  6,018,361.95   sFT  0.99993211   -1 08 54.4
HT2430;UTM  10      - 4,162,939.168   555,089.591   MT  0.99963738   +0 22 51.4
HT2430
HT2430!             -  Elev Factor  x  Scale Factor =   Combined Factor
HT2430!SPC CA 3     -   1.00000483  x   0.99993211  =   0.99993694
HT2430!UTM  10      -   1.00000483  x   0.99963738  =   0.99964221
HT2430
HT2430                          SUPERSEDED SURVEY CONTROL
HT2430
HT2430  NAD 83(1998)-  37 36 42.83405(N)    122 22 32.92625(W) AD(1998.50) 1
HT2430  ELLIP H (05/31/01)  -30.770  (m)                       GP(1998.50) 2 1
HT2430  NAD 83(1992)-  37 36 42.82728(N)    122 22 32.92011(W) AD(1991.35) 3
HT2430  NAD 83(1992)-  37 36 42.82738(N)    122 22 32.92013(W) AD(1991.35) 3
HT2430  ELLIP H (11/17/92)  -30.651  (m)                       GP(1991.35) 5 1
HT2430  NAD 83(1986)-  37 36 42.82510(N)    122 22 32.91626(W) AD(1984.00) 3
HT2430  NGVD 29 (10/13/92)    1.02   (m)            3.3    (f) LEVELING    3
HT2430
HT2430.Superseded values are not recommended for survey control.
HT2430.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT2430.See file dsdata.txt to determine how the superseded data were derived.
HT2430
HT2430_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG5508962939(NAD 83)
HT2430_MARKER: I = METAL ROD
HT2430_SETTING: 49 = STAINLESS STEEL ROD W/O SLEEVE (10 FT.+)
HT2430_SP_SET: STAINLESS STEEL ROD
HT2430_STAMPING: X 1383 1986
HT2430_MARK LOGO: NGS
HT2430_PROJECTION: PROJECTING 1 CENTIMETERS
HT2430_MAGNETIC: N = NO MAGNETIC MATERIAL
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HT2430_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
HT2430_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
HT2430+SATELLITE: SATELLITE OBSERVATIONS - January 29, 2002
HT2430_ROD/PIPE-DEPTH: 19.5 meters
HT2430
HT2430  HISTORY     - Date     Condition        Report By
HT2430  HISTORY     - 1986     MONUMENTED       NGS
HT2430  HISTORY     - 19920618 GOOD             NGS
HT2430  HISTORY     - 20001205 GOOD             NGS
HT2430  HISTORY     - 20020129 GOOD             NGS
HT2430
HT2430                          STATION DESCRIPTION
HT2430
HT2430'DESCRIBED BY NATIONAL GEODETIC SURVEY 1986
HT2430'IN SAN FRANCISCO INTL AIRPORT.
HT2430'THE MARK IS ABOVE LEVEL WITH THE ASPHALT.
HT2430'IN SAN FRANCISCO INTERNATIONAL AIRPORT, ABOUT 1.0 KM (0.6 MI)
HT2430'EAST-SOUTHEAST OF THE CENTER OF THE MAIN TERMINAL PARKING GARAGE, SET
HT2430'THROUGH THE ASPHALT AND NEAR THE CENTER OF THE ASPHALT TRIANGLE
HT2430'INTERSECTION OF TAXIWAY L AND G, 32.6 METERS (107 FT) WEST-NORTHWEST
HT2430'OF THE CENTERLINE OF TAXIWAY L, 3.7 METERS (12.0 FT) EAST-SOUTHEAST OF
HT2430'THE EXTENDED CENTERLINE OF TAXIWAY G, 4.0 METERS (13.0 FT) SOUTHEAST
HT2430'OF THE SOUTH CORNER OF A 4- BY 4-FOOT CATCH BASIN.  NOTE--ACCESS TO
HT2430'DATUM POINT IS HAD THROUGH A 5-INCH LOGO CAP.
HT2430
HT2430                          STATION RECOVERY (1992)
HT2430
HT2430'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1992
HT2430'CALL AT LEAST A WEEK IN ADVANCE TO MAKE ARRANGEMENTS TO BE ESCORTED TO
HT2430'STATION.  NEW FAA SECURITY REQUIREMENTS MAY SPECIFY BADGES, TRUCK TAG
HT2430'NUMBERS, PERSONNEL NAME AND IDENTIFICATION.  EAR PROTECTION IS
HT2430'SUGGESTED.
HT2430'STATION IS LOCATED AT THE SAN FRANCISCO INTERNATIONAL AIRPORT, ABOUT 1
HT2430'KM (0.6 MI) EAST-SOUTHEAST OF THE CONTROL TOWER, IN A PAVED
HT2430'TRIANGULAR-SHAPED PLOT BORDERED BY L TAXI, G TAXI NORTH, AND G TAXI
HT2430'SOUTH.  OWNERSHIP--CITY AND COUNTY OF SAN FRANCISCO, SAN FRANCISCO
HT2430'AIRPORT COMMISSION. SAN FRANCISCO, CA 94102.  CONTACT GLEN BROTMAN,
HT2430'AIRFIELD OPERATIONS, PHONE 415-876-2223 FOR ACCESS.  CHIEF AIRPORT
HT2430'SURVEYOR RAYMOND MASON, PHONE 415-737-7765, IS FAMILIAR WITH THE
HT2430'STATION SITE.
HT2430'STATION MARK IS A PUNCH HOLE TOP CENTER ON A STEEL ROD ENCASED IN A
HT2430'PVC PIPE WITH LOGO CAP PROJECTING 2 CM.  IT IS 1.2 PACE SOUTHWEST OF
HT2430'A FIBERGLASS WITNESS POST, 4 PACES SOUTHEAST OF THE SOUTHEAST CORNER
HT2430'OF A CATCH BASIN, 23 PACES WEST OF THE WEST EDGE OF L TAXI, 34 PACES
HT2430'SOUTHEAST OF THE EDGE OF G TAXI NORTH, AND 30 PACES NORTHEAST OF THE
HT2430'EDGE OF G TAXI SOUTH.
HT2430'DESCRIBED BY G.R.HEID
HT2430
HT2430                          STATION RECOVERY (2000)
HT2430
HT2430'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 2000 (BW)
HT2430'THIS STATION IS DESIGNATED AS A SENONDARY AIRPORT CONTROL
HT2430'STATION (SACS).
HT2430'
HT2430'THE STATION IS LOCATED AT THE SAN FRANCISCO INTERNATIONAL AIRPORT
HT2430'IN A TRIANGULAR CONCRETE ISLAND SOUTHEAST OF RUNWAY 1R-19L,
HT2430'BORDERED BY TAXIWAYS L TO THE SOUTHEAST, TAXIWAY G-NORTH, ON THE
HT2430'NORTH, AND G-SOUTH TO THE SOUTH.
HT2430'
HT2430'OWNERSHIP--THE CITY AND COUNTY OS SAN FRANCISCO, SAN FRANCISCO
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 HT2430'AIRPORT COMMISSION, SAN FRANCISCO CA 94102.
 HT2430'FOR ACCESS--CONTACT--AIRFIELD OPERATIONS--GLEN BROTMAN,
 HT2430'PHONE-650-794-3349.  CHIEF AIRPORT SURVEYOR--HUGO TUPAC,
 HT2430'PHONE--650-821-7770, FAX--650-635-2246.  FAA FACILITIES MANAGER--PAUL
 HT2430'CANDELARIE, PHONE--650-876-2839.
 HT2430'
 HT2430'NOTE--CONTACT THE AIRPORT A MINIMUM OF ONE WEEK IN ADVANCE TO
 HT2430'MAKE ARRANGEMENTS FOR AN ESCORT.  BADGES AND VEHICLE PASSES ARE
 HT2430'REQUIRED.   ESCORT BY AN AIRPORT SAFETY OFFICIAL IS MANDITORY WHILE
 HT2430'WORKING AROUND RUNWAYS.  AIRPORT SURVEY PERSONNEL CAN ESCORT
 HT2430'YOU TO ALL STATION ON THE AIRPORT.  EAR PROTECTION IS HIGHLY
 HT2430'ADVISED.
 HT2430'
 HT2430'TO REACH THE STATION FROM THE OVERPASS OF HIGHWAY 101 NORTH AND
 HT2430'MILLBRAE AVENUE.  TAKE THE MILLBRAE EXIT EAST ON MILLBRAE AVENUE
 HT2430'OFF OF HIGHWAY 101 NORTH AND GO 0.3 MILE TO SOUTH MCDANALD
 HT2430'AVENUE.  TURN LEFT, WEST, ONTO SOUTH MCDONALD AVENUE AND
 HT2430'CONTINUE FOR 0.02 MILES TO MILLBRAE GATE.  THERE IS A CALL BOX AT THE
 HT2430'GATE TO CONTACT AIRPORT AUTHORITIES TO OPEN THE GATE AND
 HT2430'PROVIDE ESCORT.  ADVANCED ARRANGEMENTS CAN BE MADE FOR AIRPORT
 HT2430'PERSONNEL TO MEET YOU AT THE GATE AT SPECIFIC TIMES AND ESCORT
 HT2430'YOU ON THE AIRPORT.  PASS THROUGH THE GATE ON ACCESS ROAD (OLD
 HT2430'BAYSHORE ROAD)  AND CONTINUE NORTHWEST FOR 0.05 MILES TO THE
 HT2430'AIRPORT SERVICE ROAD, TURNING RIGHT, NORTHEAST, ON THE SERVICE
 HT2430'ROAD FOR 0.5 MILES TO THE STATION ON THE LEFT.
 HT2430'
 HT2430'THE STATION IS IN THE CENTER OF THE CONCRETE ISLAND, 4 M (13.12 FT)
 HT2430'SOUTHEAST OF THE SOUTHEAST CORNER OF A CATCH BASIN, 22 M (72.18 FT)
 HT2430'WEST OF THE WEST EDGE OF TAXIWAY L, 33 M (108.27 FT) SOUTHEAST OF
 HT2430'THE SOUTHEAST EDGE OF TAXIWAY G-NORTH, 29 M NORTHEAST OF THE
 HT2430'NORTHEAST EDGE OF TAXIWAY G-SOUTH.
 HT2430'
 HT2430'NOTE--SANDBAGS ARE HIGHLY RECOMMENDED FOR ANY TROPOD SETUP
 HT2430'DUE TO CONCRETE BASE AND AIRCRAFT TURBULANCE.
 HT2430'
 HT2430
 HT2430                          STATION RECOVERY (2002)
 HT2430
 HT2430'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 2002 (DAH)
 HT2430'RECOVERED AS DESCRIBED
 HT2430'
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0548 ***********************************************************************
 HT0548  DESIGNATION -  Z 813
 HT0548  PID         -  HT0548
 HT0548  STATE/COUNTY-  CA/SAN MATEO
 HT0548  USGS QUAD   -  MONTARA MOUNTAIN (1997)
 HT0548
 HT0548                         *CURRENT SURVEY CONTROL
 HT0548  ___________________________________________________________________
 HT0548* NAD 83(1986)-  37 36 48.     (N)    122 23 59.     (W)     SCALED
 HT0548* NAVD 88     -         2.56   (+/-2cm)       8.4    (feet)  VERTCON
 HT0548  ___________________________________________________________________
 HT0548  GEOID HEIGHT-        -32.62  (meters)                      GEOID09
 HT0548  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0548
 HT0548.The horizontal coordinates were scaled from a topographic map and have
 HT0548.an estimated accuracy of +/- 6 seconds.
 HT0548
 HT0548.The NAVD 88 height was computed by applying the VERTCON shift value to
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 HT0548.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0548.The vertical order pertains to the NGVD 29 superseded value.
 HT0548
 HT0548.The geoid height was determined by GEOID09.
 HT0548
 HT0548;                    North         East     Units  Estimated Accuracy
 HT0548;SPC CA 3     -   625,260.    1,832,290.      MT  (+/- 180 meters Scaled)
 HT0548
 HT0548                          SUPERSEDED SURVEY CONTROL
 HT0548
 HT0548  NGVD 29 (??/??/92)    1.718  (m)           5.64   (f) ADJ UNCH    1 2
 HT0548
 HT0548.Superseded values are not recommended for survey control.
 HT0548.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0548.See file dsdata.txt to determine how the superseded data were derived.
 HT0548
 HT0548_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG529630(NAD 83)
 HT0548_MARKER: DB = BENCH MARK DISK
 HT0548_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT0548_SP_SET: CULVERT
 HT0548_STAMPING: Z 813 1952
 HT0548_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT0548
 HT0548  HISTORY     - Date     Condition        Report By
 HT0548  HISTORY     - 1952     MONUMENTED       CGS
 HT0548  HISTORY     - 1956     GOOD             NGS
 HT0548  HISTORY     - 1965     GOOD             NGS
 HT0548  HISTORY     - 1986     MARK NOT FOUND   NGS
 HT0548
 HT0548                          STATION DESCRIPTION
 HT0548
 HT0548'DESCRIBED BY NATIONAL GEODETIC SURVEY 1956
 HT0548'1.1 MI NW FROM MILLBRAE.
 HT0548'1.1 MILES NORTHWEST ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD
 HT0548'FROM THE STATION AT MILLBRAE, 1.4 MILES SOUTHEAST OF THE
 HT0548'STATION AT SAN BRUNO, ABOUT 0.2 MILE NORTHWEST FROM THE CROSSING
 HT0548'OF CENTER STREET, AT 16-INCH IRON PIPE CULVERT NO. 12.52, IN
 HT0548'THE TOP OF THE NORTHWEST END OF THE SOUTHWEST CONCRETE HEAD
 HT0548'WALL, 19.4 FEET SOUTHWEST OF THE SOUTHWEST RAIL OF THE SOUTHWEST
 HT0548'MAIN TRACK, AND ABOUT 6 FEET LOWER THAN THE TRACK.
 HT0548
 HT0548                          STATION RECOVERY (1965)
 HT0548
 HT0548'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1965
 HT0548'RECOVERED IN GOOD CONDITION.
 HT0548
 HT0548                          STATION RECOVERY (1986)
 HT0548
 HT0548'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0548'NOT RECOVERED.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0547 ***********************************************************************
 HT0547  DESIGNATION -  Y 813
 HT0547  PID         -  HT0547
 HT0547  STATE/COUNTY-  CA/SAN MATEO
 HT0547  USGS QUAD   -  MONTARA MOUNTAIN (1997)
 HT0547
 HT0547                         *CURRENT SURVEY CONTROL
 HT0547  ___________________________________________________________________
 HT0547* NAD 83(1986)-  37 37 08.     (N)    122 24 15.     (W)     SCALED
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HT0547* NAVD 88     -         3.97   (+/-2cm)      13.0    (feet)  VERTCON
HT0547  __________________________________________________________________
HT0547  GEOID HEIGHT-         -32.62  (meters)                     GEOID09
HT0547  VERT ORDER  -  FIRST     CLASS II (See Below)
HT0547
HT0547.The horizontal coordinates were scaled from a topographic map and have
HT0547.an estimated accuracy of +/- 6 seconds.
HT0547
HT0547.The NAVD 88 height was computed by applying the VERTCON shift value to
HT0547.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
HT0547.The vertical order pertains to the NGVD 29 superseded value.
HT0547
HT0547.The geoid height was determined by GEOID09.
HT0547
HT0547;                    North         East    Units  Estimated Accuracy
HT0547;SPC CA 3     -   625,890.    1,831,910.      MT  (+/- 180 meters Scaled)
HT0547
HT0547                          SUPERSEDED SURVEY CONTROL
HT0547
HT0547  NGVD 29 (??/??/92)    3.126  (m)           10.26   (f) ADJ UNCH    1 2
HT0547
HT0547.Superseded values are not recommended for survey control.
HT0547.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT0547.See file dsdata.txt to determine how the superseded data were derived.
HT0547
HT0547_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG525636(NAD 83)
HT0547_MARKER: DB = BENCH MARK DISK
HT0547_SETTING: 32 = SET IN A RETAINING WALL OR CONCRETE LEDGE
HT0547_SP_SET: CULVERT HEADWALL
HT0547_STAMPING: Y 813 1952
HT0547_MARK LOGO: CGS
HT0547_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
HT0547+STABILITY: SURFACE MOTION
HT0547_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
HT0547+SATELLITE: SATELLITE OBSERVATIONS - October 31, 2004
HT0547
HT0547  HISTORY     - Date     Condition        Report By
HT0547  HISTORY     - 1952     MONUMENTED       CGS
HT0547  HISTORY     - 1964     GOOD             NGS
HT0547  HISTORY     - 1986     GOOD             NGS
HT0547  HISTORY     - 20041031 GOOD             SMCSS
HT0547  HISTORY     - 20061220 MARK NOT FOUND   CONDOR
HT0547
HT0547                          STATION DESCRIPTION
HT0547
HT0547'DESCRIBED BY NATIONAL GEODETIC SURVEY 1964
HT0547'1 MI SE FROM SAN BRUNO.
HT0547'0.95 MILES SOUTHEAST ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD
HT0547'FROM THE STATION AT SAN BRUNO, 6 RAILS NORTHWEST ALONG THE
HT0547'RAILROAD FROM THE LOMITA PARK PASSENGER STOP, IN THE TOP OF
HT0547'THE SOUTHEAST END OF THE SOUTHWEST CONCRETE HEAD WALL OF TWIN
HT0547'36-INCH CORRUGATED METAL PIPE CULVERT 11.94, 18.1 FEET SOUTHWEST
HT0547'OF THE SOUTHWEST RAIL OF THE SOUTHWEST MAIN TRACK, AND ABOUT 2
HT0547'FEET LOWER THAN THE TRACK.
HT0547
HT0547                          STATION RECOVERY (1986)
HT0547
HT0547'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
HT0547'RECOVERED IN GOOD CONDITION. THE DESCRIPTION IS ADEQUATE EXCEPT ADD
HT0547'NEAR THE EAST END OF SAN FELIPE AVENUE.
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 HT0547
 HT0547                          STATION RECOVERY (2004)
 HT0547
 HT0547'RECOVERY NOTE BY SMITH AND COMPANY SURVEYING SRV INC 2004 (MW)
 HT0547'RECOVERED IN GOOD CONDITION.
 HT0547
 HT0547                          STATION RECOVERY (2006)
 HT0547
 HT0547'RECOVERY NOTE BY CONDOR TECHNOLOGIES 2006 (DLS)
 HT0547'DESTROYED- SOMEBODY POPPED THAT DISK RIGHT OFF THE HEADWALL- LEFT THE
 HT0547'IMPRINT IN THE CONCRETE
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0541 ***********************************************************************
 HT0541  DESIGNATION -  35
 HT0541  PID         -  HT0541
 HT0541  STATE/COUNTY-  CA/SAN MATEO
 HT0541  USGS QUAD   -  SAN MATEO (1997)
 HT0541
 HT0541                         *CURRENT SURVEY CONTROL
 HT0541  ___________________________________________________________________
 HT0541* NAD 83(1986)-  37 37 09.     (N)    122 22 23.     (W)     SCALED
 HT0541* NAVD 88     -         2.62   (+/-2cm)       8.6    (feet)  VERTCON
 HT0541  ___________________________________________________________________
 HT0541  GEOID HEIGHT-         -32.60  (meters)                     GEOID09
 HT0541  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0541
 HT0541.This mark is at San Francisco Intl Airport (SFO)
 HT0541
 HT0541.The horizontal coordinates were scaled from a topographic map and have
 HT0541.an estimated accuracy of +/- 6 seconds.
 HT0541
 HT0541.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0541.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0541.The vertical order pertains to the NGVD 29 superseded value.
 HT0541
 HT0541.The geoid height was determined by GEOID09.
 HT0541
 HT0541;                   North         East     Units  Estimated Accuracy
 HT0541;SPC CA 3     -   625,860.    1,834,660.      MT  (+/- 180 meters Scaled)
 HT0541
 HT0541                          SUPERSEDED SURVEY CONTROL
 HT0541
 HT0541  NGVD 29 (??/??/92)    1.787  (m)            5.86   (f) ADJ UNCH    1 2
 HT0541
 HT0541.Superseded values are not recommended for survey control.
 HT0541.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0541.See file dsdata.txt to determine how the superseded data were derived.
 HT0541
 HT0541_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG553637(NAD 83)
 HT0541_MARKER: Z = SEE DESCRIPTION
 HT0541_SETTING: 45 = UNSPECIFIED DEEP UNSLEEVED SETTING (10 FT.+)
 HT0541_SP_SET: 60 FT IRON PIPE
 HT0541_MARK LOGO: USE
 HT0541_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 HT0541
 HT0541  HISTORY     - Date     Condition        Report By
 HT0541  HISTORY     - 1956     MONUMENTED       DOD
 HT0541  HISTORY     - 1972     GOOD             NGS
 HT0541  HISTORY     - 1977     GOOD             NGS
 HT0541  HISTORY     - 1986     GOOD             NGS
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 HT0541
 HT0541                          STATION DESCRIPTION
 HT0541
 HT0541'DESCRIBED BY US DEPARTMENT OF DEFENSE 1956
 HT0541'AT SAN FRANCISCO AIRPORT.
 HT0541'AT THE SAN FRANCISCO INTERNATIONAL AIRPORT, ABOUT 0.5 MILE
 HT0541'NORTHEAST OF THE NEW TERMINAL BUILDING, AT THE CROSSING AND
 HT0541'ON THE WEST EDGE OF RUNWAY 19-L 1-R, BETWEEN RUNWAYS 28 R 10 L
 HT0541'AND 28 L 10 R, 294 FEET NORTH OF THE NORTH EDGE OF RUNWAY
 HT0541'28 L 10 R, 250 FEET EAST OF THE T.V.O.R BUILDING (C.A.A.), 219
 HT0541'FEET SOUTH OF THE SOUTH EDGE OF RUNWAY 28 R 10 L, 24.1 FEET
 HT0541'NORTHEAST OF RUNWAY LIGHT NO. D 57, AND ABOUT 1 1/2 FEET LOWER
 HT0541'THAN THE RUNWAY.  NOTE-- THE TOP OF A 1-INCH IRON PIPE DROVE
 HT0541'60-FEET INTO THE GROUND, ACCESS TO WHICH IS HAD THROUGH AN
 HT0541'8-INCH CLAY PIPE WITH A CONCRETE LID.
 HT0541
 HT0541                          STATION RECOVERY (1972)
 HT0541
 HT0541'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1972
 HT0541'RECOVERED IN GOOD CONDITION.
 HT0541
 HT0541                          STATION RECOVERY (1977)
 HT0541
 HT0541'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1977
 HT0541'RECOVERED IN GOOD CONDITION.
 HT0541
 HT0541                          STATION RECOVERY (1986)
 HT0541
 HT0541'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0541'RECOVERED IN GOOD CONDITION EXCEPT THAT THE MARK IS THE TOP OF THE
 HT0541'1-INCH IRON PIPE.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0540 ***********************************************************************
 HT0540  DESIGNATION -  34
 HT0540  PID         -  HT0540
 HT0540  STATE/COUNTY-  CA/SAN MATEO
 HT0540  USGS QUAD   -  MONTARA MOUNTAIN (1997)
 HT0540
 HT0540                         *CURRENT SURVEY CONTROL
 HT0540  ___________________________________________________________________
 HT0540* NAD 83(1986)-  37 37 16.     (N)    122 22 39.     (W)     SCALED
 HT0540* NAVD 88     -         2.07   (+/-2cm)       6.8    (feet)  VERTCON
 HT0540  ___________________________________________________________________
 HT0540  GEOID HEIGHT-        -32.61  (meters)                      GEOID09
 HT0540  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0540
 HT0540.This mark is at San Francisco Intl Airport (SFO)
 HT0540
 HT0540.The horizontal coordinates were scaled from a topographic map and have
 HT0540.an estimated accuracy of +/- 6 seconds.
 HT0540
 HT0540.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0540.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0540.The vertical order pertains to the NGVD 29 superseded value.
 HT0540
 HT0540.The geoid height was determined by GEOID09.
 HT0540
 HT0540;                   North         East    Units  Estimated Accuracy
 HT0540;SPC CA 3     -   626,080.    1,834,270.      MT  (+/- 180 meters Scaled)
 HT0540
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HT0540                          SUPERSEDED SURVEY CONTROL
HT0540
HT0540  NGVD 29 (??/??/92)    1.242  (m)            4.07   (f) ADJ UNCH    1 2
HT0540
HT0540.Superseded values are not recommended for survey control.
HT0540.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT0540.See file dsdata.txt to determine how the superseded data were derived.
HT0540
HT0540_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG549639(NAD 83)
HT0540_MARKER: Z = SEE DESCRIPTION
HT0540_SETTING: 45 = UNSPECIFIED DEEP UNSLEEVED SETTING (10 FT.+)
HT0540_SP_SET: 60 FT IRON PIPE
HT0540_MARK LOGO: USE
HT0540_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
HT0540
HT0540  HISTORY     - Date     Condition        Report By
HT0540  HISTORY     - UNK      MONUMENTED       DOD
HT0540  HISTORY     - 1956     GOOD             NGS
HT0540  HISTORY     - 1977     GOOD             NGS
HT0540  HISTORY     - 1986     GOOD             NGS
HT0540
HT0540                          STATION DESCRIPTION
HT0540
HT0540'DESCRIBED BY NATIONAL GEODETIC SURVEY 1956
HT0540'AT SAN FRANCISCO AIRPORT.
HT0540'AT THE SAN FRANCISCO INTERNATIONAL AIRPORT, 0.3 MILE NORTHEAST
HT0540'ACROSS COUNTRY FROM THE NEW TERMINAL BUILDING, AT THE CROSSING
HT0540'OF TAXIWAY NO. 3, BETWEEN RUNWAYS 10L AND 10R, 285 FEET NORTHEAST
HT0540'OF THE NORTHEAST EDGE OF RUNWAY 10R, 213 FEET SOUTHWEST OF THE
HT0540'SOUTHWEST EDGE OF RUNWAY 10L, 91 FEET NORTHWEST OF THE NORTHWEST
HT0540'EDGE OF THE TAXIWAY, 5.5 FEET SOUTHWEST OF A BLACK AND YELLOW
HT0540'STRIPPED 4- BY 4-INCH POST, ABOUT 1 FOOT LOWER THAN THE RUNWAY,
HT0540'AND ABOUT 1 FOOT UNDERGROUND.  NOTE-- THE TOP OF A 1-INCH IRON
HT0540'PIPE DROVE 60-FEET INTO THE GROUND, ACCESS TO WHICH IS HAD
HT0540'THROUGH AN 8-INCH CLAY PIPE WITH A 10-INCH CONCRETE LID.
HT0540
HT0540                          STATION RECOVERY (1977)
HT0540
HT0540'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1977
HT0540'AT THE SAN FRANCISCO INTL AIRPORT, 0.3 MILE NORTHEAST ACROSS COUNTRY
HT0540'FROM THE NEW TERMINAL BUILDING, AT THE CROSSING OF TAXIWAY NO. E,
HT0540'BETWEEN RUNWAYS 10L AND 10R, 285 FEET NORTHEAST OF THE NORTHEAST EDGE
HT0540'OF RUNWAY 10R, 213 FEET SOUTHWEST OF THE SOUTHWEST EDGE OF RUNWAY
HT0540'10L, 91 FEET NORTHWEST OF THE NORTHWEST EDGE OF THE TAXIWAY NO.E,
HT0540'ABOUT 1 FOOT LOWER THAN THE RUNWAY, AND ABOUT 1 FOOT UNDERGROUND,
HT0540'SOUTH OF TAXIWAY NO. T. NOTE-- THE TOP OF A 1 INCH IRON PIPE DROVE 60
HT0540'FEET INTO THE GROUND, ACCESS TO WHICH IS HAD THROUGH AN 8 INCH CLAY
HT0540'PIPE WITH A 10 INCH CONCRETE LID.
HT0540
HT0540                          STATION RECOVERY (1986)
HT0540
HT0540'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
HT0540'RECOVERED IN GOOD CONDITION. NEW DESCRIPTION FOLLOWS. IN SAN FRANCISCO
HT0540'INTERNATIONAL AIRPORT, ABOUT 1.0 KM (0.6 MI) NORTHEAST OF THE MAIN
HT0540'TERMINAL PARKING GARAGE, 28.1 METERS (92.2 FT) NORTHWEST OF THE
HT0540'NORTHWEST PAINTED EDGE OF TAXIWAY E, 34.5 METERS (113 FT) NORTH OF THE
HT0540'WEST OF A 28L-10R RUNWAY SIGN, 25.1 METERS (82.3 FT) WEST-SOUTHWEST OF
HT0540'THE SOUTHERNMOST 1 OF 5 BLUE TAXI LIGHTS, BETWEEN 2 WITNESS POSTS.
HT0540'NOTE--THE MARK IS THE TOP OF A 1-INCH IRON PIPE SET 60 FT DEEP AND
HT0540'FLUSH WITH THE GROUND.
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 HT0540'THE MARK IS 0.3 METERS  S FROM  A WITNESS POST
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0537 ***********************************************************************
 HT0537  DESIGNATION -  R 737 C OF SF
 HT0537  PID         -  HT0537
 HT0537  STATE/COUNTY-  CA/SAN MATEO
 HT0537  USGS QUAD   -  MONTARA MOUNTAIN (1997)
 HT0537
 HT0537                         *CURRENT SURVEY CONTROL
 HT0537  ___________________________________________________________________
 HT0537* NAD 83(1986)-  37 37 20.     (N)    122 23 29.     (W)     SCALED
 HT0537* NAVD 88     -         1.73   (+/-2cm)       5.7    (feet)  VERTCON
 HT0537  ___________________________________________________________________
 HT0537  GEOID HEIGHT-         -32.61  (meters)                     GEOID09
 HT0537  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0537
 HT0537.This mark is at San Francisco Intl Airport (SFO)
 HT0537
 HT0537.The horizontal coordinates were scaled from a topographic map and have
 HT0537.an estimated accuracy of +/- 6 seconds.
 HT0537
 HT0537.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0537.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0537.The vertical order pertains to the NGVD 29 superseded value.
 HT0537
 HT0537.The geoid height was determined by GEOID09.
 HT0537
 HT0537;                    North         East     Units  Estimated Accuracy
 HT0537;SPC CA 3     -   626,230.    1,833,050.      MT  (+/- 180 meters Scaled)
 HT0537
 HT0537                          SUPERSEDED SURVEY CONTROL
 HT0537
 HT0537  NGVD 29 (??/??/92)    0.891  (m)            2.92   (f) ADJ UNCH    1 2
 HT0537
 HT0537.Superseded values are not recommended for survey control.
 HT0537.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0537.See file dsdata.txt to determine how the superseded data were derived.
 HT0537
 HT0537_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG537640(NAD 83)
 HT0537_MARKER: DD = SURVEY DISK
 HT0537_SETTING: 36 = SET IN A MASSIVE STRUCTURE
 HT0537_SP_SET: BUILDING
 HT0537_STAMPING: R 737 1944
 HT0537_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 HT0537
 HT0537  HISTORY     - Date     Condition        Report By
 HT0537  HISTORY     - 1944     MONUMENTED       CA3290
 HT0537  HISTORY     - 1968     GOOD             NGS
 HT0537  HISTORY     - 1972     GOOD             NGS
 HT0537
 HT0537                          STATION DESCRIPTION
 HT0537
 HT0537'DESCRIBED BY NATIONAL GEODETIC SURVEY 1968
 HT0537'AT SAN FRANCISCO INTL AIRPORT.
 HT0537'AN UPDATED DESCRIPTION FOLLOWS-- AT THE SAN FRANCISCO INTERNATIONAL
 HT0537'AIRPORT, AT THE WEST CORNER OF A CONCRETE SHOP BUILDING OF
 HT0537'QANTAS AIRLINE, IN THE TOP OF A CONCRETE PROJECTION OF THE WEST
 HT0537'CORNER OF THE CONCRETE FOUNDATION, 59.2 FEET SOUTHWEST OF BENCH
 HT0537'MARK Y 736, 52.6 FEET EAST OF AND ACROSS A DRIVEWAY FROM
 HT0537'FIREHOUSE 1, 5.5 FEET SOUTHEAST OF THE SOUTHEAST CURB OF THE
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 HT0537'DRIVEWAY, 0.7 FOOT NORTHWEST OF THE NORTHWEST FACE OF THE
 HT0537'BUILDING AND ABOUT 1 FOOT HIGHER THAN A SIDEWALK.  NOTE-- NUMBERS
 HT0537'5.953 HAVE BEEN PUNCHED ON THE DISK WITH A SHARP OBJECT.
 HT0537
 HT0537                          STATION RECOVERY (1972)
 HT0537
 HT0537'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1972
 HT0537'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0538 ***********************************************************************
 HT0538  DESIGNATION -  Y 736 C OF SF
 HT0538  PID         -  HT0538
 HT0538  STATE/COUNTY-  CA/SAN MATEO
 HT0538  USGS QUAD   -  MONTARA MOUNTAIN (1997)
 HT0538
 HT0538                         *CURRENT SURVEY CONTROL
 HT0538  ___________________________________________________________________
 HT0538* NAD 83(1986)-  37 37 20.     (N)    122 23 29.     (W)     SCALED
 HT0538* NAVD 88     -         1.73   (+/-2cm)       5.7    (feet)  VERTCON
 HT0538  ___________________________________________________________________
 HT0538  GEOID HEIGHT-         -32.61  (meters)                     GEOID09
 HT0538  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0538
 HT0538.This mark is at San Francisco Intl Airport (SFO)
 HT0538
 HT0538.The horizontal coordinates were scaled from a topographic map and have
 HT0538.an estimated accuracy of +/- 6 seconds.
 HT0538
 HT0538.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0538.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0538.The vertical order pertains to the NGVD 29 superseded value.
 HT0538
 HT0538.The geoid height was determined by GEOID09.
 HT0538
 HT0538;                    North         East     Units  Estimated Accuracy
 HT0538;SPC CA 3     -   626,230.    1,833,050.      MT  (+/- 180 meters Scaled)
 HT0538
 HT0538                          SUPERSEDED SURVEY CONTROL
 HT0538
 HT0538  NGVD 29 (??/??/92)    0.896  (m)            2.94   (f) ADJ UNCH    1 2
 HT0538
 HT0538.Superseded values are not recommended for survey control.
 HT0538.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0538.See file dsdata.txt to determine how the superseded data were derived.
 HT0538
 HT0538_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG537640(NAD 83)
 HT0538_MARKER: DD = SURVEY DISK
 HT0538_SETTING: 36 = SET IN A MASSIVE STRUCTURE
 HT0538_SP_SET: BUILDING
 HT0538_STAMPING: Y 736 1944
 HT0538_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 HT0538
 HT0538  HISTORY     - Date     Condition        Report By
 HT0538  HISTORY     - 1944     MONUMENTED       CA3290
 HT0538  HISTORY     - 1968     GOOD             NGS
 HT0538  HISTORY     - 1972     GOOD             NGS
 HT0538
 HT0538                          STATION DESCRIPTION
 HT0538
 HT0538'DESCRIBED BY NATIONAL GEODETIC SURVEY 1968
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 HT0538'AT SAN FRANCISCO AIRPORT.
 HT0538'AN UPDATED DESCRIPTION FOLLOWS-- AT THE SAN FRANCISCO INTERNATIONAL
 HT0538'AIRPORT AT THE NORTHEAST CORNER OF A CONCRETE SHOP BUILDING OF
 HT0538'QANTAS AIRLINE, IN THE TOP OF A PROJECTION OF THE NORTHEAST
 HT0538'CORNER OF THE CONCRETE FOUNDATION, 47.0 FEET SOUTH OF THE
 HT0538'SOUTHEAST CORNER OF FIREHOUSE 1.  IT IS 1.0 FOOT NORTH OF THE
 HT0538'NORTH FACE OF THE SHOP BUILDING, AND ABOUT 1 FOOT HIGHER THAN
 HT0538'THE DRIVEWAY.
 HT0538
 HT0538                          STATION RECOVERY (1972)
 HT0538
 HT0538'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1972
 HT0538'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0542 ***********************************************************************
 HT0542  DESIGNATION -  L 553
 HT0542  PID         -  HT0542
 HT0542  STATE/COUNTY-  CA/SAN MATEO
 HT0542  USGS QUAD   -  SAN MATEO (1997)
 HT0542
 HT0542                         *CURRENT SURVEY CONTROL
 HT0542  ___________________________________________________________________
 HT0542* NAD 83(1986)-  37 37 28.     (N)    122 22 31.     (W)     SCALED
 HT0542* NAVD 88     -         3.02   (+/-2cm)       9.9    (feet)  VERTCON
 HT0542  ___________________________________________________________________
 HT0542  GEOID HEIGHT-         -32.60  (meters)                     GEOID09
 HT0542  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0542
 HT0542.This mark is at San Francisco Intl Airport (SFO)
 HT0542
 HT0542.The horizontal coordinates were scaled from a topographic map and have
 HT0542.an estimated accuracy of +/- 6 seconds.
 HT0542
 HT0542.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0542.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0542.The vertical order pertains to the NGVD 29 superseded value.
 HT0542
 HT0542.The geoid height was determined by GEOID09.
 HT0542
 HT0542;                   North         East     Units  Estimated Accuracy
 HT0542;SPC CA 3     -   626,450.    1,834,480.      MT  (+/- 180 meters Scaled)
 HT0542
 HT0542                          SUPERSEDED SURVEY CONTROL
 HT0542
 HT0542  NGVD 29 (??/??/92)    2.192  (m)           7.19   (f) ADJ UNCH    1 2
 HT0542
 HT0542.Superseded values are not recommended for survey control.
 HT0542.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0542.See file dsdata.txt to determine how the superseded data were derived.
 HT0542
 HT0542_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG551643(NAD 83)
 HT0542_MARKER: DB = BENCH MARK DISK
 HT0542_SETTING: 34 = SET IN THE FOOTINGS OF SMALL/MEDIUM STRUCTURES
 HT0542_SP_SET: BUILDING FOUNDATION
 HT0542_STAMPING: L 553 1956
 HT0542_MARK LOGO: CGS
 HT0542_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
 HT0542+STABILITY: SURFACE MOTION
 HT0542
 HT0542  HISTORY     - Date     Condition        Report By
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 HT0542  HISTORY     - 1956     MONUMENTED       CGS
 HT0542  HISTORY     - 1972     GOOD             NGS
 HT0542  HISTORY     - 1983     GOOD             USGS
 HT0542  HISTORY     - 1986     GOOD             NGS
 HT0542  HISTORY     - 20060129 GOOD             GEOCAC
 HT0542
 HT0542                          STATION DESCRIPTION
 HT0542
 HT0542'DESCRIBED BY COAST AND GEODETIC SURVEY 1956
 HT0542'AT SAN FRANCISCO AIRPORT.
 HT0542'AT THE SAN FRANCISCO INTERNATIONAL AIRPORT, AT FIREHOUSE NO.
 HT0542'3, IN THE TOP OF THE SOUTHEAST EDGE OF THE CONCRETE FOUNDATION
 HT0542'AND AT THE EAST CORNER OF THE BUILDING, 0.5 FOOT SOUTH OF THE
 HT0542'EAST CORNER OF THE BUILDING, 0.3 FOOT NORTHEAST OF THE NORTHEAST
 HT0542'EDGE OF A CONCRETE DRAIN BOX, 0.4 FOOT ABOVE THE GROUND, AND
 HT0542'ABOUT 0.6 FOOT HIGHER THAN A DRIVEWAY.
 HT0542
 HT0542                          STATION RECOVERY (1972)
 HT0542
 HT0542'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1972
 HT0542'RECOVERED IN GOOD CONDITION.
 HT0542
 HT0542                          STATION RECOVERY (1983)
 HT0542
 HT0542'RECOVERY NOTE BY US GEOLOGICAL SURVEY 1983
 HT0542'RECOVERED IN GOOD CONDITION.
 HT0542
 HT0542                          STATION RECOVERY (1986)
 HT0542
 HT0542'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0542'RECOVERED IN GOOD CONDITION. THE DESCRIPTION IS ADEQUATE EXCEPT ADD AT
 HT0542'FIREHOUSE NUMBER 2 NOT NUMBER 3.
 HT0542
 HT0542                          STATION RECOVERY (2006)
 HT0542
 HT0542'RECOVERY NOTE BY GEOCACHING 2006 (SW)
 HT0542'OLD FIREHOUSE IS NOW USED BY A TENANT AS A GARAGE FOR VEHICLE
 HT0542'MAINTENANCE.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0534 ***********************************************************************
 HT0534  DESIGNATION -  Z 736 C OF SF
 HT0534  PID         -  HT0534
 HT0534  STATE/COUNTY-  CA/SAN MATEO
 HT0534  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0534
 HT0534                         *CURRENT SURVEY CONTROL
 HT0534  ___________________________________________________________________
 HT0534* NAD 83(1986)-  37 37 30.     (N)    122 23 36.     (W)     SCALED
 HT0534* NAVD 88     -         1.03   (+/-2cm)       3.4    (feet)  VERTCON
 HT0534  ___________________________________________________________________
 HT0534  GEOID HEIGHT-         -32.61  (meters)                     GEOID09
 HT0534  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0534
 HT0534.This mark is at San Francisco Intl Airport (SFO)
 HT0534
 HT0534.The horizontal coordinates were scaled from a topographic map and have
 HT0534.an estimated accuracy of +/- 6 seconds.
 HT0534
 HT0534.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0534.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
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 HT0534.The vertical order pertains to the NGVD 29 superseded value.
 HT0534
 HT0534.The geoid height was determined by GEOID09.
 HT0534
 HT0534;                    North         East     Units  Estimated Accuracy
 HT0534;SPC CA 3     -   626,540.    1,832,880.      MT  (+/- 180 meters Scaled)
 HT0534
 HT0534                          SUPERSEDED SURVEY CONTROL
 HT0534
 HT0534  NGVD 29 (??/??/92)    0.197  (m)            0.65   (f) ADJ UNCH    1 2
 HT0534
 HT0534.Superseded values are not recommended for survey control.
 HT0534.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0534.See file dsdata.txt to determine how the superseded data were derived.
 HT0534
 HT0534_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG535643(NAD 83)
 HT0534_MARKER: DD = SURVEY DISK
 HT0534_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT0534_SP_SET: CULVERT
 HT0534_STAMPING: Z 736 1944
 HT0534_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT0534
 HT0534  HISTORY     - Date     Condition        Report By
 HT0534  HISTORY     - 1944     MONUMENTED       CA3290
 HT0534  HISTORY     - 1956     GOOD             NGS
 HT0534  HISTORY     - 1968     MARK NOT FOUND   NGS
 HT0534
 HT0534                          STATION DESCRIPTION
 HT0534
 HT0534'DESCRIBED BY NATIONAL GEODETIC SURVEY 1956
 HT0534'AT SAN FRANCISCO AIRPORT.
 HT0534'AT THE SAN FRANCISCO INTERNATIONAL AIRPORT, AT THE FORMER MAIN
 HT0534'ENTRANCE, IN THE TOP OF THE CONCRETE HEAD WALL OF A CULVERT
 HT0534'(BURIED BY A FILL) 270.0 FEET WEST OF THE SOUTHWEST CORNER OF
 HT0534'THE FORMER ADMINISTRATION BUILDING, 84.0 FEET NORTHWEST OF A
 HT0534'FIRE PLUG, 81.1 FEET SOUTHEAST OF BENCH MARK W 736, 23 FEET
 HT0534'SOUTH OF THE SOUTH CURB OF THE EAST BOUND TRAFFIC LANES, 19 1/2
 HT0534'FEET EAST OF THE CENTER LINE OF A PRIVATE ROAD LEADING SOUTH
 HT0534'TO THE NEW ADMINISTRATION BUILDING, 1.3 FEET NORTH OF A WITNESS
 HT0534'POST, AND ABOUT 2 1/2 FEET LOWER THAN THE ROAD.  NOTE-- ACCESS
 HT0534'IS HAD TO MARK THROUGH A 6-INCH CLAY PIPE WITH A 10-INCH WOODEN
 HT0534'COVER.
 HT0534
 HT0534                          STATION RECOVERY (1968)
 HT0534
 HT0534'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1968
 HT0534'MARK NOT FOUND.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0544 ***********************************************************************
 HT0544  DESIGNATION -  42 C OF SF
 HT0544  PID         -  HT0544
 HT0544  STATE/COUNTY-  CA/SAN MATEO
 HT0544  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0544
 HT0544                         *CURRENT SURVEY CONTROL
 HT0544  ___________________________________________________________________
 HT0544* NAD 83(1986)-  37 37 32.     (N)    122 22 34.     (W)     SCALED
 HT0544* NAVD 88     -         3.63   (+/-2cm)      11.9    (feet)  VERTCON
 HT0544  ___________________________________________________________________
 HT0544  GEOID HEIGHT-        -32.61  (meters)                      GEOID09
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 HT0544  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0544
 HT0544.This mark is at San Francisco Intl Airport (SFO)
 HT0544
 HT0544.The horizontal coordinates were scaled from a topographic map and have
 HT0544.an estimated accuracy of +/- 6 seconds.
 HT0544
 HT0544.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0544.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0544.The vertical order pertains to the NGVD 29 superseded value.
 HT0544
 HT0544.The geoid height was determined by GEOID09.
 HT0544
 HT0544;                    North         East     Units  Estimated Accuracy
 HT0544;SPC CA 3     -   626,580.    1,834,410.      MT  (+/- 180 meters Scaled)
 HT0544
 HT0544                          SUPERSEDED SURVEY CONTROL
 HT0544
 HT0544  NGVD 29 (??/??/92)    2.807  (m)           9.21   (f) ADJ UNCH    1 2
 HT0544
 HT0544.Superseded values are not recommended for survey control.
 HT0544.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0544.See file dsdata.txt to determine how the superseded data were derived.
 HT0544
 HT0544_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG550644(NAD 83)
 HT0544_MARKER: Z = SEE DESCRIPTION
 HT0544_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT0544_SP_SET: STEEL LEG CONCRETE FOUNDATION
 HT0544_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT0544
 HT0544  HISTORY     - Date     Condition        Report By
 HT0544  HISTORY     - UNK      MONUMENTED       CA3290
 HT0544  HISTORY     - 1956     GOOD             NGS
 HT0544
 HT0544                          STATION DESCRIPTION
 HT0544
 HT0544'DESCRIBED BY NATIONAL GEODETIC SURVEY 1956
 HT0544'AT SAN FRANCISCO AIRPORT.
 HT0544'AT THE SAN FRANCISCO INTERNATIONAL AIRPORT, AT THE RADAR TOWER,
 HT0544'ON THE TOP OF THE EAST CORNER OF THE NORTHEAST CONCRETE
 HT0544'FOUNDATION OF THE NORTHEAST STEEL LEG, 17.7 FEET EAST OF BENCH
 HT0544'MARK K 553 1956, ABOUT 1 1/2 FEET HIGHER THAN THE GROUND, AND
 HT0544'MARKED WITH WHITE PAINTED LETTERS AND NUMBERS B M 42.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0543 ***********************************************************************
 HT0543  DESIGNATION -  K 553
 HT0543  PID         -  HT0543
 HT0543  STATE/COUNTY-  CA/SAN MATEO
 HT0543  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0543
 HT0543                         *CURRENT SURVEY CONTROL
 HT0543  ___________________________________________________________________
 HT0543* NAD 83(1986)-  37 37 32.     (N)    122 22 34.     (W)     SCALED
 HT0543* NAVD 88     -         3.63   (+/-2cm)      11.9    (feet)  VERTCON
 HT0543  ___________________________________________________________________
 HT0543  GEOID HEIGHT-         -32.61  (meters)                     GEOID09
 HT0543  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0543
 HT0543.This mark is at San Francisco Intl Airport (SFO)
 HT0543
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HT0543.The horizontal coordinates were scaled from a topographic map and have
HT0543.an estimated accuracy of +/- 6 seconds.
HT0543
HT0543.The NAVD 88 height was computed by applying the VERTCON shift value to
HT0543.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
HT0543.The vertical order pertains to the NGVD 29 superseded value.
HT0543
HT0543.The geoid height was determined by GEOID09.
HT0543
HT0543;                    North         East     Units  Estimated Accuracy
HT0543;SPC CA 3     -   626,580.    1,834,410.      MT  (+/- 180 meters Scaled)
HT0543
HT0543                          SUPERSEDED SURVEY CONTROL
HT0543
HT0543  NGVD 29 (??/??/92)    2.807  (m)            9.21   (f) ADJ UNCH    1 2
HT0543
HT0543.Superseded values are not recommended for survey control.
HT0543.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT0543.See file dsdata.txt to determine how the superseded data were derived.
HT0543
HT0543_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG550644(NAD 83)
HT0543_MARKER: DB = BENCH MARK DISK
HT0543_SETTING: 30 = SET IN A LIGHT STRUCTURE
HT0543_SP_SET: STEP
HT0543_STAMPING: K 553 1956
HT0543_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
HT0543
HT0543  HISTORY     - Date     Condition        Report By
HT0543  HISTORY     - 1956     MONUMENTED       CGS
HT0543  HISTORY     - 1968     GOOD             NGS
HT0543
HT0543                          STATION DESCRIPTION
HT0543
HT0543'DESCRIBED BY COAST AND GEODETIC SURVEY 1956
HT0543'AT SAN FRANCISCO AIRPORT.
HT0543'AT THE SAN FRANCISCO INTERNATIONAL AIRPORT, AT THE RADAR TOWER,
HT0543'IN THE TOP OF THE WEST SIDE OF A CONCRETE FOUNDATION FOR THE
HT0543'WEST LEG AND THE STEEL STEPS OF THE TOWER, 5.0 FEET EAST OF THE
HT0543'NORTH CORNER OF THE C.A.A. BUILDING, AND ABOUT 1 1/2 FEET HIGHER
HT0543'THAN THE GROUND.
HT0543
HT0543                          STATION RECOVERY (1968)
HT0543
HT0543'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1968
HT0543'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
HT0528 ***********************************************************************
HT0528  DESIGNATION -  X 813
HT0528  PID         -  HT0528
HT0528  STATE/COUNTY-  CA/SAN MATEO
HT0528  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
HT0528
HT0528                         *CURRENT SURVEY CONTROL
HT0528  ___________________________________________________________________
HT0528* NAD 83(1986)-  37 37 44.     (N)    122 24 39.     (W)     SCALED
HT0528* NAVD 88     -         5.78   (+/-2cm)      19.0    (feet)  VERTCON
HT0528  ___________________________________________________________________
HT0528  GEOID HEIGHT-         -32.63  (meters)                     GEOID09
HT0528  VERT ORDER  -  FIRST     CLASS II (See Below)
HT0528
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 HT0528.The horizontal coordinates were scaled from a topographic map and have
 HT0528.an estimated accuracy of +/- 6 seconds.
 HT0528
 HT0528.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0528.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0528.The vertical order pertains to the NGVD 29 superseded value.
 HT0528
 HT0528.The geoid height was determined by GEOID09.
 HT0528
 HT0528;                    North         East     Units  Estimated Accuracy
 HT0528;SPC CA 3     -   627,010.    1,831,350.      MT  (+/- 180 meters Scaled)
 HT0528
 HT0528                          SUPERSEDED SURVEY CONTROL
 HT0528
 HT0528  NGVD 29 (??/??/92)    4.942  (m)           16.21   (f) ADJ UNCH    1 2
 HT0528
 HT0528.Superseded values are not recommended for survey control.
 HT0528.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0528.See file dsdata.txt to determine how the superseded data were derived.
 HT0528
 HT0528_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG519648(NAD 83)
 HT0528_MARKER: DB = BENCH MARK DISK
 HT0528_SETTING: 36 = SET IN A MASSIVE STRUCTURE
 HT0528_SP_SET: ABUTMENT
 HT0528_STAMPING: X 813 1952
 HT0528_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 HT0528
 HT0528  HISTORY     - Date     Condition        Report By
 HT0528  HISTORY     - 1952     MONUMENTED       CGS
 HT0528  HISTORY     - 1956     GOOD             NGS
 HT0528  HISTORY     - 1965     GOOD             NGS
 HT0528  HISTORY     - 1986     MARK NOT FOUND   NGS
 HT0528
 HT0528                          STATION DESCRIPTION
 HT0528
 HT0528'DESCRIBED BY NATIONAL GEODETIC SURVEY 1956
 HT0528'AT SAN BRUNO.
 HT0528'AT SAN BRUNO, 0.15 MILE SOUTHEAST ALONG THE SOUTHERN PACIFIC
 HT0528'COMPANY RAILROAD FROM THE STATION, 0.2 MILE SOUTHEAST OF MILEPOST
 HT0528'11, AT WOODEN BRIDGE NO. 11.21, IN THE TOP OF THE SOUTHWEST
 HT0528'END OF THE NORTHWEST CONCRETE ABUTMENT, 6.6 FEET SOUTHWEST OF
 HT0528'THE SOUTHWEST RAIL OF THE SOUTHWEST MAIN TRACK, AND ABOUT 1 1/2
 HT0528'FEET LOWER THAN THE TRACK.
 HT0528
 HT0528                          STATION RECOVERY (1965)
 HT0528
 HT0528'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1965
 HT0528'RECOVERED IN GOOD CONDITION.
 HT0528
 HT0528                          STATION RECOVERY (1986)
 HT0528
 HT0528'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0528'NOT RECOVERED, BRIDGE HAS BEEN REMOVED.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0532 ***********************************************************************
 HT0532  DESIGNATION -  H 553
 HT0532  PID         -  HT0532
 HT0532  STATE/COUNTY-  CA/SAN MATEO
 HT0532  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0532
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HT0532                         *CURRENT SURVEY CONTROL
HT0532  ___________________________________________________________________
HT0532* NAD 83(1986)-  37 38 00.     (N)    122 23 51.     (W)     SCALED
HT0532* NAVD 88     -         2.33   (+/-2cm)       7.6    (feet)  VERTCON
HT0532  ___________________________________________________________________
HT0532  GEOID HEIGHT-         -32.62  (meters)                     GEOID09
HT0532  VERT ORDER   -  FIRST     CLASS II (See Below)
HT0532
HT0532.The horizontal coordinates were scaled from a topographic map and have
HT0532.an estimated accuracy of +/- 6 seconds.
HT0532
HT0532.The NAVD 88 height was computed by applying the VERTCON shift value to
HT0532.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
HT0532.The vertical order pertains to the NGVD 29 superseded value.
HT0532
HT0532.The geoid height was determined by GEOID09.
HT0532
HT0532;                    North         East     Units  Estimated Accuracy
HT0532;SPC CA 3     -   627,480.    1,832,540.      MT  (+/- 180 meters Scaled)
HT0532
HT0532                          SUPERSEDED SURVEY CONTROL
HT0532
HT0532  NGVD 29 (??/??/92)    1.500  (m)            4.92   (f) ADJ UNCH    1 2
HT0532
HT0532.Superseded values are not recommended for survey control.
HT0532.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT0532.See file dsdata.txt to determine how the superseded data were derived.
HT0532
HT0532_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG531653(NAD 83)
HT0532_MARKER: DB = BENCH MARK DISK
HT0532_SETTING: 36 = SET IN A MASSIVE STRUCTURE
HT0532_SP_SET: BUILDING
HT0532_STAMPING: H 553 1956
HT0532_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
HT0532
HT0532  HISTORY     - Date     Condition        Report By
HT0532  HISTORY     - 1956     MONUMENTED       CGS
HT0532  HISTORY     - 1968     GOOD             NGS
HT0532  HISTORY     - 1986     MARK NOT FOUND   NGS
HT0532
HT0532                          STATION DESCRIPTION
HT0532
HT0532'DESCRIBED BY COAST AND GEODETIC SURVEY 1956
HT0532'0.8 MI E FROM SAN MATEO.
HT0532'0.8 MILE EAST ALONG SAN BRUNO AVENUE FROM THE SOUTHERN PACIFIC
HT0532'COMPANY RAILROAD STATION AT SAN BRUNO, AT THE UNITED AIR LINES
HT0532'MAINTENANCE BASE OF THE SAN FRANCISCO INTERNATIONAL AIRPORT,
HT0532'SET VERTICALLY IN THE SOUTHWEST FACE OF A CONCRETE WALL AND
HT0532'DOOR COLUMN, 1.4 FEET NORTHWEST OF THE SOUTH CORNER OF THE
HT0532'BUILDING, 0.3 FOOT SOUTHEAST OF THE SOUTHEAST EDGE OF A CONCRETE
HT0532'AND METAL DOOR GUARD, AND ABOUT 1 FOOT ABOVE THE DRIVE.
HT0532
HT0532                          STATION RECOVERY (1968)
HT0532
HT0532'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1968
HT0532'RECOVERED IN GOOD CONDITION.
HT0532
HT0532                          STATION RECOVERY (1986)
HT0532
HT0532'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
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 HT0532'NOT RECOVERED. THE DESCRIBED BUILDING IS NOT LOCATED ON THE CURRENT
 HT0532'UNITED AIRLINES PROPERTY.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 DG6888 ***********************************************************************
 DG6888  HT_MOD       -  This is a Height Modernization Survey Station.
 DG6888  DESIGNATION -  SEAPLANE
 DG6888  PID         -  DG6888
 DG6888  STATE/COUNTY-  CA/SAN MATEO
 DG6888  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 DG6888
 DG6888                         *CURRENT SURVEY CONTROL
 DG6888  ___________________________________________________________________
 DG6888* NAD 83(2007)-  37 38 06.88788(N)    122 23 08.17798(W)     ADJUSTED
 DG6888* NAVD 88     -         3.00   (meters)       9.8    (feet)  GPS OBS
 DG6888  ___________________________________________________________________
 DG6888  EPOCH DATE  -        2007.00
 DG6888  X           -  -2,708,726.064 (meters)                     COMP
 DG6888  Y           -  -4,270,640.549 (meters)                     COMP
 DG6888  Z           -   3,873,444.070 (meters)                     COMP
 DG6888  LAPLACE CORR-          1.07  (seconds)                     DEFLEC09
 DG6888  ELLIP HEIGHT-        -29.637 (meters)          (02/10/07) ADJUSTED
 DG6888  GEOID HEIGHT-        -32.61  (meters)                      GEOID09
 DG6888
 DG6888  ------- Accuracy Estimates (at 95% Confidence Level in cm) --------
 DG6888  Type    PID    Designation                      North   East  Ellip
 DG6888  -------------------------------------------------------------------
 DG6888  NETWORK DG6888 SEAPLANE                          0.27   0.29   1.14
 DG6888  -------------------------------------------------------------------
 DG6888
 DG6888.The horizontal coordinates were established by GPS observations
 DG6888.and adjusted by the National Geodetic Survey in February 2007.
 DG6888
 DG6888.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
 DG6888.See National Readjustment for more information.
 DG6888.The horizontal coordinates are valid at the epoch date displayed above.
 DG6888.The epoch date for horizontal control is a decimal equivalence
 DG6888.of Year/Month/Day.
 DG6888
 DG6888.The orthometric height was determined by GPS observations and a
 DG6888.high-resolution geoid model using precise GPS observation and
 DG6888.processing techniques.
 DG6888
 DG6888.The X, Y, and Z were computed from the position and the ellipsoidal ht.
 DG6888
 DG6888.The Laplace correction was computed from DEFLEC09 derived deflections.
 DG6888
 DG6888.The ellipsoidal height was determined by GPS observations
 DG6888.and is referenced to NAD 83.
 DG6888
 DG6888.The geoid height was determined by GEOID09.
 DG6888
 DG6888;                    North         East     Units Scale Factor Converg.
 DG6888;SPC CA 3     -   627,666.988 1,833,588.443   MT  0.99993121   -1 09 15.9
 DG6888;SPC CA 3     - 2,059,270.78  6,015,698.08   sFT  0.99993121   -1 09 15.9
 DG6888;UTM  10      - 4,165,523.614   554,208.587   MT  0.99963619   +0 22 30.6
 DG6888
 DG6888!             -  Elev Factor  x  Scale Factor =   Combined Factor
 DG6888!SPC CA 3     -   1.00000465  x   0.99993121  =   0.99993586
 DG6888!UTM  10      -   1.00000465  x   0.99963619  =   0.99964084
 DG6888
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 DG6888                          SUPERSEDED SURVEY CONTROL
 DG6888
 DG6888  NAD 83(1998)-  37 38 06.88353(N)    122 23 08.17330(W) AD(2002.75) B
 DG6888  ELLIP H (08/23/04)  -29.568  (m)                       GP(       ) 4 1
 DG6888
 DG6888.Superseded values are not recommended for survey control.
 DG6888.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 DG6888.See file dsdata.txt to determine how the superseded data were derived.
 DG6888
 DG6888_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG5420865523(NAD 83)
 DG6888_MARKER: DD = SURVEY DISK
 DG6888_SETTING: 37 = SET IN A MASSIVE RETAINING WALL
 DG6888_SP_SET: THICK CONCRETE WALL
 DG6888_STAMPING: SEAPLANE
 DG6888_MARK LOGO: CSRC
 DG6888_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
 DG6888+STABILITY: SURFACE MOTION
 DG6888_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
 DG6888+SATELLITE: SATELLITE OBSERVATIONS - 2002
 DG6888
 DG6888  HISTORY     - Date     Condition        Report By
 DG6888  HISTORY     - 2002     MONUMENTED       CSRC
 DG6888
 DG6888                          STATION DESCRIPTION
 DG6888
 DG6888'DESCRIBED BY CALIFORNIA SPATIAL REFERENCE CENTER 2002 (RAF)
 DG6888'THE STATION IS 1.7 KM (1.05 MI) EAST-NORTHEAST OF SAN BRUNO, CA. THE
 DG6888'STATION IS ON THE  NORTH SHORE OF THE SEAPLANE HARBOR, NORTH OF SAN
 DG6888'FRANCISCO  AIRPORT, IN SAN BRUNO.
 DG6888'
 DG6888'FROM THE INTERSECTION OF HWY 101 AND HWY 380 (WEST)/NORTH  ACCESS
 DG6888'RD(EAST), EXIT ON NORTH ACCESS ROAD.  DRIVE EAST FOR 1.3 KM (0.8  MI),
 DG6888'FOLLOWING THE ROAD WHEN IT MAKES A SHARP RIGHT TURN.  TURN LEFT  ONTO
 DG6888'CLEARWATER DR AND DRIVE 0.2 KM (0.1 MI), WITH THE CITY COLLEGE OF  SF
 DG6888'AIRCRAFT TECHNICIAN SCHOOL ON THE RIGHT AND THE WATER QUALITY  CONTROL
 DG6888'PLANT ON THE LEFT.  NEAR THE END OF THE ROAD, BEAR RIGHT AND GO  ABOUT
 DG6888'114 M (375 FT) TOWARDS THE OCEAN.  THE STATION IS ABOUT 114 M  (375
 DG6888'FT) SOUTHERLY OF THE INTERSECTION OF NORTH ACCESS ROAD AND  CLEARWATER
 DG6888'DRIVE, 1.1 M (3.5 FT) SOUTHERLY OF THE SOUTHERLY FACE OF A  CONCRETE
 DG6888'SEAWALL, 3.5 M (11.4 FT) EASTERLY OF THE EASTERLY EDGE OF A  CONCRETE
 DG6888'LAUNCH RAMP, 4.0 M (13 FT) EAST-SOUTHEASTERLY OF THE SOUTHEAST  CORNER
 DG6888'OF A 3.0 M (10 FT) HIGH CHAIN LINK FENCE, AND 2.6 M (8.5 FT)  WESTERLY
 DG6888'OF THE WESTERLY EDGE OF A 91 CM (36 IN) DIAMETER STEEL PIPE.   THE
 DG6888'MARK IS AN 8.9 CM (3.5 IN) ALUMINUM CALIFORNIA SPATIAL REFERENCE
 DG6888'CENTER DISK STAMPED 'SEAPLANE 2002', CEMENTED IN A DRILL HOLE IN THE
 DG6888'TOP OF A 30 CM (1 FT) WIDE CONCRETE WALL AT THE NORTHWEST CORNER OF A
 DG6888'2.1 M (7 FT) BY 6.7 M (22 FT) CONCRETE STRUCTURE WITH A 91 CM (36 IN)
 DG6888'DIAMETER STEEL PIPE.
 DG6888'
 DG6888'THIS STATION IS SET NEAR BENCH MARKS FOR TIDE GAGE 941 4413. THIS
 DG6888'STATION WAS OBSERVED AS PART OF THE SOUTH SAN FRANCISCO BAY HEIGHT
 DG6888'MODERNIZATION  PROJECT.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0647 ***********************************************************************
 HT0647  DESIGNATION -  P 571 RESET 1950
 HT0647  PID         -  HT0647
 HT0647  STATE/COUNTY-  CA/SAN MATEO
 HT0647  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0647
 HT0647                         *CURRENT SURVEY CONTROL
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 HT0647  ________________________________________________________________
 HT0647* NAD 83(1986)-  37 38 32.     (N)    122 24 47.     (W)     SCALED
 HT0647* NAVD 88     -         4.96   (+/-2cm)      16.3    (feet)  VERTCON
 HT0647  ________________________________________________________________
 HT0647  GEOID HEIGHT-         -32.63  (meters)                     GEOID09
 HT0647  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0647
 HT0647.The horizontal coordinates were scaled from a topographic map and have
 HT0647.an estimated accuracy of +/- 6 seconds.
 HT0647
 HT0647.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0647.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0647.The vertical order pertains to the NGVD 29 superseded value.
 HT0647
 HT0647.The geoid height was determined by GEOID09.
 HT0647
 HT0647;                    North         East     Units  Estimated Accuracy
 HT0647;SPC CA 3     -   628,490.    1,831,180.      MT  (+/- 180 meters Scaled)
 HT0647
 HT0647                          SUPERSEDED SURVEY CONTROL
 HT0647
 HT0647  NGVD 29 (??/??/92)    4.123  (m)           13.53   (f) ADJ UNCH    1 2
 HT0647
 HT0647.Superseded values are not recommended for survey control.
 HT0647.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0647.See file dsdata.txt to determine how the superseded data were derived.
 HT0647
 HT0647_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG517662(NAD 83)
 HT0647_MARKER: DB = BENCH MARK DISK
 HT0647_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT0647_SP_SET: CULVERT
 HT0647_STAMPING: P 571 1939 RESET 1950
 HT0647_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT0647
 HT0647  HISTORY     - Date     Condition        Report By
 HT0647  HISTORY     - 1950     MONUMENTED       CGS
 HT0647  HISTORY     - 1956     GOOD             NGS
 HT0647  HISTORY     - 1965     GOOD             NGS
 HT0647
 HT0647                          STATION DESCRIPTION
 HT0647
 HT0647'DESCRIBED BY NATIONAL GEODETIC SURVEY 1956
 HT0647'1 MI S FROM SAN FRANCISCO.
 HT0647'1.0 MILE SOUTH ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD FROM
 HT0647'THE STATION AT SOUTH SAN FRANCISCO, AT CROSSING NO. 10.2 OF SOUTH
 HT0647'LYNDEN AVENUE, IN THE TOP OF THE EAST END OF THE SOUTH CONCRETE
 HT0647'HEAD WALL OF A 12-INCH CONCRETE PIPE CULVERT UNDER THE AVENUE,
 HT0647'32.0 FEET WEST OF THE WEST RAIL OF THE WEST MAIN TRACK, 27 1/2
 HT0647'FEET SOUTH OF THE CENTER LINE OF THE AVENUE, 18.8 FEET EAST OF
 HT0647'THE CURB OF DOLLAR AVENUE, 13.3 FEET EAST OF THE CENTER OF A
 HT0647'CROSSING SIGNAL, AND ABOUT 1 FOOT LOWER THAN THE RAILROAD TRACK.
 HT0647
 HT0647                          STATION RECOVERY (1965)
 HT0647
 HT0647'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1965
 HT0647'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0526 ***********************************************************************
 HT0526  DESIGNATION -  U 813
 HT0526  PID         -  HT0526
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HT0526  STATE/COUNTY-  CA/SAN MATEO
HT0526  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
HT0526
HT0526                          *CURRENT SURVEY CONTROL
HT0526  ___________________________________________________________________
HT0526* NAD 83(1986)-  37 38 46.     (N)    122 25 19.     (W)     SCALED
HT0526* NAVD 88     -         7.43   (+/-2cm)       24.4    (feet)  VERTCON
HT0526  ___________________________________________________________________
HT0526  GEOID HEIGHT-         -32.65  (meters)                      GEOID09
HT0526  VERT ORDER  -  FIRST     CLASS II (See Below)
HT0526
HT0526.The horizontal coordinates were scaled from a topographic map and have
HT0526.an estimated accuracy of +/- 6 seconds.
HT0526
HT0526.The NAVD 88 height was computed by applying the VERTCON shift value to
HT0526.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
HT0526.The vertical order pertains to the NGVD 29 superseded value.
HT0526
HT0526.The geoid height was determined by GEOID09.
HT0526
HT0526;                    North         East     Units  Estimated Accuracy
HT0526;SPC CA 3     -   628,940.    1,830,410.      MT  (+/- 180 meters Scaled)
HT0526
HT0526                          SUPERSEDED SURVEY CONTROL
HT0526
HT0526  NGVD 29 (??/??/92)    6.591  (m)           21.62   (f) ADJ UNCH    1 2
HT0526
HT0526.Superseded values are not recommended for survey control.
HT0526.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT0526.See file dsdata.txt to determine how the superseded data were derived.
HT0526
HT0526_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG509667(NAD 83)
HT0526_MARKER: DB = BENCH MARK DISK
HT0526_SETTING: 32 = SET IN A RETAINING WALL OR CONCRETE LEDGE
HT0526_SP_SET: CULVERT HEADWALL
HT0526_STAMPING: U 813 1952
HT0526_MARK LOGO: CGS
HT0526_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
HT0526+STABILITY: SURFACE MOTION
HT0526
HT0526  HISTORY     - Date     Condition        Report By
HT0526  HISTORY     - 1952     MONUMENTED       CGS
HT0526  HISTORY     - 1986     GOOD             NGS
HT0526
HT0526                          STATION DESCRIPTION
HT0526
HT0526'DESCRIBED BY COAST AND GEODETIC SURVEY 1952
HT0526'0.5 MI NW FROM TANFORAN.
HT0526'0.5 MILE NORTHWEST ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD
HT0526'FROM THE STATION AT TANFORAN, AT THE HAZELWOOD DRIVE CROSSING,
HT0526'3.7 MILES SOUTHEAST OF COLMA, IN THE TOP OF THE NORTHWEST END
HT0526'OF THE SOUTHWEST HEAD WALL OF A LARGE STONE ARCH CULVERT, 75
HT0526'FEET NORTHWEST OF THE CENTER LINE OF THE DRIVE, 12.5 FEET
HT0526'SOUTHWEST OF THE SOUTHWEST RAIL, AND ABOUT 6 FEET LOWER THAN
HT0526'THE TRACK.
HT0526
HT0526                          STATION RECOVERY (1986)
HT0526
HT0526'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
HT0526'RECOVERED IN GOOD CONDITION. THE DESCRIPTION IS ADEQUATE EXCEPT ADD
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 HT0526'TANFORAN IS NOW CONSIDERED TO BE PART OF SOUTH SAN FRANCISCO, AND THE
 HT0526'MARK IS AT THE SPRUCE AVENUE CROSSING OF THE SOUTHERN PACIFIC COMPANY
 HT0526'RAILROAD.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0645 ***********************************************************************
 HT0645  DESIGNATION -  N 571
 HT0645  PID         -  HT0645
 HT0645  STATE/COUNTY-  CA/SAN MATEO
 HT0645  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0645
 HT0645                         *CURRENT SURVEY CONTROL
 HT0645  ___________________________________________________________________
 HT0645* NAD 83(1986)-  37 38 58.     (N)    122 24 36.     (W)     SCALED
 HT0645* NAVD 88     -         4.91   (+/-2cm)      16.1    (feet)  VERTCON
 HT0645  ___________________________________________________________________
 HT0645  GEOID HEIGHT-         -32.63  (meters)                     GEOID09
 HT0645  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0645
 HT0645.The horizontal coordinates were scaled from a topographic map and have
 HT0645.an estimated accuracy of +/- 6 seconds.
 HT0645
 HT0645.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0645.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0645.The vertical order pertains to the NGVD 29 superseded value.
 HT0645
 HT0645.The geoid height was determined by GEOID09.
 HT0645
 HT0645;                    North         East     Units  Estimated Accuracy
 HT0645;SPC CA 3     -   629,290.    1,831,470.      MT  (+/- 180 meters Scaled)
 HT0645
 HT0645                          SUPERSEDED SURVEY CONTROL
 HT0645
 HT0645  NGVD 29 (??/??/92)    4.083  (m)           13.40   (f) ADJ UNCH    1 2
 HT0645
 HT0645.Superseded values are not recommended for survey control.
 HT0645.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0645.See file dsdata.txt to determine how the superseded data were derived.
 HT0645
 HT0645_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG520670(NAD 83)
 HT0645_MARKER: DB = BENCH MARK DISK
 HT0645_SETTING: 36 = SET IN A MASSIVE STRUCTURE
 HT0645_SP_SET: ABUTMENT
 HT0645_STAMPING: N 571 1939
 HT0645_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 HT0645
 HT0645  HISTORY     - Date     Condition        Report By
 HT0645  HISTORY     - 1939     MONUMENTED       CGS
 HT0645  HISTORY     - 1956     GOOD             NGS
 HT0645  HISTORY     - 1965     GOOD             NGS
 HT0645
 HT0645                          STATION DESCRIPTION
 HT0645
 HT0645'DESCRIBED BY NATIONAL GEODETIC SURVEY 1956
 HT0645'0.5 MI SW FROM SAN FRANCISCO.
 HT0645'0.5 MILE SOUTHWEST ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD
 HT0645'FROM THE STATION AT SOUTH SAN FRANCISCO, AT WOODEN BRIDGE 9.72,
 HT0645'IN THE TOP OF THE SOUTHEAST END OF THE SOUTHWEST CONCRETE ABUTMENT,
 HT0645'33.1 FEET SOUTHEAST OF THE SOUTEAST RAIL OF THE SOUTHEAST MAIN
 HT0645'TRACK, 2 1/2 FEET SOUTHEAST OF THE SOUTHEAST WOODEN GUARDRAIL,
 HT0645'AND ABOUT 1 FOOT LOWER THAN THE MAIN TRACK.
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 HT0645
 HT0645                          STATION RECOVERY (1965)
 HT0645
 HT0645'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1965
 HT0645'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0642 ***********************************************************************
 HT0642  DESIGNATION -  G 553
 HT0642  PID         -  HT0642
 HT0642  STATE/COUNTY-  CA/SAN MATEO
 HT0642  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0642
 HT0642                         *CURRENT SURVEY CONTROL
 HT0642  ___________________________________________________________________
 HT0642* NAD 83(1986)-  37 39 02.     (N)    122 22 47.     (W)     SCALED
 HT0642* NAVD 88     -         5.24   (+/-2cm)       17.2   (feet)  VERTCON
 HT0642  ___________________________________________________________________
 HT0642  GEOID HEIGHT-         -32.60  (meters)                     GEOID09
 HT0642  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0642
 HT0642.The horizontal coordinates were scaled from a topographic map and have
 HT0642.an estimated accuracy of +/- 6 seconds.
 HT0642
 HT0642.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0642.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0642.The vertical order pertains to the NGVD 29 superseded value.
 HT0642
 HT0642.The geoid height was determined by GEOID09.
 HT0642
 HT0642;                    North         East    Units  Estimated Accuracy
 HT0642;SPC CA 3     -   629,360.    1,834,140.      MT  (+/- 180 meters Scaled)
 HT0642
 HT0642                          SUPERSEDED SURVEY CONTROL
 HT0642
 HT0642  NGVD 29 (??/??/92)    4.416  (m)           14.49   (f) ADJ UNCH    1 2
 HT0642
 HT0642.Superseded values are not recommended for survey control.
 HT0642.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0642.See file dsdata.txt to determine how the superseded data were derived.
 HT0642
 HT0642_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG547672(NAD 83)
 HT0642_MARKER: DB = BENCH MARK DISK
 HT0642_SETTING: 36 = SET IN A MASSIVE STRUCTURE
 HT0642_SP_SET: BUILDING
 HT0642_STAMPING: G 553 1956
 HT0642_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 HT0642
 HT0642  HISTORY     - Date     Condition        Report By
 HT0642  HISTORY     - 1956     MONUMENTED       CGS
 HT0642  HISTORY     - 1973     GOOD             NGS
 HT0642
 HT0642                          STATION DESCRIPTION
 HT0642
 HT0642'DESCRIBED BY COAST AND GEODETIC SURVEY 1956
 HT0642'1.5 MI E FROM SAN FRANCISCO.
 HT0642'0.1 MILE SOUTH ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD FROM
 HT0642'THE STATION AT SOUTH SAN FRANCISCO, THENCE 1.4 MILE EAST ALONG
 HT0642'GRAND AVENUE, AT THE W.P. FULLER PAINT COMPANY YARD, AT THE
 HT0642'SOUTHWEST CORNER OF A LARGE CONCRETE BUILDING, SET VERTICALLY
 HT0642'IN THE SOUTH FACE OF THE SOUTH CONCRETE WALL, 5.4 FEET WEST OF
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 HT0642'THE CENTER OF AN ELEVATOR DOOR, 1.0 FEET EAST OF THE SOUTHWEST
 HT0642'CORNER OF THE BUILDING, 2.3 FEET ABOVE THE ASPHALT AND ABOUT
 HT0642'2 FEET HIGHER THAN THE GROUND.
 HT0642
 HT0642                          STATION RECOVERY (1973)
 HT0642
 HT0642'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1973
 HT0642'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0640 ***********************************************************************
 HT0640  DESIGNATION -  TIDAL 3
 HT0640  PID         -  HT0640
 HT0640  STATE/COUNTY-  CA/SAN MATEO
 HT0640  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0640
 HT0640                         *CURRENT SURVEY CONTROL
 HT0640  ___________________________________________________________________
 HT0640* NAD 83(1986)-  37 39 03.     (N)    122 23 17.     (W)     SCALED
 HT0640* NAVD 88     -         4.31   (+/-2cm)      14.1    (feet)  VERTCON
 HT0640  ___________________________________________________________________
 HT0640  GEOID HEIGHT-         -32.61  (meters)                     GEOID09
 HT0640  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0640
 HT0640.The horizontal coordinates were scaled from a topographic map and have
 HT0640.an estimated accuracy of +/- 6 seconds.
 HT0640
 HT0640.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0640.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0640.The vertical order pertains to the NGVD 29 superseded value.
 HT0640
 HT0640.The geoid height was determined by GEOID09.
 HT0640
 HT0640;                    North         East     Units  Estimated Accuracy
 HT0640;SPC CA 3     -   629,400.    1,833,410.      MT  (+/- 180 meters Scaled)
 HT0640
 HT0640                          SUPERSEDED SURVEY CONTROL
 HT0640
 HT0640  NGVD 29 (??/??/92)    3.482  (m)           11.42   (f) ADJ UNCH    1 2
 HT0640
 HT0640.Superseded values are not recommended for survey control.
 HT0640.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0640.See file dsdata.txt to determine how the superseded data were derived.
 HT0640
 HT0640_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG539672(NAD 83)
 HT0640_MARKER: DB = BENCH MARK DISK
 HT0640_SETTING: 36 = SET IN A MASSIVE STRUCTURE
 HT0640_SP_SET: BUILDING
 HT0640_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 HT0640
 HT0640  HISTORY     - Date     Condition        Report By
 HT0640  HISTORY     - UNK      MONUMENTED       CGS
 HT0640  HISTORY     - 1956     GOOD             NGS
 HT0640
 HT0640                          STATION DESCRIPTION
 HT0640
 HT0640'DESCRIBED BY NATIONAL GEODETIC SURVEY 1956
 HT0640'1.1 MI E FROM SAN FRANCISCO.
 HT0640'0.1 MILE SOUTH ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD FROM
 HT0640'THE STATION AT SOUTH SAN FRANCISCO, THENCE 1.0 MILE EAST ALONG
 HT0640'GRAND AVENUE, ON POINT SAN BRUNO, AT THE SWIFT COMPANY PACKING
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 HT0640'PLANT, AT THE SOUTHEAST CORNER OF BRICK BUILDING NO 13, SET
 HT0640'VERTICALLY IN THE EAST FACE OF A BRICK WALL, 175 FEET SOUTH
 HT0640'OF THE CENTER LINE OF THE AVENUE, 130.0 FEET WEST OF THE SOUTHWEST
 HT0640'CORNER OF A LARGE BRICK CHIMNEY EAST OF THE BUILDING, 1.0
 HT0640'FEET NORTH OF THE SOUTHEAST CORNER OF THE BUILDING, 2.5 FEET
 HT0640'HIGHER THAN THE GROUND, AND 2 1/2 FEET LOWER THAN THE TOP OF
 HT0640'A LOADING PLATFORM.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0641 ***********************************************************************
 HT0641  DESIGNATION -  BM 5 TIDAL MARK
 HT0641  PID         -  HT0641
 HT0641  STATE/COUNTY-  CA/SAN MATEO
 HT0641  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0641
 HT0641                         *CURRENT SURVEY CONTROL
 HT0641  ___________________________________________________________________
 HT0641* NAD 83(1986)-  37 39 04.     (N)    122 22 59.     (W)     SCALED
 HT0641* NAVD 88     -         3.71   (+/-2cm)      12.2    (feet)  VERTCON
 HT0641  ___________________________________________________________________
 HT0641  GEOID HEIGHT-         -32.61  (meters)                     GEOID09
 HT0641  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0641
 HT0641.The horizontal coordinates were scaled from a topographic map and have
 HT0641.an estimated accuracy of +/- 6 seconds.
 HT0641
 HT0641.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0641.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0641.The vertical order pertains to the NGVD 29 superseded value.
 HT0641
 HT0641.The geoid height was determined by GEOID09.
 HT0641
 HT0641;                    North         East     Units  Estimated Accuracy
 HT0641;SPC CA 3     -   629,420.    1,833,850.      MT   (+/- 180 meters Scaled)
 HT0641
 HT0641                          SUPERSEDED SURVEY CONTROL
 HT0641
 HT0641  NGVD 29 (??/??/92)    2.892  (m)           9.49   (f) ADJ UNCH    1 2
 HT0641
 HT0641.Superseded values are not recommended for survey control.
 HT0641.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0641.See file dsdata.txt to determine how the superseded data were derived.
 HT0641
 HT0641_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG544672(NAD 83)
 HT0641_MARKER: DB = BENCH MARK DISK
 HT0641_SETTING: 36 = SET IN A MASSIVE STRUCTURE
 HT0641_SP_SET: BUILDING
 HT0641_STAMPING: NO 5 1941
 HT0641_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 HT0641
 HT0641  HISTORY     - Date     Condition        Report By
 HT0641  HISTORY     - 1941     MONUMENTED       CGS
 HT0641  HISTORY     - 1956     GOOD             NGS
 HT0641
 HT0641                          STATION DESCRIPTION
 HT0641
 HT0641'DESCRIBED BY NATIONAL GEODETIC SURVEY 1956
 HT0641'1.4 MI E FROM SAN FRANCISCO.
 HT0641'0.1 MILE SOUTHEAST ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD
 HT0641'FROM THE STATION AT SOUTH SAN FRANCISCO, THENCE 1.3 MILE EAST
 HT0641'ALONG GRAND AVENUE, 375 FEET SOUTHWEST OF THE SOUTHWEST CORNER
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 HT0641'OF THE W.P. FULLER INDUSTRIAL BUILDING, AT A CONCRETE STORAGE
 HT0641'BUILDING (INSIDE OF A FENCE) FOR INFLAMMABLE MATERIAL, IN THE
 HT0641'TOP OF THE CENTER OF A LARGE CONCRETE BASE FOUNDATION WHICH
 HT0641'PROJECTS 1 FOOT ABOVE THE GROUND, 270 FEET SOUTH OF THE CENTER
 HT0641'LINE OF THE AVENUE, 23.5 FEET SOUTH OF THE NORTHWEST CORNER
 HT0641'OF THE FENCE, 2.0 FEET EAST OF THE FENCE, AND ABOUT 3 1/2 FEET
 HT0641'LOWER THAN THE STREET.  NOTE-- THIS MARK WILL BE DESTROYED BY
 HT0641'A FILL, A W.P. FULLER AND COMPANY ENGINEER WILL NOTIFY THE COAST
 HT0641'AND GEODETIC SURVEY AS TO WHEN THE FILL WILL BE CONSTRUCTED.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0638 ***********************************************************************
 HT0638  DESIGNATION -  L 571 RESET 1948
 HT0638  PID         -  HT0638
 HT0638  STATE/COUNTY-  CA/SAN MATEO
 HT0638  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0638
 HT0638                         *CURRENT SURVEY CONTROL
 HT0638  ___________________________________________________________________
 HT0638* NAD 83(1986)-  37 39 15.     (N)     122 24 26.     (W)     SCALED
 HT0638* NAVD 88     -         6.60   (+/-2cm)      21.7     (feet)  VERTCON
 HT0638  ___________________________________________________________________
 HT0638  GEOID HEIGHT-         -32.63  (meters)                      GEOID09
 HT0638  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0638
 HT0638.The horizontal coordinates were scaled from a topographic map and have
 HT0638.an estimated accuracy of +/- 6 seconds.
 HT0638
 HT0638.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0638.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0638.The vertical order pertains to the NGVD 29 superseded value.
 HT0638
 HT0638.The geoid height was determined by GEOID09.
 HT0638
 HT0638;                    North         East     Units  Estimated Accuracy
 HT0638;SPC CA 3     -   629,810.    1,831,720.      MT  (+/- 180 meters Scaled)
 HT0638
 HT0638                          SUPERSEDED SURVEY CONTROL
 HT0638
 HT0638  NGVD 29 (??/??/92)    5.770  (m)           18.93   (f) ADJ UNCH    1 2
 HT0638
 HT0638.Superseded values are not recommended for survey control.
 HT0638.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0638.See file dsdata.txt to determine how the superseded data were derived.
 HT0638
 HT0638_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG522676(NAD 83)
 HT0638_MARKER: DB = BENCH MARK DISK
 HT0638_SETTING: 36 = SET IN A MASSIVE STRUCTURE
 HT0638_SP_SET: PIER
 HT0638_STAMPING: L 571 RESET 1948 1939
 HT0638_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 HT0638
 HT0638  HISTORY     - Date     Condition        Report By
 HT0638  HISTORY     - 1939     MONUMENTED       CGS
 HT0638  HISTORY     - 1956     GOOD             NGS
 HT0638  HISTORY     - 1965     GOOD             NGS
 HT0638
 HT0638                          STATION DESCRIPTION
 HT0638
 HT0638'DESCRIBED BY NATIONAL GEODETIC SURVEY 1956
 HT0638'AT SAN FRANCISCO.
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 HT0638'AT SOUTH SAN FRANCISCO, AT THE CROSSING OF GRAND AVENUE, INSIDE
 HT0638'OF THE STATE HIGHWAY YARDS, IN THE TOP OF THE CENTER OF THE
 HT0638'FOURTH CONCRETE PIER NORTH OF THE SOUTH END OF THE WEST U.S.
 HT0638'101 BAYSHORE HIGHWAY OVERPASS, 106.9 FEET SOUTH OF THE SOUTH
 HT0638'CURB OF THE AVENUE, 100.2 FEET NORTHWEST OF THE WEST RAIL OF THE
 HT0638'WEST MAIN TRACK OF THE SOUTHERN PACIFIC COMPANY RAILROAD, AND
 HT0638'ABOUT 4 1/2 FEET HIGHER THAN THE TRACK.
 HT0638
 HT0638                          STATION RECOVERY (1965)
 HT0638
 HT0638'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1965
 HT0638'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0639 ***********************************************************************
 HT0639  DESIGNATION -  M 571
 HT0639  PID         -  HT0639
 HT0639  STATE/COUNTY-  CA/SAN MATEO
 HT0639  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0639
 HT0639                         *CURRENT SURVEY CONTROL
 HT0639  ___________________________________________________________________
 HT0639* NAD 83(1986)-  37 39 15.     (N)    122 23 47.     (W)     SCALED
 HT0639* NAVD 88     -         5.81   (+/-2cm)      19.1    (feet)  VERTCON
 HT0639  ___________________________________________________________________
 HT0639  GEOID HEIGHT-        -32.62  (meters)                      GEOID09
 HT0639  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0639
 HT0639.The horizontal coordinates were scaled from a topographic map and have
 HT0639.an estimated accuracy of +/- 6 seconds.
 HT0639
 HT0639.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0639.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0639.The vertical order pertains to the NGVD 29 superseded value.
 HT0639
 HT0639.The geoid height was determined by GEOID09.
 HT0639
 HT0639;                   North         East     Units  Estimated Accuracy
 HT0639;SPC CA 3     -   629,790.    1,832,680.      MT  (+/- 180 meters Scaled)
 HT0639
 HT0639                          SUPERSEDED SURVEY CONTROL
 HT0639
 HT0639  NGVD 29 (??/??/92)    4.980  (m)           16.34    (f) ADJ UNCH    1 2
 HT0639
 HT0639.Superseded values are not recommended for survey control.
 HT0639.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0639.See file dsdata.txt to determine how the superseded data were derived.
 HT0639
 HT0639_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG532676(NAD 83)
 HT0639_MARKER: DB = BENCH MARK DISK
 HT0639_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT0639_SP_SET: WALL
 HT0639_STAMPING: M 571 1939
 HT0639_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT0639
 HT0639  HISTORY     - Date     Condition        Report By
 HT0639  HISTORY     - 1939     MONUMENTED       CGS
 HT0639  HISTORY     - 1956     GOOD             NGS
 HT0639
 HT0639                          STATION DESCRIPTION
 HT0639
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 HT0639'DESCRIBED BY NATIONAL GEODETIC SURVEY 1956
 HT0639'AT SAN FRANCISCO.
 HT0639'AT SOUTH SAN FRANCISCO, 0.1 MILE SOUTH ALONG THE SOUTHERN PACIFIC
 HT0639'COMPANY RAILROAD, THENCE 0.5 MILE EAST ALONG GRAND AVENUE,
 HT0639'ON THE OUTSIDE OF A CURVE, AT THE CONCRETE BUILDING OF THE SOUTH
 HT0639'SAN FRANCISCO COLD STORAGE COMPANY, SET VERTICALLY IN THE SOUTH
 HT0639'FACE OF THE SOUTH CONCRETE WALL, 64.5 FEET EAST OF THE SOUTHWEST
 HT0639'CORNER OF THE SOUTH SAN FRANCISCO FIRE HOUSE STATION, 54 FEET
 HT0639'NORTH OF THE CENTER LINE OF THE AVENUE, 49.5 FEET EAST OF THE
 HT0639'SOUTHWEST CORNER OF THE BUILDING, 3 1/2 FEET EAST OF THE CENER
 HT0639'OF A SMALL DOOR TO AN OFFICE, 3.2 FEET HIGHER THAN THE CONCRETE
 HT0639'AND WOODEN SIDEWALK, AND ABOUT 3 1/2 FEET HIGHER THAN THE AVENUE.
 HT0639'NOTE-- IT WAS REPORTED IN 1960 THAT THE SOUTH SAN FRANCISCO COLD
 HT0639'STORAGEG CO. IS NOW THE GENERAL COLD STORAGE CO.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0525 ***********************************************************************
 HT0525  DESIGNATION -  T 813
 HT0525  PID         -  HT0525
 HT0525  STATE/COUNTY-  CA/SAN MATEO
 HT0525  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0525
 HT0525                        *CURRENT SURVEY CONTROL
 HT0525  ___________________________________________________________________
 HT0525* NAD 83(1986)-  37 39 28.     (N)    122 26 13.     (W)     SCALED
 HT0525* NAVD 88     -        14.45   (+/-2cm)      47.4    (feet)  VERTCON
 HT0525  ___________________________________________________________________
 HT0525  GEOID HEIGHT-         -32.67  (meters)                     GEOID09
 HT0525  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0525
 HT0525.The horizontal coordinates were scaled from a topographic map and have
 HT0525.an estimated accuracy of +/- 6 seconds.
 HT0525
 HT0525.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0525.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0525.The vertical order pertains to the NGVD 29 superseded value.
 HT0525
 HT0525.The geoid height was determined by GEOID09.
 HT0525
 HT0525;                    North         East    Units  Estimated Accuracy
 HT0525;SPC CA 3     -   630,260.    1,829,110.      MT  (+/- 180 meters Scaled)
 HT0525
 HT0525                         SUPERSEDED SURVEY CONTROL
 HT0525
 HT0525  NGVD 29 (??/??/92)   13.602  (m)           44.63   (f) ADJ UNCH    1 2
 HT0525
 HT0525.Superseded values are not recommended for survey control.
 HT0525.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0525.See file dsdata.txt to determine how the superseded data were derived.
 HT0525
 HT0525_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG496679(NAD 83)
 HT0525_MARKER: DB = BENCH MARK DISK
 HT0525_SETTING: 32 = SET IN A RETAINING WALL OR CONCRETE LEDGE
 HT0525_SP_SET: DITCH RETAINING WALL
 HT0525_STAMPING: T 813 1952
 HT0525_MARK LOGO: CGS
 HT0525_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
 HT0525+STABILITY: SURFACE MOTION
 HT0525
 HT0525  HISTORY     - Date     Condition        Report By
 HT0525  HISTORY     - 1952     MONUMENTED       CGS
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 HT0525  HISTORY     - 1986     GOOD             NGS
 HT0525
 HT0525                          STATION DESCRIPTION
 HT0525
 HT0525'DESCRIBED BY COAST AND GEODETIC SURVEY 1952
 HT0525'2.7 MI SE FROM COLMA.
 HT0525'2.7 MILES SOUTHEAST ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD
 HT0525'FROM THE STATION AT COLMA, 0.1 MILE SOUTH OF THE GRAND AVENUE
 HT0525'CROSSING, IN THE TOP OF THE NORTHEAST END OF THE NORTHWEST
 HT0525'CONCRETE RETAINING WALL FOR A LARGE DRAINAGE DITCH, 58.5 FEET
 HT0525'SOUTHWEST OF THE SOUTHWEST RAIL, 52 1/2 FEET SOUTHWEST OF THE
 HT0525'NORTHWEST CORNER OF A TRESTLE, 9.0 FEET SOUTH OF A POWER LINE
 HT0525'POLE, 0.7 FOOT SOUTHWEST OF THE NORTHEAST END OF THE WALL,
 HT0525'AND ABOUT 1 1/2 FEET LOWER THAN THE TRACK.
 HT0525
 HT0525                          STATION RECOVERY (1986)
 HT0525
 HT0525'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0525'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT3821 ***********************************************************************
 HT3821  TIDAL BM     -  This is a Tidal Bench Mark.
 HT3821  DESIGNATION -  K 571 RESET
 HT3821  PID         -  HT3821
 HT3821  STATE/COUNTY-  CA/SAN MATEO
 HT3821  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT3821
 HT3821                         *CURRENT SURVEY CONTROL
 HT3821  ___________________________________________________________________
 HT3821* NAD 83(1986)-  37 39 33.     (N)    122 24 04.     (W)     SCALED
 HT3821* NAVD 88     -         5.87   (+/-2cm)      19.3    (feet)  VERTCON
 HT3821  ___________________________________________________________________
 HT3821  GEOID HEIGHT-         -32.62  (meters)                      GEOID09
 HT3821  VERT ORDER  -  THIRD (See Below)
 HT3821
 HT3821.The horizontal coordinates were scaled from a topographic map and have
 HT3821.an estimated accuracy of +/- 6 seconds.
 HT3821
 HT3821.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT3821.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT3821.The vertical order pertains to the NGVD 29 superseded value.
 HT3821
 HT3821.This Tidal Bench Mark is designated as VM 17230
 HT3821.by the CENTER FOR OPERATIONAL OCEANOGRAPHIC PRODUCTS AND SERVICES.
 HT3821
 HT3821.The geoid height was determined by GEOID09.
 HT3821
 HT3821;                   North         East    Units  Estimated Accuracy
 HT3821;SPC CA 3     -   630,350.    1,832,270.      MT  (+/- 180 meters Scaled)
 HT3821
 HT3821                          SUPERSEDED SURVEY CONTROL
 HT3821
 HT3821  NGVD 29 (08/19/04)    5.04   (m)           16.5    (f) RESET       3
 HT3821
 HT3821.Superseded values are not recommended for survey control.
 HT3821.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT3821.See file dsdata.txt to determine how the superseded data were derived.
 HT3821
 HT3821_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG528681(NAD 83)
 HT3821_MARKER: DV = VERTICAL CONTROL DISK
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 HT3821_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
 HT3821_SP_SET: CONCRETE POST
 HT3821_STAMPING: K 571 RESET 1982
 HT3821_MARK LOGO: NGS
 HT3821_MAGNETIC: N = NO MAGNETIC MATERIAL
 HT3821_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
 HT3821+STABILITY: SURFACE MOTION
 HT3821
 HT3821  HISTORY     - Date     Condition        Report By
 HT3821  HISTORY     - 1982     MONUMENTED       NGS
 HT3821
 HT3821                          STATION DESCRIPTION
 HT3821
 HT3821'DESCRIBED BY NATIONAL GEODETIC SURVEY 1982
 HT3821'0.5 KM (0.30 MI) NORTHEAST ALONG INDUSTRIAL WAY FROM EAST GRAND
 HT3821'AVENUE, 6.25 METERS (20.51 FT) WEST FROM THE CENTER OF INDUSTRIAL
 HT3821'WAY, 20.4 METERS (66.9 FT) SOUTHWEST FROM A FIRE HYDRANT, 22 METERS
 HT3821'(72.2 FT) NORTHWEST FROM A ENTRANCE TO US STEEL PARKING LOT, 3.1
 HT3821'METERS (10.2 FT) EAST OF AN ANGLE IRON RAIL, 0.9 METERS (3.0 FT)
 HT3821'NORTH OF A TELEPHONE POLE, 0.3 METERS (1.0 FT) SOUTH OF A PLASTIC
 HT3821'WITNESS POST, FLUSH WITH THE SURFACE, NEAR THE SOUTH END OF A NARROW
 HT3821'PARKING AREA, ABOUT 20 FEET (6.1 M) EAST OF THE EAST RAIL OF THE
 HT3821'SOUTHERN PACIFIC RAILROAD, ABOUT 6 FEET (1.8 M) HIGHER THAN THE
 HT3821'RAILROAD, ABOUT 0.2 KM (0.10 MI) EAST OF US HIGHWAY 101, SET IN THE
 HT3821'TOP OF A CONCRETE POST FLUSH WITH THE GROUND.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0524 ***********************************************************************
 HT0524  DESIGNATION -  W 6
 HT0524  PID         -  HT0524
 HT0524  STATE/COUNTY-  CA/SAN MATEO
 HT0524  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0524
 HT0524                         *CURRENT SURVEY CONTROL
 HT0524  ___________________________________________________________________
 HT0524* NAD 83(1986)-  37 40 07.     (N)    122 26 56.     (W)     SCALED
 HT0524* NAVD 88     -        27.63   (+/-2cm)      90.6    (feet)  VERTCON
 HT0524  ___________________________________________________________________
 HT0524  GEOID HEIGHT-         -32.69  (meters)                     GEOID09
 HT0524  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0524
 HT0524.The horizontal coordinates were scaled from a topographic map and have
 HT0524.an estimated accuracy of +/- 6 seconds.
 HT0524
 HT0524.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0524.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0524.The vertical order pertains to the NGVD 29 superseded value.
 HT0524
 HT0524.The geoid height was determined by GEOID09.
 HT0524
 HT0524;                    North         East     Units  Estimated Accuracy
 HT0524;SPC CA 3     -   631,480.    1,828,080.      MT  (+/- 180 meters Scaled)
 HT0524
 HT0524                          SUPERSEDED SURVEY CONTROL
 HT0524
 HT0524  NGVD 29 (??/??/92)   26.784  (m)           87.87   (f) ADJ UNCH    1 2
 HT0524
 HT0524.Superseded values are not recommended for survey control.
 HT0524.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0524.See file dsdata.txt to determine how the superseded data were derived.
 HT0524
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 HT0524_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG486691(NAD 83)
 HT0524_MARKER: DB = BENCH MARK DISK
 HT0524_SETTING: 66 = SET IN ROCK OUTCROP
 HT0524_SP_SET: ROCK
 HT0524_MARK LOGO: CGS
 HT0524_STABILITY: A = MOST RELIABLE AND EXPECTED TO HOLD
 HT0524+STABILITY: POSITION/ELEVATION WELL
 HT0524
 HT0524  HISTORY     - Date     Condition        Report By
 HT0524  HISTORY     - 1952     MONUMENTED       CGS
 HT0524  HISTORY     - 1965     GOOD             NGS
 HT0524  HISTORY     - 1986     GOOD             NGS
 HT0524
 HT0524                          STATION DESCRIPTION
 HT0524
 HT0524'DESCRIBED BY COAST AND GEODETIC SURVEY 1952
 HT0524'1.7 MI SE FROM COLMA.
 HT0524'1.7 MILES SOUTHEAST ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD
 HT0524'FROM THE STATION AT COLMA, AT THE HOLY CROSS CEMETERY, BETWEEN
 HT0524'THE RAILROAD AND THE OLD MISSION ROAD, SET VERTICALLY IN THE
 HT0524'NORTHEAST FACE OF A 3-FOOT HIGH CONICAL ROCK IN SHRUBBERY,
 HT0524'81.7 FEET EAST OF THE EAST RAIL, 66.4 FEET NORTHWEST OF THE
 HT0524'NORTHEAST CORNER OF THE OFFICE BUILDING, 36 1/2 FEET SOUTHWEST
 HT0524'OF THE CENTER LINE OF THE ROAD, AND ABOUT 2 FEET HIGHER THAN
 HT0524'THE ROAD.
 HT0524
 HT0524                          STATION RECOVERY (1965)
 HT0524
 HT0524'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1965
 HT0524'RECOVERED IN GOOD CONDITION.
 HT0524
 HT0524                          STATION RECOVERY (1986)
 HT0524
 HT0524'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0524'RECOVERED IN GOOD CONDITION. THE DESCRIPTION IS ADEQUATE EXCEPT ADD
 HT0524'THE OFFICE BUILDING IS NOW MACHINIST UNION LOCAL NUMBER 68.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0523 ***********************************************************************
 HT0523  DESIGNATION -  P 109
 HT0523  PID         -  HT0523
 HT0523  STATE/COUNTY-  CA/SAN MATEO
 HT0523  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0523
 HT0523                         *CURRENT SURVEY CONTROL
 HT0523  ___________________________________________________________________
 HT0523* NAD 83(1986)-  37 40 56.     (N)    122 27 46.     (W)     SCALED
 HT0523* NAVD 88     -        46.89   (+/-2cm)     153.8    (feet)  VERTCON
 HT0523  ___________________________________________________________________
 HT0523  GEOID HEIGHT-         -32.72  (meters)                     GEOID09
 HT0523  VERT ORDER  -  FIRST     CLASS II (See Below)
 HT0523
 HT0523.The horizontal coordinates were scaled from a topographic map and have
 HT0523.an estimated accuracy of +/- 6 seconds.
 HT0523
 HT0523.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0523.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0523.The vertical order pertains to the NGVD 29 superseded value.
 HT0523
 HT0523.The geoid height was determined by GEOID09.
 HT0523
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 HT0523;                    North         East     Units  Estimated Accuracy
 HT0523;SPC CA 3     -   633,020.    1,826,890.      MT  (+/- 180 meters Scaled)
 HT0523
 HT0523                          SUPERSEDED SURVEY CONTROL
 HT0523
 HT0523  NGVD 29 (??/??/92)   46.037  (m)          151.04   (f) ADJ UNCH    1 2
 HT0523
 HT0523.Superseded values are not recommended for survey control.
 HT0523.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0523.See file dsdata.txt to determine how the superseded data were derived.
 HT0523
 HT0523_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG473706(NAD 83)
 HT0523_MARKER: DB = BENCH MARK DISK
 HT0523_SETTING: 38 = SET IN THE ABUTMENT OR PIER OF A LARGE BRIDGE
 HT0523_SP_SET: BRIDGE ABUTMENT
 HT0523_STAMPING: P 109 1932
 HT0523_MARK LOGO: CGS
 HT0523_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 HT0523
 HT0523  HISTORY     - Date     Condition        Report By
 HT0523  HISTORY     - 1932     MONUMENTED       CGS
 HT0523  HISTORY     - 1952     GOOD             NGS
 HT0523  HISTORY     - 1962     GOOD             NGS
 HT0523  HISTORY     - 1986     GOOD             NGS
 HT0523
 HT0523                          STATION DESCRIPTION
 HT0523
 HT0523'DESCRIBED BY NATIONAL GEODETIC SURVEY 1952
 HT0523'0.5 MI SE FROM COLMA.
 HT0523'0.5 MILE SOUTHEAST ALONG THE SOUTHERN PACIFIC COMPANY RAILROAD FROM
 HT0523'THE STATION AT COLMA, AT THE OVERPASS CROSSING OVER U.S. HIGHWAY
 HT0523'101, IN THE TOP OF THE NORTHWEST CORNER OF THE SOUTH CONCRETE
 HT0523'ABUTMENT AND JUST OUTSIDE THE HAND RAIL, 9 1/4 RAILS SOUTHEAST
 HT0523'OF MILE POST 9, 6.2 FEET SOUTHWEST OF THE SOUTHWEST RAIL, AND
 HT0523'ABOUT LEVEL WITH THE TRACK.
 HT0523
 HT0523                          STATION RECOVERY (1962)
 HT0523
 HT0523'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1962
 HT0523'RECOVERED IN GOOD CONDITION.
 HT0523
 HT0523                          STATION RECOVERY (1986)
 HT0523
 HT0523'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0523'RECOVERED IN GOOD CONDITION. NEW DESCRIPTION FOLLOWS. IN COLMA, AT THE
 HT0523'JUNCTION OF EL CAMINO REAL (STATE HIGHWAY 82) AND F STREET, IN TOP OF
 HT0523'THE NORTHWEST CORNER OF THE SOUTH CONCRETE ABUTMENT FOR A RAILROAD
 HT0523'BRIDGE THAT HAS BEEN REMOVED FROM THE EAST SIDE OF THE HIGHWAY, JUST
 HT0523'OUTSIDE THE IRON HANDRAIL.
 HT0523'THE MARK IS 4.6 M ABOVE HIGHWAY 82.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0483 ***********************************************************************
 HT0483  DESIGNATION -  M 1241
 HT0483  PID         -  HT0483
 HT0483  STATE/COUNTY-  CA/SAN MATEO
 HT0483  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0483
 HT0483                         *CURRENT SURVEY CONTROL
 HT0483  ___________________________________________________________________
 HT0483* NAD 83(1986)-  37 41 05.     (N)    122 28 18.     (W)     SCALED
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HT0483* NAVD 88     -        71.210  (meters)     233.63   (feet)  ADJUSTED
HT0483 ___________________________________________________________________
HT0483  GEOID HEIGHT-         -32.74  (meters)                     GEOID09
HT0483  DYNAMIC HT  -          71.162 (meters)     233.47  (feet)  COMP
HT0483  MODELED GRAV-     979,952.4   (mgal)                       NAVD 88
HT0483  OBS GRAVITY -     979,955.9   (mgal)                       GRAV_OBS
HT0483
HT0483  VERT ORDER  -  FIRST     CLASS I
HT0483
HT0483.The horizontal coordinates were scaled from a topographic map and have
HT0483.an estimated accuracy of +/- 6 seconds.
HT0483
HT0483.The orthometric height was determined by differential leveling and
HT0483.adjusted in June 1991.
HT0483
HT0483.The geoid height was determined by GEOID09.
HT0483
HT0483.The dynamic height is computed by dividing the NAVD 88
HT0483.geopotential number by the normal gravity value computed on the
HT0483.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
HT0483.degrees latitude (g = 980.6199 gals.).
HT0483
HT0483.The modeled gravity was interpolated from observed gravity values.
HT0483.The observed gravity was obtained from relative gravimeter ties
HT0483.to the IGSN71 gravity network.
HT0483
HT0483;                    North         East     Units  Estimated Accuracy
HT0483;SPC CA 3     -   633,310.    1,826,110.      MT  (+/- 180 meters Scaled)
HT0483
HT0483                          SUPERSEDED SURVEY CONTROL
HT0483
HT0483  NGVD 29 (10/21/93)   70.364  (m)          230.85   (f) ADJUSTED    1 1
HT0483
HT0483.Superseded values are not recommended for survey control.
HT0483.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT0483.See file dsdata.txt to determine how the superseded data were derived.
HT0483
HT0483_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG465709(NAD 83)
HT0483_MARKER: DB = BENCH MARK DISK
HT0483_SETTING: 31 = SET IN A PAVEMENT SUCH AS STREET, SIDEWALK, CURB, ETC.
HT0483_SP_SET: CONCRETE GUARDRAIL
HT0483_STAMPING: M 1241 1972
HT0483_MARK LOGO: NGS
HT0483_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
HT0483
HT0483  HISTORY     - Date     Condition        Report By
HT0483  HISTORY     - 1972     MONUMENTED       NGS
HT0483  HISTORY     - 1977     GOOD             NGS
HT0483  HISTORY     - 1986     GOOD             NGS
HT0483
HT0483                          STATION DESCRIPTION
HT0483
HT0483'DESCRIBED BY NATIONAL GEODETIC SURVEY 1972
HT0483'AT DALY CITY.
HT0483'AT THE JUNCTION OF EASTMOOR AVENUE AND SULLIVAN AVENUE AT DALY
HT0483'CITY, IN THE TOP AND 5.0 FEET EAST OF THE WEST END OF THE NORTH
HT0483'CONCRETE GUARDRAIL BASE OF EASTMOOR AVENUE BRIDGE 35-181 OVER
HT0483'INTERSTATE HIGHWAY 280, 6.0 FEET NORTH OF THE NORTH CURB OF
HT0483'EASTMOOR AVENUE, 39 FEET EAST OF THE EAST CURB LINE OF SULLIVAN
HT0483'AVENUE, 5.3 FEET EAST OF THE EAST END OF A CYCLONE FENCE, AND ABOUT
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 HT0483'2 1/2 FEET HIGHER THAN THE AVENUES.
 HT0483
 HT0483                          STATION RECOVERY (1977)
 HT0483
 HT0483'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1977
 HT0483'RECOVERED IN GOOD CONDITION.
 HT0483
 HT0483                          STATION RECOVERY (1986)
 HT0483
 HT0483'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0483'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0481 ***********************************************************************
 HT0481  DESIGNATION -  L 1241
 HT0481  PID         -  HT0481
 HT0481  STATE/COUNTY-  CA/SAN MATEO
 HT0481  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0481
 HT0481                         *CURRENT SURVEY CONTROL
 HT0481  ___________________________________________________________________
 HT0481* NAD 83(2007)-  37 41 09.43316(N)    122 28 56.41929(W)     ADJUSTED
 HT0481* NAVD 88     -       123.180  (meters)     404.13   (feet)  ADJUSTED
 HT0481  ___________________________________________________________________
 HT0481  EPOCH DATE  -        2007.00
 HT0481  X           -  -2,714,136.777 (meters)                     COMP
 HT0481  Y           -  -4,263,240.759 (meters)                     COMP
 HT0481  Z           -   3,877,972.784 (meters)                     COMP
 HT0481  LAPLACE CORR-           5.60  (seconds)                    DEFLEC09
 HT0481  ELLIP HEIGHT-          90.400 (meters)        (02/10/07) ADJUSTED
 HT0481  GEOID HEIGHT-         -32.77  (meters)                     GEOID09
 HT0481  DYNAMIC HT  -         123.095 (meters)     403.85  (feet)  COMP
 HT0481
 HT0481  ------- Accuracy Estimates (at 95% Confidence Level in cm) --------
 HT0481  Type    PID    Designation                      North   East  Ellip
 HT0481  -------------------------------------------------------------------
 HT0481  NETWORK HT0481 L 1241                            0.29   0.31   1.18
 HT0481  -------------------------------------------------------------------
 HT0481  MODELED GRAV-     979,941.0   (mgal)                       NAVD 88
 HT0481
 HT0481  VERT ORDER  -  FIRST     CLASS I
 HT0481
 HT0481.The horizontal coordinates were established by GPS observations
 HT0481.and adjusted by the National Geodetic Survey in February 2007.
 HT0481
 HT0481.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
 HT0481.See National Readjustment for more information.
 HT0481.The horizontal coordinates are valid at the epoch date displayed above.
 HT0481.The epoch date for horizontal control is a decimal equivalence
 HT0481.of Year/Month/Day.
 HT0481
 HT0481.The orthometric height was determined by differential leveling and
 HT0481.adjusted in June 1991.
 HT0481
 HT0481.The X, Y, and Z were computed from the position and the ellipsoidal ht.
 HT0481
 HT0481.The Laplace correction was computed from DEFLEC09 derived deflections.
 HT0481
 HT0481.The ellipsoidal height was determined by GPS observations
 HT0481.and is referenced to NAD 83.
 HT0481
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HT0481.The geoid height was determined by GEOID09.
HT0481
HT0481.The dynamic height is computed by dividing the NAVD 88
HT0481.geopotential number by the normal gravity value computed on the
HT0481.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
HT0481.degrees latitude (g = 980.6199 gals.).
HT0481
HT0481.The modeled gravity was interpolated from observed gravity values.
HT0481
HT0481;                    North         East     Units Scale Factor Converg.
HT0481;SPC CA 3     -   633,469.732 1,825,171.781   MT  0.99992982   -1 12 49.1
HT0481;SPC CA 3     - 2,078,308.61  5,988,084.42   sFT  0.99992982   -1 12 49.1
HT0481;UTM  10      - 4,171,097.909   545,642.570   MT  0.99962566   +0 18 59.3
HT0481
HT0481!             -  Elev Factor  x  Scale Factor =   Combined Factor
HT0481!SPC CA 3     -   0.99998581  x   0.99992982  =   0.99991564
HT0481!UTM  10      -   0.99998581  x   0.99962566  =   0.99961148
HT0481
HT0481                          SUPERSEDED SURVEY CONTROL
HT0481
HT0481  NAD 83(1998)-  37 41 09.42923(N)    122 28 56.41440(W) AD(2002.75) B
HT0481  ELLIP H (08/23/04)   90.474  (m)                       GP(        ) 4 1
HT0481  NAD 83(1992)-  37 41 09.42414(N)    122 28 56.41045(W) AD(1997.30) 1
HT0481  ELLIP H (07/10/98)   90.413  (m)                       GP(1997.30) 4 1
HT0481  NAD 83(1992)-  37 41 09.42198(N)    122 28 56.40906(W) AD(1995.42) 1
HT0481  ELLIP H (12/22/97)   90.473  (m)                       GP(1995.42) 4 1
HT0481  NAVD 88 (12/22/97)  123.18   (m)          404.1    (f) LEVELING    3
HT0481  NGVD 29 (??/??/92)  122.330  (m)          401.34   (f) ADJ UNCH    1 1
HT0481
HT0481.Superseded values are not recommended for survey control.
HT0481.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT0481.See file dsdata.txt to determine how the superseded data were derived.
HT0481
HT0481_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG4564271097(NAD 83)
HT0481_MARKER: DB = BENCH MARK DISK
HT0481_SETTING: 31 = SET IN A PAVEMENT SUCH AS STREET, SIDEWALK, CURB, ETC.
HT0481_SP_SET: CONCRETE CATCH BASIN
HT0481_STAMPING: L 1241 1972
HT0481_MARK LOGO: NGS
HT0481_MAGNETIC: N = NO MAGNETIC MATERIAL
HT0481_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
HT0481_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
HT0481+SATELLITE: SATELLITE OBSERVATIONS - September 28, 2002
HT0481
HT0481  HISTORY     - Date     Condition        Report By
HT0481  HISTORY     - 1972     MONUMENTED       NGS
HT0481  HISTORY     - 1977     GOOD             NGS
HT0481  HISTORY     - 1986     GOOD             NGS
HT0481  HISTORY     - 19950915 GOOD             NGS
HT0481  HISTORY     - 200209   GOOD             JOHFRA
HT0481  HISTORY     - 20020928 GOOD             INDIV
HT0481
HT0481                          STATION DESCRIPTION
HT0481
HT0481'DESCRIBED BY NATIONAL GEODETIC SURVEY 1972
HT0481'AT DALY CITY.
HT0481'AT THE JUNCTION OF EASTMOOR AVENUE AND AN ASPHALT STREET SOUTH
HT0481'TO THE WESTMOOR HIGH SCHOOL PARKING LOT AT DALY CITY, IN THE TOP
HT0481'AND AT THE NORTHEAST CORNER OF A CONCRETE CATCH BASIN AT THE WEST
HT0481'CURB OF THE STREET, 18 FEET SOUTH OF THE SOUTH CURB LINE OF THE
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 HT0481'AVENUE, 155 FEET WEST OF THE EXTENDED CENTER LINE OF TERRACE
 HT0481'VIEW COURT, 255 FEET WEST OF THE EXTENDED CENTER LINE OF GILMAN
 HT0481'DRIVE, 0.8 FOOT WEST OF THE WEST CURB OF THE STREET TO THE
 HT0481'PARKING LOT, AND ABOUT 1 FOOT HIGHER THAN THE STREET AND AVENUE.
 HT0481
 HT0481                          STATION RECOVERY (1977)
 HT0481
 HT0481'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1977
 HT0481'RECOVERED IN GOOD CONDITION.
 HT0481
 HT0481                          STATION RECOVERY (1986)
 HT0481
 HT0481'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0481'RECOVERED IN GOOD CONDITION. THE DESCRIPTION IS ADEQUATE EXCEPT ADD
 HT0481'7.0 METERS (23.0 FT) EAST-NORTHEAST OF AN IRON ENTRANCE SIGN TO THE
 HT0481'SCHOOL, AND 8.5 METERS (28.0 FT) NORTH OF A 15 MPH STREET SIGN.
 HT0481
 HT0481                          STATION RECOVERY (1995)
 HT0481
 HT0481'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1995 (JDD)
 HT0481'THE STATION WAS RECOVERED.  TO REACH THE STATION FROM THE INTERSECTION
 HT0481'OF INTERSTATE HIGHWAY 280 AND EASTMOOR AVENUE IN DALY CITY, GO WEST ON
 HT0481'EASTMOOR AVENUE FOR 0.6 MI (1.0 KM) TO A PAVED SIDE ROAD LEFT, THE
 HT0481'ENTRANCE TO WESTMOOR HIGH SCHOOL AND THE STATION ON THE LEFT IN THE
 HT0481'SOUTHWEST QUADRANT.
 HT0481
 HT0481                          STATION RECOVERY (2002)
 HT0481
 HT0481'RECOVERY NOTE BY JOHNSON-FRANK 2002 (MSP)
 HT0481'RECOVERED AS DESCRIBED. FROM THE INTERSECTION OF HWY 1 AND HWY
 HT0481'35/SKYLINE BLVD, DRIVE NORTH ON HWY 35 FOR 1 MI.   EXIT ON WESTMOOR
 HT0481'AVE, TURN RIGHT AND DRIVE EAST FOR 0.4 MI AS THE ROAD STARTS TO CURVE
 HT0481'LEFT (NORTH).  CONTINUE FOR 0.1 MI TO THE ENTRANCE TO WESTMOOR HIGH
 HT0481'SCHOOL AND THE  STATION ON THE RIGHT AS PREVIOUSLY DESCRIBED. THIS
 HT0481'STATION WAS OBSERVED AS PART OF THE SOUTH SAN FRANCISCO BAY HEIGHT
 HT0481'MODERNIZATION  PROJECT.
 HT0481
 HT0481                          STATION RECOVERY (2002)
 HT0481
 HT0481'RECOVERY NOTE BY INDIVIDUAL CONTRIBUTORS 2002 (DBT)
 HT0481'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0521 ***********************************************************************
 HT0521  DESIGNATION -  N 1241
 HT0521  PID         -  HT0521
 HT0521  STATE/COUNTY-  CA/SAN MATEO
 HT0521  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0521
 HT0521                         *CURRENT SURVEY CONTROL
 HT0521  ___________________________________________________________________
 HT0521* NAD 83(1986)-  37 41 36.     (N)    122 28 15.     (W)     SCALED
 HT0521* NAVD 88     -        58.520  (meters)     191.99   (feet)  ADJUSTED
 HT0521  ___________________________________________________________________
 HT0521  GEOID HEIGHT-         -32.73  (meters)                     GEOID09
 HT0521  DYNAMIC HT  -          58.480 (meters)     191.86  (feet)  COMP
 HT0521  MODELED GRAV-     979,952.7   (mgal)                       NAVD 88
 HT0521
 HT0521  VERT ORDER  -  FIRST     CLASS I
 HT0521
 HT0521.The horizontal coordinates were scaled from a topographic map and have
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 HT0521.an estimated accuracy of +/- 6 seconds.
 HT0521
 HT0521.The orthometric height was determined by differential leveling and
 HT0521.adjusted in June 1991.
 HT0521
 HT0521.The geoid height was determined by GEOID09.
 HT0521
 HT0521.The dynamic height is computed by dividing the NAVD 88
 HT0521.geopotential number by the normal gravity value computed on the
 HT0521.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 HT0521.degrees latitude (g = 980.6199 gals.).
 HT0521
 HT0521.The modeled gravity was interpolated from observed gravity values.
 HT0521
 HT0521;                    North         East     Units  Estimated Accuracy
 HT0521;SPC CA 3     -   634,270.    1,826,200.      MT  (+/- 180 meters Scaled)
 HT0521
 HT0521                          SUPERSEDED SURVEY CONTROL
 HT0521
 HT0521  NGVD 29 (??/??/92)   57.676  (m)          189.23   (f) ADJ UNCH    1 1
 HT0521
 HT0521.Superseded values are not recommended for survey control.
 HT0521.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0521.See file dsdata.txt to determine how the superseded data were derived.
 HT0521
 HT0521_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG466719(NAD 83)
 HT0521_MARKER: DB = BENCH MARK DISK
 HT0521_SETTING: 31 = SET IN A PAVEMENT SUCH AS STREET, SIDEWALK, CURB, ETC.
 HT0521_SP_SET: BRIDGE GUARDRAIL
 HT0521_STAMPING: N 1241 1972
 HT0521_MARK LOGO: NGS
 HT0521_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT0521
 HT0521  HISTORY     - Date     Condition        Report By
 HT0521  HISTORY     - 1972     MONUMENTED       NGS
 HT0521  HISTORY     - 1977     GOOD             NGS
 HT0521  HISTORY     - 1986     GOOD             NGS
 HT0521
 HT0521                          STATION DESCRIPTION
 HT0521
 HT0521'DESCRIBED BY NATIONAL GEODETIC SURVEY 1972
 HT0521'AT DALY CITY.
 HT0521'AT THE NORTHEAST CORNER OF THE JUNCTION OF JUNIPERO SERRA
 HT0521'BOULEVARD AND SCHOOL STREET AT DALY CITY, 5.2 FEET EAST OF THE
 HT0521'WEST END OF THE NORTH CONCRETE GUARDRAIL BASE OF SCHOOL STREET
 HT0521'BRIDGE 35-183 OVER INTERSTATE HIGHWAY 280, 38 FEET EAST OF THE
 HT0521'EAST CURB LINE OF THE BOULEVARD, 26 FEET NORTH OF THE CENTER
 HT0521'LINE OF SCHOOL STREET, ABOUT 1 1/2 FEET HIGHER THAN THE CONCRETE
 HT0521'WALK WAY, AND 2 1/2 FEET HIGHER THAN THE STREET.
 HT0521
 HT0521                          STATION RECOVERY (1977)
 HT0521
 HT0521'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1977
 HT0521'RECOVERED IN GOOD CONDITION.
 HT0521
 HT0521                          STATION RECOVERY (1986)
 HT0521
 HT0521'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1986
 HT0521'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
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HT0520 ***********************************************************************
HT0520  DESIGNATION -  P 1241
HT0520  PID         -  HT0520
HT0520  STATE/COUNTY-  CA/SAN MATEO
HT0520  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
HT0520
HT0520                         *CURRENT SURVEY CONTROL
HT0520  ___________________________________________________________________
HT0520* NAD 83(1986)-  37 42 18.     (N)    122 28 16.     (W)     SCALED
HT0520* NAVD 88     -        73.250  (meters)     240.32   (feet)  ADJUSTED
HT0520  ___________________________________________________________________
HT0520  GEOID HEIGHT-         -32.72  (meters)                     GEOID09
HT0520  DYNAMIC HT  -          73.201 (meters)     240.16  (feet)  COMP
HT0520  MODELED GRAV-     979,957.4   (mgal)                       NAVD 88
HT0520
HT0520  VERT ORDER  -  FIRST     CLASS I
HT0520
HT0520.The horizontal coordinates were scaled from a topographic map and have
HT0520.an estimated accuracy of +/- 6 seconds.
HT0520
HT0520.The orthometric height was determined by differential leveling and
HT0520.adjusted in June 1991.
HT0520
HT0520.The geoid height was determined by GEOID09.
HT0520
HT0520.The dynamic height is computed by dividing the NAVD 88
HT0520.geopotential number by the normal gravity value computed on the
HT0520.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
HT0520.degrees latitude (g = 980.6199 gals.).
HT0520
HT0520.The modeled gravity was interpolated from observed gravity values.
HT0520
HT0520;                    North         East     Units  Estimated Accuracy
HT0520;SPC CA 3     -   635,560.    1,826,210.      MT  (+/- 180 meters Scaled)
HT0520
HT0520                          SUPERSEDED SURVEY CONTROL
HT0520
HT0520  NGVD 29 (??/??/92)   72.407  (m)          237.56   (f) ADJ UNCH    1 1
HT0520
HT0520.Superseded values are not recommended for survey control.
HT0520.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT0520.See file dsdata.txt to determine how the superseded data were derived.
HT0520
HT0520_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG466732(NAD 83)
HT0520_MARKER: DB = BENCH MARK DISK
HT0520_SETTING: 36 = SET IN A MASSIVE STRUCTURE
HT0520_SP_SET: BRIDGE
HT0520_STAMPING: P 1241 1972
HT0520_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
HT0520
HT0520  HISTORY     - Date     Condition        Report By
HT0520  HISTORY     - 1972     MONUMENTED       NGS
HT0520  HISTORY     - 1977     GOOD             NGS
HT0520
HT0520                          STATION DESCRIPTION
HT0520
HT0520'DESCRIBED BY NATIONAL GEODETIC SURVEY 1972
HT0520'AT DALY CITY.
HT0520'AT THE SOUTHWEST CORNER OF THE JUNCTION OF JUNIPERO SERRA
HT0520'BOULEVARD AND KNOWLES AVENUE AT DALY CITY, IN THE TOP AND 5.0
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 HT0520'FEET NORTH OF THE SOUTH END OF THE SOUTH CONCRETE GUARDRAIL
 HT0520'BASE OF KNOWLES AVENUE BRIDGE 35-172 OVER INTERSTATE HIGHWAY 280,
 HT0520'5.9 FEET WEST OF THE WEST CURB OF THE BOULEVARD, 70 FEET SOUTH
 HT0520'OF THE SOUTH LANES OF THE AVENUE, 1 1/2 FEET HIGHER THAN THE
 HT0520'CONCRETE WALK WAY, 2 1/2 FEET HIGHER THAN THE BOULEVARD.
 HT0520
 HT0520                          STATION RECOVERY (1977)
 HT0520
 HT0520'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1977
 HT0520'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0519 ***********************************************************************
 HT0519  DESIGNATION -  N 109 RESET 1964
 HT0519  PID         -  HT0519
 HT0519  STATE/COUNTY-  CA/SAN MATEO
 HT0519  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0519
 HT0519                         *CURRENT SURVEY CONTROL
 HT0519  ___________________________________________________________________
 HT0519* NAD 83(1986)-  37 42 29.     (N)    122 28 06.     (W)     SCALED
 HT0519* NAVD 88     -        82.137  (meters)     269.48   (feet)  ADJUSTED
 HT0519  ___________________________________________________________________
 HT0519  GEOID HEIGHT-         -32.71  (meters)                     GEOID09
 HT0519  DYNAMIC HT  -          82.082 (meters)     269.30  (feet)  COMP
 HT0519  MODELED GRAV-     979,956.5   (mgal)                       NAVD 88
 HT0519
 HT0519  VERT ORDER  -  FIRST     CLASS I
 HT0519
 HT0519.The horizontal coordinates were scaled from a topographic map and have
 HT0519.an estimated accuracy of +/- 6 seconds.
 HT0519
 HT0519.The orthometric height was determined by differential leveling and
 HT0519.adjusted in June 1991.
 HT0519
 HT0519.The geoid height was determined by GEOID09.
 HT0519
 HT0519.The dynamic height is computed by dividing the NAVD 88
 HT0519.geopotential number by the normal gravity value computed on the
 HT0519.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 HT0519.degrees latitude (g = 980.6199 gals.).
 HT0519
 HT0519.The modeled gravity was interpolated from observed gravity values.
 HT0519
 HT0519;                   North         East     Units  Estimated Accuracy
 HT0519;SPC CA 3     -   635,900.    1,826,460.      MT  (+/- 180 meters Scaled)
 HT0519
 HT0519                          SUPERSEDED SURVEY CONTROL
 HT0519
 HT0519  NGVD 29 (??/??/92)   81.292  (m)          266.71   (f) ADJ UNCH    1 1
 HT0519
 HT0519.Superseded values are not recommended for survey control.
 HT0519.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0519.See file dsdata.txt to determine how the superseded data were derived.
 HT0519
 HT0519_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG468735(NAD 83)
 HT0519_MARKER: DD = SURVEY DISK
 HT0519_SETTING: 36 = SET IN A MASSIVE STRUCTURE
 HT0519_SP_SET: BRIDGE
 HT0519_STAMPING: N 109 RESET 1964
 HT0519_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
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 HT0519
 HT0519  HISTORY     - Date     Condition        Report By
 HT0519  HISTORY     - 1964     MONUMENTED       CADH
 HT0519  HISTORY     - 1972     GOOD             NGS
 HT0519  HISTORY     - 1977     GOOD             NGS
 HT0519
 HT0519                          STATION DESCRIPTION
 HT0519
 HT0519'DESCRIBED BY NATIONAL GEODETIC SURVEY 1972
 HT0519'AT DALY CITY.
 HT0519'AT THE ST. CHARLES AVENUE BRIDGE, OVER INTERSTATE HIGHWAY 280,
 HT0519'TO A BART STATION AT DALY CITY, 0.2 MILE SOUTHEAST ALONG ST.
 HT0519'CHARLES AVENUE FROM THE JUNCTION OF ALEMANY BOULEVARD, 0.05 MILE
 HT0519'SOUTHEAST ALONG ST. CHARLES AVENUE FROM THE JUNCTION OF BELLE
 HT0519'AVENUE, IN THE TOP AND 13.0 FEET NORTHWEST OF THE SOUTHEAST END
 HT0519'OF THE NORTHEAST CONCRETE WALK WAY OF THE BRIDGE, 3.0 FEET
 HT0519'SOUTHWEST OF THE SOUTHWEST FACE OF THE NORTHEAST CONCRETE
 HT0519'GUARDRAIL BASE, AND ABOUT 1 FOOT HIGHER THAN THE AVENUE.
 HT0519
 HT0519                          STATION RECOVERY (1977)
 HT0519
 HT0519'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1977
 HT0519'RECOVERED IN GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT0600 ***********************************************************************
 HT0600  DESIGNATION -  L 568
 HT0600  PID         -  HT0600
 HT0600  STATE/COUNTY-  CA/SAN MATEO
 HT0600  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT0600
 HT0600                         *CURRENT SURVEY CONTROL
 HT0600  ___________________________________________________________________
 HT0600* NAD 83(1986)-  37 42 30.     (N)    122 29 09.     (W)     SCALED
 HT0600* NAVD 88     -        29.80   (+/-2cm)      97.8    (feet)  VERTCON
 HT0600  ___________________________________________________________________
 HT0600  GEOID HEIGHT-         -32.77  (meters)                     GEOID09
 HT0600  VERT ORDER  -  SECOND    CLASS 0 (See Below)
 HT0600
 HT0600.The horizontal coordinates were scaled from a topographic map and have
 HT0600.an estimated accuracy of +/- 6 seconds.
 HT0600
 HT0600.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT0600.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT0600.The vertical order pertains to the NGVD 29 superseded value.
 HT0600
 HT0600.The geoid height was determined by GEOID09.
 HT0600
 HT0600;                    North         East    Units  Estimated Accuracy
 HT0600;SPC CA 3     -   635,960.    1,824,920.      MT  (+/- 180 meters Scaled)
 HT0600
 HT0600                          SUPERSEDED SURVEY CONTROL
 HT0600
 HT0600  NGVD 29 (??/??/92)   28.960  (m)           95.01   (f) ADJ UNCH    2 0
 HT0600
 HT0600.Superseded values are not recommended for survey control.
 HT0600.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0600.See file dsdata.txt to determine how the superseded data were derived.
 HT0600
 HT0600_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG453735(NAD 83)
 HT0600_MARKER: DB = BENCH MARK DISK
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 HT0600_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT0600_SP_SET: CULVERT
 HT0600_STAMPING: L 568 1939
 HT0600_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT0600
 HT0600  HISTORY     - Date     Condition        Report By
 HT0600  HISTORY     - 1939     MONUMENTED       CGS
 HT0600  HISTORY     - 1958     GOOD             NGS
 HT0600  HISTORY     - 1958     MARK NOT FOUND   NGS
 HT0600
 HT0600                          STATION DESCRIPTION
 HT0600
 HT0600'DESCRIBED BY NATIONAL GEODETIC SURVEY 1958
 HT0600'0.9 MI W FROM DALY CITY.
 HT0600'0.9 MILE WEST ALONG STATE HIGHWAY 1 FROM THE WEST CITY LIMITS
 HT0600'OF DALY CITY, SAN MATEO COUNTY, OPPOSITE THE EAST END OF THE
 HT0600'TRIANGLE FORMED AT THE Y-JUNCTION OF LAKE MERCED BOULEVARD,
 HT0600'AT A CULVERT UNDER STATE HIGHWAY 1, IN THE TOP OF THE SOUTHEAST
 HT0600'CORNER OF THE SOUTH CONCRETE HEADWALL, 35 FEET SOUTH OF THE
 HT0600'CENTERLINE OF THE HIGHWAY, AND 14 FEET WEST OF THE CENTERLINE
 HT0600'OF A FARM ROAD.  A STANDARD DISK, STAMPED L 568 1939.  NOTE-- THERE
 HT0600'IS NOW A SIX-LANE HIGHWAY AT THIS LOCATION AND NO CONCRETE
 HT0600'HEADWALL.
 HT0600
 HT0600                          STATION RECOVERY (1958)
 HT0600
 HT0600'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1958
 HT0600'MARK NOT FOUND.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT2273 ***********************************************************************
 HT2273  DESIGNATION -  W 1320
 HT2273  PID         -  HT2273
 HT2273  STATE/COUNTY-  CA/SAN FRANCISCO
 HT2273  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT2273
 HT2273                         *CURRENT SURVEY CONTROL
 HT2273  ___________________________________________________________________
 HT2273* NAD 83(1986)-  37 42 48.     (N)    122 28 18.     (W)     SCALED
 HT2273* NAVD 88     -        58.189  (meters)     190.91   (feet)  ADJUSTED
 HT2273  ___________________________________________________________________
 HT2273  GEOID HEIGHT-         -32.71  (meters)                     GEOID09
 HT2273  DYNAMIC HT  -          58.150 (meters)     190.78  (feet)  COMP
 HT2273  MODELED GRAV-     979,963.4   (mgal)                       NAVD 88
 HT2273  OBS GRAVITY -     979,965.8   (mgal)                       GRAV_OBS
 HT2273
 HT2273  VERT ORDER  -  FIRST     CLASS I
 HT2273
 HT2273.The horizontal coordinates were scaled from a topographic map and have
 HT2273.an estimated accuracy of +/- 6 seconds.
 HT2273
 HT2273.The orthometric height was determined by differential leveling and
 HT2273.adjusted in June 1991.
 HT2273
 HT2273.The geoid height was determined by GEOID09.
 HT2273
 HT2273.The dynamic height is computed by dividing the NAVD 88
 HT2273.geopotential number by the normal gravity value computed on the
 HT2273.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 HT2273.degrees latitude (g = 980.6199 gals.).
 HT2273
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HT2273.The modeled gravity was interpolated from observed gravity values.
HT2273.The observed gravity was obtained from relative gravimeter ties
HT2273.to the IGSN71 gravity network.
HT2273
HT2273;                    North         East     Units  Estimated Accuracy
HT2273;SPC CA 3     -   636,490.    1,826,180.      MT  (+/- 180 meters Scaled)
HT2273
HT2273                          SUPERSEDED SURVEY CONTROL
HT2273
HT2273  NGVD 29 (10/21/93)   57.345  (m)          188.14   (f) ADJUSTED    1 1
HT2273
HT2273.Superseded values are not recommended for survey control.
HT2273.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT2273.See file dsdata.txt to determine how the superseded data were derived.
HT2273
HT2273_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG465741(NAD 83)
HT2273_MARKER: DB = BENCH MARK DISK
HT2273_SETTING: 30 = SET IN A LIGHT STRUCTURE
HT2273_SP_SET: CURB
HT2273_STAMPING: W 1320 1977
HT2273_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
HT2273
HT2273  HISTORY     - Date     Condition        Report By
HT2273  HISTORY     - 1977     MONUMENTED       NGS
HT2273
HT2273                          STATION DESCRIPTION
HT2273
HT2273'DESCRIBED BY NATIONAL GEODETIC SURVEY 1977
HT2273'IN SAN FRANCISCO.
HT2273'AT SAN FRANCISCO, SET IN THE CURB ON THE WEST SIDE OF JUNIPERO
HT2273'SERRA BLVD, JUST NORTH OF WHERE IT CROSSES BROTHERHOOD WAY.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
HT0602 ***********************************************************************
HT0602  DESIGNATION -  M 568 RESET 1955
HT0602  PID         -  HT0602
HT0602  STATE/COUNTY-  CA/SAN FRANCISCO
HT0602  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
HT0602
HT0602                         *CURRENT SURVEY CONTROL
HT0602  ___________________________________________________________________
HT0602* NAD 83(1986)-  37 43 08.     (N)    122 30 01.     (W)     SCALED
HT0602* NAVD 88     -        12.67   (+/-2cm)      41.6    (feet)  VERTCON
HT0602  ___________________________________________________________________
HT0602  GEOID HEIGHT-         -32.80  (meters)                     GEOID09
HT0602  VERT ORDER  -  THIRD (See Below)
HT0602
HT0602.The horizontal coordinates were scaled from a topographic map and have
HT0602.an estimated accuracy of +/- 6 seconds.
HT0602
HT0602.The NAVD 88 height was computed by applying the VERTCON shift value to
HT0602.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
HT0602.The vertical order pertains to the NGVD 29 superseded value.
HT0602
HT0602.The geoid height was determined by GEOID09.
HT0602
HT0602;                    North         East     Units  Estimated Accuracy
HT0602;SPC CA 3     -   637,160.    1,823,670.      MT  (+/- 180 meters Scaled)
HT0602
HT0602                          SUPERSEDED SURVEY CONTROL
HT0602
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 HT0602  NGVD 29 (??/??/??)   11.83   (m)           38.8    (f) RESET       3
 HT0602
 HT0602.Superseded values are not recommended for survey control.
 HT0602.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT0602.See file dsdata.txt to determine how the superseded data were derived.
 HT0602
 HT0602_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG440747(NAD 83)
 HT0602_MARKER: DB = BENCH MARK DISK
 HT0602_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT0602_SP_SET: FLAGPOLE CONCRETE BASE
 HT0602_STAMPING: M 568 RESET 1955
 HT0602_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT0602
 HT0602  HISTORY     - Date     Condition        Report By
 HT0602  HISTORY     - 1955     MONUMENTED       CGS
 HT0602
 HT0602                          STATION DESCRIPTION
 HT0602
 HT0602'DESCRIBED BY COAST AND GEODETIC SURVEY 1955
 HT0602'IN SAN FRANCISCO.
 HT0602'ABOUT 0.8 MILE NORTH ALONG SKYLINE BLVD. FROM THE SOUTH CITY
 HT0602'LIMITS OF SAN FRANCISCO, ON THE WEST SHORE OF LAKE MERCED.
 HT0602'SET IN A DRILL HOLE IN THE CONCRETE BASE OF THE FLAG POLE IN FRONT
 HT0602'OF THE SAN FRANCISCO POLICE PISTOL RANGE BUILDING.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT2272 ***********************************************************************
 HT2272  DESIGNATION -  V 1320
 HT2272  PID         -  HT2272
 HT2272  STATE/COUNTY-  CA/SAN FRANCISCO
 HT2272  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT2272
 HT2272                         *CURRENT SURVEY CONTROL
 HT2272  ___________________________________________________________________
 HT2272* NAD 83(1986)-  37 43 17.     (N)    122 28 32.     (W)     SCALED
 HT2272* NAVD 88     -        49.702  (meters)     163.06   (feet)  ADJUSTED
 HT2272  ___________________________________________________________________
 HT2272  GEOID HEIGHT-         -32.71  (meters)                     GEOID09
 HT2272  DYNAMIC HT  -          49.669 (meters)     162.96  (feet)  COMP
 HT2272  MODELED GRAV-     979,968.2   (mgal)                       NAVD 88
 HT2272
 HT2272  VERT ORDER  -  FIRST     CLASS I
 HT2272
 HT2272.The horizontal coordinates were scaled from a topographic map and have
 HT2272.an estimated accuracy of +/- 6 seconds.
 HT2272
 HT2272.The orthometric height was determined by differential leveling and
 HT2272.adjusted in June 1991.
 HT2272
 HT2272.The geoid height was determined by GEOID09.
 HT2272
 HT2272.The dynamic height is computed by dividing the NAVD 88
 HT2272.geopotential number by the normal gravity value computed on the
 HT2272.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 HT2272.degrees latitude (g = 980.6199 gals.).
 HT2272
 HT2272.The modeled gravity was interpolated from observed gravity values.
 HT2272
 HT2272;                   North         East     Units  Estimated Accuracy
 HT2272;SPC CA 3     -   637,390.    1,825,850.      MT  (+/- 180 meters Scaled)
 HT2272
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 HT2272                          SUPERSEDED SURVEY CONTROL
 HT2272
 HT2272  NGVD 29 (10/21/93)   48.860  (m)          160.30   (f) ADJUSTED    1 1
 HT2272
 HT2272.Superseded values are not recommended for survey control.
 HT2272.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT2272.See file dsdata.txt to determine how the superseded data were derived.
 HT2272
 HT2272_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG462750(NAD 83)
 HT2272_MARKER: DB = BENCH MARK DISK
 HT2272_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT2272_SP_SET: CURB
 HT2272_STAMPING: V 1320 1977
 HT2272_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT2272
 HT2272  HISTORY     - Date     Condition        Report By
 HT2272  HISTORY     - 1977     MONUMENTED       NGS
 HT2272
 HT2272                          STATION DESCRIPTION
 HT2272
 HT2272'DESCRIBED BY NATIONAL GEODETIC SURVEY 1977
 HT2272'IN SAN FRANCISCO.
 HT2272'AT SAN FRANCISCO, ON THE CAMPUS OF CALIFORNIA STATE UNIVERSITY IN THE
 HT2272'SOUTHWEST PART OF THE CITY , SET IN THE TOP OF A CONCRETE
 HT2272'BORDER OF THE
 HT2272'H H L ENERGY CONSERVATION BUILDING AT THE NORTHEAST CORNER, JUST NORTH
 HT2272'OF A 15 MINUTE PARKING ZONE, AND 0.6 FOOT WEST OF THE SIDEWALK.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT2271 ***********************************************************************
 HT2271  DESIGNATION -  M 6 C OF SF
 HT2271  PID         -  HT2271
 HT2271  STATE/COUNTY-  CA/SAN FRANCISCO
 HT2271  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT2271
 HT2271                         *CURRENT SURVEY CONTROL
 HT2271  ___________________________________________________________________
 HT2271* NAD 83(1986)-  37 43 47.     (N)    122 28 30.     (W)     SCALED
 HT2271* NAVD 88     -        63.620  (meters)     208.73   (feet)  ADJUSTED
 HT2271  ___________________________________________________________________
 HT2271  GEOID HEIGHT-         -32.70  (meters)                     GEOID09
 HT2271  DYNAMIC HT  -          63.578 (meters)     208.59  (feet)  COMP
 HT2271  MODELED GRAV-     979,966.0   (mgal)                       NAVD 88
 HT2271
 HT2271  VERT ORDER  -  FIRST     CLASS I
 HT2271
 HT2271.The horizontal coordinates were scaled from a topographic map and have
 HT2271.an estimated accuracy of +/- 6 seconds.
 HT2271
 HT2271.The orthometric height was determined by differential leveling and
 HT2271.adjusted in June 1991.
 HT2271
 HT2271.The geoid height was determined by GEOID09.
 HT2271
 HT2271.The dynamic height is computed by dividing the NAVD 88
 HT2271.geopotential number by the normal gravity value computed on the
 HT2271.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 HT2271.degrees latitude (g = 980.6199 gals.).
 HT2271
 HT2271.The modeled gravity was interpolated from observed gravity values.
 HT2271
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 HT2271;                    North         East     Units  Estimated Accuracy
 HT2271;SPC CA 3     -   638,310.    1,825,920.      MT  (+/- 180 meters Scaled)
 HT2271
 HT2271                          SUPERSEDED SURVEY CONTROL
 HT2271
 HT2271  NGVD 29 (10/21/93)   62.779  (m)          205.97   (f) ADJUSTED    1 1
 HT2271
 HT2271.Superseded values are not recommended for survey control.
 HT2271.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT2271.See file dsdata.txt to determine how the superseded data were derived.
 HT2271
 HT2271_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG462759(NAD 83)
 HT2271_MARKER: DD = SURVEY DISK
 HT2271_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT2271_SP_SET: SIDEWALK
 HT2271_STAMPING: M 6 1974
 HT2271_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT2271
 HT2271  HISTORY     - Date     Condition        Report By
 HT2271  HISTORY     - 1974     MONUMENTED       CA3290
 HT2271  HISTORY     - 1977     GOOD             NGS
 HT2271
 HT2271                          STATION DESCRIPTION
 HT2271
 HT2271'DESCRIBED BY NATIONAL GEODETIC SURVEY 1977
 HT2271'IN SAN FRANCISCO.
 HT2271'AT SAN FRANCISCO, ON 19 TH AVE AT STONETOWN MALL, A DISK SET IN THE
 HT2271'SIDEWALK IN THE CENTER OF A PAINTED WHITE CROSS, 10 FEET SOUTH OF
 HT2271'THE STEPS LEADING TO THE MALL AT THE NORTH END, AND 5 FEET WEST OF THE
 HT2271'WEST CURB OF 19 TH AVE.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT1841 ***********************************************************************
 HT1841  DESIGNATION -  N 568
 HT1841  PID         -  HT1841
 HT1841  STATE/COUNTY-  CA/SAN FRANCISCO
 HT1841  USGS QUAD   -
 HT1841
 HT1841                         *CURRENT SURVEY CONTROL
 HT1841  ___________________________________________________________________
 HT1841* NAD 83(1986)-  37 43 47.     (N)    122 30 10.     (W)     SCALED
 HT1841* NAVD 88     -        17.71   (+/-2cm)      58.1    (feet)  VERTCON
 HT1841  ___________________________________________________________________
 HT1841  GEOID HEIGHT-         -32.79  (meters)                     GEOID09
 HT1841  VERT ORDER  -  SECOND    CLASS 0 (See Below)
 HT1841
 HT1841.The horizontal coordinates were scaled from a topographic map and have
 HT1841.an estimated accuracy of +/- 6 seconds.
 HT1841
 HT1841.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT1841.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT1841.The vertical order pertains to the NGVD 29 superseded value.
 HT1841
 HT1841.The geoid height was determined by GEOID09.
 HT1841
 HT1841;                    North         East     Units  Estimated Accuracy
 HT1841;SPC CA 3     -   638,370.    1,823,470.      MT  (+/- 180 meters Scaled)
 HT1841
 HT1841                          SUPERSEDED SURVEY CONTROL
 HT1841
 HT1841  NGVD 29 (??/??/92)   16.874  (m)           55.36   (f) ADJ UNCH    2 0
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 HT1841
 HT1841.Superseded values are not recommended for survey control.
 HT1841.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT1841.See file dsdata.txt to determine how the superseded data were derived.
 HT1841
 HT1841_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG438759(NAD 83)
 HT1841_MARKER: DB = BENCH MARK DISK
 HT1841_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT1841_SP_SET: WALL
 HT1841_STAMPING: N 568 1939
 HT1841_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT1841_SATELLITE: THE SITE LOCATION WAS REPORTED AS NOT SUITABLE FOR
 HT1841+SATELLITE: SATELLITE OBSERVATIONS - January 11, 2009
 HT1841
 HT1841  HISTORY     - Date     Condition        Report By
 HT1841  HISTORY     - 1939     MONUMENTED       CGS
 HT1841  HISTORY     - 1973     GOOD             NGS
 HT1841  HISTORY     - 20090109 GOOD             GEOCAC
 HT1841  HISTORY     - 20090111 GOOD             GEOCAC
 HT1841
 HT1841                          STATION DESCRIPTION
 HT1841
 HT1841'DESCRIBED BY NATIONAL GEODETIC SURVEY 1973
 HT1841'AT SAN FRANCISCO.
 HT1841'AT SAN FRANCISCO, SAN FRANCISCO COUNTY, AT THE NORTHEAST CORNER
 HT1841'OF FORT FUNSTON, 78 FEET SOUTH OF THE CENTER OF THE ENTRANCE, 20.7
 HT1841'FEET SOUTHWEST OF A FENCE, IN THE CONCRETE WALL OF A PUMP HOUSE,
 HT1841'8 INCHES FROM THE NORTHWEST CORNER, AND ABOUT 4 FEET ABOVE THE
 HT1841'GROUND.  A STANDARD DISK, STAMPED N 568 1939 AND SET VERTICALLY.
 HT1841
 HT1841                          STATION RECOVERY (2009)
 HT1841
 HT1841'RECOVERY NOTE BY GEOCACHING 2009 (RM)
 HT1841'RECOVERED BENCHMARK IN GOOD CONDITION.  NGS DESCRIPTION (1973) IS
 HT1841'ADEQUATE.
 HT1841
 HT1841                          STATION RECOVERY (2009)
 HT1841
 HT1841'RECOVERY NOTE BY GEOCACHING 2009 (RM)
 HT1841'PERMISSION WAS GRANTED TO PROCEED THROUGH THE SAN FRANCISCO ZOO GATES
 HT1841'TO
 HT1841'ACCESS THE PUMPHOUSE FROM THE NORTHWEST WHERE THE STATION WAS
 HT1841'RECOVERED IN
 HT1841'GOOD CONDITION.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 AB7677 ***********************************************************************
 AB7677  DESIGNATION -  HPGN D CA 04 GE
 AB7677  PID         -  AB7677
 AB7677  STATE/COUNTY-  CA/SAN FRANCISCO
 AB7677  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 AB7677
 AB7677                         *CURRENT SURVEY CONTROL
 AB7677  ___________________________________________________________________
 AB7677* NAD 83(2007)-  37 44 00.33344(N)    122 29 49.03035(W)     ADJUSTED
 AB7677* NAVD 88     -        23.69   (meters)      77.7    (feet)  LEVELING
 AB7677  ___________________________________________________________________
 AB7677  EPOCH DATE  -        2007.00
 AB7677  X           -  -2,713,450.334 (meters)                     COMP
 AB7677  Y           -  -4,259,763.765 (meters)                     COMP
 AB7677  Z           -   3,882,080.400 (meters)                     COMP
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AB7677  LAPLACE CORR-          6.47  (seconds)                      DEFLEC09
AB7677  ELLIP HEIGHT-         -9.035 (meters)           (02/10/07) ADJUSTED
AB7677  GEOID HEIGHT-        -32.76  (meters)                      GEOID09
AB7677
AB7677  ------- Accuracy Estimates (at 95% Confidence Level in cm) --------
AB7677  Type    PID    Designation                      North   East  Ellip
AB7677  -------------------------------------------------------------------
AB7677  NETWORK AB7677 HPGN D CA 04 GE                   0.71   1.16   5.84
AB7677  -------------------------------------------------------------------
AB7677  VERT ORDER  -  THIRD ?
AB7677
AB7677.The horizontal coordinates were established by GPS observations
AB7677.and adjusted by the National Geodetic Survey in February 2007.
AB7677
AB7677.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
AB7677.See National Readjustment for more information.
AB7677.The horizontal coordinates are valid at the epoch date displayed above.
AB7677.The epoch date for horizontal control is a decimal equivalence
AB7677.of Year/Month/Day.
AB7677
AB7677.The orthometric height was determined by differential leveling.
AB7677.The vertical network tie was performed by a horz. field party for horz.
AB7677.obs reductions. Reset procedures were used to establish the elevation.
AB7677
AB7677.The X, Y, and Z were computed from the position and the ellipsoidal ht.
AB7677
AB7677.The Laplace correction was computed from DEFLEC09 derived deflections.
AB7677
AB7677.The ellipsoidal height was determined by GPS observations
AB7677.and is referenced to NAD 83.
AB7677
AB7677.The geoid height was determined by GEOID09.
AB7677
AB7677;                    North         East     Units Scale Factor Converg.
AB7677;SPC CA 3     -   638,764.560 1,823,995.524   MT  0.99992923   -1 13 21.4
AB7677;SPC CA 3     - 2,095,680.06  5,984,225.31   sFT  0.99992923   -1 13 21.4
AB7677;UTM  10      - 4,176,357.833   544,325.733   MT  0.99962420   +0 18 28.3
AB7677
AB7677!             -  Elev Factor  x  Scale Factor =   Combined Factor
AB7677!SPC CA 3     -   1.00000142  x   0.99992923  =   0.99993065
AB7677!UTM  10      -   1.00000142  x   0.99962420  =   0.99962562
AB7677
AB7677                          SUPERSEDED SURVEY CONTROL
AB7677
AB7677  NAD 83(1992)-  37 44 00.31877(N)    122 29 49.01603(W) AD(1991.35) 1
AB7677  ELLIP H (10/31/96)   -8.940  (m)                       GP(       ) 4 1
AB7677
AB7677.Superseded values are not recommended for survey control.
AB7677.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
AB7677.See file dsdata.txt to determine how the superseded data were derived.
AB7677
AB7677_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG4432576357(NAD 83)
AB7677_MARKER: DD = SURVEY DISK
AB7677_SETTING: 50 = ALUMINUM ALLOY ROD W/O SLEEVE (10 FT.+)
AB7677_STAMPING: CA-HPGN-DENSIFICATION STA. 04-GE 1994
AB7677_MARK LOGO: CADT
AB7677_PROJECTION: FLUSH
AB7677_MAGNETIC: M = MARKER EQUIPPED WITH BAR MAGNET
AB7677_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
AB7677_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
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 AB7677+SATELLITE: SATELLITE OBSERVATIONS - 1994
 AB7677_ROD/PIPE-DEPTH: 7.8  meters
 AB7677
 AB7677  HISTORY     - Date     Condition        Report By
 AB7677  HISTORY     - 1994     MONUMENTED       CADT
 AB7677
 AB7677                          STATION DESCRIPTION
 AB7677
 AB7677'DESCRIBED BY CALTRANS 1994 (DAN)
 AB7677'THE STATION IS LOCATED NEAR THE INTERSECTION OF SKYLINE BLVD (STATE
 AB7677'HIGHWAY 35) AND SLOAT BLVD AT THE NORTHEAST CORNER OF THE SAN
 AB7677'FRANCISCO ZOO, ABOUT 6 MI (9.7 KM) SOUTHWEST OF DOWNTOWN SAN
 AB7677'FRANCISCO.  TO REACH THE STATION FROM THE INTERSECTION OF SLOAT BLVD
 AB7677'(STATE HIGHWAY 35) AND 19TH AVE (STATE HIGHWAY 1) , GO WEST ON SLOAT
 AB7677'BLVD, CROSSING OVER SUNSET BLVD, FOR 1.2 MI (1.9 KM) TO THE
 AB7677'Y-INTERSECTION WITH SKYLINE BLVD (STATE HIGHWAY 35) .  BEAR LEFT AND
 AB7677'GO SOUTHWEST ON SKYLINE BLVD FOR ABOUT 165 FT (50.3 M) TO THE STATION
 AB7677'ON THE LEFT IN THE RAISED MEDIAN ISLAND AT POST MILE 1.8.  THE STATION
 AB7677'IS A SURVEY DISK ENCASED IN PVC PIPE WITH ACCESS COVER SET IN CONCRETE
 AB7677'FLUSH WITH THE SURFACE OF THE RAISED MEDIAN ISLAND, ABOUT 165 FT (50.3
 AB7677'M) SOUTHWEST OF THE INTERSECTION OF SKYLINE BLVD AND SLOAT BLVD, 118.5
 AB7677'FT (36.1 M) NORTHWEST OF THE NORTHWEST CORNER OF THE HOUSE AT 379
 AB7677'SKYLINE BLVD, 96.4 FT (29.4 M) NORTHEAST OF A LIGHT POST AT THE SOUTH
 AB7677'END OF THE MEDIAN ISLAND, 74.3 FT (22.6 M) SOUTHWEST OF LIGHT POST
 AB7677'E0/1 AT THE NORTH END OF THE MEDIAN ISLAND, 65.0 FT (19.8 M) WEST OF
 AB7677'AND ACROSS THE NORTH-BOUND LANES OF SKYLINE BLVD FROM LIGHT POST 0/6,
 AB7677'18.4 FT (5.6 M) EAST OF THE WEST CURB OF THE MEDIAN ISLAND AND 7.3 FT
 AB7677'(2.2 M) WEST OF THE EAST CURB OF THE MEDIAN ISLAND.  THE DISK IS 0.3
 AB7677'FT (0.1 M) BELOW THE LID OF THE ACCESS COVER.  THIS STATION WAS
 AB7677'OCCUPIED AS PART OF A CALIFORNIA HPGN DENSIFICATION SURVEY IN 1994.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT1842 ***********************************************************************
 HT1842  DESIGNATION -  P 568
 HT1842  PID         -  HT1842
 HT1842  STATE/COUNTY-  CA/SAN FRANCISCO
 HT1842  USGS QUAD   -
 HT1842
 HT1842                         *CURRENT SURVEY CONTROL
 HT1842  ___________________________________________________________________
 HT1842* NAD 83(1986)-  37 44 10.     (N)    122 30 23.     (W)     SCALED
 HT1842* NAVD 88     -        10.20   (+/-2cm)      33.5    (feet)  VERTCON
 HT1842  ___________________________________________________________________
 HT1842  GEOID HEIGHT-         -32.79  (meters)                     GEOID09
 HT1842  VERT ORDER  -  SECOND    CLASS 0 (See Below)
 HT1842
 HT1842.The horizontal coordinates were scaled from a topographic map and have
 HT1842.an estimated accuracy of +/- 6 seconds.
 HT1842
 HT1842.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT1842.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT1842.The vertical order pertains to the NGVD 29 superseded value.
 HT1842
 HT1842.The geoid height was determined by GEOID09.
 HT1842
 HT1842;                   North         East    Units  Estimated Accuracy
 HT1842;SPC CA 3     -   639,080.    1,823,170.      MT  (+/- 180 meters Scaled)
 HT1842
 HT1842                          SUPERSEDED SURVEY CONTROL
 HT1842
 HT1842  NGVD 29 (??/??/92)    9.361  (m)           30.71   (f) ADJ UNCH    2 0
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 HT1842
 HT1842.Superseded values are not recommended for survey control.
 HT1842.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT1842.See file dsdata.txt to determine how the superseded data were derived.
 HT1842
 HT1842_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG434766(NAD 83)
 HT1842_MARKER: DB = BENCH MARK DISK
 HT1842_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT1842_SP_SET: CULVERT
 HT1842_STAMPING: P 568 1939
 HT1842_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT1842
 HT1842  HISTORY     - Date     Condition        Report By
 HT1842  HISTORY     - 1939     MONUMENTED       CGS
 HT1842  HISTORY     - 1973     GOOD             NGS
 HT1842
 HT1842                          STATION DESCRIPTION
 HT1842
 HT1842'DESCRIBED BY NATIONAL GEODETIC SURVEY 1973
 HT1842'AT SAN FRANCISCO.
 HT1842'AT SAN FRANCISCO, SAN FRANCISCO COUNTY, ON GREAT HIGHWAY, AT THE
 HT1842'FOOT OF WAWONA STREET, 75 FEET SOUTH OF A COMFORT STATION, 39
 HT1842'FEET EAST OF THE EAST BOUNDARY OF THE MIDDLE LANE, AT THE EAST
 HT1842'END OF A CULVERT UNDER THE HIGHWAY, AND IN THE TOP OF A SOUTH
 HT1842'HEADWALL.  A STANDARD DISK, STAMPED P 568 1939.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT2270 ***********************************************************************
 HT2270  DESIGNATION -  U 1320
 HT2270  PID         -  HT2270
 HT2270  STATE/COUNTY-  CA/SAN FRANCISCO
 HT2270  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT2270
 HT2270                         *CURRENT SURVEY CONTROL
 HT2270  ___________________________________________________________________
 HT2270* NAD 83(2007)-  37 44 15.72379(N)    122 28 31.93050(W)     ADJUSTED
 HT2270* NAVD 88     -        83.942  (meters)     275.40   (feet)  ADJUSTED
 HT2270  ___________________________________________________________________
 HT2270  EPOCH DATE  -        2007.00
 HT2270  X           -  -2,711,727.558 (meters)                     COMP
 HT2270  Y           -  -4,260,572.965 (meters)                     COMP
 HT2270  Z           -   3,882,492.556 (meters)                     COMP
 HT2270  LAPLACE CORR-           5.70  (seconds)                    DEFLEC09
 HT2270  ELLIP HEIGHT-          51.257 (meters)          (02/10/07) ADJUSTED
 HT2270  GEOID HEIGHT-         -32.68  (meters)                     GEOID09
 HT2270  DYNAMIC HT  -          83.886 (meters)     275.22  (feet)  COMP
 HT2270
 HT2270  ------- Accuracy Estimates (at 95% Confidence Level in cm) --------
 HT2270  Type    PID    Designation                       North   East  Ellip
 HT2270  -------------------------------------------------------------------
 HT2270  NETWORK HT2270 U 1320                             0.49   0.84   4.31
 HT2270  -------------------------------------------------------------------
 HT2270  MODELED GRAV-     979,961.5   (mgal)                       NAVD 88
 HT2270  OBS GRAVITY -     979,965.1   (mgal)                       GRAV_OBS
 HT2270
 HT2270  VERT ORDER  -  FIRST     CLASS I
 HT2270
 HT2270.The horizontal coordinates were established by GPS observations
 HT2270.and adjusted by the National Geodetic Survey in February 2007.
 HT2270
 HT2270.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
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HT2270.See National Readjustment for more information.
HT2270.The horizontal coordinates are valid at the epoch date displayed above.
HT2270.The epoch date for horizontal control is a decimal equivalence
HT2270.of Year/Month/Day.
HT2270
HT2270.The orthometric height was determined by differential leveling and
HT2270.adjusted in June 1991.
HT2270
HT2270.The X, Y, and Z were computed from the position and the ellipsoidal ht.
HT2270
HT2270.The Laplace correction was computed from DEFLEC09 derived deflections.
HT2270
HT2270.The ellipsoidal height was determined by GPS observations
HT2270.and is referenced to NAD 83.
HT2270
HT2270.The geoid height was determined by GEOID09.
HT2270
HT2270.The dynamic height is computed by dividing the NAVD 88
HT2270.geopotential number by the normal gravity value computed on the
HT2270.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
HT2270.degrees latitude (g = 980.6199 gals.).
HT2270
HT2270.The modeled gravity was interpolated from observed gravity values.
HT2270.The observed gravity was obtained from relative gravimeter ties
HT2270.to the IGSN71 gravity network.
HT2270
HT2270;                   North         East     Units Scale Factor Converg.
HT2270;SPC CA 3     -   639,198.858 1,825,892.844   MT  0.99992921   -1 12 34.2
HT2270;SPC CA 3     - 2,097,104.92  5,990,450.11   sFT  0.99992921   -1 12 34.2
HT2270;UTM  10      - 4,176,842.504   546,210.203   MT  0.99962630   +0 19 15.6
HT2270
HT2270!             -  Elev Factor  x  Scale Factor =   Combined Factor
HT2270!SPC CA 3     -   0.99999196  x   0.99992921  =   0.99992117
HT2270!UTM  10      -   0.99999196  x   0.99962630  =   0.99961826
HT2270
HT2270                          SUPERSEDED SURVEY CONTROL
HT2270
HT2270  NAD 83(1992)-  37 44 15.71536(N)    122 28 31.92128(W) AD(1997.30) 1
HT2270  ELLIP H (07/10/98)   51.275  (m)                       GP(1997.30) 4 1
HT2270  NAD 83(1992)-  37 44 15.71326(N)    122 28 31.91994(W) AD(1995.42) 1
HT2270  ELLIP H (12/22/97)   51.336  (m)                       GP(        ) 4 1
HT2270  NAVD 88 (12/22/97)   83.94   (m)          275.4    (f) LEVELING    3
HT2270  NGVD 29 (10/21/93)   83.101  (m)          272.64   (f) ADJUSTED    1 1
HT2270
HT2270.Superseded values are not recommended for survey control.
HT2270.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
HT2270.See file dsdata.txt to determine how the superseded data were derived.
HT2270
HT2270_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG4621076842(NAD 83)
HT2270_MARKER: DB = BENCH MARK DISK
HT2270_SETTING: 30 = SET IN A LIGHT STRUCTURE
HT2270_SP_SET: CONCRETE CATCH BASIN
HT2270_STAMPING: U 1320 1977
HT2270_MARK LOGO: NGS
HT2270_MAGNETIC: N = NO MAGNETIC MATERIAL
HT2270_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
HT2270_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
HT2270+SATELLITE: SATELLITE OBSERVATIONS - September 15, 1995
HT2270
HT2270  HISTORY     - Date     Condition        Report By
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 HT2270  HISTORY     - 1977     MONUMENTED       NGS
 HT2270  HISTORY     - 19950915 GOOD             NGS
 HT2270
 HT2270                          STATION DESCRIPTION
 HT2270
 HT2270'DESCRIBED BY NATIONAL GEODETIC SURVEY 1977
 HT2270'IN SAN FRANCISCO.
 HT2270'AT SAN FRANCISCO, ON THE WEST SIDE OF 19TH AVE, IN THE SOUTH END OF
 HT2270'LARSEN PARK, SET IN THE TOP OF A CATCH BASIN JUST NORTH OF A SET OF
 HT2270'STEPS LEADING TO THE ENTRANCE OF AN INDOOR SWIMMING POOL.
 HT2270
 HT2270                          STATION RECOVERY (1995)
 HT2270
 HT2270'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1995 (JDD)
 HT2270'THE STATION WAS RECOVERED.  TO REACH THE STATION FROM THE INTERSECTION
 HT2270'OF LINCOLN AND AND STATE HIGHWAY 1, 19TH STREET, AT THE SOUTH END OF
 HT2270'GOLDEN GATE PARK GO SOUTH ON 19TH STREET FOR 1.95 MI (3.14 KM) TO THE
 HT2270'STATION ON THE RIGHT.$THE STATION IS NEAR THE ENTRANCE TO THE CHARLIE
 HT2270'SAVA SWIMMING POOL IN LARSEN PARK.  IT IS 27.6 M (90.6 FT) NORTH OF
 HT2270'THE CENTERLINE OF WAWONA, 20.3 M (66.6 FT) WEST OF THE CENTERLINE OF
 HT2270'19TH STREET, 7.3 M (24.0 FT) NORTHEAST OF A FLAG POLE, 4.4 M (14.4 FT)
 HT2270'EAST OF THE SOUTHEAST CORNER OF THE SWIMMING POOL BUILDING AND 1.1 M
 HT2270'(3.6 FT) NORTH OF THE CENTERLINE OF A CONCRETE STAIRWAY.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT2269 ***********************************************************************
 HT2269  DESIGNATION -  T 1320
 HT2269  PID         -  HT2269
 HT2269  STATE/COUNTY-  CA/SAN FRANCISCO
 HT2269  USGS QUAD   -  SAN FRANCISCO SOUTH (1995)
 HT2269
 HT2269                         *CURRENT SURVEY CONTROL
 HT2269  ___________________________________________________________________
 HT2269* NAD 83(1986)-  37 44 49.     (N)    122 28 34.     (W)    SCALED
 HT2269* NAVD 88     -       128.511  (meters)     421.62   (feet)  ADJUSTED
 HT2269  ___________________________________________________________________
 HT2269  GEOID HEIGHT-         -32.67  (meters)                     GEOID09
 HT2269  DYNAMIC HT  -         128.425 (meters)     421.34  (feet)  COMP
 HT2269  MODELED GRAV-     979,957.5   (mgal)                       NAVD 88
 HT2269
 HT2269  VERT ORDER  -  FIRST     CLASS I
 HT2269
 HT2269.The horizontal coordinates were scaled from a topographic map and have
 HT2269.an estimated accuracy of +/- 6 seconds.
 HT2269
 HT2269.The orthometric height was determined by differential leveling and
 HT2269.adjusted in June 1991.
 HT2269
 HT2269.The geoid height was determined by GEOID09.
 HT2269
 HT2269.The dynamic height is computed by dividing the NAVD 88
 HT2269.geopotential number by the normal gravity value computed on the
 HT2269.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 HT2269.degrees latitude (g = 980.6199 gals.).
 HT2269
 HT2269.The modeled gravity was interpolated from observed gravity values.
 HT2269
 HT2269;                   North         East    Units  Estimated Accuracy
 HT2269;SPC CA 3     -   640,230.    1,825,860.      MT  (+/- 180 meters Scaled)
 HT2269
 HT2269                          SUPERSEDED SURVEY CONTROL
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 HT2269
 HT2269  NGVD 29 (10/21/93)  127.671  (m)          418.87   (f) ADJUSTED    1 1
 HT2269
 HT2269.Superseded values are not recommended for survey control.
 HT2269.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 HT2269.See file dsdata.txt to determine how the superseded data were derived.
 HT2269
 HT2269_U.S. NATIONAL GRID SPATIAL ADDRESS: 10SEG461778(NAD 83)
 HT2269_MARKER: DB = BENCH MARK DISK
 HT2269_SETTING: 30 = SET IN A LIGHT STRUCTURE
 HT2269_SP_SET: CURB
 HT2269_STAMPING: T 1320 1977
 HT2269_STABILITY: D = MARK OF QUESTIONABLE OR UNKNOWN STABILITY
 HT2269
 HT2269  HISTORY     - Date     Condition        Report By
 HT2269  HISTORY     - 1977     MONUMENTED       NGS
 HT2269
 HT2269                          STATION DESCRIPTION
 HT2269
 HT2269'DESCRIBED BY NATIONAL GEODETIC SURVEY 1977
 HT2269'IN SAN FRANCISCO.
 HT2269'AT SAN FRANCISCO, SET IN THE NORTHWEST CURB AT THE INTERSECTION OF
 HT2269'19TH AVE AND RIVERA STREET.
1        National Geodetic Survey,   Retrieval Date = JUNE  2, 2010
 HT1843 ***********************************************************************
 HT1843  DESIGNATION -  Q 568
 HT1843  PID         -  HT1843
 HT1843  STATE/COUNTY-  CA/SAN FRANCISCO
 HT1843  USGS QUAD   -  POINT BONITA (1993)
 HT1843
 HT1843                         *CURRENT SURVEY CONTROL
 HT1843  ___________________________________________________________________
 HT1843* NAD 83(1986)-  37 45 03.     (N)    122 30 30.     (W)     SCALED
 HT1843* NAVD 88     -         7.56   (+/-2cm)      24.8    (feet)  VERTCON
 HT1843  ___________________________________________________________________
 HT1843  GEOID HEIGHT-         -32.77  (meters)                     GEOID09
 HT1843  VERT ORDER  -  SECOND    CLASS 0 (See Below)
 HT1843
 HT1843.The horizontal coordinates were scaled from a topographic map and have
 HT1843.an estimated accuracy of +/- 6 seconds.
 HT1843
 HT1843.The NAVD 88 height was computed by applying the VERTCON shift value to
 HT1843.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
 HT1843.The vertical order pertains to the NGVD 29 superseded va
```
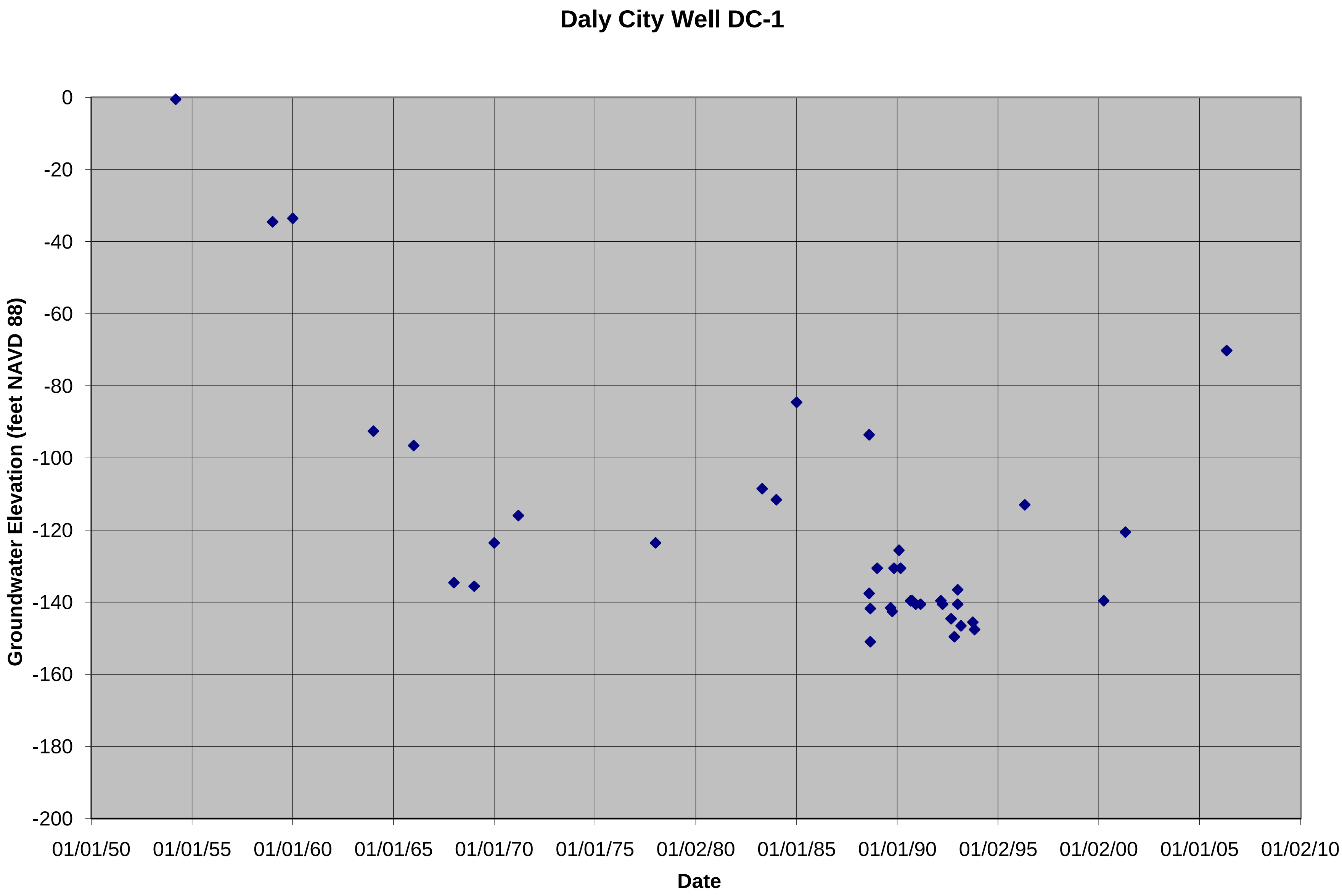
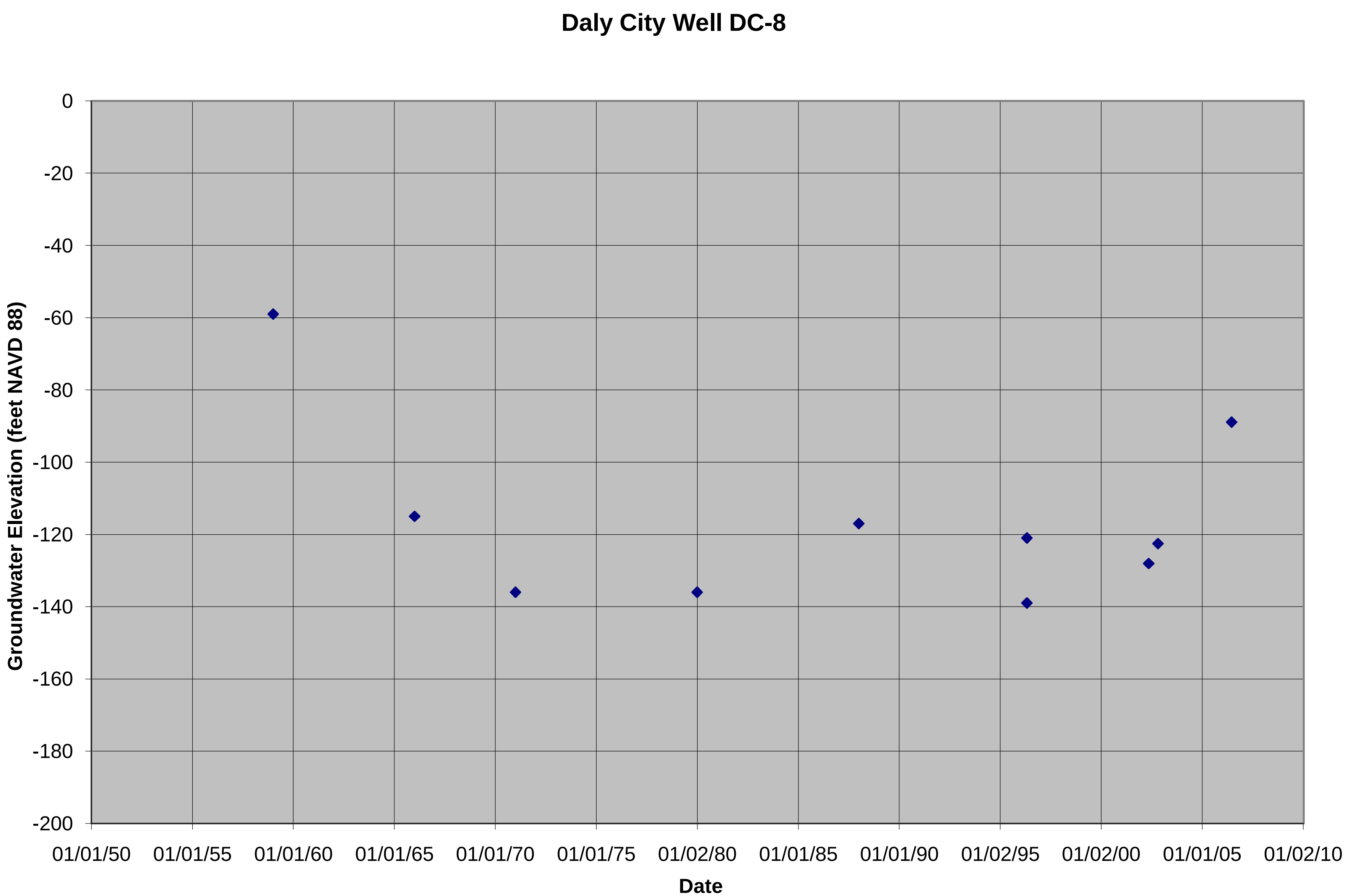
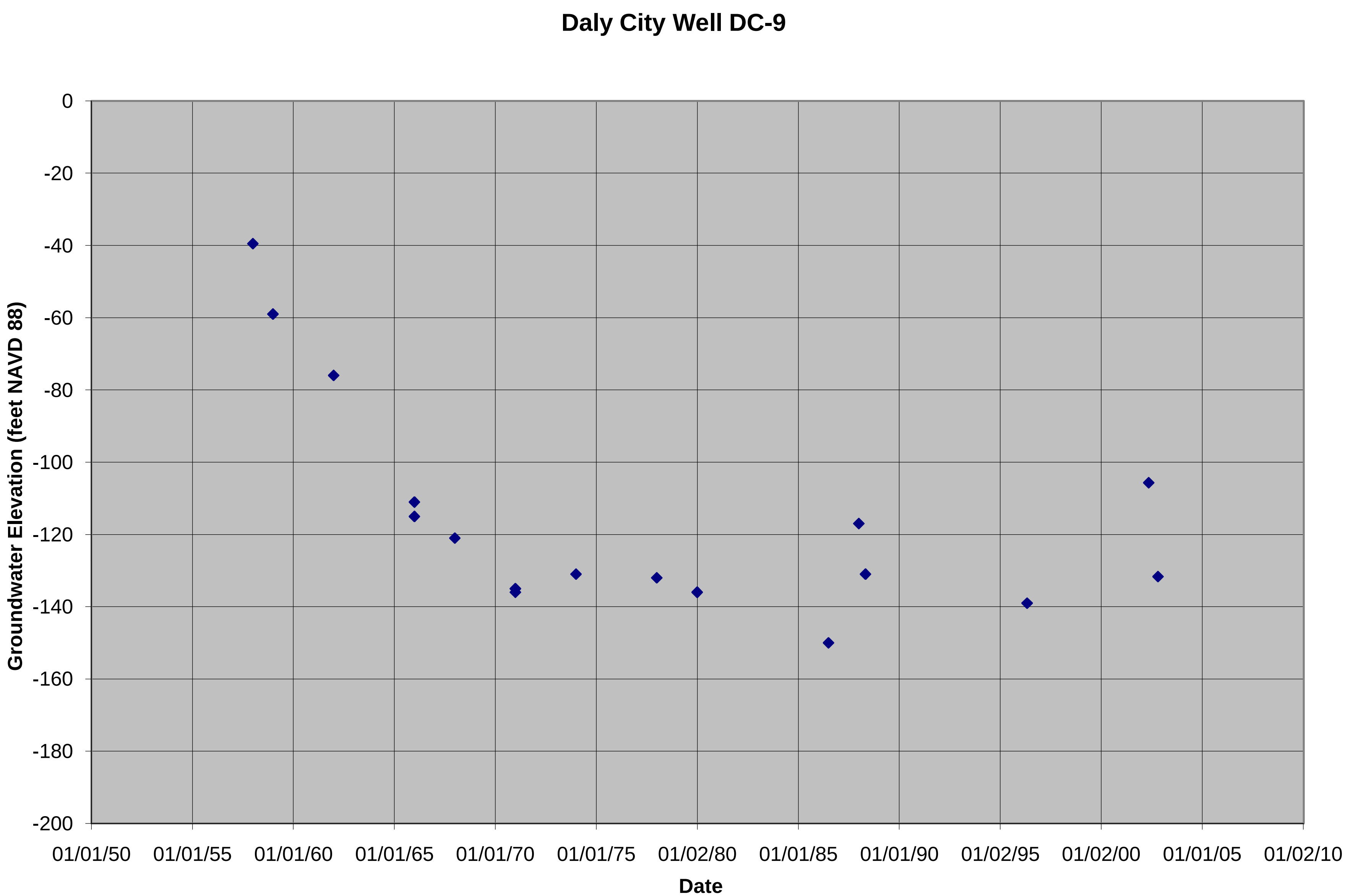
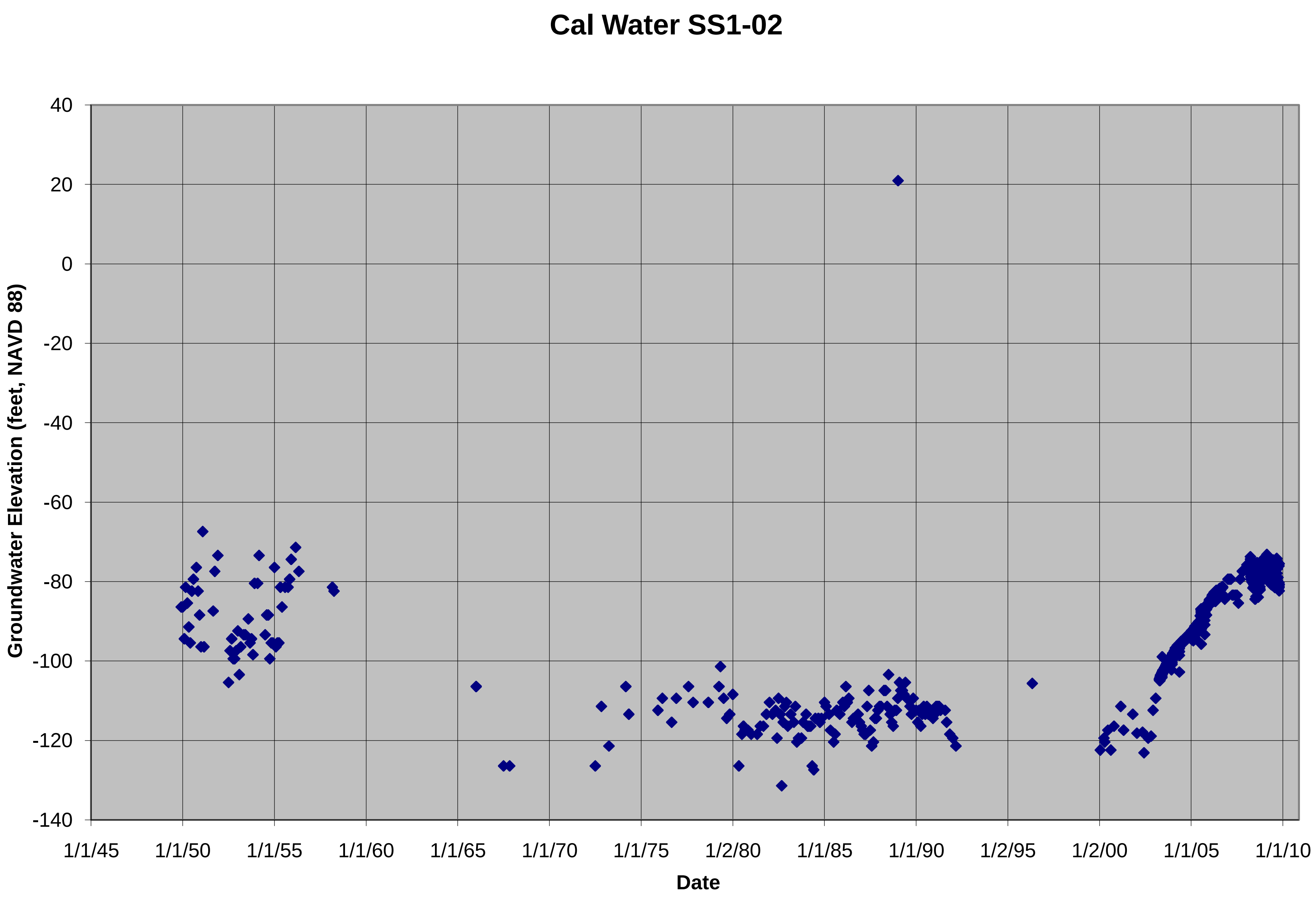

APPENDIX C



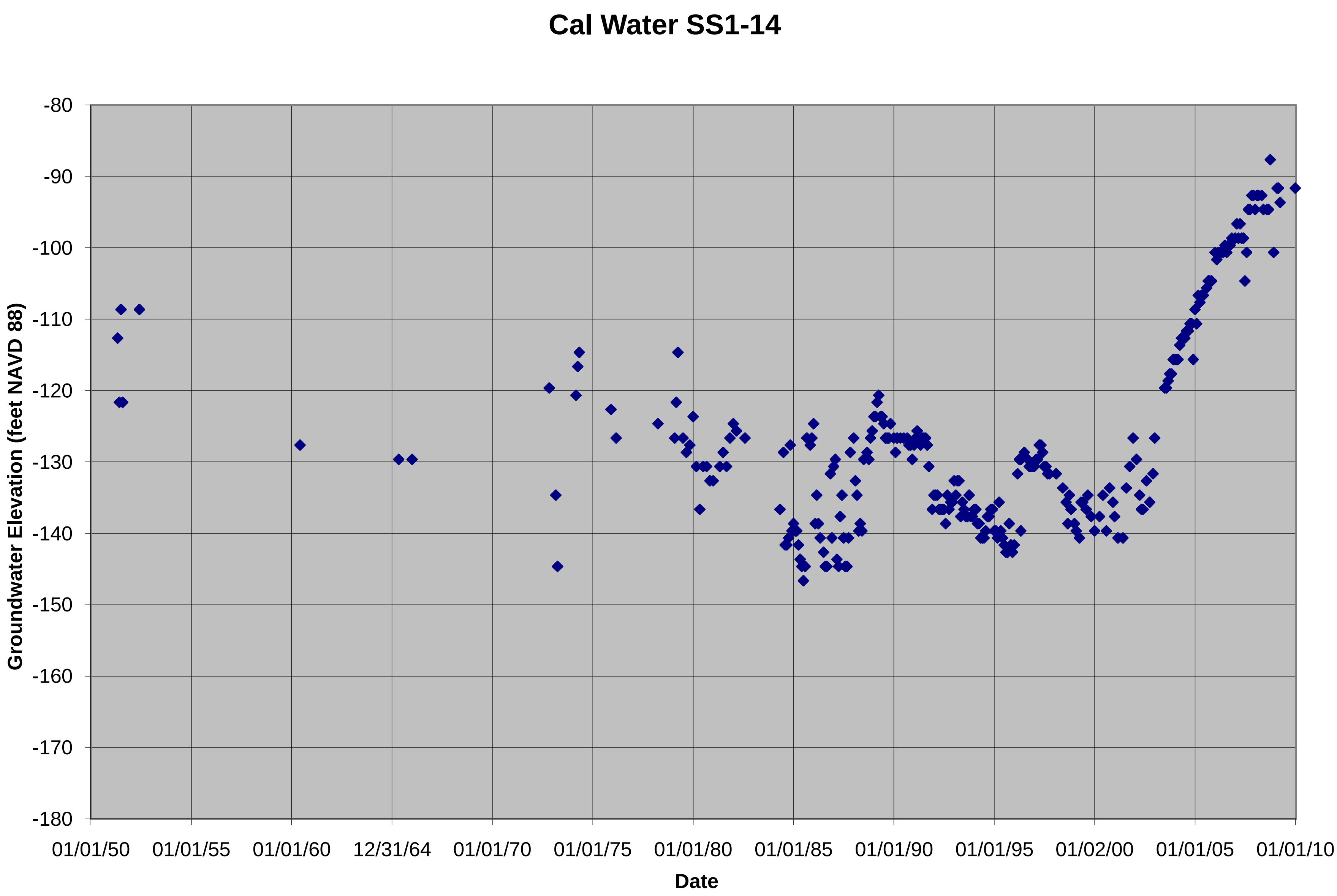
Daly City Well DC-1
Groundwater Elevation (feet NAVD 88)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
01/01/50
01/01/55
01/01/60
01/01/65
01/01/70
01/01/75
01/02/80
01/01/85
01/01/90
01/02/95
01/02/00
01/01/05
01/02/10
Date


Daly City Well DC-8
Groundwater Elevation (feet NAVD 88)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
01/01/50
01/01/55
01/01/60
01/01/65
01/01/70
01/01/75
01/02/80
01/01/85
01/01/90
01/02/95
01/02/00
01/01/05
01/02/10
Date


Daly City Well DC-9
Groundwater Elevation (feet NAVD 88)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
01/01/50
01/01/55
01/01/60
01/01/65
01/01/70
01/01/75
01/02/80
01/01/85
01/01/90
01/02/95
01/02/00
01/01/05
01/02/10
Date



Cal Water SS1-02
Groundwater Elevation (feet, NAVD 88)
40
20
0
-20
-40
-60
-80
-100
-120
-140
1/1/45
1/1/50
1/1/55
1/1/60
1/1/65
1/1/70
1/1/75
1/2/80
1/1/85
1/1/90
1/2/95
1/2/00
1/1/05
1/1/10
Date



Cal Water SS1-14
Groundwater Elevation (feet NAVD 88)
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
01/01/50
01/01/55
01/01/60
12/31/64
01/01/70
01/01/75
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01/01/85
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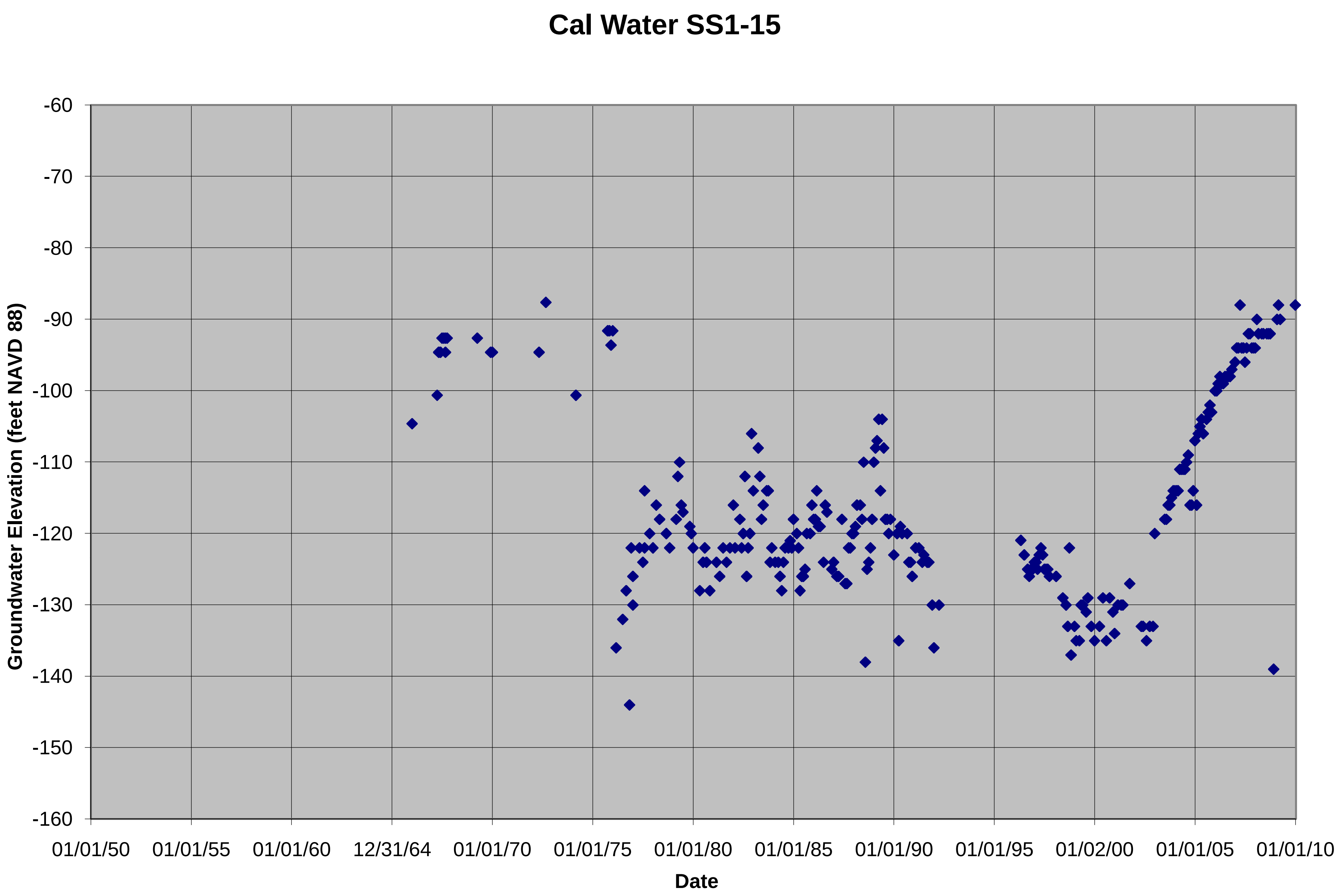
01/01/05
01/01/10
Date



Cal Water SS1-15
Groundwater Elevation (feet NAVD 88)
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
01/01/50
01/01/55
01/01/60
12/31/64
01/01/70
01/01/75
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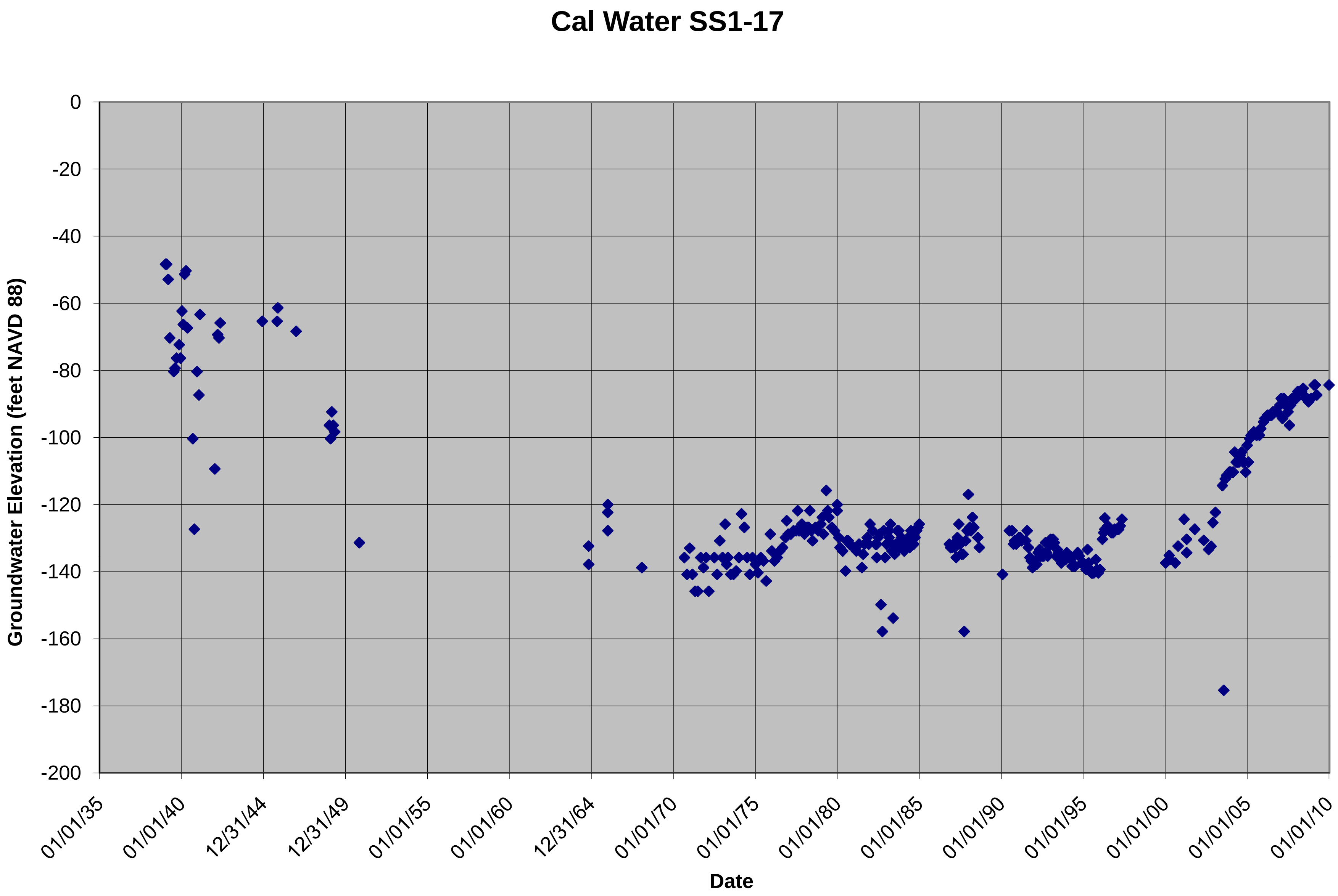
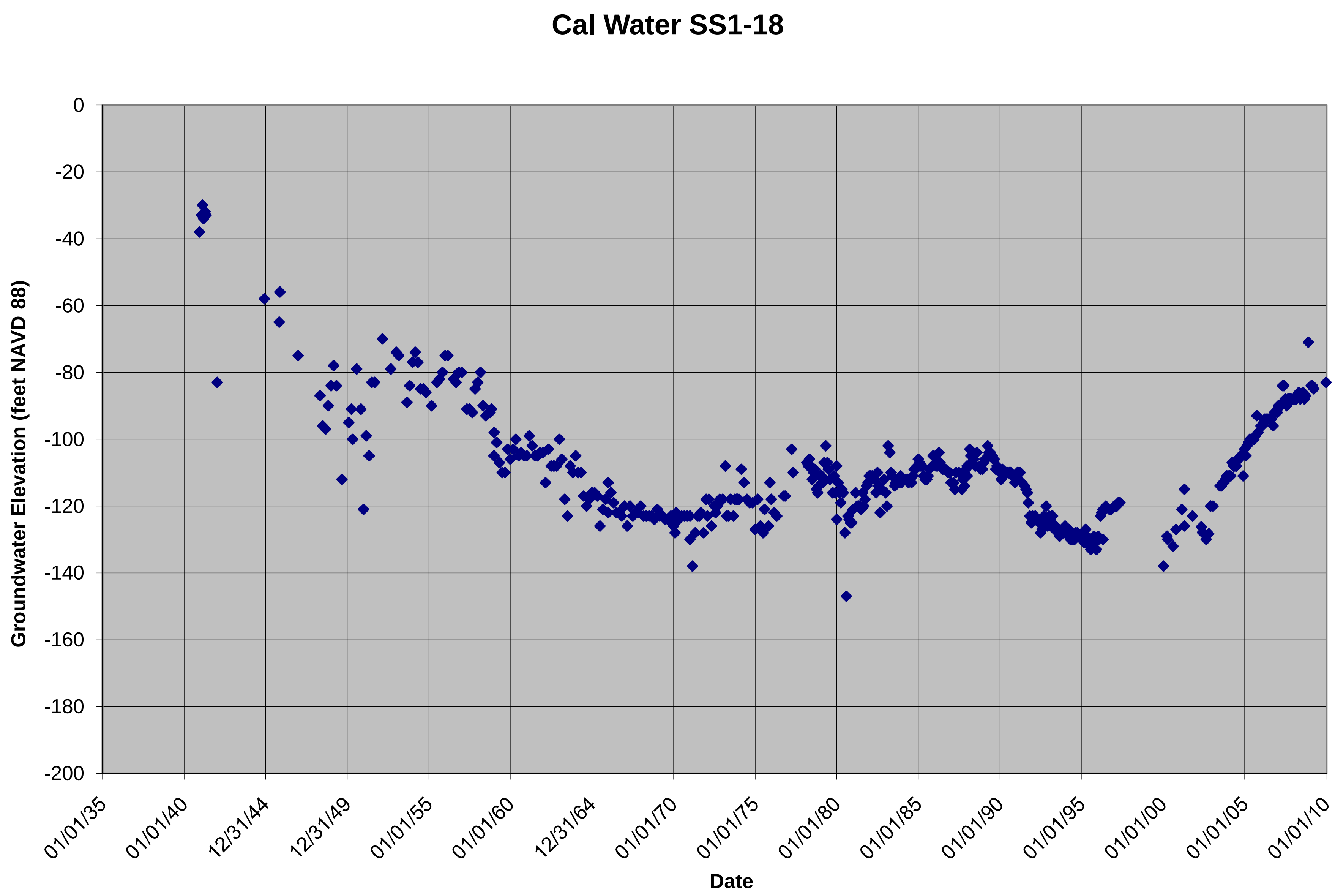
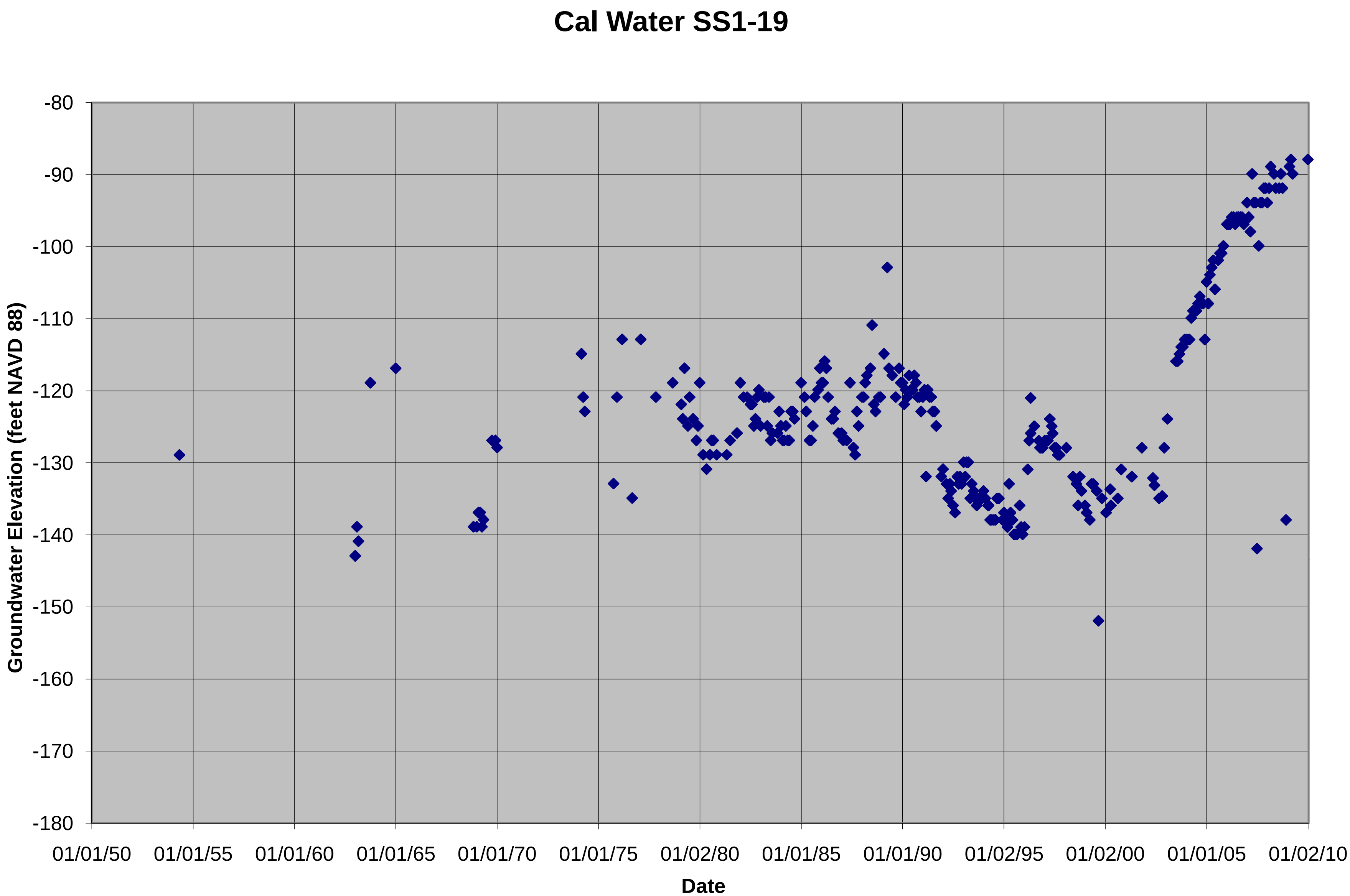
01/01/85
01/01/90
01/01/95
01/02/00
01/01/05
01/01/10
Date



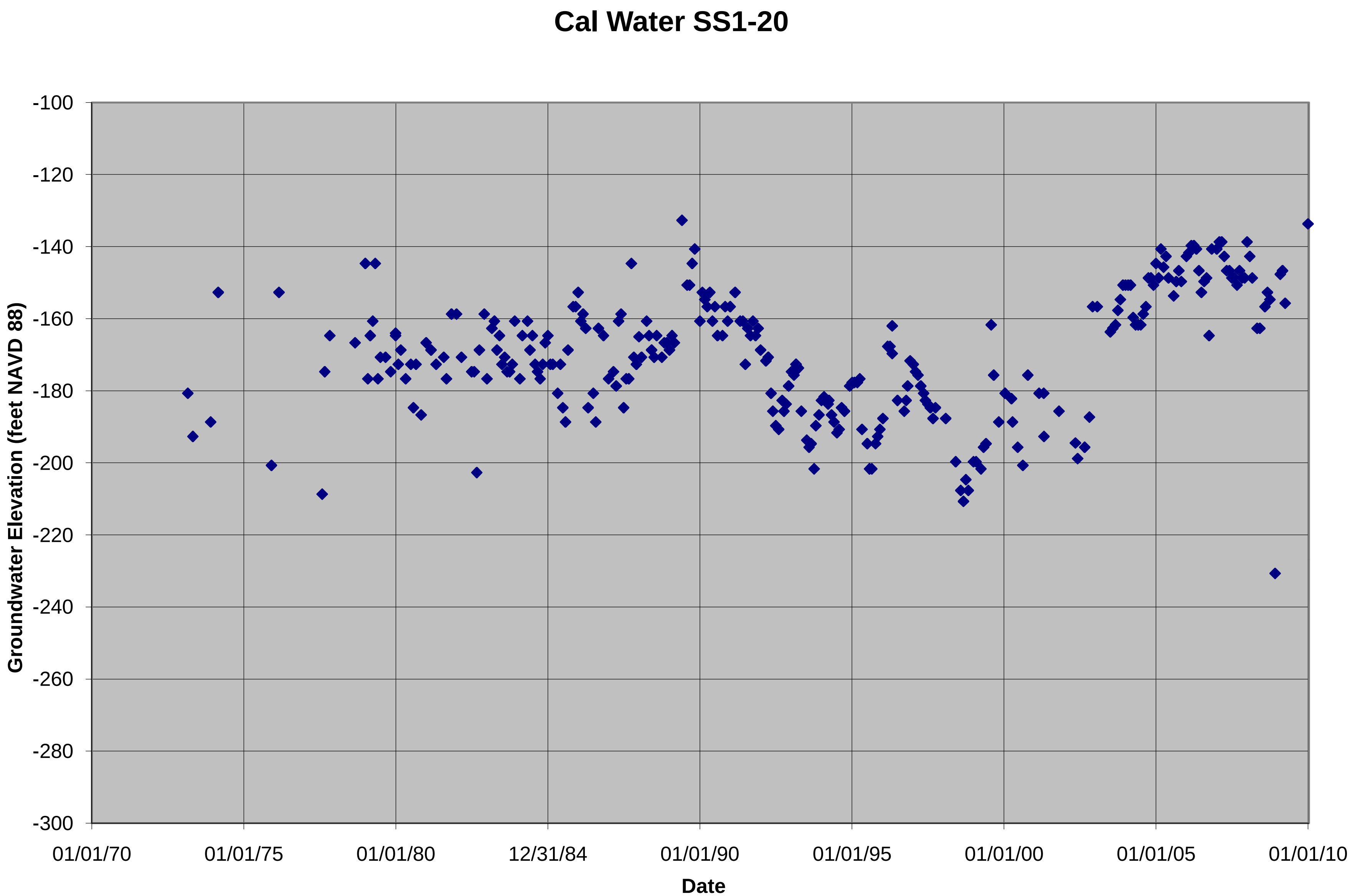
Cal Water SS1-17
Groundwater Elevation (feet NAVD 88)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
01/01/35
01/01/40
12/31/44
12/31/49
01/01/55
01/01/60
12/31/64
01/01/70
01/01/75
01/01/80
01/01/85
01/01/90
01/01/95
01/01/00
01/01/05
01/01/10
Date

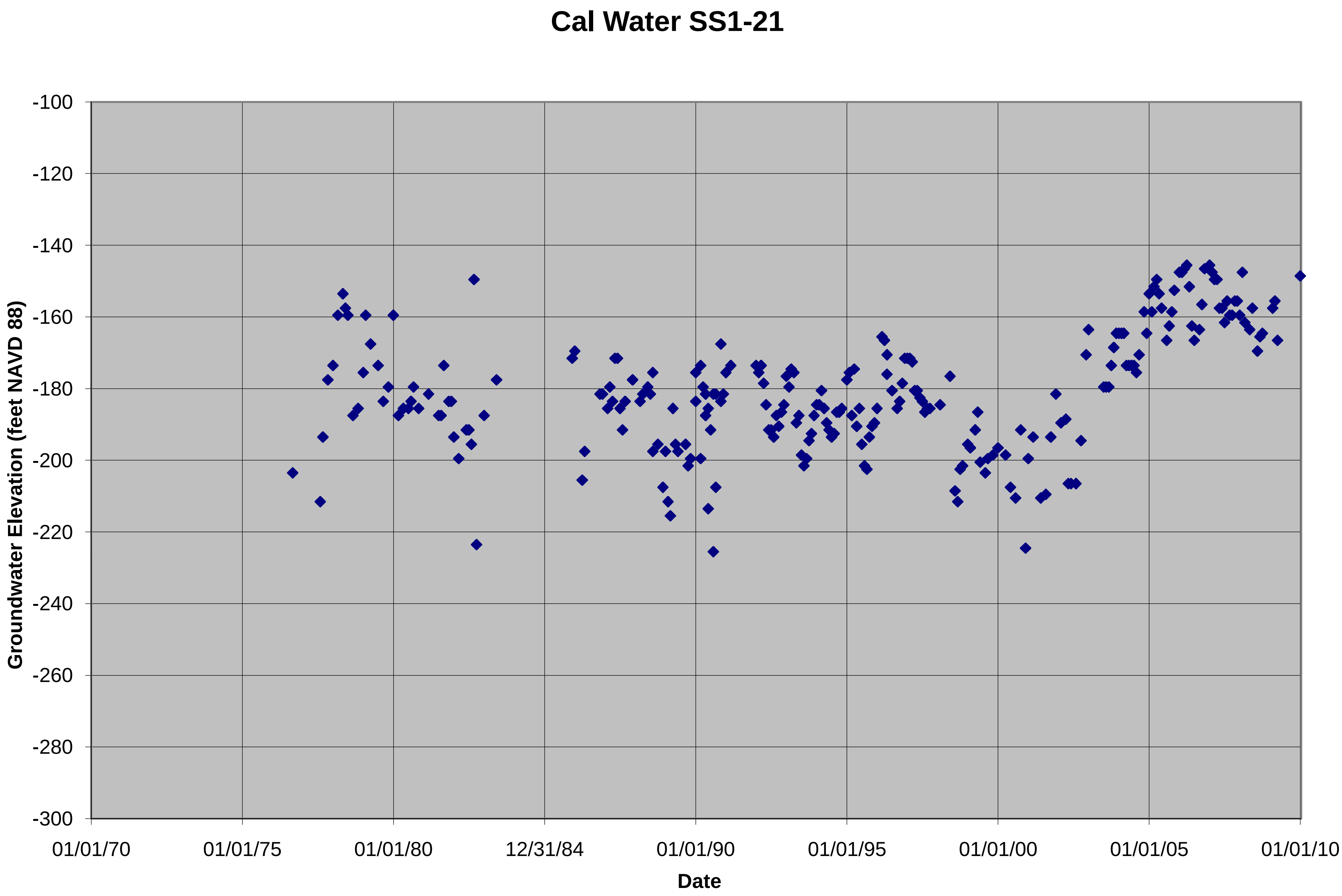


Cal Water SS1-18
Groundwater Elevation (feet NAVD 88)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
01/01/35
01/01/40
12/31/44
12/31/49
01/01/55
01/01/60
12/31/64
01/01/70
01/01/75
01/01/80
01/01/85
01/01/90
01/01/95
01/01/00
01/01/05
01/01/10
Date



Cal Water SS1-19
Groundwater Elevation (feet NAVD 88)
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
01/01/50
01/01/55
01/01/60
01/01/65
01/01/70
01/01/75
01/02/80
01/01/85
01/01/90
01/02/95
01/02/00
01/01/05
01/02/10
Date


Cal Water SS1-20
Groundwater Elevation (feet NAVD 88)
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300
01/01/70
01/01/75
01/01/80
12/31/84
01/01/90
01/01/95
01/01/00
01/01/05
01/01/10
Date


Cal Water SS1-21
Groundwater Elevation (feet NAVD 88)
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
-300
01/01/70
01/01/75
01/01/80
12/31/84
01/01/90
01/01/95
01/01/00
01/01/05
01/01/10
Date

APPENDIX D

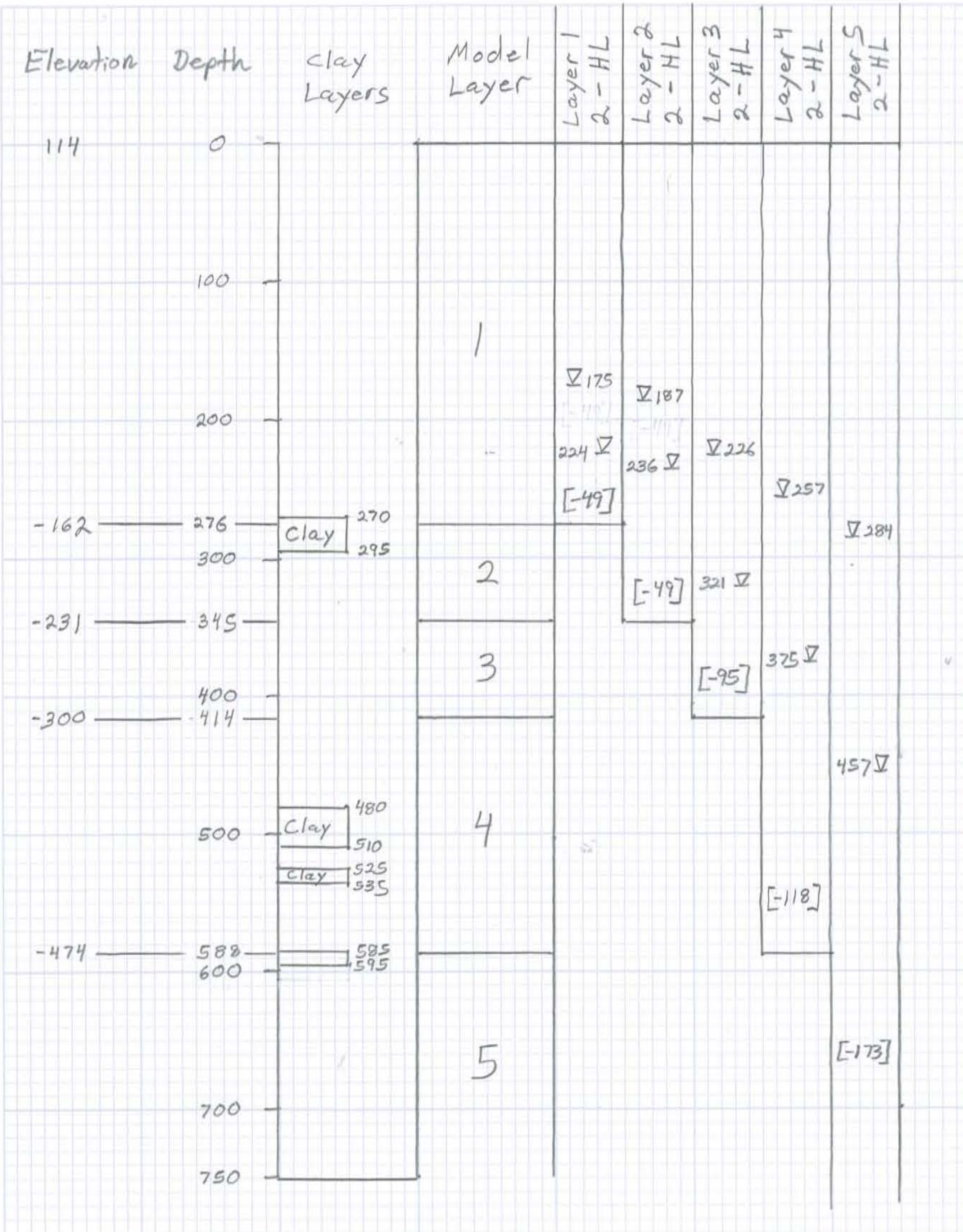
Form: Vta.(comp 11/93)
COMPUTATIONS

Job No.: ______ By: PML Date: 4/6/12

Checked By: ______ Date: ______ Sheet No. 1 of 4

Subject: CUP-19 Scenario 2 Compared to Historic Lows

FUGRO



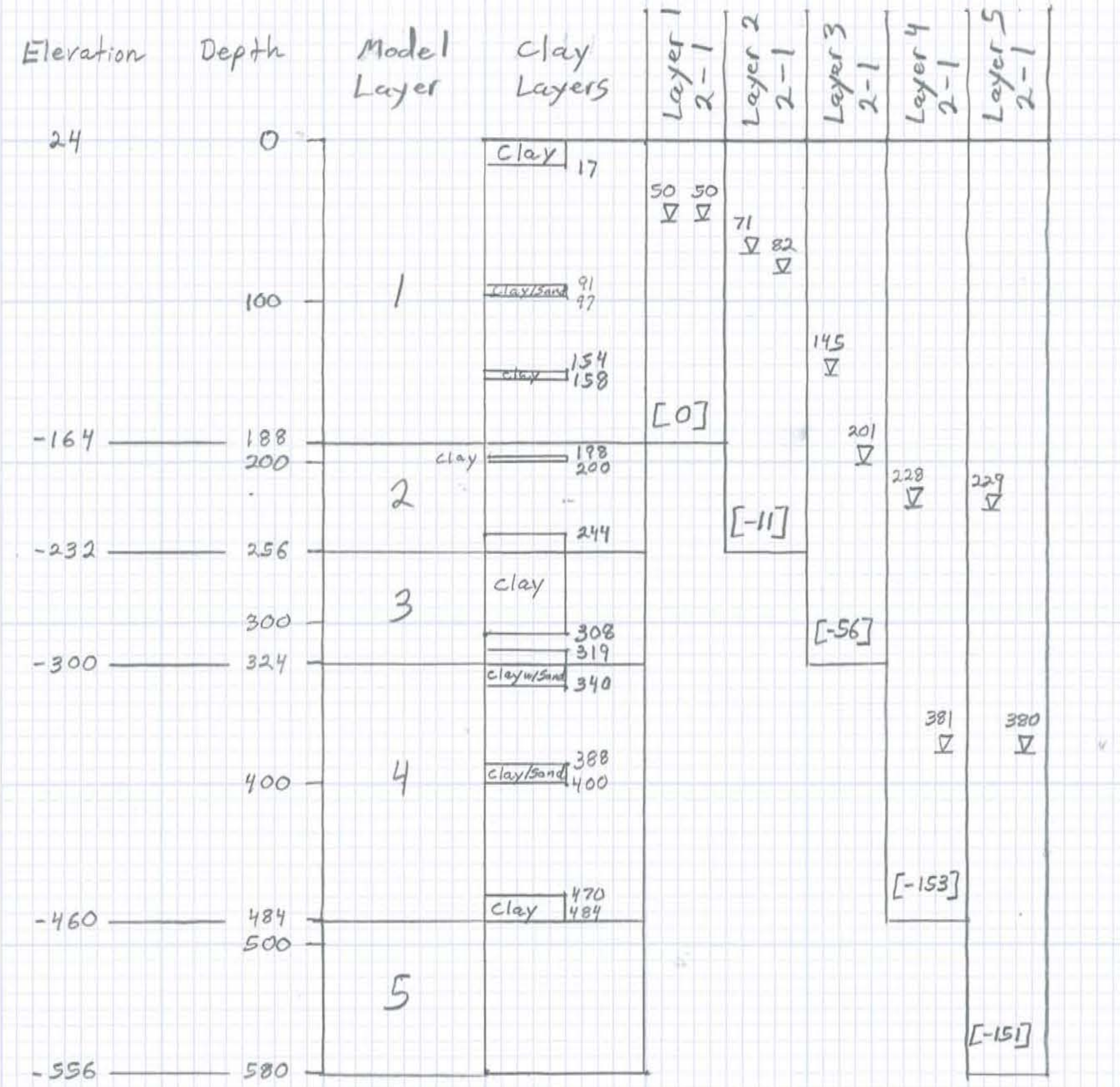
Form: Vta.(comp 11/93)
COMPUTATIONS

Job No.: ______ By: PML Date: 4/6/12

Checked By: ______ Date: ______ Sheet No. ____ of ____

Subject: CUP-41-4 Scenario 2

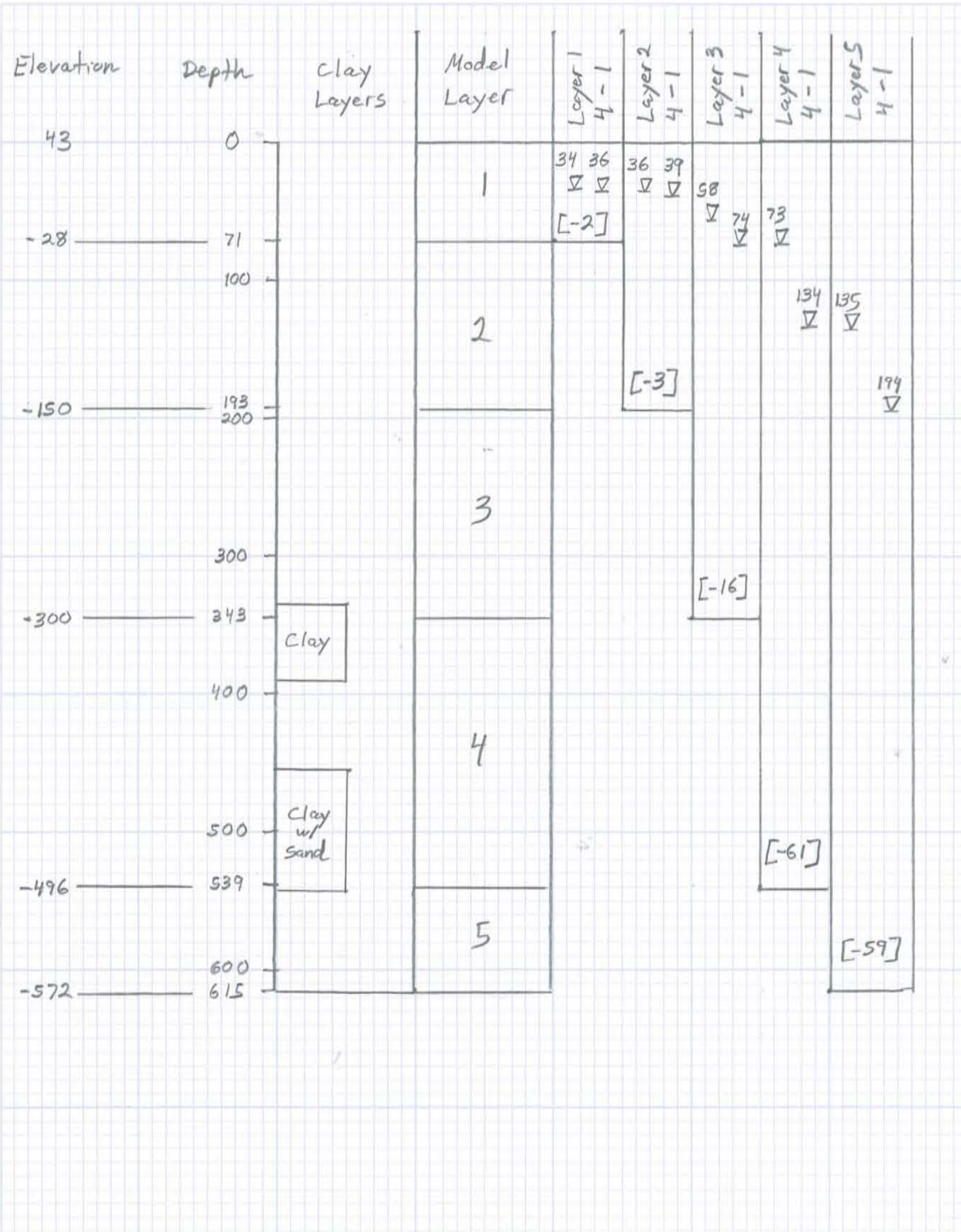
Compared to Scenario 1



Form: Vta.(comp 11/93)
COMPUTATIONS

Job No.: ______ By: PML Date: 4/6/12
Checked By: ______ Date: ______ Sheet No. 3 of 4
Subject: LMPS Scenario 4

Compared to 1



Form: Vta.(comp 11/93)

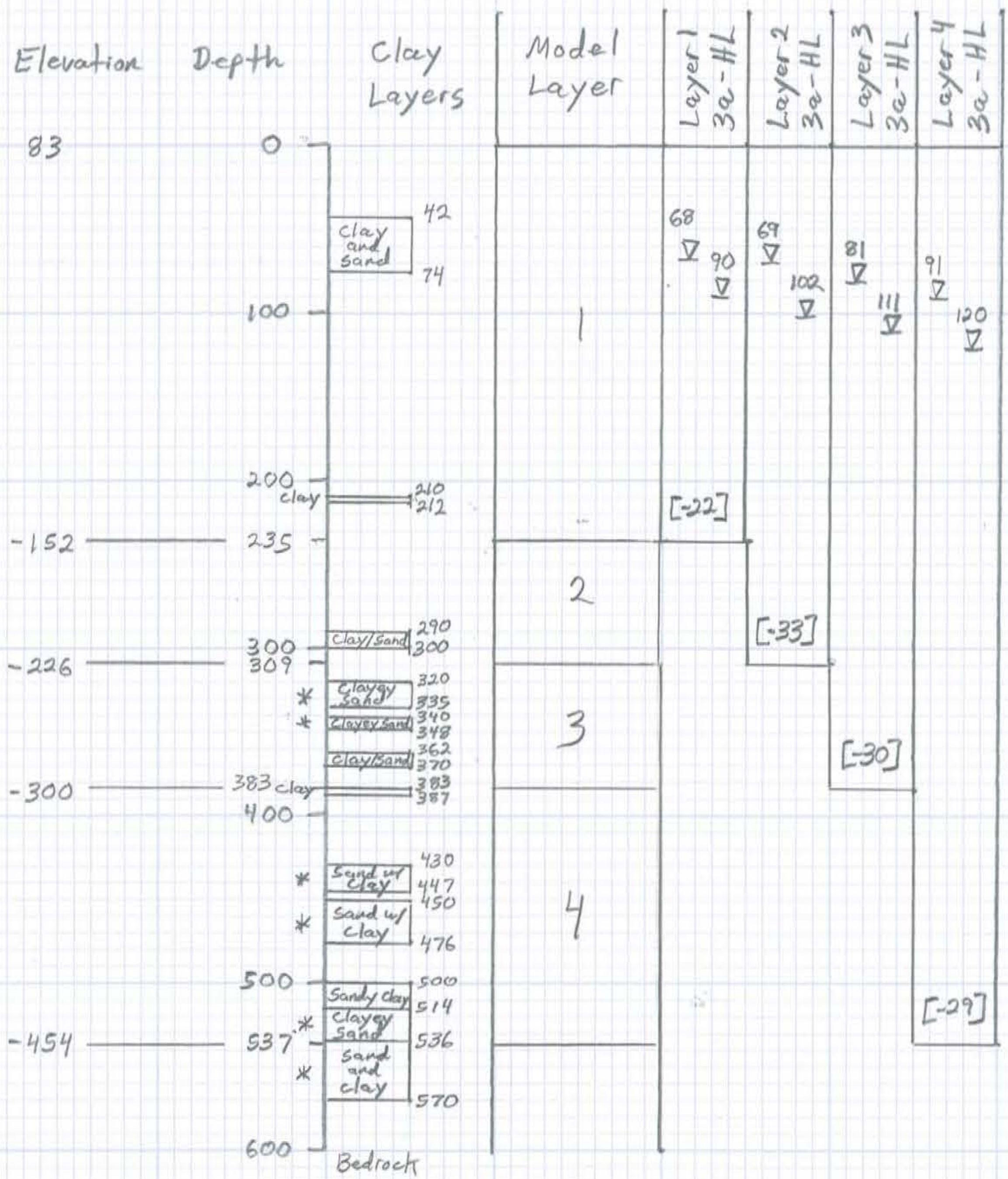
COMPUTATIONS

Job No.: ______ By: PML Date: 4/6/12

Checked By: ______ Date: ______ Sheet No. 4 of 4

Subject: South Sunset Scenario 3a

Compared to Historic Lows



APPENDIX E

Date	4/5/2012	
Job No.	103.128	
Boring ID	CUP-19	
Scenario	2 to HL	
Elevation	114	feet AMSL
Depth to Compressible	270	feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec
1	175	224	0.005	0.01	0.03	0.18
2	187	236	0.005	0.01	0.03	0.18
3	226	321	0.005	0.01	0.03	0.18
4	257	375	0.005	0.01	0.03	0.18
5	284	457	0.005	0.01	0.03	0.18

Model Layer	Sub Layer	Material	Depth Top (feet)	Depth Bottom (feet)	Depth Middle (feet)	Elevation Top (feet)	Elevation Bottom (feet)	Elevation Middle (feet)	Thickness (feet)	Unit wt (pcf)	Total Head Initial (feet)	Total Head Final (feet)	Total Stress Mid point (psf)	Total Stress Bottom (psf)	Initial Stresses @ mid point Effective (psf)	Initial Stresses @ mid point Pore Water (feet)	Initial Stresses @ mid point Pore Water (psf)	Final Stresses @ mid point Effective (psf)	Final Stresses @ mid point Pore Water (feet)	Final Stresses @ mid point Pore Water (psf)	Delta Eff. Stress (psf)	$\sigma'_{vf}/\sigma'_{vi}$	Comp Index	Settlement Sand (inches)	Settlement Clay (inches)	Settlement Total (inches)
1	1	Sand	0	50	25	114	64	89	50	123	175	224	3,075	6,149	3,075	0	0	3,075	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	2	Sand	50	100	75	64	14	39	50	124	175	224	9,242	12,334	9,242	0	0	9,242	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	3	Sand	100	150	125	14	-36	-11	50	124	175	224	15,436	18,537	15,436	0	0	15,436	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	4	Sand	150	200	175	-36	-86	-61	50	124	175	224	21,648	24,759	21,648	0	0	21,648	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	5	Sand	200	250	225	-86	-136	-111	50	125	175	224	27,879	30,999	27,879	0	0	27,879	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	6	Sand	250	270	260	-136	-156	-146	20	125	175	224	32,251	33,502	32,251	0	0	32,251	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	7	Clay	270	276	273	-156	-162	-159	6	125	175	224	33,878	34,253	27,763	98	6,115	30,820	49	3,058	3,058	1.11	0.030	0.00	0.10	0.10
2	8	Clay	276	295	285.5	-162	-181	-171.5	19	126	187	236	35,446	36,639	29,300	99	6,146	32,357	50	3,089	3,058	1.10	0.030	0.00	0.29	0.29
2	9	Sand	295	320	307.5	-181	-206	-193.5	25	126	187	236	38,213	39,787	30,694	121	7,519	33,752	72	4,462	3,058	1.10	0.005	0.06	0.00	0.06
2	10	Sand	320	345	332.5	-206	-231	-218.5	25	126	187	236	41,362	42,936	32,282	146	9,079	35,340	97	6,022	3,058	1.09	0.005	0.06	0.00	0.06
3	11	Sand	345	370	357.5	-231	-256	-243.5	25	126	226	321	44,515	46,094	36,310	132	8,206	42,238	37	2,278	5,928	1.16	0.005	0.10	0.00	0.10
3	12	Sand	370	400	385	-256	-286	-271	30	126	226	321	47,989	49,884	38,068	159	9,922	43,996	64	3,994	5,928	1.16	0.005	0.11	0.00	0.11
3	13	Sand	400	414	407	-286	-300	-293	14	127	226	321	50,771	51,658	39,477	181	11,294	45,405	86	5,366	5,928	1.15	0.005	0.05	0.00	0.05
4	14	Sand	414	440	427	-300	-326	-313	26	127	257	375	53,311	54,964	42,703	170	10,608	50,066	52	3,245	7,363	1.17	0.005	0.11	0.00	0.11
4	15	Sand	440	480	460	-326	-366	-346	40	127	257	375	57,506	60,049	44,839	203	12,667	52,202	85	5,304	7,363	1.16	0.005	0.16	0.00	0.16
4	16	Clay	480	495	487.5	-366	-381	-373.5	15	128	257	375	61,005	61,962	46,622	231	14,383	53,985	113	7,020	7,363	1.16	0.030	0.00	0.34	0.34
4	17	Clay	495	510	502.5	-381	-396	-388.5	15	128	257	375	62,918	63,875	47,599	246	15,319	54,962	128	7,956	7,363	1.15	0.030	0.00	0.34	0.34
4	18	Sand	510	525	517.5	-396	-411	-403.5	15	128	257	375	64,831	65,787	48,576	261	16,255	55,939	143	8,892	7,363	1.15	0.005	0.06	0.00	0.06
4	19	Clay	525	535	530	-411	-421	-416	10	128	257	375	66,425	67,063	49,390	273	17,035	56,753	155	9,672	7,363	1.15	0.030	0.00	0.22	0.22
4	20	Sand	535	560	547.5	-421	-446	-433.5	25	128	257	375	68,657	70,251	50,530	291	18,127	57,893	173	10,764	7,363	1.15	0.005	0.09	0.00	0.09
4	21	Sand	560	585	572.5	-446	-471	-458.5	25	128	257	375	71,850	73,450	52,163	316	19,687	59,526	198	12,324	7,363	1.14	0.005	0.09	0.00	0.09
4	22	Clay	585	588	586.5	-471	-474	-472.5	3	128	257	375	73,641	73,833	53,081	330	20,561	60,444	212	13,198	7,363	1.14	0.030	0.00	0.06	0.06
5	23	Clay	588	595	591.5	-474	-481	-477.5	7	128	284	457	74,281	74,729	55,093	308	19,188	65,888	135	8,393	10,795	1.20	0.030	0.00	0.20	0.20
5	24	Sand	595	600	597.5	-481	-486	-483.5	5	128	284	457	75,050	75,371	55,487	314	19,562	66,283	141	8,767	10,795	1.19	0.005	0.02	0.00	0.02
5	25	Sand	600	650	625	-486	-536	-511	50	128	284	457	78,580	81,788	57,301	341	21,278	68,096	168	10,483	10,795	1.19	0.005	0.22	0.00	0.22
5	26	Sand	650	700	675	-536	-586	-561	50	128	284	457	84,997	88,206	60,599	391	24,398	71,394	218	13,603	10,795	1.18	0.005	0.21	0.00	0.21
5	27	Sand	700	750	725	-586	-636	-611	50	128	284	457	91,415	94,624	63,897	441	27,518	74,692	268	16,723	10,795	1.17	0.005	0.20	0.00	0.20
																							Total Settlement (in) =	1.54	1.55	3.09
																							Total Layer Thickness (feet) =	405	75	480

Date	4/5/2012	
Job No.	103.128	
Boring ID	CUP-19	
Scenario	4 to HL	
Elevation	114	feet AMSL
Depth to Compressible	270	feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec
1	175	221	0.005	0.01	0.03	0.18
2	187	232	0.005	0.01	0.03	0.18
3	226	314	0.005	0.01	0.03	0.18
4	257	369	0.005	0.01	0.03	0.18
5	284	452	0.005	0.01	0.03	0.18

Model	Sub		Depth			Elevation					Total Head		Total Stress		Initial Stresses @ mid point			Final Stresses @ mid point			Delta	$\sigma'_{vf}/\sigma'_{vi}$	Comp	Settlement		
Layer	Layer	Material	Top (feet)	Bottom (feet)	Middle (feet)	Top (feet)	Bottom (feet)	Middle (feet)	Thickness (feet)	Unit wt (pcf)	Initial (feet)	Final (feet)	Mid point (psf)	Bottom (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Eff. Stress (psf)		Index	Sand (inches)	Clay (inches)	Total (inches)
1	1	Sand	0	50	25	114	64	89	50	123	175	221	3,075	6,149	3,075	0	0	3,075	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	2	Sand	50	100	75	64	14	39	50	124	175	221	9,242	12,334	9,242	0	0	9,242	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	3	Sand	100	150	125	14	-36	-11	50	124	175	221	15,436	18,537	15,436	0	0	15,436	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	4	Sand	150	200	175	-36	-86	-61	50	124	175	221	21,648	24,759	21,648	0	0	21,648	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	5	Sand	200	250	225	-86	-136	-111	50	125	175	221	27,879	30,999	27,879	0	0	27,879	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	6	Sand	250	270	260	-136	-156	-146	20	125	175	221	32,251	33,502	32,251	0	0	32,251	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	7	Clay	270	276	273	-156	-162	-159	6	125	175	221	33,878	34,253	27,763	98	6,115	30,633	52	3,245	2,870	1.10	0.030	0.00	0.09	0.09
2	8	Clay	276	295	285.5	-162	-181	-171.5	19	126	187	232	35,446	36,639	29,300	99	6,146	32,108	54	3,338	2,808	1.10	0.030	0.00	0.27	0.27
2	9	Sand	295	320	307.5	-181	-206	-193.5	25	126	187	232	38,213	39,787	30,694	121	7,519	33,502	76	4,711	2,808	1.09	0.005	0.06	0.00	0.06
2	10	Sand	320	345	332.5	-206	-231	-218.5	25	126	187	232	41,362	42,936	32,282	146	9,079	35,090	101	6,271	2,808	1.09	0.005	0.05	0.00	0.05
3	11	Sand	345	370	357.5	-231	-256	-243.5	25	126	226	314	44,515	46,094	36,310	132	8,206	41,801	44	2,714	5,491	1.15	0.005	0.09	0.00	0.09
3	12	Sand	370	400	385	-256	-286	-271	30	126	226	314	47,989	49,884	38,068	159	9,922	43,559	71	4,430	5,491	1.14	0.005	0.11	0.00	0.11
3	13	Sand	400	414	407	-286	-300	-293	14	127	226	314	50,771	51,658	39,477	181	11,294	44,968	93	5,803	5,491	1.14	0.005	0.05	0.00	0.05
4	14	Sand	414	440	427	-300	-326	-313	26	127	257	369	53,311	54,964	42,703	170	10,608	49,692	58	3,619	6,989	1.16	0.005	0.10	0.00	0.10
4	15	Sand	440	480	460	-326	-366	-346	40	127	257	369	57,506	60,049	44,839	203	12,667	51,828	91	5,678	6,989	1.16	0.005	0.15	0.00	0.15
4	16	Clay	480	495	487.5	-366	-381	-373.5	15	128	257	369	61,005	61,962	46,622	231	14,383	53,611	119	7,394	6,989	1.15	0.030	0.00	0.33	0.33
4	17	Clay	495	510	502.5	-381	-396	-388.5	15	128	257	369	62,918	63,875	47,599	246	15,319	54,588	134	8,330	6,989	1.15	0.030	0.00	0.32	0.32
4	18	Sand	510	525	517.5	-396	-411	-403.5	15	128	257	369	64,831	65,787	48,576	261	16,255	55,565	149	9,266	6,989	1.14	0.005	0.05	0.00	0.05
4	19	Clay	525	535	530	-411	-421	-416	10	128	257	369	66,425	67,063	49,390	273	17,035	56,379	161	10,046	6,989	1.14	0.030	0.00	0.21	0.21
4	20	Sand	535	560	547.5	-421	-446	-433.5	25	128	257	369	68,657	70,251	50,530	291	18,127	57,519	179	11,138	6,989	1.14	0.005	0.08	0.00	0.08
4	21	Sand	560	585	572.5	-446	-471	-458.5	25	128	257	369	71,850	73,450	52,163	316	19,687	59,152	204	12,698	6,989	1.13	0.005	0.08	0.00	0.08
4	22	Clay	585	588	586.5	-471	-474	-472.5	3	128	257	369	73,641	73,833	53,081	330	20,561	60,069	218	13,572	6,989	1.13	0.030	0.00	0.06	0.06
5	23	Clay	588	595	591.5	-474	-481	-477.5	7	128	284	452	74,281	74,729	55,093	308	19,188	65,576	140	8,705	10,483	1.19	0.030	0.00	0.19	0.19
5	24	Sand	595	600	597.5	-481	-486	-483.5	5	128	284	452	75,050	75,371	55,487	314	19,562	65,971	146	9,079	10,483	1.19	0.005	0.02	0.00	0.02
5	25	Sand	600	650	625	-486	-536	-511	50	128	284	452	78,580	81,788	57,301	341	21,278	67,784	173	10,795	10,483	1.18	0.005	0.22	0.00	0.22
5	26	Sand	650	700	675	-536	-586	-561	50	128	284	452	84,997	88,206	60,599	391	24,398	71,082	223	13,915	10,483	1.17	0.005	0.21	0.00	0.21
5	27	Sand	700	750	725	-586	-636	-611	50	128	284	452	91,415	94,624	63,897	441	27,518	74,380	273	17,035	10,483	1.16	0.005	0.20	0.00	0.20
																							Total Settlement (in) =	1.48	1.47	2.94
																							Total Layer Thickness (feet) =	405	75	480

Date 4/5/2012
Job No. 103.128

Boring ID CUP-19
Scenario 2 to 1
Elevation 114 feet AMSL
Depth to Compressible 270 feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec
1	193	224	0.005	0.01	0.03	0.18
2	201	236	0.005	0.01	0.03	0.18
3	229	321	0.005	0.01	0.03	0.18
4	250	375	0.005	0.01	0.03	0.18
5	308	457	0.005	0.01	0.03	0.18

Model	Sub		Depth			Elevation					Total Head		Total Stress		Initial Stresses @ mid point			Final Stresses @ mid point			Delta	$\sigma'_{vf}/\sigma'_{vi}$	Comp	Settlement		
Layer	Layer	Material	Top (feet)	Bottom (feet)	Middle (feet)	Top (feet)	Bottom (feet)	Middle (feet)	Thickness (feet)	Unit wt (pcf)	Initial (feet)	Final (feet)	Mid point (psf)	Bottom (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Eff. Stress (psf)		Index	Sand (inches)	Clay (inches)	Total (inches)
1	1	Sand	0	50	25	114	64	89	50	123	193	224	3,075	6,149	3,075	0	0	3,075	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	2	Sand	50	100	75	64	14	39	50	124	193	224	9,242	12,334	9,242	0	0	9,242	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	3	Sand	100	150	125	14	-36	-11	50	124	193	224	15,436	18,537	15,436	0	0	15,436	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	4	Sand	150	200	175	-36	-86	-61	50	124	193	224	21,648	24,759	21,648	0	0	21,648	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	5	Sand	200	250	225	-86	-136	-111	50	125	193	224	27,879	30,999	27,879	0	0	27,879	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	6	Sand	250	270	260	-136	-156	-146	20	125	193	224	32,251	33,502	32,251	0	0	32,251	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	7	Clay	270	276	273	-156	-162	-159	6	125	193	224	33,878	34,253	28,886	80	4,992	30,820	49	3,058	1,934	1.07	0.030	0.00	0.06	0.06
2	8	Clay	276	295	285.5	-162	-181	-171.5	19	126	201	236	35,446	36,639	30,173	85	5,273	32,357	50	3,089	2,184	1.07	0.030	0.00	0.21	0.21
2	9	Sand	295	320	307.5	-181	-206	-193.5	25	126	201	236	38,213	39,787	31,568	107	6,646	33,752	72	4,462	2,184	1.07	0.005	0.04	0.00	0.04
2	10	Sand	320	345	332.5	-206	-231	-218.5	25	126	201	236	41,362	42,936	33,156	132	8,206	35,340	97	6,022	2,184	1.07	0.005	0.04	0.00	0.04
3	11	Sand	345	370	357.5	-231	-256	-243.5	25	126	229	321	44,515	46,094	36,497	129	8,018	42,238	37	2,278	5,741	1.16	0.005	0.10	0.00	0.10
3	12	Sand	370	400	385	-256	-286	-271	30	126	229	321	47,989	49,884	38,255	156	9,734	43,996	64	3,994	5,741	1.15	0.005	0.11	0.00	0.11
3	13	Sand	400	414	407	-286	-300	-293	14	127	229	321	50,771	51,658	39,664	178	11,107	45,405	86	5,366	5,741	1.14	0.005	0.05	0.00	0.05
4	14	Sand	414	440	427	-300	-326	-313	26	127	250	375	53,311	54,964	42,266	177	11,045	50,066	52	3,245	7,800	1.18	0.005	0.11	0.00	0.11
4	15	Sand	440	480	460	-326	-366	-346	40	127	250	375	57,506	60,049	44,402	210	13,104	52,202	85	5,304	7,800	1.18	0.005	0.17	0.00	0.17
4	16	Clay	480	495	487.5	-366	-381	-373.5	15	128	250	375	61,005	61,962	46,185	238	14,820	53,985	113	7,020	7,800	1.17	0.030	0.00	0.37	0.37
4	17	Clay	495	510	502.5	-381	-396	-388.5	15	128	250	375	62,918	63,875	47,162	253	15,756	54,962	128	7,956	7,800	1.17	0.030	0.00	0.36	0.36
4	18	Sand	510	525	517.5	-396	-411	-403.5	15	128	250	375	64,831	65,787	48,139	268	16,692	55,939	143	8,892	7,800	1.16	0.005	0.06	0.00	0.06
4	19	Clay	525	535	530	-411	-421	-416	10	128	250	375	66,425	67,063	48,953	280	17,472	56,753	155	9,672	7,800	1.16	0.030	0.00	0.23	0.23
4	20	Sand	535	560	547.5	-421	-446	-433.5	25	128	250	375	68,657	70,251	50,093	298	18,564	57,893	173	10,764	7,800	1.16	0.005	0.09	0.00	0.09
4	21	Sand	560	585	572.5	-446	-471	-458.5	25	128	250	375	71,850	73,450	51,726	323	20,124	59,526	198	12,324	7,800	1.15	0.005	0.09	0.00	0.09
4	22	Clay	585	588	586.5	-471	-474	-472.5	3	128	250	375	73,641	73,833	52,644	337	20,998	60,444	212	13,198	7,800	1.15	0.030	0.00	0.06	0.06
5	23	Clay	588	595	591.5	-474	-481	-477.5	7	128	308	457	74,281	74,729	56,591	284	17,690	65,888	135	8,393	9,298	1.16	0.030	0.00	0.17	0.17
5	24	Sand	595	600	597.5	-481	-486	-483.5	5	128	308	457	75,050	75,371	56,985	290	18,065	66,283	141	8,767	9,298	1.16	0.005	0.02	0.00	0.02
5	25	Sand	600	650	625	-486	-536	-511	50	128	308	457	78,580	81,788	58,799	317	19,781	68,096	168	10,483	9,298	1.16	0.005	0.19	0.00	0.19
5	26	Sand	650	700	675	-536	-586	-561	50	128	308	457	84,997	88,206	62,096	367	22,901	71,394	218	13,603	9,298	1.15	0.005	0.18	0.00	0.18
5	27	Sand	700	750	725	-586	-636	-611	50	128	308	457	91,415	94,624	65,394	417	26,021	74,692	268	16,723	9,298	1.14	0.005	0.17	0.00	0.17
																							Total Settlement (in) =	1.43	1.46	2.89
																							Total Layer Thickness (feet) =	405	75	480

Date	4/5/2012							
Job No.	103.128							
			Model	Initial Head	Final Head	Sand		Clay
Boring ID	CUP-19		Layer	(feet)	(feet)	Cer	Cec	Cer	Cec
Scenario	4 to 1		1	193	221	0.005	0.01	0.03	0.18
Elevation	114	feet AMSL	2	201	232	0.005	0.01	0.03	0.18
Depth to Compressible	270	feet	3	229	314	0.005	0.01	0.03	0.18
			4	250	369	0.005	0.01	0.03	0.18
			5	308	452	0.005	0.01	0.03	0.18

Model	Sub		Depth			Elevation					Total Head		Total Stress		Initial Stresses @ mid point			Final Stresses @ mid point			Delta	$\sigma'_{vf}/\sigma'_{vi}$	Comp	Settlement		
Layer	Layer	Material	Top (feet)	Bottom (feet)	Middle (feet)	Top (feet)	Bottom (feet)	Middle (feet)	Thickness (feet)	Unit wt (pcf)	Initial (feet)	Final (feet)	Mid point (psf)	Bottom (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Eff. Stress (psf)		Index	Sand (inches)	Clay (inches)	Total (inches)
1	1	Sand	0	50	25	114	64	89	50	123	193	221	3,075	6,149	3,075	0	0	3,075	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	2	Sand	50	100	75	64	14	39	50	124	193	221	9,242	12,334	9,242	0	0	9,242	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	3	Sand	100	150	125	14	-36	-11	50	124	193	221	15,436	18,537	15,436	0	0	15,436	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	4	Sand	150	200	175	-36	-86	-61	50	124	193	221	21,648	24,759	21,648	0	0	21,648	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	5	Sand	200	250	225	-86	-136	-111	50	125	193	221	27,879	30,999	27,879	0	0	27,879	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	6	Sand	250	270	260	-136	-156	-146	20	125	193	221	32,251	33,502	32,251	0	0	32,251	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	7	Clay	270	276	273	-156	-162	-159	6	125	193	221	33,878	34,253	28,886	80	4,992	30,633	52	3,245	1,747	1.06	0.030	0.00	0.06	0.06
2	8	Clay	276	295	285.5	-162	-181	-171.5	19	126	201	232	35,446	36,639	30,173	85	5,273	32,108	54	3,338	1,934	1.06	0.030	0.00	0.18	0.18
2	9	Sand	295	320	307.5	-181	-206	-193.5	25	126	201	232	38,213	39,787	31,568	107	6,646	33,502	76	4,711	1,934	1.06	0.005	0.04	0.00	0.04
2	10	Sand	320	345	332.5	-206	-231	-218.5	25	126	201	232	41,362	42,936	33,156	132	8,206	35,090	101	6,271	1,934	1.06	0.005	0.04	0.00	0.04
3	11	Sand	345	370	357.5	-231	-256	-243.5	25	126	229	314	44,515	46,094	36,497	129	8,018	41,801	44	2,714	5,304	1.15	0.005	0.09	0.00	0.09
3	12	Sand	370	400	385	-256	-286	-271	30	126	229	314	47,989	49,884	38,255	156	9,734	43,559	71	4,430	5,304	1.14	0.005	0.10	0.00	0.10
3	13	Sand	400	414	407	-286	-300	-293	14	127	229	314	50,771	51,658	39,664	178	11,107	44,968	93	5,803	5,304	1.13	0.005	0.05	0.00	0.05
4	14	Sand	414	440	427	-300	-326	-313	26	127	250	369	53,311	54,964	42,266	177	11,045	49,692	58	3,619	7,426	1.18	0.005	0.11	0.00	0.11
4	15	Sand	440	480	460	-326	-366	-346	40	127	250	369	57,506	60,049	44,402	210	13,104	51,828	91	5,678	7,426	1.17	0.005	0.16	0.00	0.16
4	16	Clay	480	495	487.5	-366	-381	-373.5	15	128	250	369	61,005	61,962	46,185	238	14,820	53,611	119	7,394	7,426	1.16	0.030	0.00	0.35	0.35
4	17	Clay	495	510	502.5	-381	-396	-388.5	15	128	250	369	62,918	63,875	47,162	253	15,756	54,588	134	8,330	7,426	1.16	0.030	0.00	0.34	0.34
4	18	Sand	510	525	517.5	-396	-411	-403.5	15	128	250	369	64,831	65,787	48,139	268	16,692	55,565	149	9,266	7,426	1.15	0.005	0.06	0.00	0.06
4	19	Clay	525	535	530	-411	-421	-416	10	128	250	369	66,425	67,063	48,953	280	17,472	56,379	161	10,046	7,426	1.15	0.030	0.00	0.22	0.22
4	20	Sand	535	560	547.5	-421	-446	-433.5	25	128	250	369	68,657	70,251	50,093	298	18,564	57,519	179	11,138	7,426	1.15	0.005	0.09	0.00	0.09
4	21	Sand	560	585	572.5	-446	-471	-458.5	25	128	250	369	71,850	73,450	51,726	323	20,124	59,152	204	12,698	7,426	1.14	0.005	0.09	0.00	0.09
4	22	Clay	585	588	586.5	-471	-474	-472.5	3	128	250	369	73,641	73,833	52,644	337	20,998	60,069	218	13,572	7,426	1.14	0.030	0.00	0.06	0.06
5	23	Clay	588	595	591.5	-474	-481	-477.5	7	128	308	452	74,281	74,729	56,591	284	17,690	65,576	140	8,705	8,986	1.16	0.030	0.00	0.16	0.16
5	24	Sand	595	600	597.5	-481	-486	-483.5	5	128	308	452	75,050	75,371	56,985	290	18,065	65,971	146	9,079	8,986	1.16	0.005	0.02	0.00	0.02
5	25	Sand	600	650	625	-486	-536	-511	50	128	308	452	78,580	81,788	58,799	317	19,781	67,784	173	10,795	8,986	1.15	0.005	0.19	0.00	0.19
5	26	Sand	650	700	675	-536	-586	-561	50	128	308	452	84,997	88,206	62,096	367	22,901	71,082	223	13,915	8,986	1.14	0.005	0.18	0.00	0.18
5	27	Sand	700	750	725	-586	-636	-611	50	128	308	452	91,415	94,624	65,394	417	26,021	74,380	273	17,035	8,986	1.14	0.005	0.17	0.00	0.17
																							Total Settlement (in) =	1.36	1.38	2.74
																							Total Layer Thickness (feet) =	405	75	480

Date 5/7/2012
Job No. 103.128

Boring ID CUP-41-4
Scenario 2 To HL
Elevation 24 feet AMSL
Depth to Compressible 158 feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	104	50	0.005	0.01	0.03	0.18	0.025	0.15
2	124	82	0.005	0.01	0.03	0.18	0.025	0.15
3	151	201	0.005	0.01	0.03	0.18	0.025	0.15
4	218	381	0.005	0.01	0.03	0.18	0.025	0.15
5	207	380	0.005	0.01	0.03	0.18	0.025	0.15

Model	Sub		Depth			Elevation					Total Head		Total Stress		Initial Stresses @ mid point			Final Stresses @ mid point			Delta	$\sigma'_{vf}/\sigma'_{vi}$	Comp	Settlement		
Layer	Layer	Material	Top (feet)	Bottom (feet)	Middle (feet)	Top (feet)	Bottom (feet)	Middle (feet)	Thickness (feet)	Unit wt (pcf)	Initial (feet)	Final (feet)	Mid point (psf)	Bottom (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Eff. Stress (psf)		Index	Sand (inches)	Clay (inches)	Total (inches)
1	1	Clay	0	17	8.5	24	7	15.5	17	123	104	50	1,045	2,091	1,045	0	0	1,045	0	0	0	1.00	0.030	Incomp.	Incomp.	0.00
1	2	Sand	17	50	33.5	7	-26	-9.5	33	124	104	50	4,132	6,173	4,132	0	0	4,132	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	3	Sand	50	91	70.5	-26	-67	-46.5	41	124	104	50	8,716	11,259	8,716	0	0	8,716	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	4	CLS	91	97	94	-67	-73	-70	6	124	104	50	11,633	12,006	11,633	0	0	11,633	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	5	Sand	97	154	125.5	-73	-130	-101.5	57	125	104	50	15,563	19,120	15,563	0	0	15,563	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	6	Clay	154	158	156	-130	-134	-132	4	125	104	50	19,370	19,620	19,370	0	0	19,370	0	0	0	1.00	0.030	Incomp.	Incomp.	0.00
1	7	Sand	158	188	173	-134	-164	-149	30	125	104	50	21,498	23,375	17,192	69	4,306	13,823	123	7,675	-3,370	0.80	0.005	-0.17	0.00	-0.17
2	8	Sand	188	198	193	-164	-174	-169	10	126	124	82	24,003	24,631	19,698	69	4,306	17,077	111	6,926	-2,621	0.87	0.005	-0.04	0.00	-0.04
2	9	Clay	198	200	199	-174	-176	-175	2	126	124	82	24,757	24,883	20,077	75	4,680	17,456	117	7,301	-2,621	0.87	0.030	0.00	-0.04	-0.04
2	10	Sand	200	244	222	-176	-220	-198	44	126	124	82	27,654	30,424	21,538	98	6,115	18,918	140	8,736	-2,621	0.88	0.005	-0.15	0.00	-0.15
2	11	Clay	244	256	250	-220	-232	-226	12	126	124	82	31,182	31,940	23,320	126	7,862	20,699	168	10,483	-2,621	0.89	0.030	0.00	-0.22	-0.22
3	12	Clay	256	282	269	-232	-258	-245	26	126	151	201	33,583	35,225	26,219	118	7,363	29,339	68	4,243	3,120	1.12	0.030	0.00	0.46	0.46
3	13	Clay	282	308	295	-258	-284	-271	26	127	151	201	36,872	38,520	27,887	144	8,986	31,007	94	5,866	3,120	1.11	0.030	0.00	0.43	0.43
3	14	Sand	308	319	313.5	-284	-295	-289.5	11	127	151	201	39,219	39,918	29,079	163	10,140	32,199	113	7,020	3,120	1.11	0.005	0.03	0.00	0.03
3	15	CLS	319	324	321.5	-295	-300	-297.5	5	127	151	201	40,236	40,554	29,597	171	10,639	32,717	121	7,519	3,120	1.11	0.025	0.00	0.07	0.07
4	16	CLS	324	340	332	-300	-316	-308	16	128	218	381	41,574	42,594	34,460	114	7,114	41,574	0	0	7,114	1.21	0.025	0.00	0.39	0.39
4	17	Sand	340	388	364	-316	-364	-340	48	128	218	381	45,655	48,716	36,545	146	9,110	45,655	0	0	9,110	1.25	0.005	0.28	0.00	0.28
4	18	CLS	388	400	394	-364	-376	-370	12	128	218	381	49,481	50,246	38,499	176	10,982	48,670	13	811	10,171	1.26	0.025	0.00	0.37	0.37
4	19	Sand	400	470	435	-376	-446	-411	70	128	218	381	54,710	59,173	41,169	217	13,541	51,340	54	3,370	10,171	1.25	0.005	0.40	0.00	0.40
4	20	Clay	470	484	477	-446	-460	-453	14	128	218	381	60,066	60,959	43,904	259	16,162	54,076	96	5,990	10,171	1.23	0.030	0.00	0.46	0.46
5	21	Sand	484	520	502	-460	-496	-478	36	128	207	380	63,262	65,564	44,854	295	18,408	55,649	122	7,613	10,795	1.24	0.005	0.20	0.00	0.20
5	22	Sand	520	580	550	-496	-556	-526	60	128	207	380	69,403	73,241	47,999	343	21,403	58,795	170	10,608	10,795	1.22	0.005	0.32	0.00	0.32
																							Total Settlement (in) =	0.87	1.90	2.77
																							Total Layer Thickness (feet) =	309	113	422

Date	5/7/2012	
Job No.	103.128	
Boring ID	CUP-41-4	
Scenario	4 To HL	
Elevation	24	feet AMSL
Depth to Compressible	158	feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	104	50	0.005	0.01	0.03	0.18	0.025	0.15
2	124	82	0.005	0.01	0.03	0.18	0.025	0.15
3	151	201	0.005	0.01	0.03	0.18	0.025	0.15
4	218	382	0.005	0.01	0.03	0.18	0.025	0.15
5	207	382	0.005	0.01	0.03	0.18	0.025	0.15

Model	Sub		Depth			Elevation					Total Head		Total Stress		Initial Stresses @ mid point			Final Stresses @ mid point			Delta	$\sigma'_{vf}/\sigma'_{vi}$	Comp	Settlement		
Layer	Layer	Material	Top (feet)	Bottom (feet)	Middle (feet)	Top (feet)	Bottom (feet)	Middle (feet)	Thickness (feet)	Unit wt (pcf)	Initial (feet)	Final (feet)	Mid point (psf)	Bottom (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Eff. Stress (psf)		Index	Sand (inches)	Clay (inches)	Total (inches)
1	1	Clay	0	17	8.5	24	7	15.5	17	123	104	50	1,045	2,091	1,045	0	0	1,045	0	0	0	1.00	0.030	Incomp.	Incomp.	0.00
1	2	Sand	17	50	33.5	7	-26	-9.5	33	124	104	50	4,132	6,173	4,132	0	0	4,132	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	3	Sand	50	91	70.5	-26	-67	-46.5	41	124	104	50	8,716	11,259	8,716	0	0	8,716	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	4	CLS	91	97	94	-67	-73	-70	6	124	104	50	11,633	12,006	11,633	0	0	11,633	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	5	Sand	97	154	125.5	-73	-130	-101.5	57	125	104	50	15,563	19,120	15,563	0	0	15,563	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	6	Clay	154	158	156	-130	-134	-132	4	125	104	50	19,370	19,620	19,370	0	0	19,370	0	0	0	1.00	0.030	Incomp.	Incomp.	0.00
1	7	Sand	158	188	173	-134	-164	-149	30	125	104	50	21,498	23,375	17,192	69	4,306	13,823	123	7,675	-3,370	0.80	0.005	-0.17	0.00	-0.17
2	8	Sand	188	198	193	-164	-174	-169	10	126	124	82	24,003	24,631	19,698	69	4,306	17,077	111	6,926	-2,621	0.87	0.005	-0.04	0.00	-0.04
2	9	Clay	198	200	199	-174	-176	-175	2	126	124	82	24,757	24,883	20,077	75	4,680	17,456	117	7,301	-2,621	0.87	0.030	0.00	-0.04	-0.04
2	10	Sand	200	244	222	-176	-220	-198	44	126	124	82	27,654	30,424	21,538	98	6,115	18,918	140	8,736	-2,621	0.88	0.005	-0.15	0.00	-0.15
2	11	Clay	244	256	250	-220	-232	-226	12	126	124	82	31,182	31,940	23,320	126	7,862	20,699	168	10,483	-2,621	0.89	0.030	0.00	-0.22	-0.22
3	12	Clay	256	282	269	-232	-258	-245	26	126	151	201	33,583	35,225	26,219	118	7,363	29,339	68	4,243	3,120	1.12	0.030	0.00	0.46	0.46
3	13	Clay	282	308	295	-258	-284	-271	26	127	151	201	36,872	38,520	27,887	144	8,986	31,007	94	5,866	3,120	1.11	0.030	0.00	0.43	0.43
3	14	Sand	308	319	313.5	-284	-295	-289.5	11	127	151	201	39,219	39,918	29,079	163	10,140	32,199	113	7,020	3,120	1.11	0.005	0.03	0.00	0.03
3	15	CLS	319	324	321.5	-295	-300	-297.5	5	127	151	201	40,236	40,554	29,597	171	10,639	32,717	121	7,519	3,120	1.11	0.025	0.00	0.07	0.07
4	16	CLS	324	340	332	-300	-316	-308	16	128	218	382	41,574	42,594	34,460	114	7,114	41,574	0	0	7,114	1.21	0.025	0.00	0.39	0.39
4	17	Sand	340	388	364	-316	-364	-340	48	128	218	382	45,655	48,716	36,545	146	9,110	45,655	0	0	9,110	1.25	0.005	0.28	0.00	0.28
4	18	CLS	388	400	394	-364	-376	-370	12	128	218	382	49,481	50,246	38,499	176	10,982	48,732	12	749	10,234	1.27	0.025	0.00	0.37	0.37
4	19	Sand	400	470	435	-376	-446	-411	70	128	218	382	54,710	59,173	41,169	217	13,541	51,402	53	3,307	10,234	1.25	0.005	0.40	0.00	0.40
4	20	Clay	470	484	477	-446	-460	-453	14	128	218	382	60,066	60,959	43,904	259	16,162	54,138	95	5,928	10,234	1.23	0.030	0.00	0.46	0.46
5	21	Sand	484	520	502	-460	-496	-478	36	128	207	382	63,262	65,564	44,854	295	18,408	55,774	120	7,488	10,920	1.24	0.005	0.20	0.00	0.20
5	22	Sand	520	580	550	-496	-556	-526	60	128	207	382	69,403	73,241	47,999	343	21,403	58,919	168	10,483	10,920	1.23	0.005	0.32	0.00	0.32
																							Total Settlement (in) =	0.88	1.90	2.79
																							Total Layer Thickness (feet) =	309	113	422

Date	5/7/2012	
Job No.	103.128	
Boring ID	CUP-41-4	
Scenario	2 To 1	
Elevation	24	feet AMSL
Depth to Compressible	158	feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	50	50	0.005	0.01	0.03	0.18	0.025	0.15
2	71	82	0.005	0.01	0.03	0.18	0.025	0.15
3	145	201	0.005	0.01	0.03	0.18	0.025	0.15
4	228	381	0.005	0.01	0.03	0.18	0.025	0.15
5	229	380	0.005	0.01	0.03	0.18	0.025	0.15

Model Layer	Sub Layer	Material	Depth Top (feet)	Depth Bottom (feet)	Depth Middle (feet)	Elevation Top (feet)	Elevation Bottom (feet)	Elevation Middle (feet)	Thickness (feet)	Unit wt (pcf)	Total Head Initial (feet)	Total Head Final (feet)	Total Stress Mid point (psf)	Total Stress Bottom (psf)	Initial Stresses @ mid point Effective (psf)	Initial Pore Water (feet)	Initial Pore Water (psf)	Final Stresses @ mid point Effective (psf)	Final Pore Water (feet)	Final Pore Water (psf)	Delta Eff. Stress (psf)	$\sigma'_{vf}/\sigma'_{vi}$	Comp Index	Settlement Sand (inches)	Settlement Clay (inches)	Settlement Total (inches)
1	1	Clay	0	17	8.5	24	7	15.5	17	123	50	50	1,045	2,091	1,045	0	0	1,045	0	0	0	1.00	0.030	Incomp.	Incomp.	0.00
1	2	Sand	17	50	33.5	7	-26	-9.5	33	124	50	50	4,132	6,173	4,132	0	0	4,132	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	3	Sand	50	91	70.5	-26	-67	-46.5	41	124	50	50	8,716	11,259	8,716	0	0	8,716	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	4	CLS	91	97	94	-67	-73	-70	6	124	50	50	11,633	12,006	11,633	0	0	11,633	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	5	Sand	97	154	125.5	-73	-130	-101.5	57	125	50	50	15,563	19,120	15,563	0	0	15,563	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	6	Clay	154	158	156	-130	-134	-132	4	125	50	50	19,370	19,620	19,370	0	0	19,370	0	0	0	1.00	0.030	Incomp.	Incomp.	0.00
1	7	Sand	158	188	173	-134	-164	-149	30	125	50	50	21,498	23,375	13,823	123	7,675	13,823	123	7,675	0	1.00	0.005	0.00	0.00	0.00
2	8	Sand	188	198	193	-164	-174	-169	10	126	71	82	24,003	24,631	16,390	122	7,613	17,077	111	6,926	686	1.04	0.005	0.01	0.00	0.01
2	9	Clay	198	200	199	-174	-176	-175	2	126	71	82	24,757	24,883	16,770	128	7,987	17,456	117	7,301	686	1.04	0.030	0.00	0.01	0.01
2	10	Sand	200	244	222	-176	-220	-198	44	126	71	82	27,654	30,424	18,231	151	9,422	18,918	140	8,736	686	1.04	0.005	0.04	0.00	0.04
2	11	Clay	244	256	250	-220	-232	-226	12	126	71	82	31,182	31,940	20,013	179	11,170	20,699	168	10,483	686	1.03	0.030	0.00	0.06	0.06
3	12	Clay	256	282	269	-232	-258	-245	26	126	145	201	33,583	35,225	25,845	124	7,738	29,339	68	4,243	3,494	1.14	0.030	0.00	0.52	0.52
3	13	Clay	282	308	295	-258	-284	-271	26	127	145	201	36,872	38,520	27,512	150	9,360	31,007	94	5,866	3,494	1.13	0.030	0.00	0.49	0.49
3	14	Sand	308	319	313.5	-284	-295	-289.5	11	127	145	201	39,219	39,918	28,705	169	10,514	32,199	113	7,020	3,494	1.12	0.005	0.03	0.00	0.03
3	15	CLS	319	324	321.5	-295	-300	-297.5	5	127	145	201	40,236	40,554	29,222	177	11,014	32,717	121	7,519	3,494	1.12	0.025	0.00	0.07	0.07
4	16	CLS	324	340	332	-300	-316	-308	16	128	228	381	41,574	42,594	35,084	104	6,490	41,574	0	0	6,490	1.18	0.025	0.00	0.35	0.35
4	17	Sand	340	388	364	-316	-364	-340	48	128	228	381	45,655	48,716	37,169	136	8,486	45,655	0	0	8,486	1.23	0.005	0.26	0.00	0.26
4	18	CLS	388	400	394	-364	-376	-370	12	128	228	381	49,481	50,246	39,123	166	10,358	48,670	13	811	9,547	1.24	0.025	0.00	0.34	0.34
4	19	Sand	400	470	435	-376	-446	-411	70	128	228	381	54,710	59,173	41,793	207	12,917	51,340	54	3,370	9,547	1.23	0.005	0.38	0.00	0.38
4	20	Clay	470	484	477	-446	-460	-453	14	128	228	381	60,066	60,959	44,528	249	15,538	54,076	96	5,990	9,547	1.21	0.030	0.00	0.43	0.43
5	21	Sand	484	520	502	-460	-496	-478	36	128	229	380	63,262	65,564	46,226	273	17,035	55,649	122	7,613	9,422	1.20	0.005	0.17	0.00	0.17
5	22	Sand	520	580	550	-496	-556	-526	60	128	229	380	69,403	73,241	49,372	321	20,030	58,795	170	10,608	9,422	1.19	0.005	0.27	0.00	0.27
																							Total Settlement (in) =	1.17	2.27	3.44
																							Total Layer Thickness (feet) =	309	113	422

Date 5/7/2012
Job No. 103.128

Boring ID CUP-41-4
Scenario 4 To 1
Elevation 24 feet AMSL
Depth to Compressible 158 feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	50	50	0.005	0.01	0.03	0.18	0.025	0.15
2	71	82	0.005	0.01	0.03	0.18	0.025	0.15
3	145	201	0.005	0.01	0.03	0.18	0.025	0.15
4	228	382	0.005	0.01	0.03	0.18	0.025	0.15
5	229	382	0.005	0.01	0.03	0.18	0.025	0.15

Model Layer	Sub Layer	Material	Depth Top (feet)	Depth Bottom (feet)	Depth Middle (feet)	Elevation Top (feet)	Elevation Bottom (feet)	Elevation Middle (feet)	Thickness (feet)	Unit wt (pcf)	Total Head Initial (feet)	Total Head Final (feet)	Total Stress Mid point (psf)	Total Stress Bottom (psf)	Initial Stresses @ mid point Effective (psf)	Initial Pore Water (feet)	Initial Pore Water (psf)	Final Stresses @ mid point Effective (psf)	Final Pore Water (feet)	Final Pore Water (psf)	Delta Eff. Stress (psf)	$\sigma'_{vf}/\sigma'_{vi}$	Comp Index	Settlement Sand (inches)	Settlement Clay (inches)	Settlement Total (inches)
1	1	Clay	0	17	8.5	24	7	15.5	17	123	50	50	1,045	2,091	1,045	0	0	1,045	0	0	0	1.00	0.030	Incomp.	Incomp.	0.00
1	2	Sand	17	50	33.5	7	-26	-9.5	33	124	50	50	4,132	6,173	4,132	0	0	4,132	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	3	Sand	50	91	70.5	-26	-67	-46.5	41	124	50	50	8,716	11,259	8,716	0	0	8,716	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	4	CLS	91	97	94	-67	-73	-70	6	124	50	50	11,633	12,006	11,633	0	0	11,633	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	5	Sand	97	154	125.5	-73	-130	-101.5	57	125	50	50	15,563	19,120	15,563	0	0	15,563	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	6	Clay	154	158	156	-130	-134	-132	4	125	50	50	19,370	19,620	19,370	0	0	19,370	0	0	0	1.00	0.030	Incomp.	Incomp.	0.00
1	7	Sand	158	188	173	-134	-164	-149	30	125	50	50	21,498	23,375	13,823	123	7,675	13,823	123	7,675	0	1.00	0.005	0.00	0.00	0.00
2	8	Sand	188	198	193	-164	-174	-169	10	126	71	82	24,003	24,631	16,390	122	7,613	17,077	111	6,926	686	1.04	0.005	0.01	0.00	0.01
2	9	Clay	198	200	199	-174	-176	-175	2	126	71	82	24,757	24,883	16,770	128	7,987	17,456	117	7,301	686	1.04	0.030	0.00	0.01	0.01
2	10	Sand	200	244	222	-176	-220	-198	44	126	71	82	27,654	30,424	18,231	151	9,422	18,918	140	8,736	686	1.04	0.005	0.04	0.00	0.04
2	11	Clay	244	256	250	-220	-232	-226	12	126	71	82	31,182	31,940	20,013	179	11,170	20,699	168	10,483	686	1.03	0.030	0.00	0.06	0.06
3	12	Clay	256	282	269	-232	-258	-245	26	126	145	201	33,583	35,225	25,845	124	7,738	29,339	68	4,243	3,494	1.14	0.030	0.00	0.52	0.52
3	13	Clay	282	308	295	-258	-284	-271	26	127	145	201	36,872	38,520	27,512	150	9,360	31,007	94	5,866	3,494	1.13	0.030	0.00	0.49	0.49
3	14	Sand	308	319	313.5	-284	-295	-289.5	11	127	145	201	39,219	39,918	28,705	169	10,514	32,199	113	7,020	3,494	1.12	0.005	0.03	0.00	0.03
3	15	CLS	319	324	321.5	-295	-300	-297.5	5	127	145	201	40,236	40,554	29,222	177	11,014	32,717	121	7,519	3,494	1.12	0.025	0.00	0.07	0.07
4	16	CLS	324	340	332	-300	-316	-308	16	128	228	382	41,574	42,594	35,084	104	6,490	41,574	0	0	6,490	1.18	0.025	0.00	0.35	0.35
4	17	Sand	340	388	364	-316	-364	-340	48	128	228	382	45,655	48,716	37,169	136	8,486	45,655	0	0	8,486	1.23	0.005	0.26	0.00	0.26
4	18	CLS	388	400	394	-364	-376	-370	12	128	228	382	49,481	50,246	39,123	166	10,358	48,732	12	749	9,610	1.25	0.025	0.00	0.34	0.34
4	19	Sand	400	470	435	-376	-446	-411	70	128	228	382	54,710	59,173	41,793	207	12,917	51,402	53	3,307	9,610	1.23	0.005	0.38	0.00	0.38
4	20	Clay	470	484	477	-446	-460	-453	14	128	228	382	60,066	60,959	44,528	249	15,538	54,138	95	5,928	9,610	1.22	0.030	0.00	0.43	0.43
5	21	Sand	484	520	502	-460	-496	-478	36	128	229	382	63,262	65,564	46,226	273	17,035	55,774	120	7,488	9,547	1.21	0.005	0.18	0.00	0.18
5	22	Sand	520	580	550	-496	-556	-526	60	128	229	382	69,403	73,241	49,372	321	20,030	58,919	168	10,483	9,547	1.19	0.005	0.28	0.00	0.28
																							Total Settlement (in) =	1.17	2.28	3.45
																							Total Layer Thickness (feet) =	309	113	422

Date	4/5/2012
Job No.	103.128
Boring ID	LMPS
Scenario	2 to HL
Elevation	43 feet AMSL
Depth to Compressible	71 feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	32	34	0.005	0.01	0.03	0.18	0.025	0.15
2	33	37	0.005	0.01	0.03	0.18	0.025	0.15
3	50	68	0.005	0.01	0.03	0.18	0.025	0.15
4	65	88	0.005	0.01	0.03	0.18	0.025	0.15
5	113	198	0.005	0.01	0.03	0.18	0.025	0.15

Model Layer	Sub Layer	Material	Depth Top (feet)	Depth Bottom (feet)	Depth Middle (feet)	Elevation Top (feet)	Elevation Bottom (feet)	Elevation Middle (feet)	Thickness (feet)	Unit wt (pcf)	Total Head Initial (feet)	Total Head Final (feet)
1	1	Sand	0	71	35.5	43	-28	7.5	71	123	32	34
2	2	Sand	71	100	85.5	-28	-57	-42.5	29	124	33	37
2	3	Sand	100	143	121.5	-57	-100	-78.5	43	124	33	37
2	4	Sand	143	193	168	-100	-150	-125	50	124	33	37
3	5	Sand	193	233	213	-150	-190	-170	40	125	50	68
3	6	Sand	233	283	258	-190	-240	-215	50	125	50	68
3	7	Sand	283	333	308	-240	-290	-265	50	125	50	68
3	8	Clay	333	343	338	-290	-300	-295	10	126	50	68
4	9	Clay	343	360	351.5	-300	-317	-308.5	17	126	65	88
4	10	Clay	360	375	367.5	-317	-332	-324.5	15	126	65	88
4	11	Clay	375	390	382.5	-332	-347	-339.5	15	126	65	88
4	12	Sand	390	420	405	-347	-377	-362	30	126	65	88
4	13	Sand	420	454	437	-377	-411	-394	34	127	65	88
4	14	CLS	454	474	464	-411	-431	-421	20	127	65	88
4	15	CLS	474	494	484	-431	-451	-441	20	127	65	88
4	16	CLS	494	514	504	-451	-471	-461	20	128	65	88
4	17	CLS	514	539	526.5	-471	-496	-483.5	25	128	65	88
5	18	CLS	539	542	540.5	-496	-499	-497.5	3	128	113	198
5	19	Sand	542	555	548.5	-499	-512	-505.5	13	128	113	198
5	20	Sand	555	575	565	-512	-532	-522	20	128	113	198
5	21	Sand	575	595	585	-532	-552	-542	20	128	113	198
5	22	Sand	595	615	605	-552	-572	-562	20	128	113	198

Model Layer	Sub Layer	Total Stress Mid point (psf)	Total Stress Bottom (psf)	Initial Stresses @ mid point Effective (psf)	Initial Pore Water (feet)	Initial Pore Water (psf)	Final Stresses @ mid point Effective (psf)	Final Pore Water (feet)	Final Pore Water (psf)	Delta Eff. Stress (psf)	$\sigma'_{vf}/\sigma'_{vi}$	Comp Index	Settlement Sand (inches)	Settlement Clay (inches)	Settlement Total (inches)
1	1	4,367	8,733	4,367	0	0	4,367	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
2	2	10,531	12,329	7,255	53	3,276	7,505	49	3,026	250	1.03	0.005	0.03	0.00	0.03
2	3	14,995	17,661	9,473	89	5,522	9,722	85	5,273	250	1.03	0.005	0.03	0.00	0.03
2	4	20,761	23,861	12,337	135	8,424	12,587	131	8,174	250	1.02	0.005	0.03	0.00	0.03
3	5	26,361	28,861	16,190	163	10,171	17,313	145	9,048	1,123	1.07	0.005	0.07	0.00	0.07
3	6	31,986	35,111	19,007	208	12,979	20,130	190	11,856	1,123	1.06	0.005	0.07	0.00	0.07
3	7	38,236	41,361	22,137	258	16,099	23,260	240	14,976	1,123	1.05	0.005	0.06	0.00	0.06
3	8	41,991	42,621	24,020	288	17,971	25,143	270	16,848	1,123	1.05	0.030	0.00	0.07	0.07
4	9	43,692	44,763	25,814	287	17,878	27,250	264	16,442	1,435	1.06	0.030	0.00	0.14	0.14
4	10	45,708	46,653	26,832	303	18,876	28,267	280	17,441	1,435	1.05	0.030	0.00	0.12	0.12
4	11	47,598	48,543	27,786	318	19,812	29,221	295	18,377	1,435	1.05	0.030	0.00	0.12	0.12
4	12	50,433	52,323	29,217	340	21,216	30,652	317	19,781	1,435	1.05	0.005	0.04	0.00	0.04
4	13	54,482	56,641	31,269	372	23,213	32,704	349	21,778	1,435	1.05	0.005	0.04	0.00	0.04
4	14	57,911	59,181	33,013	399	24,898	34,449	376	23,462	1,435	1.04	0.025	0.00	0.11	0.11
4	15	60,451	61,721	34,305	419	26,146	35,741	396	24,710	1,435	1.04	0.025	0.00	0.11	0.11
4	16	63,001	64,281	35,607	439	27,394	37,043	416	25,958	1,435	1.04	0.025	0.00	0.10	0.10
4	17	65,881	67,481	37,083	462	28,798	38,519	439	27,362	1,435	1.04	0.025	0.00	0.12	0.12
5	18	67,673	67,865	40,997	428	26,676	46,301	343	21,372	5,304	1.13	0.025	0.00	0.05	0.05
5	19	68,697	69,529	41,522	436	27,175	46,826	351	21,871	5,304	1.13	0.005	0.04	0.00	0.04
5	20	70,809	72,089	42,604	452	28,205	47,908	367	22,901	5,304	1.12	0.005	0.06	0.00	0.06
5	21	73,369	74,649	43,916	472	29,453	49,220	387	24,149	5,304	1.12	0.005	0.06	0.00	0.06
5	22	75,929	77,209	45,228	492	30,701	50,532	407	25,397	5,304	1.12	0.005	0.06	0.00	0.06
												Total Settlement (in) =	0.59	0.95	1.53
												Total Layer Thickness (feet) =	399	145	544

Date	4/5/2012	
Job No.	103.128	
Boring ID	LMPS	
Scenario	3a to HL	
Elevation	43	feet AMSL
Depth to Compressible	71	feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	32	48	0.005	0.01	0.03	0.18	0.025	0.15
2	33	51	0.005	0.01	0.03	0.18	0.025	0.15
3	50	79	0.005	0.01	0.03	0.18	0.025	0.15
4	65	135	0.005	0.01	0.03	0.18	0.025	0.15
5	113	145	0.005	0.01	0.03	0.18	0.025	0.15

Model Layer	Sub Layer	Material	Depth Top (feet)	Depth Bottom (feet)	Depth Middle (feet)	Elevation Top (feet)	Elevation Bottom (feet)	Elevation Middle (feet)	Thickness (feet)	Unit wt (pcf)	Total Head Initial (feet)	Total Head Final (feet)	Total Stress Mid point (psf)	Total Stress Bottom (psf)	Initial Stresses @ mid point Effective (psf)	Initial Pore Water (feet)	Initial Pore Water (psf)	Final Stresses @ mid point Effective (psf)	Final Pore Water (feet)	Final Pore Water (psf)	Delta Eff. Stress (psf)	$\sigma'_{vf}/\sigma'_{vi}$	Comp Index	Settlement Sand (inches)	Settlement Clay (inches)	Settlement Total (inches)
1	1	Sand	0	71	35.5	43	-28	7.5	71	123	32	48	4,367	8,733	4,367	0	0	4,367	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
2	2	Sand	71	100	85.5	-28	-57	-42.5	29	124	33	51	10,531	12,329	7,255	53	3,276	8,378	35	2,153	1,123	1.15	0.005	0.11	0.00	0.11
2	3	Sand	100	143	121.5	-57	-100	-78.5	43	124	33	51	14,995	17,661	9,473	89	5,522	10,596	71	4,399	1,123	1.12	0.005	0.13	0.00	0.13
2	4	Sand	143	193	168	-100	-150	-125	50	124	33	51	20,761	23,861	12,337	135	8,424	13,460	117	7,301	1,123	1.09	0.005	0.11	0.00	0.11
3	5	Sand	193	233	213	-150	-190	-170	40	125	50	79	26,361	28,861	16,190	163	10,171	17,999	134	8,362	1,810	1.11	0.005	0.11	0.00	0.11
3	6	Sand	233	283	258	-190	-240	-215	50	125	50	79	31,986	35,111	19,007	208	12,979	20,816	179	11,170	1,810	1.10	0.005	0.12	0.00	0.12
3	7	Sand	283	333	308	-240	-290	-265	50	125	50	79	38,236	41,361	22,137	258	16,099	23,946	229	14,290	1,810	1.08	0.005	0.10	0.00	0.10
3	8	Clay	333	343	338	-290	-300	-295	10	126	50	79	41,991	42,621	24,020	288	17,971	25,829	259	16,162	1,810	1.08	0.030	0.00	0.11	0.11
4	9	Clay	343	360	351.5	-300	-317	-308.5	17	126	65	135	43,692	44,763	25,814	287	17,878	30,182	217	13,510	4,368	1.17	0.030	0.00	0.42	0.42
4	10	Clay	360	375	367.5	-317	-332	-324.5	15	126	65	135	45,708	46,653	26,832	303	18,876	31,200	233	14,508	4,368	1.16	0.030	0.00	0.35	0.35
4	11	Clay	375	390	382.5	-332	-347	-339.5	15	126	65	135	47,598	48,543	27,786	318	19,812	32,154	248	15,444	4,368	1.16	0.030	0.00	0.34	0.34
4	12	Sand	390	420	405	-347	-377	-362	30	126	65	135	50,433	52,323	29,217	340	21,216	33,585	270	16,848	4,368	1.15	0.005	0.11	0.00	0.11
4	13	Sand	420	454	437	-377	-411	-394	34	127	65	135	54,482	56,641	31,269	372	23,213	35,637	302	18,845	4,368	1.14	0.005	0.12	0.00	0.12
4	14	CLS	454	474	464	-411	-431	-421	20	127	65	135	57,911	59,181	33,013	399	24,898	37,381	329	20,530	4,368	1.13	0.025	0.00	0.32	0.32
4	15	CLS	474	494	484	-431	-451	-441	20	127	65	135	60,451	61,721	34,305	419	26,146	38,673	349	21,778	4,368	1.13	0.025	0.00	0.31	0.31
4	16	CLS	494	514	504	-451	-471	-461	20	128	65	135	63,001	64,281	35,607	439	27,394	39,975	369	23,026	4,368	1.12	0.025	0.00	0.30	0.30
4	17	CLS	514	539	526.5	-471	-496	-483.5	25	128	65	135	65,881	67,481	37,083	462	28,798	41,451	392	24,430	4,368	1.12	0.025	0.00	0.36	0.36
5	18	CLS	539	542	540.5	-496	-499	-497.5	3	128	113	145	67,673	67,865	40,997	428	26,676	42,994	396	24,679	1,997	1.05	0.025	0.00	0.02	0.02
5	19	Sand	542	555	548.5	-499	-512	-505.5	13	128	113	145	68,697	69,529	41,522	436	27,175	43,519	404	25,178	1,997	1.05	0.005	0.02	0.00	0.02
5	20	Sand	555	575	565	-512	-532	-522	20	128	113	145	70,809	72,089	42,604	452	28,205	44,601	420	26,208	1,997	1.05	0.005	0.02	0.00	0.02
5	21	Sand	575	595	585	-532	-552	-542	20	128	113	145	73,369	74,649	43,916	472	29,453	45,913	440	27,456	1,997	1.05	0.005	0.02	0.00	0.02
5	22	Sand	595	615	605	-552	-572	-562	20	128	113	145	75,929	77,209	45,228	492	30,701	47,225	460	28,704	1,997	1.04	0.005	0.02	0.00	0.02
																							Total Settlement (in) =	0.99	2.54	3.53
																							Total Layer Thickness (feet) =	399	145	544

Date	4/5/2012
Job No.	103.128
Boring ID	LMPS
Scenario	3b to HL
Elevation	43 feet AMSL
Depth to Compressible	71 feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	32	48	0.005	0.01	0.03	0.18	0.025	0.15
2	33	51	0.005	0.01	0.03	0.18	0.025	0.15
3	50	78	0.005	0.01	0.03	0.18	0.025	0.15
4	65	135	0.005	0.01	0.03	0.18	0.025	0.15
5	113	145	0.005	0.01	0.03	0.18	0.025	0.15

Model Layer	Sub Layer	Material	Depth			Elevation					Total Head		Total Stress		Initial Stresses @ mid point			Final Stresses @ mid point			Delta	$\sigma'_{vf}/\sigma'_{vi}$	Comp	Settlement		
			Top (feet)	Bottom (feet)	Middle (feet)	Top (feet)	Bottom (feet)	Middle (feet)	Thickness (feet)	Unit wt (pcf)	Initial (feet)	Final (feet)	Mid point (psf)	Bottom (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Eff. Stress (psf)		Index	Sand (inches)	Clay (inches)	Total (inches)
1	1	Sand	0	71	35.5	43	-28	7.5	71	123	32	48	4,367	8,733	4,367	0	0	4,367	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
2	2	Sand	71	100	85.5	-28	-57	-42.5	29	124	33	51	10,531	12,329	7,255	53	3,276	8,378	35	2,153	1,123	1.15	0.005	0.11	0.00	0.11
2	3	Sand	100	143	121.5	-57	-100	-78.5	43	124	33	51	14,995	17,661	9,473	89	5,522	10,596	71	4,399	1,123	1.12	0.005	0.13	0.00	0.13
2	4	Sand	143	193	168	-100	-150	-125	50	124	33	51	20,761	23,861	12,337	135	8,424	13,460	117	7,301	1,123	1.09	0.005	0.11	0.00	0.11
3	5	Sand	193	233	213	-150	-190	-170	40	125	50	78	26,361	28,861	16,190	163	10,171	17,937	135	8,424	1,747	1.11	0.005	0.11	0.00	0.11
3	6	Sand	233	283	258	-190	-240	-215	50	125	50	78	31,986	35,111	19,007	208	12,979	20,754	180	11,232	1,747	1.09	0.005	0.11	0.00	0.11
3	7	Sand	283	333	308	-240	-290	-265	50	125	50	78	38,236	41,361	22,137	258	16,099	23,884	230	14,352	1,747	1.08	0.005	0.10	0.00	0.10
3	8	Clay	333	343	338	-290	-300	-295	10	126	50	78	41,991	42,621	24,020	288	17,971	25,767	260	16,224	1,747	1.07	0.030	0.00	0.11	0.11
4	9	Clay	343	360	351.5	-300	-317	-308.5	17	126	65	135	43,692	44,763	25,814	287	17,878	30,182	217	13,510	4,368	1.17	0.030	0.00	0.42	0.42
4	10	Clay	360	375	367.5	-317	-332	-324.5	15	126	65	135	45,708	46,653	26,832	303	18,876	31,200	233	14,508	4,368	1.16	0.030	0.00	0.35	0.35
4	11	Clay	375	390	382.5	-332	-347	-339.5	15	126	65	135	47,598	48,543	27,786	318	19,812	32,154	248	15,444	4,368	1.16	0.030	0.00	0.34	0.34
4	12	Sand	390	420	405	-347	-377	-362	30	126	65	135	50,433	52,323	29,217	340	21,216	33,585	270	16,848	4,368	1.15	0.005	0.11	0.00	0.11
4	13	Sand	420	454	437	-377	-411	-394	34	127	65	135	54,482	56,641	31,269	372	23,213	35,637	302	18,845	4,368	1.14	0.005	0.12	0.00	0.12
4	14	CLS	454	474	464	-411	-431	-421	20	127	65	135	57,911	59,181	33,013	399	24,898	37,381	329	20,530	4,368	1.13	0.025	0.00	0.32	0.32
4	15	CLS	474	494	484	-431	-451	-441	20	127	65	135	60,451	61,721	34,305	419	26,146	38,673	349	21,778	4,368	1.13	0.025	0.00	0.31	0.31
4	16	CLS	494	514	504	-451	-471	-461	20	128	65	135	63,001	64,281	35,607	439	27,394	39,975	369	23,026	4,368	1.12	0.025	0.00	0.30	0.30
4	17	CLS	514	539	526.5	-471	-496	-483.5	25	128	65	135	65,881	67,481	37,083	462	28,798	41,451	392	24,430	4,368	1.12	0.025	0.00	0.36	0.36
5	18	CLS	539	542	540.5	-496	-499	-497.5	3	128	113	145	67,673	67,865	40,997	428	26,676	42,994	396	24,679	1,997	1.05	0.025	0.00	0.02	0.02
5	19	Sand	542	555	548.5	-499	-512	-505.5	13	128	113	145	68,697	69,529	41,522	436	27,175	43,519	404	25,178	1,997	1.05	0.005	0.02	0.00	0.02
5	20	Sand	555	575	565	-512	-532	-522	20	128	113	145	70,809	72,089	42,604	452	28,205	44,601	420	26,208	1,997	1.05	0.005	0.02	0.00	0.02
5	21	Sand	575	595	585	-532	-552	-542	20	128	113	145	73,369	74,649	43,916	472	29,453	45,913	440	27,456	1,997	1.05	0.005	0.02	0.00	0.02
5	22	Sand	595	615	605	-552	-572	-562	20	128	113	145	75,929	77,209	45,228	492	30,701	47,225	460	28,704	1,997	1.04	0.005	0.02	0.00	0.02
																							Total Settlement (in) =	0.98	2.54	3.52
																							Total Layer Thickness (feet) =	399	145	544

Date 4/5/2012
Job No. 103.128

Boring ID	LMPS		
Scenario	4 to HL		
Elevation	43	feet AMSL	
Depth to Compressible	71	feet	

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	32	36	0.005	0.01	0.03	0.18	0.025	0.15
2	33	39	0.005	0.01	0.03	0.18	0.025	0.15
3	50	74	0.005	0.01	0.03	0.18	0.025	0.15
4	65	134	0.005	0.01	0.03	0.18	0.025	0.15
5	113	194	0.005	0.01	0.03	0.18	0.025	0.15

Model Layer	Sub Layer	Material	Depth Top (feet)	Depth Bottom (feet)	Depth Middle (feet)	Elevation Top (feet)	Elevation Bottom (feet)	Elevation Middle (feet)	Thickness (feet)	Unit wt (pcf)	Total Head Initial (feet)	Total Head Final (feet)	Total Stress Mid point (psf)	Total Stress Bottom (psf)	Initial Stresses @ mid point Effective (psf)	Initial Pore Water (feet)	Initial Pore Water (psf)	Final Stresses @ mid point Effective (psf)	Final Pore Water (feet)	Final Pore Water (psf)	Delta Eff. Stress (psf)	$\sigma'_{vf}/\sigma'_{vi}$	Comp Index	Settlement Sand (inches)	Settlement Clay (inches)	Settlement Total (inches)
1	1	Sand	0	71	35.5	43	-28	7.5	71	123	32	36	4,367	8,733	4,367	0	0	4,367	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
2	2	Sand	71	100	85.5	-28	-57	-42.5	29	124	33	39	10,531	12,329	7,255	53	3,276	7,629	47	2,902	374	1.05	0.005	0.04	0.00	0.04
2	3	Sand	100	143	121.5	-57	-100	-78.5	43	124	33	39	14,995	17,661	9,473	89	5,522	9,847	83	5,148	374	1.04	0.005	0.04	0.00	0.04
2	4	Sand	143	193	168	-100	-150	-125	50	124	33	39	20,761	23,861	12,337	135	8,424	12,711	129	8,050	374	1.03	0.005	0.04	0.00	0.04
3	5	Sand	193	233	213	-150	-190	-170	40	125	50	74	26,361	28,861	16,190	163	10,171	17,687	139	8,674	1,498	1.09	0.005	0.09	0.00	0.09
3	6	Sand	233	283	258	-190	-240	-215	50	125	50	74	31,986	35,111	19,007	208	12,979	20,504	184	11,482	1,498	1.08	0.005	0.10	0.00	0.10
3	7	Sand	283	333	308	-240	-290	-265	50	125	50	74	38,236	41,361	22,137	258	16,099	23,634	234	14,602	1,498	1.07	0.005	0.09	0.00	0.09
3	8	Clay	333	343	338	-290	-300	-295	10	126	50	74	41,991	42,621	24,020	288	17,971	25,517	264	16,474	1,498	1.06	0.030	0.00	0.09	0.09
4	9	Clay	343	360	351.5	-300	-317	-308.5	17	126	65	134	43,692	44,763	25,814	287	17,878	30,120	218	13,572	4,306	1.17	0.030	0.00	0.41	0.41
4	10	Clay	360	375	367.5	-317	-332	-324.5	15	126	65	134	45,708	46,653	26,832	303	18,876	31,138	234	14,570	4,306	1.16	0.030	0.00	0.35	0.35
4	11	Clay	375	390	382.5	-332	-347	-339.5	15	126	65	134	47,598	48,543	27,786	318	19,812	32,092	249	15,506	4,306	1.15	0.030	0.00	0.34	0.34
4	12	Sand	390	420	405	-347	-377	-362	30	126	65	134	50,433	52,323	29,217	340	21,216	33,523	271	16,910	4,306	1.15	0.005	0.11	0.00	0.11
4	13	Sand	420	454	437	-377	-411	-394	34	127	65	134	54,482	56,641	31,269	372	23,213	35,575	303	18,907	4,306	1.14	0.005	0.11	0.00	0.11
4	14	CLS	454	474	464	-411	-431	-421	20	127	65	134	57,911	59,181	33,013	399	24,898	37,319	330	20,592	4,306	1.13	0.025	0.00	0.32	0.32
4	15	CLS	474	494	484	-431	-451	-441	20	127	65	134	60,451	61,721	34,305	419	26,146	38,611	350	21,840	4,306	1.13	0.025	0.00	0.31	0.31
4	16	CLS	494	514	504	-451	-471	-461	20	128	65	134	63,001	64,281	35,607	439	27,394	39,913	370	23,088	4,306	1.12	0.025	0.00	0.30	0.30
4	17	CLS	514	539	526.5	-471	-496	-483.5	25	128	65	134	65,881	67,481	37,083	462	28,798	41,389	393	24,492	4,306	1.12	0.025	0.00	0.36	0.36
5	18	CLS	539	542	540.5	-496	-499	-497.5	3	128	113	194	67,673	67,865	40,997	428	26,676	46,051	347	21,622	5,054	1.12	0.025	0.00	0.05	0.05
5	19	Sand	542	555	548.5	-499	-512	-505.5	13	128	113	194	68,697	69,529	41,522	436	27,175	46,576	355	22,121	5,054	1.12	0.005	0.04	0.00	0.04
5	20	Sand	555	575	565	-512	-532	-522	20	128	113	194	70,809	72,089	42,604	452	28,205	47,659	371	23,150	5,054	1.12	0.005	0.06	0.00	0.06
5	21	Sand	575	595	585	-532	-552	-542	20	128	113	194	73,369	74,649	43,916	472	29,453	48,971	391	24,398	5,054	1.12	0.005	0.06	0.00	0.06
5	22	Sand	595	615	605	-552	-572	-562	20	128	113	194	75,929	77,209	45,228	492	30,701	50,283	411	25,646	5,054	1.11	0.005	0.06	0.00	0.06
																							Total Settlement (in) =	0.83	2.52	3.35
																							Total Layer Thickness (feet) =	399	145	544

Date	4/5/2012
Job No.	103.128
Boring ID	LMPS
Scenario	2 to 1
Elevation	43 feet AMSL
Depth to Compressible	71 feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	34	34	0.005	0.01	0.03	0.18	0.025	0.15
2	36	37	0.005	0.01	0.03	0.18	0.025	0.15
3	58	68	0.005	0.01	0.03	0.18	0.025	0.15
4	73	88	0.005	0.01	0.03	0.18	0.025	0.15
5	135	198	0.005	0.01	0.03	0.18	0.025	0.15

Model Layer	Sub Layer	Material	Depth Top (feet)	Depth Bottom (feet)	Depth Middle (feet)	Elevation Top (feet)	Elevation Bottom (feet)	Elevation Middle (feet)	Thickness (feet)	Unit wt (pcf)	Total Head Initial (feet)	Total Head Final (feet)	Total Stress Mid point (psf)	Total Stress Bottom (psf)	Initial Stresses @ mid point Effective (psf)	Initial Pore Water (feet)	Initial Pore Water (psf)	Final Stresses @ mid point Effective (psf)	Final Pore Water (feet)	Final Pore Water (psf)	Delta Eff. Stress (psf)	$\sigma'_{vf}/\sigma'_{vi}$	Comp Index	Settlement Sand (inches)	Settlement Clay (inches)	Settlement Total (inches)
1	1	Sand	0	71	35.5	43	-28	7.5	71	123	34	34	4,367	8,733	4,367	0	0	4,367	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
2	2	Sand	71	100	85.5	-28	-57	-42.5	29	124	36	37	10,531	12,329	7,442	50	3,089	7,505	49	3,026	62	1.01	0.005	0.01	0.00	0.01
2	3	Sand	100	143	121.5	-57	-100	-78.5	43	124	36	37	14,995	17,661	9,660	86	5,335	9,722	85	5,273	62	1.01	0.005	0.01	0.00	0.01
2	4	Sand	143	193	168	-100	-150	-125	50	124	36	37	20,761	23,861	12,524	132	8,237	12,587	131	8,174	62	1.00	0.005	0.01	0.00	0.01
3	5	Sand	193	233	213	-150	-190	-170	40	125	58	68	26,361	28,861	16,689	155	9,672	17,313	145	9,048	624	1.04	0.005	0.04	0.00	0.04
3	6	Sand	233	283	258	-190	-240	-215	50	125	58	68	31,986	35,111	19,506	200	12,480	20,130	190	11,856	624	1.03	0.005	0.04	0.00	0.04
3	7	Sand	283	333	308	-240	-290	-265	50	125	58	68	38,236	41,361	22,636	250	15,600	23,260	240	14,976	624	1.03	0.005	0.04	0.00	0.04
3	8	Clay	333	343	338	-290	-300	-295	10	126	58	68	41,991	42,621	24,519	280	17,472	25,143	270	16,848	624	1.03	0.030	0.00	0.04	0.04
4	9	Clay	343	360	351.5	-300	-317	-308.5	17	126	73	88	43,692	44,763	26,314	279	17,378	27,250	264	16,442	936	1.04	0.030	0.00	0.09	0.09
4	10	Clay	360	375	367.5	-317	-332	-324.5	15	126	73	88	45,708	46,653	27,331	295	18,377	28,267	280	17,441	936	1.03	0.030	0.00	0.08	0.08
4	11	Clay	375	390	382.5	-332	-347	-339.5	15	126	73	88	47,598	48,543	28,285	310	19,313	29,221	295	18,377	936	1.03	0.030	0.00	0.08	0.08
4	12	Sand	390	420	405	-347	-377	-362	30	126	73	88	50,433	52,323	29,716	332	20,717	30,652	317	19,781	936	1.03	0.005	0.02	0.00	0.02
4	13	Sand	420	454	437	-377	-411	-394	34	127	73	88	54,482	56,641	31,768	364	22,714	32,704	349	21,778	936	1.03	0.005	0.03	0.00	0.03
4	14	CLS	454	474	464	-411	-431	-421	20	127	73	88	57,911	59,181	33,513	391	24,398	34,449	376	23,462	936	1.03	0.025	0.00	0.07	0.07
4	15	CLS	474	494	484	-431	-451	-441	20	127	73	88	60,451	61,721	34,805	411	25,646	35,741	396	24,710	936	1.03	0.025	0.00	0.07	0.07
4	16	CLS	494	514	504	-451	-471	-461	20	128	73	88	63,001	64,281	36,107	431	26,894	37,043	416	25,958	936	1.03	0.025	0.00	0.07	0.07
4	17	CLS	514	539	526.5	-471	-496	-483.5	25	128	73	88	65,881	67,481	37,583	454	28,298	38,519	439	27,362	936	1.02	0.025	0.00	0.08	0.08
5	18	CLS	539	542	540.5	-496	-499	-497.5	3	128	135	198	67,673	67,865	42,370	406	25,303	46,301	343	21,372	3,931	1.09	0.025	0.00	0.03	0.03
5	19	Sand	542	555	548.5	-499	-512	-505.5	13	128	135	198	68,697	69,529	42,895	414	25,802	46,826	351	21,871	3,931	1.09	0.005	0.03	0.00	0.03
5	20	Sand	555	575	565	-512	-532	-522	20	128	135	198	70,809	72,089	43,977	430	26,832	47,908	367	22,901	3,931	1.09	0.005	0.04	0.00	0.04
5	21	Sand	575	595	585	-532	-552	-542	20	128	135	198	73,369	74,649	45,289	450	28,080	49,220	387	24,149	3,931	1.09	0.005	0.04	0.00	0.04
5	22	Sand	595	615	605	-552	-572	-562	20	128	135	198	75,929	77,209	46,601	470	29,328	50,532	407	25,397	3,931	1.08	0.005	0.04	0.00	0.04
																							Total Settlement (in) =	0.34	0.61	0.95
																							Total Layer Thickness (feet) =	399	145	544

Date 4/5/2012
Job No. 103.128

Boring ID LMPS
Scenario 3a to 1
Elevation 43 feet AMSL
Depth to Compressible 71 feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	34	48	0.005	0.01	0.03	0.18	0.025	0.15
2	36	51	0.005	0.01	0.03	0.18	0.025	0.15
3	58	79	0.005	0.01	0.03	0.18	0.025	0.15
4	73	135	0.005	0.01	0.03	0.18	0.025	0.15
5	135	145	0.005	0.01	0.03	0.18	0.025	0.15

Model	Sub		Depth			Elevation					Total Head		Total Stress		Initial Stresses @ mid point			Final Stresses @ mid point			Delta	$\sigma'_{vf}/\sigma'_{vi}$	Comp	Settlement		
Layer	Layer	Material	Top (feet)	Bottom (feet)	Middle (feet)	Top (feet)	Bottom (feet)	Middle (feet)	Thickness (feet)	Unit wt (pcf)	Initial (feet)	Final (feet)	Mid point (psf)	Bottom (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Eff. Stress (psf)		Index	Sand (inches)	Clay (inches)	Total (inches)
1	1	Sand	0	71	35.5	43	-28	7.5	71	123	34	48	4,367	8,733	4,367	0	0	4,367	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
2	2	Sand	71	100	85.5	-28	-57	-42.5	29	124	36	51	10,531	12,329	7,442	50	3,089	8,378	35	2,153	936	1.13	0.005	0.09	0.00	0.09
2	3	Sand	100	143	121.5	-57	-100	-78.5	43	124	36	51	14,995	17,661	9,660	86	5,335	10,596	71	4,399	936	1.10	0.005	0.10	0.00	0.10
2	4	Sand	143	193	168	-100	-150	-125	50	124	36	51	20,761	23,861	12,524	132	8,237	13,460	117	7,301	936	1.07	0.005	0.09	0.00	0.09
3	5	Sand	193	233	213	-150	-190	-170	40	125	58	79	26,361	28,861	16,689	155	9,672	17,999	134	8,362	1,310	1.08	0.005	0.08	0.00	0.08
3	6	Sand	233	283	258	-190	-240	-215	50	125	58	79	31,986	35,111	19,506	200	12,480	20,816	179	11,170	1,310	1.07	0.005	0.08	0.00	0.08
3	7	Sand	283	333	308	-240	-290	-265	50	125	58	79	38,236	41,361	22,636	250	15,600	23,946	229	14,290	1,310	1.06	0.005	0.07	0.00	0.07
3	8	Clay	333	343	338	-290	-300	-295	10	126	58	79	41,991	42,621	24,519	280	17,472	25,829	259	16,162	1,310	1.05	0.030	0.00	0.08	0.08
4	9	Clay	343	360	351.5	-300	-317	-308.5	17	126	73	135	43,692	44,763	26,314	279	17,378	30,182	217	13,510	3,869	1.15	0.030	0.00	0.36	0.36
4	10	Clay	360	375	367.5	-317	-332	-324.5	15	126	73	135	45,708	46,653	27,331	295	18,377	31,200	233	14,508	3,869	1.14	0.030	0.00	0.31	0.31
4	11	Clay	375	390	382.5	-332	-347	-339.5	15	126	73	135	47,598	48,543	28,285	310	19,313	32,154	248	15,444	3,869	1.14	0.030	0.00	0.30	0.30
4	12	Sand	390	420	405	-347	-377	-362	30	126	73	135	50,433	52,323	29,716	332	20,717	33,585	270	16,848	3,869	1.13	0.005	0.10	0.00	0.10
4	13	Sand	420	454	437	-377	-411	-394	34	127	73	135	54,482	56,641	31,768	364	22,714	35,637	302	18,845	3,869	1.12	0.005	0.10	0.00	0.10
4	14	CLS	454	474	464	-411	-431	-421	20	127	73	135	57,911	59,181	33,513	391	24,398	37,381	329	20,530	3,869	1.12	0.025	0.00	0.28	0.28
4	15	CLS	474	494	484	-431	-451	-441	20	127	73	135	60,451	61,721	34,805	411	25,646	38,673	349	21,778	3,869	1.11	0.025	0.00	0.27	0.27
4	16	CLS	494	514	504	-451	-471	-461	20	128	73	135	63,001	64,281	36,107	431	26,894	39,975	369	23,026	3,869	1.11	0.025	0.00	0.27	0.27
4	17	CLS	514	539	526.5	-471	-496	-483.5	25	128	73	135	65,881	67,481	37,583	454	28,298	41,451	392	24,430	3,869	1.10	0.025	0.00	0.32	0.32
5	18	CLS	539	542	540.5	-496	-499	-497.5	3	128	135	145	67,673	67,865	42,370	406	25,303	42,994	396	24,679	624	1.01	0.025	0.00	0.01	0.01
5	19	Sand	542	555	548.5	-499	-512	-505.5	13	128	135	145	68,697	69,529	42,895	414	25,802	43,519	404	25,178	624	1.01	0.005	0.00	0.00	0.00
5	20	Sand	555	575	565	-512	-532	-522	20	128	135	145	70,809	72,089	43,977	430	26,832	44,601	420	26,208	624	1.01	0.005	0.01	0.00	0.01
5	21	Sand	575	595	585	-532	-552	-542	20	128	135	145	73,369	74,649	45,289	450	28,080	45,913	440	27,456	624	1.01	0.005	0.01	0.00	0.01
5	22	Sand	595	615	605	-552	-572	-562	20	128	135	145	75,929	77,209	46,601	470	29,328	47,225	460	28,704	624	1.01	0.005	0.01	0.00	0.01
																							Total Settlement (in) =	0.75	2.21	2.95
																							Total Layer Thickness (feet) =	399	145	544

Date	4/5/2012	
Job No.	103.128	
Boring ID	LMPS	
Scenario	3b to 1	
Elevation	43	feet AMSL
Depth to Compressible	71	feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	34	48	0.005	0.01	0.03	0.18	0.025	0.15
2	36	51	0.005	0.01	0.03	0.18	0.025	0.15
3	58	78	0.005	0.01	0.03	0.18	0.025	0.15
4	73	135	0.005	0.01	0.03	0.18	0.025	0.15
5	135	145	0.005	0.01	0.03	0.18	0.025	0.15

Model Layer	Sub Layer	Material	Depth Top (feet)	Depth Bottom (feet)	Depth Middle (feet)	Elevation Top (feet)	Elevation Bottom (feet)	Elevation Middle (feet)	Thickness (feet)	Unit wt (pcf)	Total Head Initial (feet)	Total Head Final (feet)	Total Stress Mid point (psf)	Total Stress Bottom (psf)	Initial Stresses @ mid point Effective (psf)	Initial Pore Water (feet)	Initial Pore Water (psf)	Final Stresses @ mid point Effective (psf)	Final Pore Water (feet)	Final Pore Water (psf)	Delta Eff. Stress (psf)	$\sigma'_{vf}/\sigma'_{vi}$	Comp Index	Settlement Sand (inches)	Settlement Clay (inches)	Settlement Total (inches)
1	1	Sand	0	71	35.5	43	-28	7.5	71	123	34	48	4,367	8,733	4,367	0	0	4,367	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
2	2	Sand	71	100	85.5	-28	-57	-42.5	29	124	36	51	10,531	12,329	7,442	50	3,089	8,378	35	2,153	936	1.13	0.005	0.09	0.00	0.09
2	3	Sand	100	143	121.5	-57	-100	-78.5	43	124	36	51	14,995	17,661	9,660	86	5,335	10,596	71	4,399	936	1.10	0.005	0.10	0.00	0.10
2	4	Sand	143	193	168	-100	-150	-125	50	124	36	51	20,761	23,861	12,524	132	8,237	13,460	117	7,301	936	1.07	0.005	0.09	0.00	0.09
3	5	Sand	193	233	213	-150	-190	-170	40	125	58	78	26,361	28,861	16,689	155	9,672	17,937	135	8,424	1,248	1.07	0.005	0.08	0.00	0.08
3	6	Sand	233	283	258	-190	-240	-215	50	125	58	78	31,986	35,111	19,506	200	12,480	20,754	180	11,232	1,248	1.06	0.005	0.08	0.00	0.08
3	7	Sand	283	333	308	-240	-290	-265	50	125	58	78	38,236	41,361	22,636	250	15,600	23,884	230	14,352	1,248	1.06	0.005	0.07	0.00	0.07
3	8	Clay	333	343	338	-290	-300	-295	10	126	58	78	41,991	42,621	24,519	280	17,472	25,767	260	16,224	1,248	1.05	0.030	0.00	0.08	0.08
4	9	Clay	343	360	351.5	-300	-317	-308.5	17	126	73	135	43,692	44,763	26,314	279	17,378	30,182	217	13,510	3,869	1.15	0.030	0.00	0.36	0.36
4	10	Clay	360	375	367.5	-317	-332	-324.5	15	126	73	135	45,708	46,653	27,331	295	18,377	31,200	233	14,508	3,869	1.14	0.030	0.00	0.31	0.31
4	11	Clay	375	390	382.5	-332	-347	-339.5	15	126	73	135	47,598	48,543	28,285	310	19,313	32,154	248	15,444	3,869	1.14	0.030	0.00	0.30	0.30
4	12	Sand	390	420	405	-347	-377	-362	30	126	73	135	50,433	52,323	29,716	332	20,717	33,585	270	16,848	3,869	1.13	0.005	0.10	0.00	0.10
4	13	Sand	420	454	437	-377	-411	-394	34	127	73	135	54,482	56,641	31,768	364	22,714	35,637	302	18,845	3,869	1.12	0.005	0.10	0.00	0.10
4	14	CLS	454	474	464	-411	-431	-421	20	127	73	135	57,911	59,181	33,513	391	24,398	37,381	329	20,530	3,869	1.12	0.025	0.00	0.28	0.28
4	15	CLS	474	494	484	-431	-451	-441	20	127	73	135	60,451	61,721	34,805	411	25,646	38,673	349	21,778	3,869	1.11	0.025	0.00	0.27	0.27
4	16	CLS	494	514	504	-451	-471	-461	20	128	73	135	63,001	64,281	36,107	431	26,894	39,975	369	23,026	3,869	1.11	0.025	0.00	0.27	0.27
4	17	CLS	514	539	526.5	-471	-496	-483.5	25	128	73	135	65,881	67,481	37,583	454	28,298	41,451	392	24,430	3,869	1.10	0.025	0.00	0.32	0.32
5	18	CLS	539	542	540.5	-496	-499	-497.5	3	128	135	145	67,673	67,865	42,370	406	25,303	42,994	396	24,679	624	1.01	0.025	0.00	0.01	0.01
5	19	Sand	542	555	548.5	-499	-512	-505.5	13	128	135	145	68,697	69,529	42,895	414	25,802	43,519	404	25,178	624	1.01	0.005	0.00	0.00	0.00
5	20	Sand	555	575	565	-512	-532	-522	20	128	135	145	70,809	72,089	43,977	430	26,832	44,601	420	26,208	624	1.01	0.005	0.01	0.00	0.01
5	21	Sand	575	595	585	-532	-552	-542	20	128	135	145	73,369	74,649	45,289	450	28,080	45,913	440	27,456	624	1.01	0.005	0.01	0.00	0.01
5	22	Sand	595	615	605	-552	-572	-562	20	128	135	145	75,929	77,209	46,601	470	29,328	47,225	460	28,704	624	1.01	0.005	0.01	0.00	0.01
																							Total Settlement (in) =	0.74	2.20	2.94
																							Total Layer Thickness (feet) =	399	145	544

Date	4/5/2012
Job No.	103.128
Boring ID	LMPS
Scenario	4 to 1
Elevation	43 feet AMSL
Depth to Compressible	71 feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	34	36	0.005	0.01	0.03	0.18	0.025	0.15
2	36	39	0.005	0.01	0.03	0.18	0.025	0.15
3	58	74	0.005	0.01	0.03	0.18	0.025	0.15
4	73	134	0.005	0.01	0.03	0.18	0.025	0.15
5	135	194	0.005	0.01	0.03	0.18	0.025	0.15

Model	Sub		Depth			Elevation					Total Head		Total Stress		Initial Stresses @ mid point			Final Stresses @ mid point			Delta	$\sigma'_{vf}/\sigma'_{vi}$	Comp	Settlement		
Layer	Layer	Material	Top (feet)	Bottom (feet)	Middle (feet)	Top (feet)	Bottom (feet)	Middle (feet)	Thickness (feet)	Unit wt (pcf)	Initial (feet)	Final (feet)	Mid point (psf)	Bottom (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Eff. Stress (psf)		Index	Sand (inches)	Clay (inches)	Total (inches)
1	1	Sand	0	71	35.5	43	-28	7.5	71	123	34	36	4,367	8,733	4,367	0	0	4,367	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
2	2	Sand	71	100	85.5	-28	-57	-42.5	29	124	36	39	10,531	12,329	7,442	50	3,089	7,629	47	2,902	187	1.03	0.005	0.02	0.00	0.02
2	3	Sand	100	143	121.5	-57	-100	-78.5	43	124	36	39	14,995	17,661	9,660	86	5,335	9,847	83	5,148	187	1.02	0.005	0.02	0.00	0.02
2	4	Sand	143	193	168	-100	-150	-125	50	124	36	39	20,761	23,861	12,524	132	8,237	12,711	129	8,050	187	1.01	0.005	0.02	0.00	0.02
3	5	Sand	193	233	213	-150	-190	-170	40	125	58	74	26,361	28,861	16,689	155	9,672	17,687	139	8,674	998	1.06	0.005	0.06	0.00	0.06
3	6	Sand	233	283	258	-190	-240	-215	50	125	58	74	31,986	35,111	19,506	200	12,480	20,504	184	11,482	998	1.05	0.005	0.07	0.00	0.07
3	7	Sand	283	333	308	-240	-290	-265	50	125	58	74	38,236	41,361	22,636	250	15,600	23,634	234	14,602	998	1.04	0.005	0.06	0.00	0.06
3	8	Clay	333	343	338	-290	-300	-295	10	126	58	74	41,991	42,621	24,519	280	17,472	25,517	264	16,474	998	1.04	0.030	0.00	0.06	0.06
4	9	Clay	343	360	351.5	-300	-317	-308.5	17	126	73	134	43,692	44,763	26,314	279	17,378	30,120	218	13,572	3,806	1.14	0.030	0.00	0.36	0.36
4	10	Clay	360	375	367.5	-317	-332	-324.5	15	126	73	134	45,708	46,653	27,331	295	18,377	31,138	234	14,570	3,806	1.14	0.030	0.00	0.31	0.31
4	11	Clay	375	390	382.5	-332	-347	-339.5	15	126	73	134	47,598	48,543	28,285	310	19,313	32,092	249	15,506	3,806	1.13	0.030	0.00	0.30	0.30
4	12	Sand	390	420	405	-347	-377	-362	30	126	73	134	50,433	52,323	29,716	332	20,717	33,523	271	16,910	3,806	1.13	0.005	0.09	0.00	0.09
4	13	Sand	420	454	437	-377	-411	-394	34	127	73	134	54,482	56,641	31,768	364	22,714	35,575	303	18,907	3,806	1.12	0.005	0.10	0.00	0.10
4	14	CLS	454	474	464	-411	-431	-421	20	127	73	134	57,911	59,181	33,513	391	24,398	37,319	330	20,592	3,806	1.11	0.025	0.00	0.28	0.28
4	15	CLS	474	494	484	-431	-451	-441	20	127	73	134	60,451	61,721	34,805	411	25,646	38,611	350	21,840	3,806	1.11	0.025	0.00	0.27	0.27
4	16	CLS	494	514	504	-451	-471	-461	20	128	73	134	63,001	64,281	36,107	431	26,894	39,913	370	23,088	3,806	1.11	0.025	0.00	0.26	0.26
4	17	CLS	514	539	526.5	-471	-496	-483.5	25	128	73	134	65,881	67,481	37,583	454	28,298	41,389	393	24,492	3,806	1.10	0.025	0.00	0.31	0.31
5	18	CLS	539	542	540.5	-496	-499	-497.5	3	128	135	194	67,673	67,865	42,370	406	25,303	46,051	347	21,622	3,682	1.09	0.025	0.00	0.03	0.03
5	19	Sand	542	555	548.5	-499	-512	-505.5	13	128	135	194	68,697	69,529	42,895	414	25,802	46,576	355	22,121	3,682	1.09	0.005	0.03	0.00	0.03
5	20	Sand	555	575	565	-512	-532	-522	20	128	135	194	70,809	72,089	43,977	430	26,832	47,659	371	23,150	3,682	1.08	0.005	0.04	0.00	0.04
5	21	Sand	575	595	585	-532	-552	-542	20	128	135	194	73,369	74,649	45,289	450	28,080	48,971	391	24,398	3,682	1.08	0.005	0.04	0.00	0.04
5	22	Sand	595	615	605	-552	-572	-562	20	128	135	194	75,929	77,209	46,601	470	29,328	50,283	411	25,646	3,682	1.08	0.005	0.04	0.00	0.04
																							Total Settlement (in) =	0.59	2.18	2.77
																							Total Layer Thickness (feet) =	399	145	544

Date	5/7/2012
Job No.	103.128
Boring ID	So. Sunset Well
Scenario	3a to HL
Elevation	83 feet AMSL
Depth to Compressible	74 feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	68	90	0.005	0.01	0.03	0.18	0.025	0.15
2	69	102	0.005	0.01	0.03	0.18	0.025	0.15
3	81	111	0.005	0.01	0.03	0.18	0.025	0.15
4	91	120	0.005	0.01	0.03	0.18	0.025	0.15
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Model Layer	Sub Layer	Material	Depth Top (feet)	Depth Bottom (feet)	Depth Middle (feet)	Elevation Top (feet)	Elevation Bottom (feet)	Elevation Middle (feet)	Thickness (feet)	Unit wt (pcf)	Total Head Initial (feet)	Total Head Final (feet)	Total Stress Mid point (psf)	Total Stress Bottom (psf)	Initial Stresses @ mid point Effective (psf)	Initial Pore Water (feet)	Initial Pore Water (psf)	Final Stresses @ mid point Effective (psf)	Final Pore Water (feet)	Final Pore Water (psf)	Delta Eff. Stress (psf)	$\sigma'_{vf}/\sigma'_{vi}$	Comp Index	Settlement Sand (inches)	Settlement Clay (inches)	Settlement Total (inches)
1	1	Sand	0	42	21	83	41	62	42	123	68	90	2,583	5,166	2,583	0	0	2,583	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	2	CLS	42	57	49.5	41	26	33.5	15	124	68	90	6,096	7,026	6,096	0	0	6,096	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	3	CLS	57	74	65.5	26	9	17.5	17	124	68	90	8,080	9,134	8,080	0	0	8,080	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	4	Sand	74	100	87	9	-17	-4	26	124	68	90	10,746	12,358	9,560	19	1,186	10,746	0	0	1,186	1.12	0.005	0.08	0.00	0.08
1	5	Sand	100	150	125	-17	-67	-42	50	125	68	90	15,483	18,608	11,926	57	3,557	13,299	35	2,184	1,373	1.12	0.005	0.14	0.00	0.14
1	6	Sand	150	210	180	-67	-127	-97	60	125	68	90	22,358	26,108	15,369	112	6,989	16,742	90	5,616	1,373	1.09	0.005	0.13	0.00	0.13
1	7	Clay	210	212	211	-127	-129	-128	2	125	68	90	26,233	26,358	17,310	143	8,923	18,683	121	7,550	1,373	1.08	0.030	0.00	0.02	0.02
1	8	Sand	212	235	223.5	-129	-152	-140.5	23	126	68	90	27,807	29,256	18,104	156	9,703	19,477	134	8,330	1,373	1.08	0.005	0.04	0.00	0.04
2	9	Sand	235	265	250	-152	-182	-167	30	126	69	102	31,146	33,036	19,852	181	11,294	21,911	148	9,235	2,059	1.10	0.005	0.08	0.00	0.08
2	10	Sand	265	290	277.5	-182	-207	-194.5	25	126	69	102	34,611	36,186	21,601	209	13,010	23,660	176	10,951	2,059	1.10	0.005	0.06	0.00	0.06
2	11	CLS	290	300	295	-207	-217	-212	10	126	69	102	36,816	37,446	22,714	226	14,102	24,773	193	12,043	2,059	1.09	0.025	0.00	0.11	0.11
2	12	Sand	300	309	304.5	-217	-226	-221.5	9	126	69	102	38,013	38,580	23,318	236	14,695	25,377	203	12,636	2,059	1.09	0.005	0.02	0.00	0.02
3	13	Sand	309	320	314.5	-226	-237	-231.5	11	127	81	111	39,279	39,977	24,708	234	14,570	26,580	204	12,698	1,872	1.08	0.005	0.02	0.00	0.02
3	14	Clay	320	335	327.5	-237	-252	-244.5	15	127	81	111	40,930	41,882	25,548	247	15,382	27,420	217	13,510	1,872	1.07	0.030	0.00	0.17	0.17
3	15	Sand	335	340	337.5	-252	-257	-254.5	5	127	81	111	42,200	42,517	26,194	257	16,006	28,066	227	14,134	1,872	1.07	0.005	0.01	0.00	0.01
3	16	Clay	340	348	344	-257	-265	-261	8	127	81	111	43,025	43,533	26,614	263	16,411	28,486	233	14,539	1,872	1.07	0.030	0.00	0.09	0.09
3	17	Sand	348	362	355	-265	-279	-272	14	127	81	111	44,422	45,311	27,324	274	17,098	29,196	244	15,226	1,872	1.07	0.005	0.02	0.00	0.02
3	18	CLS	362	370	366	-279	-287	-283	8	127	81	111	45,819	46,327	28,035	285	17,784	29,907	255	15,912	1,872	1.07	0.025	0.00	0.07	0.07
3	19	Sand	370	383	376.5	-287	-300	-293.5	13	127	81	111	47,153	47,978	28,713	296	18,439	30,585	266	16,567	1,872	1.07	0.005	0.02	0.00	0.02
4	20	Clay	383	387	385	-300	-304	-302	4	127	91	120	48,232	48,486	29,886	294	18,346	31,696	265	16,536	1,810	1.06	0.030	0.00	0.04	0.04
4	21	Sand	387	417	402	-304	-334	-319	30	127	91	120	50,391	52,296	30,985	311	19,406	32,794	282	17,597	1,810	1.06	0.005	0.04	0.00	0.04
4	22	Sand	417	430	423.5	-334	-347	-340.5	13	127	91	120	53,122	53,947	32,374	333	20,748	34,183	304	18,938	1,810	1.06	0.005	0.02	0.00	0.02
4	23	CLS	430	447	438.5	-347	-364	-355.5	17	127	91	120	55,027	56,106	33,343	348	21,684	35,152	319	19,874	1,810	1.05	0.025	0.00	0.12	0.12
4	24	Clay	447	450	448.5	-364	-367	-365.5	3	127	91	120	56,297	56,487	33,989	358	22,308	35,798	329	20,498	1,810	1.05	0.030	0.00	0.02	0.02
4	25	CLS	450	476	463	-367	-393	-380	26	127	91	120	58,138	59,789	34,925	372	23,213	36,735	343	21,403	1,810	1.05	0.025	0.00	0.17	0.17
4	26	Sand	476	500	488	-393	-417	-405	24	127	91	120	61,313	62,837	36,540	397	24,773	38,350	368	22,963	1,810	1.05	0.005	0.03	0.00	0.03
4	27	Clay	500	514	507	-417	-431	-424	14	127	91	120	63,726	64,615	37,768	416	25,958	39,577	387	24,149	1,810	1.05	0.030	0.00	0.10	0.10
4	28	CLS	514	536	525	-431	-453	-442	22	127	91	120	66,012	67,409	38,930	434	27,082	40,740	405	25,272	1,810	1.05	0.025	0.00	0.13	0.13
4	29	CLS	536	570	553	-453	-487	-470	34	127	91	120	69,568	71,727	40,739	462	28,829	42,549	433	27,019	1,810	1.04	0.025	0.00	0.19	0.19
4	30	Sand	570	600	585	-487	-517	-502	30	127	91	120	73,632	75,537	42,806	494	30,826	44,616	465	29,016	1,810	1.04	0.005	0.03	0.00	0.03
																							Total Settlement (in) =	0.76	1.23	1.99
																							Total Layer Thickness (feet) =	363	163	526

Date	5/7/2012	
Job No.	103.128	
Boring ID	So. Sunset Well	
Scenario	3b to HL	
Elevation	83	feet AMSL
Depth to Compressible	74	feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	68	89	0.005	0.01	0.03	0.18	0.025	0.15
2	69	100	0.005	0.01	0.03	0.18	0.025	0.15
3	81	110	0.005	0.01	0.03	0.18	0.025	0.15
4	91	119	0.005	0.01	0.03	0.18	0.025	0.15
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Model Layer	Sub Layer	Material	Depth Top (feet)	Depth Bottom (feet)	Depth Middle (feet)	Elevation Top (feet)	Elevation Bottom (feet)	Elevation Middle (feet)	Thickness (feet)	Unit wt (pcf)	Total Head Initial (feet)	Total Head Final (feet)	Total Stress Mid point (psf)	Total Stress Bottom (psf)	Initial Stresses @ mid point Effective (psf)	Initial Pore Water (feet)	Initial Pore Water (psf)	Final Stresses @ mid point Effective (psf)	Final Pore Water (feet)	Final Pore Water (psf)	Delta Eff. Stress (psf)	$\sigma'_{vf}/\sigma'_{vi}$	Comp Index	Settlement Sand (inches)	Settlement Clay (inches)	Settlement Total (inches)
1	1	Sand	0	42	21	83	41	62	42	123	68	89	2,583	5,166	2,583	0	0	2,583	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	2	CLS	42	57	49.5	41	26	33.5	15	124	68	89	6,096	7,026	6,096	0	0	6,096	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	3	CLS	57	74	65.5	26	9	17.5	17	124	68	89	8,080	9,134	8,080	0	0	8,080	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	4	Sand	74	100	87	9	-17	-4	26	124	68	89	10,746	12,358	9,560	19	1,186	10,746	0	0	1,186	1.12	0.005	0.08	0.00	0.08
1	5	Sand	100	150	125	-17	-67	-42	50	125	68	89	15,483	18,608	11,926	57	3,557	13,237	36	2,246	1,310	1.11	0.005	0.14	0.00	0.14
1	6	Sand	150	210	180	-67	-127	-97	60	125	68	89	22,358	26,108	15,369	112	6,989	16,680	91	5,678	1,310	1.09	0.005	0.13	0.00	0.13
1	7	Clay	210	212	211	-127	-129	-128	2	125	68	89	26,233	26,358	17,310	143	8,923	18,620	122	7,613	1,310	1.08	0.030	0.00	0.02	0.02
1	8	Sand	212	235	223.5	-129	-152	-140.5	23	126	68	89	27,807	29,256	18,104	156	9,703	19,414	135	8,393	1,310	1.07	0.005	0.04	0.00	0.04
2	9	Sand	235	265	250	-152	-182	-167	30	126	69	100	31,146	33,036	19,852	181	11,294	21,786	150	9,360	1,934	1.10	0.005	0.07	0.00	0.07
2	10	Sand	265	290	277.5	-182	-207	-194.5	25	126	69	100	34,611	36,186	21,601	209	13,010	23,535	178	11,076	1,934	1.09	0.005	0.06	0.00	0.06
2	11	CLS	290	300	295	-207	-217	-212	10	126	69	100	36,816	37,446	22,714	226	14,102	24,648	195	12,168	1,934	1.09	0.025	0.00	0.11	0.11
2	12	Sand	300	309	304.5	-217	-226	-221.5	9	126	69	100	38,013	38,580	23,318	236	14,695	25,252	205	12,761	1,934	1.08	0.005	0.02	0.00	0.02
3	13	Sand	309	320	314.5	-226	-237	-231.5	11	127	81	110	39,279	39,977	24,708	234	14,570	26,518	205	12,761	1,810	1.07	0.005	0.02	0.00	0.02
3	14	Clay	320	335	327.5	-237	-252	-244.5	15	127	81	110	40,930	41,882	25,548	247	15,382	27,358	218	13,572	1,810	1.07	0.030	0.00	0.16	0.16
3	15	Sand	335	340	337.5	-252	-257	-254.5	5	127	81	110	42,200	42,517	26,194	257	16,006	28,004	228	14,196	1,810	1.07	0.005	0.01	0.00	0.01
3	16	Clay	340	348	344	-257	-265	-261	8	127	81	110	43,025	43,533	26,614	263	16,411	28,423	234	14,602	1,810	1.07	0.030	0.00	0.08	0.08
3	17	Sand	348	362	355	-265	-279	-272	14	127	81	110	44,422	45,311	27,324	274	17,098	29,134	245	15,288	1,810	1.07	0.005	0.02	0.00	0.02
3	18	CLS	362	370	366	-279	-287	-283	8	127	81	110	45,819	46,327	28,035	285	17,784	29,845	256	15,974	1,810	1.06	0.025	0.00	0.07	0.07
3	19	Sand	370	383	376.5	-287	-300	-293.5	13	127	81	110	47,153	47,978	28,713	296	18,439	30,523	267	16,630	1,810	1.06	0.005	0.02	0.00	0.02
4	20	Clay	383	387	385	-300	-304	-302	4	127	91	119	48,232	48,486	29,886	294	18,346	31,634	266	16,598	1,747	1.06	0.030	0.00	0.04	0.04
4	21	Sand	387	417	402	-304	-334	-319	30	127	91	119	50,391	52,296	30,985	311	19,406	32,732	283	17,659	1,747	1.06	0.005	0.04	0.00	0.04
4	22	Sand	417	430	423.5	-334	-347	-340.5	13	127	91	119	53,122	53,947	32,374	333	20,748	34,121	305	19,001	1,747	1.05	0.005	0.02	0.00	0.02
4	23	CLS	430	447	438.5	-347	-364	-355.5	17	127	91	119	55,027	56,106	33,343	348	21,684	35,090	320	19,937	1,747	1.05	0.025	0.00	0.11	0.11
4	24	Clay	447	450	448.5	-364	-367	-365.5	3	127	91	119	56,297	56,487	33,989	358	22,308	35,736	330	20,561	1,747	1.05	0.030	0.00	0.02	0.02
4	25	CLS	450	476	463	-367	-393	-380	26	127	91	119	58,138	59,789	34,925	372	23,213	36,672	344	21,466	1,747	1.05	0.025	0.00	0.17	0.17
4	26	Sand	476	500	488	-393	-417	-405	24	127	91	119	61,313	62,837	36,540	397	24,773	38,287	369	23,026	1,747	1.05	0.005	0.03	0.00	0.03
4	27	Clay	500	514	507	-417	-431	-424	14	127	91	119	63,726	64,615	37,768	416	25,958	39,515	388	24,211	1,747	1.05	0.030	0.00	0.10	0.10
4	28	CLS	514	536	525	-431	-453	-442	22	127	91	119	66,012	67,409	38,930	434	27,082	40,678	406	25,334	1,747	1.04	0.025	0.00	0.13	0.13
4	29	CLS	536	570	553	-453	-487	-470	34	127	91	119	69,568	71,727	40,739	462	28,829	42,486	434	27,082	1,747	1.04	0.025	0.00	0.19	0.19
4	30	Sand	570	600	585	-487	-517	-502	30	127	91	119	73,632	75,537	42,806	494	30,826	44,554	466	29,078	1,747	1.04	0.005	0.03	0.00	0.03
																							Total Settlement (in) =	0.73	1.19	1.91
																							Total Layer Thickness (feet) =	363	163	526

Date	5/7/2012
Job No.	103.128
Boring ID	So. Sunset Well
Scenario	4 to HL
Elevation	83 feet AMSL
Depth to Compressible	74 feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	68	84	0.005	0.01	0.03	0.18	0.025	0.15
2	69	95	0.005	0.01	0.03	0.18	0.025	0.15
3	81	106	0.005	0.01	0.03	0.18	0.025	0.15
4	91	117	0.005	0.01	0.03	0.18	0.025	0.15
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Model Layer	Sub Layer	Material	Depth Top (feet)	Depth Bottom (feet)	Depth Middle (feet)	Elevation Top (feet)	Elevation Bottom (feet)	Elevation Middle (feet)	Thickness (feet)	Unit wt (pcf)	Total Head Initial (feet)	Total Head Final (feet)	Total Stress Mid point (psf)	Total Stress Bottom (psf)	Initial Stresses @ mid point Effective (psf)	Initial Pore Water (feet)	Initial Pore Water (psf)	Final Stresses @ mid point Effective (psf)	Final Pore Water (feet)	Final Pore Water (psf)	Delta Eff. Stress (psf)	$\sigma'_{vf}/\sigma'_{vi}$	Comp Index	Settlement Sand (inches)	Settlement Clay (inches)	Settlement Total (inches)
1	1	Sand	0	42	21	83	41	62	42	123	68	84	2,583	5,166	2,583	0	0	2,583	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	2	CLS	42	57	49.5	41	26	33.5	15	124	68	84	6,096	7,026	6,096	0	0	6,096	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	3	CLS	57	74	65.5	26	9	17.5	17	124	68	84	8,080	9,134	8,080	0	0	8,080	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	4	Sand	74	100	87	9	-17	-4	26	124	68	84	10,746	12,358	9,560	19	1,186	10,559	3	187	998	1.10	0.005	0.07	0.00	0.07
1	5	Sand	100	150	125	-17	-67	-42	50	125	68	84	15,483	18,608	11,926	57	3,557	12,925	41	2,558	998	1.08	0.005	0.10	0.00	0.10
1	6	Sand	150	210	180	-67	-127	-97	60	125	68	84	22,358	26,108	15,369	112	6,989	16,368	96	5,990	998	1.06	0.005	0.10	0.00	0.10
1	7	Clay	210	212	211	-127	-129	-128	2	125	68	84	26,233	26,358	17,310	143	8,923	18,308	127	7,925	998	1.06	0.030	0.00	0.02	0.02
1	8	Sand	212	235	223.5	-129	-152	-140.5	23	126	68	84	27,807	29,256	18,104	156	9,703	19,102	140	8,705	998	1.06	0.005	0.03	0.00	0.03
2	9	Sand	235	265	250	-152	-182	-167	30	126	69	95	31,146	33,036	19,852	181	11,294	21,474	155	9,672	1,622	1.08	0.005	0.06	0.00	0.06
2	10	Sand	265	290	277.5	-182	-207	-194.5	25	126	69	95	34,611	36,186	21,601	209	13,010	23,223	183	11,388	1,622	1.08	0.005	0.05	0.00	0.05
2	11	CLS	290	300	295	-207	-217	-212	10	126	69	95	36,816	37,446	22,714	226	14,102	24,336	200	12,480	1,622	1.07	0.025	0.00	0.09	0.09
2	12	Sand	300	309	304.5	-217	-226	-221.5	9	126	69	95	38,013	38,580	23,318	236	14,695	24,940	210	13,073	1,622	1.07	0.005	0.02	0.00	0.02
3	13	Sand	309	320	314.5	-226	-237	-231.5	11	127	81	106	39,279	39,977	24,708	234	14,570	26,268	209	13,010	1,560	1.06	0.005	0.02	0.00	0.02
3	14	Clay	320	335	327.5	-237	-252	-244.5	15	127	81	106	40,930	41,882	25,548	247	15,382	27,108	222	13,822	1,560	1.06	0.030	0.00	0.14	0.14
3	15	Sand	335	340	337.5	-252	-257	-254.5	5	127	81	106	42,200	42,517	26,194	257	16,006	27,754	232	14,446	1,560	1.06	0.005	0.01	0.00	0.01
3	16	Clay	340	348	344	-257	-265	-261	8	127	81	106	43,025	43,533	26,614	263	16,411	28,174	238	14,851	1,560	1.06	0.030	0.00	0.07	0.07
3	17	Sand	348	362	355	-265	-279	-272	14	127	81	106	44,422	45,311	27,324	274	17,098	28,884	249	15,538	1,560	1.06	0.005	0.02	0.00	0.02
3	18	CLS	362	370	366	-279	-287	-283	8	127	81	106	45,819	46,327	28,035	285	17,784	29,595	260	16,224	1,560	1.06	0.025	0.00	0.06	0.06
3	19	Sand	370	383	376.5	-287	-300	-293.5	13	127	81	106	47,153	47,978	28,713	296	18,439	30,273	271	16,879	1,560	1.05	0.005	0.02	0.00	0.02
4	20	Clay	383	387	385	-300	-304	-302	4	127	91	117	48,232	48,486	29,886	294	18,346	31,509	268	16,723	1,622	1.05	0.030	0.00	0.03	0.03
4	21	Sand	387	417	402	-304	-334	-319	30	127	91	117	50,391	52,296	30,985	311	19,406	32,607	285	17,784	1,622	1.05	0.005	0.04	0.00	0.04
4	22	Sand	417	430	423.5	-334	-347	-340.5	13	127	91	117	53,122	53,947	32,374	333	20,748	33,996	307	19,126	1,622	1.05	0.005	0.02	0.00	0.02
4	23	CLS	430	447	438.5	-347	-364	-355.5	17	127	91	117	55,027	56,106	33,343	348	21,684	34,965	322	20,062	1,622	1.05	0.025	0.00	0.11	0.11
4	24	Clay	447	450	448.5	-364	-367	-365.5	3	127	91	117	56,297	56,487	33,989	358	22,308	35,611	332	20,686	1,622	1.05	0.030	0.00	0.02	0.02
4	25	CLS	450	476	463	-367	-393	-380	26	127	91	117	58,138	59,789	34,925	372	23,213	36,548	346	21,590	1,622	1.05	0.025	0.00	0.15	0.15
4	26	Sand	476	500	488	-393	-417	-405	24	127	91	117	61,313	62,837	36,540	397	24,773	38,163	371	23,150	1,622	1.04	0.005	0.03	0.00	0.03
4	27	Clay	500	514	507	-417	-431	-424	14	127	91	117	63,726	64,615	37,768	416	25,958	39,390	390	24,336	1,622	1.04	0.030	0.00	0.09	0.09
4	28	CLS	514	536	525	-431	-453	-442	22	127	91	117	66,012	67,409	38,930	434	27,082	40,553	408	25,459	1,622	1.04	0.025	0.00	0.12	0.12
4	29	CLS	536	570	553	-453	-487	-470	34	127	91	117	69,568	71,727	40,739	462	28,829	42,362	436	27,206	1,622	1.04	0.025	0.00	0.17	0.17
4	30	Sand	570	600	585	-487	-517	-502	30	127	91	117	73,632	75,537	42,806	494	30,826	44,429	468	29,203	1,622	1.04	0.005	0.03	0.00	0.03
																							Total Settlement (in) =	0.60	1.07	1.67
																							Total Layer Thickness (feet) =	363	163	526

Date	5/7/2012	
Job No.	103.128	
Boring ID	So. Sunset Well	
Scenario	3a to 1	
Elevation	83	feet AMSL
Depth to Compressible	74	feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	69	90	0.005	0.01	0.03	0.18	0.025	0.15
2	70	102	0.005	0.01	0.03	0.18	0.025	0.15
3	83	111	0.005	0.01	0.03	0.18	0.025	0.15
4	93	120	0.005	0.01	0.03	0.18	0.025	0.15
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Model Layer	Sub Layer	Material	Depth			Elevation			Thickness	Unit wt	Total Head		Total Stress		Initial Stresses @ mid point			Final Stresses @ mid point			Delta	$\sigma'_{vf}/\sigma'_{vi}$	Comp	Settlement		
			Top (feet)	Bottom (feet)	Middle (feet)	Top (feet)	Bottom (feet)	Middle (feet)	(feet)	(pcf)	Initial (feet)	Final (feet)	Mid point (psf)	Bottom (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Eff. Stress (psf)		Index	Sand (inches)	Clay (inches)	Total (inches)
1	1	Sand	0	42	21	83	41	62	42	123	69	90	2,583	5,166	2,583	0	0	2,583	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	2	CLS	42	57	49.5	41	26	33.5	15	124	69	90	6,096	7,026	6,096	0	0	6,096	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	3	CLS	57	74	65.5	26	9	17.5	17	124	69	90	8,080	9,134	8,080	0	0	8,080	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	4	Sand	74	100	87	9	-17	-4	26	124	69	90	10,746	12,358	9,623	18	1,123	10,746	0	0	1,123	1.12	0.005	0.07	0.00	0.07
1	5	Sand	100	150	125	-17	-67	-42	50	125	69	90	15,483	18,608	11,989	56	3,494	13,299	35	2,184	1,310	1.11	0.005	0.14	0.00	0.14
1	6	Sand	150	210	180	-67	-127	-97	60	125	69	90	22,358	26,108	15,432	111	6,926	16,742	90	5,616	1,310	1.08	0.005	0.13	0.00	0.13
1	7	Clay	210	212	211	-127	-129	-128	2	125	69	90	26,233	26,358	17,372	142	8,861	18,683	121	7,550	1,310	1.08	0.030	0.00	0.02	0.02
1	8	Sand	212	235	223.5	-129	-152	-140.5	23	126	69	90	27,807	29,256	18,166	155	9,641	19,477	134	8,330	1,310	1.07	0.005	0.04	0.00	0.04
2	9	Sand	235	265	250	-152	-182	-167	30	126	70	102	31,146	33,036	19,914	180	11,232	21,911	148	9,235	1,997	1.10	0.005	0.07	0.00	0.07
2	10	Sand	265	290	277.5	-182	-207	-194.5	25	126	70	102	34,611	36,186	21,663	208	12,948	23,660	176	10,951	1,997	1.09	0.005	0.06	0.00	0.06
2	11	CLS	290	300	295	-207	-217	-212	10	126	70	102	36,816	37,446	22,776	225	14,040	24,773	193	12,043	1,997	1.09	0.025	0.00	0.11	0.11
2	12	Sand	300	309	304.5	-217	-226	-221.5	9	126	70	102	38,013	38,580	23,380	235	14,633	25,377	203	12,636	1,997	1.09	0.005	0.02	0.00	0.02
3	13	Sand	309	320	314.5	-226	-237	-231.5	11	127	83	111	39,279	39,977	24,833	232	14,446	26,580	204	12,698	1,747	1.07	0.005	0.02	0.00	0.02
3	14	Clay	320	335	327.5	-237	-252	-244.5	15	127	83	111	40,930	41,882	25,673	245	15,257	27,420	217	13,510	1,747	1.07	0.030	0.00	0.15	0.15
3	15	Sand	335	340	337.5	-252	-257	-254.5	5	127	83	111	42,200	42,517	26,319	255	15,881	28,066	227	14,134	1,747	1.07	0.005	0.01	0.00	0.01
3	16	Clay	340	348	344	-257	-265	-261	8	127	83	111	43,025	43,533	26,739	261	16,286	28,486	233	14,539	1,747	1.07	0.030	0.00	0.08	0.08
3	17	Sand	348	362	355	-265	-279	-272	14	127	83	111	44,422	45,311	27,449	272	16,973	29,196	244	15,226	1,747	1.06	0.005	0.02	0.00	0.02
3	18	CLS	362	370	366	-279	-287	-283	8	127	83	111	45,819	46,327	28,160	283	17,659	29,907	255	15,912	1,747	1.06	0.025	0.00	0.06	0.06
3	19	Sand	370	383	376.5	-287	-300	-293.5	13	127	83	111	47,153	47,978	28,838	294	18,314	30,585	266	16,567	1,747	1.06	0.005	0.02	0.00	0.02
4	20	Clay	383	387	385	-300	-304	-302	4	127	93	120	48,232	48,486	30,011	292	18,221	31,696	265	16,536	1,685	1.06	0.030	0.00	0.03	0.03
4	21	Sand	387	417	402	-304	-334	-319	30	127	93	120	50,391	52,296	31,109	309	19,282	32,794	282	17,597	1,685	1.05	0.005	0.04	0.00	0.04
4	22	Sand	417	430	423.5	-334	-347	-340.5	13	127	93	120	53,122	53,947	32,498	331	20,623	34,183	304	18,938	1,685	1.05	0.005	0.02	0.00	0.02
4	23	CLS	430	447	438.5	-347	-364	-355.5	17	127	93	120	55,027	56,106	33,467	346	21,559	35,152	319	19,874	1,685	1.05	0.025	0.00	0.11	0.11
4	24	Clay	447	450	448.5	-364	-367	-365.5	3	127	93	120	56,297	56,487	34,113	356	22,183	35,798	329	20,498	1,685	1.05	0.030	0.00	0.02	0.02
4	25	CLS	450	476	463	-367	-393	-380	26	127	93	120	58,138	59,789	35,050	370	23,088	36,735	343	21,403	1,685	1.05	0.025	0.00	0.16	0.16
4	26	Sand	476	500	488	-393	-417	-405	24	127	93	120	61,313	62,837	36,665	395	24,648	38,350	368	22,963	1,685	1.05	0.005	0.03	0.00	0.03
4	27	Clay	500	514	507	-417	-431	-424	14	127	93	120	63,726	64,615	37,892	414	25,834	39,577	387	24,149	1,685	1.04	0.030	0.00	0.10	0.10
4	28	CLS	514	536	525	-431	-453	-442	22	127	93	120	66,012	67,409	39,055	432	26,957	40,740	405	25,272	1,685	1.04	0.025	0.00	0.12	0.12
4	29	CLS	536	570	553	-453	-487	-470	34	127	93	120	69,568	71,727	40,864	460	28,704	42,549	433	27,019	1,685	1.04	0.025	0.00	0.18	0.18
4	30	Sand	570	600	585	-487	-517	-502	30	127	93	120	73,632	75,537	42,931	492	30,701	44,616	465	29,016	1,685	1.04	0.005	0.03	0.00	0.03
																							Total Settlement (in) =	0.72	1.15	1.87
																							Total Layer Thickness (feet) =	363	163	526

Date 5/7/2012
Job No. 103.128

Boring ID So. Sunset Well
Scenario 3b to 1
Elevation 83 feet AMSL
Depth to Compressible 74 feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	69	89	0.005	0.01	0.03	0.18	0.025	0.15
2	70	100	0.005	0.01	0.03	0.18	0.025	0.15
3	83	110	0.005	0.01	0.03	0.18	0.025	0.15
4	93	119	0.005	0.01	0.03	0.18	0.025	0.15
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Model Layer	Sub Layer	Material	Depth			Elevation			Thickness	Unit wt	Total Head		Total Stress		Initial Stresses @ mid point			Final Stresses @ mid point			Delta	$\sigma'_{vf}/\sigma'_{vi}$	Comp	Settlement		
			Top (feet)	Bottom (feet)	Middle (feet)	Top (feet)	Bottom (feet)	Middle (feet)	(feet)	(pcf)	Initial (feet)	Final (feet)	Mid point (psf)	Bottom (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Effective (psf)	Pore Water (feet)	Pore Water (psf)	Eff. Stress (psf)		Index	Sand (inches)	Clay (inches)	Total (inches)
1	1	Sand	0	42	21	83	41	62	42	123	69	89	2,583	5,166	2,583	0	0	2,583	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	2	CLS	42	57	49.5	41	26	33.5	15	124	69	89	6,096	7,026	6,096	0	0	6,096	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	3	CLS	57	74	65.5	26	9	17.5	17	124	69	89	8,080	9,134	8,080	0	0	8,080	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	4	Sand	74	100	87	9	-17	-4	26	124	69	89	10,746	12,358	9,623	18	1,123	10,746	0	0	1,123	1.12	0.005	0.07	0.00	0.07
1	5	Sand	100	150	125	-17	-67	-42	50	125	69	89	15,483	18,608	11,989	56	3,494	13,237	36	2,246	1,248	1.10	0.005	0.13	0.00	0.13
1	6	Sand	150	210	180	-67	-127	-97	60	125	69	89	22,358	26,108	15,432	111	6,926	16,680	91	5,678	1,248	1.08	0.005	0.12	0.00	0.12
1	7	Clay	210	212	211	-127	-129	-128	2	125	69	89	26,233	26,358	17,372	142	8,861	18,620	122	7,613	1,248	1.07	0.030	0.00	0.02	0.02
1	8	Sand	212	235	223.5	-129	-152	-140.5	23	126	69	89	27,807	29,256	18,166	155	9,641	19,414	135	8,393	1,248	1.07	0.005	0.04	0.00	0.04
2	9	Sand	235	265	250	-152	-182	-167	30	126	70	100	31,146	33,036	19,914	180	11,232	21,786	150	9,360	1,872	1.09	0.005	0.07	0.00	0.07
2	10	Sand	265	290	277.5	-182	-207	-194.5	25	126	70	100	34,611	36,186	21,663	208	12,948	23,535	178	11,076	1,872	1.09	0.005	0.05	0.00	0.05
2	11	CLS	290	300	295	-207	-217	-212	10	126	70	100	36,816	37,446	22,776	225	14,040	24,648	195	12,168	1,872	1.08	0.025	0.00	0.10	0.10
2	12	Sand	300	309	304.5	-217	-226	-221.5	9	126	70	100	38,013	38,580	23,380	235	14,633	25,252	205	12,761	1,872	1.08	0.005	0.02	0.00	0.02
3	13	Sand	309	320	314.5	-226	-237	-231.5	11	127	83	110	39,279	39,977	24,833	232	14,446	26,518	205	12,761	1,685	1.07	0.005	0.02	0.00	0.02
3	14	Clay	320	335	327.5	-237	-252	-244.5	15	127	83	110	40,930	41,882	25,673	245	15,257	27,358	218	13,572	1,685	1.07	0.030	0.00	0.15	0.15
3	15	Sand	335	340	337.5	-252	-257	-254.5	5	127	83	110	42,200	42,517	26,319	255	15,881	28,004	228	14,196	1,685	1.06	0.005	0.01	0.00	0.01
3	16	Clay	340	348	344	-257	-265	-261	8	127	83	110	43,025	43,533	26,739	261	16,286	28,423	234	14,602	1,685	1.06	0.030	0.00	0.08	0.08
3	17	Sand	348	362	355	-265	-279	-272	14	127	83	110	44,422	45,311	27,449	272	16,973	29,134	245	15,288	1,685	1.06	0.005	0.02	0.00	0.02
3	18	CLS	362	370	366	-279	-287	-283	8	127	83	110	45,819	46,327	28,160	283	17,659	29,845	256	15,974	1,685	1.06	0.025	0.00	0.06	0.06
3	19	Sand	370	383	376.5	-287	-300	-293.5	13	127	83	110	47,153	47,978	28,838	294	18,314	30,523	267	16,630	1,685	1.06	0.005	0.02	0.00	0.02
4	20	Clay	383	387	385	-300	-304	-302	4	127	93	119	48,232	48,486	30,011	292	18,221	31,634	266	16,598	1,622	1.05	0.030	0.00	0.03	0.03
4	21	Sand	387	417	402	-304	-334	-319	30	127	93	119	50,391	52,296	31,109	309	19,282	32,732	283	17,659	1,622	1.05	0.005	0.04	0.00	0.04
4	22	Sand	417	430	423.5	-334	-347	-340.5	13	127	93	119	53,122	53,947	32,498	331	20,623	34,121	305	19,001	1,622	1.05	0.005	0.02	0.00	0.02
4	23	CLS	430	447	438.5	-347	-364	-355.5	17	127	93	119	55,027	56,106	33,467	346	21,559	35,090	320	19,937	1,622	1.05	0.025	0.00	0.10	0.10
4	24	Clay	447	450	448.5	-364	-367	-365.5	3	127	93	119	56,297	56,487	34,113	356	22,183	35,736	330	20,561	1,622	1.05	0.030	0.00	0.02	0.02
4	25	CLS	450	476	463	-367	-393	-380	26	127	93	119	58,138	59,789	35,050	370	23,088	36,672	344	21,466	1,622	1.05	0.025	0.00	0.15	0.15
4	26	Sand	476	500	488	-393	-417	-405	24	127	93	119	61,313	62,837	36,665	395	24,648	38,287	369	23,026	1,622	1.04	0.005	0.03	0.00	0.03
4	27	Clay	500	514	507	-417	-431	-424	14	127	93	119	63,726	64,615	37,892	414	25,834	39,515	388	24,211	1,622	1.04	0.030	0.00	0.09	0.09
4	28	CLS	514	536	525	-431	-453	-442	22	127	93	119	66,012	67,409	39,055	432	26,957	40,678	406	25,334	1,622	1.04	0.025	0.00	0.12	0.12
4	29	CLS	536	570	553	-453	-487	-470	34	127	93	119	69,568	71,727	40,864	460	28,704	42,486	434	27,082	1,622	1.04	0.025	0.00	0.17	0.17
4	30	Sand	570	600	585	-487	-517	-502	30	127	93	119	73,632	75,537	42,931	492	30,701	44,554	466	29,078	1,622	1.04	0.005	0.03	0.00	0.03
																							Total Settlement (in) =	0.69	1.10	1.79
																							Total Layer Thickness (feet) =	363	163	526

Date	5/7/2012
Job No.	103.128
Boring ID	So. Sunset Well
Scenario	4 to 1
Elevation	83 feet AMSL
Depth to Compressible	74 feet

Model Layer	Initial Head (feet)	Final Head (feet)	Sand Cer	Sand Cec	Clay Cer	Clay Cec	Sandy Clay Cer	Sandy Clay Cec
1	69	84	0.005	0.01	0.03	0.18	0.025	0.15
2	70	95	0.005	0.01	0.03	0.18	0.025	0.15
3	83	106	0.005	0.01	0.03	0.18	0.025	0.15
4	93	117	0.005	0.01	0.03	0.18	0.025	0.15
5	----	----	----	----	----	----	----	----

Model Layer	Sub Layer	Material	Depth Top (feet)	Depth Bottom (feet)	Depth Middle (feet)	Elevation Top (feet)	Elevation Bottom (feet)	Elevation Middle (feet)	Thickness (feet)	Unit wt (pcf)	Total Head Initial (feet)	Total Head Final (feet)	Total Stress Mid point (psf)	Total Stress Bottom (psf)	Initial Stresses @ mid point Effective (psf)	Initial Pore Water (feet)	Initial Pore Water (psf)	Final Stresses @ mid point Effective (psf)	Final Pore Water (feet)	Final Pore Water (psf)	Delta Eff. Stress (psf)	$\sigma'_{vf}/\sigma'_{vi}$	Comp Index	Settlement Sand (inches)	Settlement Clay (inches)	Settlement Total (inches)
1	1	Sand	0	42	21	83	41	62	42	123	69	84	2,583	5,166	2,583	0	0	2,583	0	0	0	1.00	0.005	Incomp.	Incomp.	0.00
1	2	CLS	42	57	49.5	41	26	33.5	15	124	69	84	6,096	7,026	6,096	0	0	6,096	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	3	CLS	57	74	65.5	26	9	17.5	17	124	69	84	8,080	9,134	8,080	0	0	8,080	0	0	0	1.00	0.025	Incomp.	Incomp.	0.00
1	4	Sand	74	100	87	9	-17	-4	26	124	69	84	10,746	12,358	9,623	18	1,123	10,559	3	187	936	1.10	0.005	0.06	0.00	0.06
1	5	Sand	100	150	125	-17	-67	-42	50	125	69	84	15,483	18,608	11,989	56	3,494	12,925	41	2,558	936	1.08	0.005	0.10	0.00	0.10
1	6	Sand	150	210	180	-67	-127	-97	60	125	69	84	22,358	26,108	15,432	111	6,926	16,368	96	5,990	936	1.06	0.005	0.09	0.00	0.09
1	7	Clay	210	212	211	-127	-129	-128	2	125	69	84	26,233	26,358	17,372	142	8,861	18,308	127	7,925	936	1.05	0.030	0.00	0.02	0.02
1	8	Sand	212	235	223.5	-129	-152	-140.5	23	126	69	84	27,807	29,256	18,166	155	9,641	19,102	140	8,705	936	1.05	0.005	0.03	0.00	0.03
2	9	Sand	235	265	250	-152	-182	-167	30	126	70	95	31,146	33,036	19,914	180	11,232	21,474	155	9,672	1,560	1.08	0.005	0.06	0.00	0.06
2	10	Sand	265	290	277.5	-182	-207	-194.5	25	126	70	95	34,611	36,186	21,663	208	12,948	23,223	183	11,388	1,560	1.07	0.005	0.05	0.00	0.05
2	11	CLS	290	300	295	-207	-217	-212	10	126	70	95	36,816	37,446	22,776	225	14,040	24,336	200	12,480	1,560	1.07	0.025	0.00	0.09	0.09
2	12	Sand	300	309	304.5	-217	-226	-221.5	9	126	70	95	38,013	38,580	23,380	235	14,633	24,940	210	13,073	1,560	1.07	0.005	0.02	0.00	0.02
3	13	Sand	309	320	314.5	-226	-237	-231.5	11	127	83	106	39,279	39,977	24,833	232	14,446	26,268	209	13,010	1,435	1.06	0.005	0.02	0.00	0.02
3	14	Clay	320	335	327.5	-237	-252	-244.5	15	127	83	106	40,930	41,882	25,673	245	15,257	27,108	222	13,822	1,435	1.06	0.030	0.00	0.13	0.13
3	15	Sand	335	340	337.5	-252	-257	-254.5	5	127	83	106	42,200	42,517	26,319	255	15,881	27,754	232	14,446	1,435	1.05	0.005	0.01	0.00	0.01
3	16	Clay	340	348	344	-257	-265	-261	8	127	83	106	43,025	43,533	26,739	261	16,286	28,174	238	14,851	1,435	1.05	0.030	0.00	0.07	0.07
3	17	Sand	348	362	355	-265	-279	-272	14	127	83	106	44,422	45,311	27,449	272	16,973	28,884	249	15,538	1,435	1.05	0.005	0.02	0.00	0.02
3	18	CLS	362	370	366	-279	-287	-283	8	127	83	106	45,819	46,327	28,160	283	17,659	29,595	260	16,224	1,435	1.05	0.025	0.00	0.05	0.05
3	19	Sand	370	383	376.5	-287	-300	-293.5	13	127	83	106	47,153	47,978	28,838	294	18,314	30,273	271	16,879	1,435	1.05	0.005	0.02	0.00	0.02
4	20	Clay	383	387	385	-300	-304	-302	4	127	93	117	48,232	48,486	30,011	292	18,221	31,509	268	16,723	1,498	1.05	0.030	0.00	0.03	0.03
4	21	Sand	387	417	402	-304	-334	-319	30	127	93	117	50,391	52,296	31,109	309	19,282	32,607	285	17,784	1,498	1.05	0.005	0.04	0.00	0.04
4	22	Sand	417	430	423.5	-334	-347	-340.5	13	127	93	117	53,122	53,947	32,498	331	20,623	33,996	307	19,126	1,498	1.05	0.005	0.02	0.00	0.02
4	23	CLS	430	447	438.5	-347	-364	-355.5	17	127	93	117	55,027	56,106	33,467	346	21,559	34,965	322	20,062	1,498	1.04	0.025	0.00	0.10	0.10
4	24	Clay	447	450	448.5	-364	-367	-365.5	3	127	93	117	56,297	56,487	34,113	356	22,183	35,611	332	20,686	1,498	1.04	0.030	0.00	0.02	0.02
4	25	CLS	450	476	463	-367	-393	-380	26	127	93	117	58,138	59,789	35,050	370	23,088	36,548	346	21,590	1,498	1.04	0.025	0.00	0.14	0.14
4	26	Sand	476	500	488	-393	-417	-405	24	127	93	117	61,313	62,837	36,665	395	24,648	38,163	371	23,150	1,498	1.04	0.005	0.03	0.00	0.03
4	27	Clay	500	514	507	-417	-431	-424	14	127	93	117	63,726	64,615	37,892	414	25,834	39,390	390	24,336	1,498	1.04	0.030	0.00	0.08	0.08
4	28	CLS	514	536	525	-431	-453	-442	22	127	93	117	66,012	67,409	39,055	432	26,957	40,553	408	25,459	1,498	1.04	0.025	0.00	0.11	0.11
4	29	CLS	536	570	553	-453	-487	-470	34	127	93	117	69,568	71,727	40,864	460	28,704	42,362	436	27,206	1,498	1.04	0.025	0.00	0.16	0.16
4	30	Sand	570	600	585	-487	-517	-502	30	127	93	117	73,632	75,537	42,931	492	30,701	44,429	468	29,203	1,498	1.03	0.005	0.03	0.00	0.03

	Sand	Clay	Total
Total Settlement (in) =	0.56	0.99	1.55
Total Layer Thickness (feet) =	363	163	526

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Technical Memorandum 10.6

Assessment of Groundwater Quality

for the Regional Groundwater Storage and Recovery Project

3 May 2012

Prepared for

San Francisco Public Utilities Commission
525 Golden Gate Avenue, 10th Floor
San Francisco, CA 94102

K/J Project No. 0864001

Supplemental Explanation for Hydrographs - TM10.6

This supplemental explanation is prepared to address discrepancies on several graphs presented in TM 10.6.

First, the x-axis on several graphs showing model results was shifted. The x-axis is named Scenario Year which should correspond to a water year[1]. However, the graph template was plotted using a calendar year, so the intervals on the x-axis represent the period from January to December. The result is that the graph is shifted 3-months later relative to Scenario Year.

Second, the shaded area representing the Design Drought was added manually and because of this process, it was not presented consistently on the graphs. By definition per the PEIR, the 8.5-year Design Drought includes one Hold year before the 7.5-year Take period. In addition, the Design Drought needs to be shifted 3-months later for the x-axis issue to be consistent with the model output. The Design Drought should be shown as Scenario Years 35.5 to 44.0 on the shifted x-axis.

The following is a list of figures in TM 10.6 where the Design Drought shaded area is shown slightly different and does not match the correct display of the Design Drought. The figures should be viewed based on the correct representation of the Design Drought as explained above.

- Figure 10.6-6 has the shifted x-axis. The Design Drought should be shown as Scenario Years 35.5 to 44.0 on the shifted x-axis.
- Attachment 10.6-A graphs with model simulated groundwater levels have the shifted x-axis. The Design Drought should be shown as Scenario Years 35.5 to 44.0 on the shifted x-axis.

[1] A water year is October 1 of the previous year to September 30 of the current (named) year.

3 May 2012

Task 10.6 Technical Memorandum

San Francisco Public Utilities Commission

Assessment of Groundwater Quality for the Regional Groundwater Storage and Recovery Project

Prepared For: Greg Bartow, SFPUC

Prepared by: Sevim Onsoy, Les Chau, and Michael Maley, Kennedy/Jenks Consultants

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1. Introduction

This Technical Memorandum (TM) was prepared to document work performed by Kennedy/Jenks Consultants (Kennedy/Jenks) pursuant to Task Order (TO) CUW30103-TO-1.14 authorized by the San Francisco Public Utilities Commission (SFPUC) under the Proposed Regional Groundwater Storage and Recovery (GSR) Project. This investigation is performed under the amended TO Pre-Design Investigation Task 10.6 Follow-up Engineering and Hydrogeological Support of the Environmental Phase. This project is funded by the SFPUC's Water System Improvement Program (WSIP).

1.1. Objective

Implementation of the GSR Project will influence groundwater levels within portions of the Westside Groundwater Basin (Westside Basin or Basin). Depending on the magnitude of the potential changes to groundwater levels, groundwater quality conditions may be influenced during the GSR Project operations. Evaluation of the potential groundwater quality effects is a management issue for the long-term sustainability of the groundwater resources in the Westside Basin. The GSR Project has installed numerous monitoring wells to collect data since 2009 for baseline conditions prerequisite of the construction of the proposed production wells. Groundwater samples are being tested for complete Title 22 parameters to ensure highest drinking water quality and results have shown no impact from any man-made activities (e.g., commercial or industrial processes).

This TM was prepared specifically to support the Environmental Impact Report (EIR) that is being prepared for the GSR Project. Associated with the EIR are several significance criteria related to groundwater and surface water conditions within the southern Westside Basin (referred to as South Westside Basin). The specific criterion to be considered by this TM for the assessment of water quality for the GSR Project is stated as follows:

> The GSR Project could potentially and "substantially" affect existing water quality conditions in the South Westside Basin.

> The GSR Project "effect" in the context of this analysis is defined as "mobilization of contaminants in groundwater as a result of pumping or increase in groundwater levels in the South Westside Basin."

Discussion of groundwater quality in this TM includes the evaluation of contaminants that are (1) currently in the groundwater flow system and are pre-existing to the GSR Project and (2) currently in soils that may be mobilized into groundwater from changes to groundwater levels and flow directions caused by the GSR Project operations. A 70 feet below ground surface (bgs) threshold depth was determined for this water quality assessment by canvassing the reported depths of contaminants in lists of active regulated sites from several state and local data sources (Section 5.1). The reported depths of contaminants were shallower than 50 feet bgs in nearly all the active and inactive regulated sites. An additional 20 feet was added as conservative buffer depth. The 70 feet bgs threshold depth can be compared to the model simulated depths to groundwater represented in the groundwater model as the uppermost layer (defined as Model Layer 1). In this water quality assessment, the groundwater model simulated depth to water was used to identify areas that might be within the 70-foot depth threshold from the ground surface and therefore might be most susceptible to groundwater quality effects (see Sections 4.3.3 and 5.2.1). More specifically, if groundwater levels rise to 70 feet bgs or shallower, then there is a potential for mobilization of existing contamination in the soil and/or shallow groundwater systems.

The overall purpose of this TM is to evaluate the potential groundwater quality issues that might result from the future operation of the GSR Project. These issues include the possible mobilization of contaminants or changes in shallow aquifer conditions due to increases in groundwater levels and storage in the South Westside Basin as a result of the GSR Project.

The specific objectives of this TM are as follows:

- To provide background information on the past and current physical setting of the GSR Project area with respect to groundwater flow and quality;
- To describe the controlling mechanisms for groundwater levels and flow conditions that could cause substantial degradation of water quality in the GSR Project area;
- To discuss groundwater flow model scenario results involving the GSR Project and the potential for water levels to rise to within 70 feet of the ground surface;
- To discuss the monitoring network currently in place with regard to the monitoring of groundwater quality; and
- To document the results of other analyses performed to assess the potential GSR Project effects on groundwater quality.

Assessment of groundwater quality effects from the GSR Project is limited to the geographic area of the GSR Project in the South Westside Basin (Figure 10.6-1) and the assessment therefore does not include any possible groundwater quality issues associated with the proposed San Francisco Groundwater Supply (SFGW) Project. Seawater intrusion is also excluded from this TM but is discussed in detail in a separate TM[1].

1.2. General Approach

The general approach used for evaluating the potential effects on groundwater quality resulting from the GSR Project operations is based on a multi-pronged approach that consists of the following three methods:

- Conceptual understanding
- Groundwater flow model analysis
- Empirical analysis

Each of these three methods was developed and performed to provide an inspection-level (i.e., qualitative) analysis for identifying areas of potential concern with respect to changes in groundwater levels and quality caused by the GSR Project. Individually, each method addresses specific issues using relevant data associated with that specific issue. The three methods collectively support each other for the basin-wide (regional) assessment of potential project effects on groundwater quality conditions.

A detailed discussion of the three methods is presented in Section 2 (for the conceptual understanding), Section 4 (for the groundwater flow modeling analysis), and Section 5 (for the empirical analysis supported by the groundwater setting in Section 3).

This TM is part of a series of technical memoranda that address various aspects of the GSR Project. Two technical memoranda with relevant data and analyses that are used in this TM include:

- Task 8B Technical Memorandum No.1 - Hydrologic Setting of the Westside Basin (also referred to as TM#1) (LSCE, 2010); and
- Task 10.1 Technical Memorandum - Groundwater Modeling Analysis for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project (also referred to as TM 10.1) (Kennedy/Jenks, 2012b).

1.3. GSR Project Overview

The GSR Project is a conjunctive use project that would allow for increased groundwater supplies in the South Westside Basin during periods of drought when SFPUC surface water supplies become limited (MWH, 2008). The GSR Project is sponsored by SFPUC in coordination with its Partner Agencies (PAs): the California Water Service Company (Cal

[1] Kennedy/Jenks, 2012c, Task 10.3 Technical Memorandum - Assessment of Potential Seawater Intrusion for the Regional Groundwater Storage and Recovery Project and the San Francisco Groundwater Supply Project, prepared for the San Francisco Public Utilities Commissions, April 2012.

Water), the City of Daly City (Daly City), and the City of San Bruno (San Bruno). Figure 10.6-2 shows the GSR Project area, locations of the PA wells, and the proposed GSR Project wells. The GSR project will be designed to provide up to 60,500 acre-feet (af) of stored water to meet SFPUC system demands during the last 7.5 years of SFPUC's Design Drought. The GSR Project plans to install 16 new production wells to pump stored groundwater during a drought.

Under the Draft GSR Operating Agreement, the SFPUC would "store" water in the South Westside Basin through the mechanism of in-lieu recharge by providing surface water as a substitute for groundwater pumping by the PAs. As a result of the in-lieu deliveries, up to 60,500 af of groundwater storage or "put" credits could accrue to the SFPUC Storage Account (SFPUC, 2007). During shortages of SFPUC system water due to drought, emergencies or scheduled maintenance, or if the SFPUC Storage Account is at its full capacity of 60,500 af, the PAs would return to pumping from their existing wells. In addition, the SFPUC and the PAs would extract groundwater from the SFPUC Storage Account using the new wells installed by the SFPUC. The SFPUC will not direct pumping during these "take" periods unless a positive balance exists in the SFPUC Storage Account and there is a drought.

The GSR Project modeling scenario (Scenario 2) and cumulative modeling scenario (Scenario 4, which includes the GSR Project) both require a "put/take/hold" sequence to simulate in-lieu groundwater recharge during wet years and groundwater extraction during dry years. Figure 10.6-3 illustrates conceptualization of changing water levels during put and take periods of the GSR Project operations. The upper graph represents the filling of the storage space with groundwater through the mechanism of in-lieu recharge during put periods where SFPUC would provide surface water as a substitute for groundwater pumping by the PAs. The lower graph represents the decline in storage during take periods where the SFPUC and the PAs would extract groundwater from the SFPUC Storage Account. This conceptualization of the GSR Project is illustrated in the context of water quality assessment and depicts the 70 feet bgs threshold depth that can be compared to the simulated depths to groundwater represented in the groundwater model uppermost layer (i.e., Model Layer 1).

The model assumptions for the GSR Project and the Cumulative Scenario are presented in TM 10.1 (Kennedy/Jenks, 2012b). Table 10.6-1 presents a summary of the model scenario pumping assumptions for five model scenarios, including the assumptions for the existing irrigation pumping. In the context of this TM, only Scenarios 1, 2, and 4 are evaluated. A detailed explanation of the model scenario pumping assumptions and the proposed put/take/hold sequence is presented in TM 10.1 (Kennedy/Jenks, 2012b).

2. Conceptual Understanding

The conceptual understanding provides the basic framework for delineating the potential mechanisms that are anticipated to affect groundwater quality as a result of possible changes in groundwater levels and flow directions during the GSR Project operations. This section also presents an overview of monitoring procedures undertaken to manage the possible GSR Project effects. Also included in this section are general descriptions of the major aquifers in the Westside Basin and the hydrogeologic processes and mechanisms that control the occurrence of groundwater flow and water quality conditions.

2.1. Aquifers in the Westside Basin

Groundwater development in the Westside Basin has occurred in various aquifer units in the Colma and Merced Formations from the Golden Gate Park area, through Daly City and South San Francisco, to San Bruno. The Merced Formation contains the primary water-producing aquifer in the Basin (LSCE, 2006). Within the two major water bearing zones in the Westside Basin, there are multiple smaller aquifer zones that are delineated vertically by different sand and clay layers within the Merced and Colma formations. The thickness and extent of these interbedded sand and clay layers vary spatially throughout the Westside Basin.

The aquifer units in the Westside Basin are informally designated as the Shallow Aquifer, the Primary Production Aquifer, and the Deep Aquifer. The Shallow Aquifer is in the northern part of the Basin, in the vicinity of Lake Merced and the southern portion of the Sunset-Richmond district of San Francisco. In the North Westside Basin, aquifer units are separated by two distinctive fine-grained units, known as the -100-foot clay and the W-clay (LSCE, 2004). The base of the Shallow Aquifer is defined to be the top of the “-100 foot clay”. The Primary Production Aquifer is present throughout the Basin, overlying the “W-clay” where it is present. Where the “W-clay” is not present in locations to the south, in the South San Francisco area, the Primary Production Aquifer is divided into shallow and deep units separated by a clay unit at approximately -300 feet mean sea level (msl). The Primary Production Aquifer in the San Bruno area is located 200 feet bgs, and it underlies a thick, surficial fine-grained unit comprised predominantly of clay and sandy clay (LSCE, 2006). The Deep Aquifer underlies the “W-clay”, and thus its extent is limited to the generally-known extent of that clay unit (LSCE, 2010).

Based on the recent water level measurements in November 2008 and January 2009 from the GSR Project monitoring wells located in Colma and South San Francisco areas (MW-CUP-19-180 in Colma and MW-CUP-22A-140 in South San Francisco), the upper portion of the Primary Production Aquifer at these locations is currently under dewatered conditions (Kennedy/Jenks, 2010). However, as discussed in Section 2.3.1, the GSR Project proposes to extract water from the deeper portion of the Primary Production Aquifer (at depths 300 feet or more below the land surface).

2.2. Potential Mechanisms Affecting Groundwater Quality Conditions

Pre-existing contamination at some existing regulated sites may have the potential to generate groundwater contaminant plumes, and ongoing activities at those sites may have the potential to further contaminate the subsurface. In the context of the operation of the GSR Project, there may potentially be the changes to water quality listed below.

For purpose of discussions throughout this TM, the phrase “water table” in these analyses generally refers to the upper surface of groundwater or the top of the saturated zone and the phrase “piezometric surface” generally denotes hydraulic heads in the deeper, confined production aquifer.

- During put periods of the GSR Project operations, groundwater levels will rise in the Primary Production Aquifer. It is possible that the water table may also rise in the unconfined Shallow Aquifer during these periods. Such water table rises could potentially mobilize contaminants trapped in the unsaturated zone, which could cause the movement and spreading of possible pre-existing contaminant plumes or exacerbate future contaminant releases.

- During extended GSR Project recovery or take periods, changes in groundwater flow directions are anticipated to occur in the Primary Production Aquifer. If the response to deeper pumping propagates to the unconfined Shallow Aquifer, this may result in changes to flow directions in the Shallow Aquifer. In turn, this could have an effect on existing groundwater remediation projects. Conceptually, pump-and-treat systems in existing remediation sites could be less effective because lowered water levels and changes in flow directions, resulting in decreased flow/mass removal and reduced groundwater plume capture, prolonging time of cleanup, and in the extreme case, causing them to go dry.

2.3. Potential Areas of Concern during GSR Project Operations

The following is a description of potential areas of concern in the context of the groundwater setting.

2.3.1. Pumping Areas

Areas containing the PA municipal wells, GSR Project wells, and other existing irrigation wells are primary areas of concerns for the groundwater quality assessment described herein. Figure 10.6-3 shows the GSR Project area, locations of the PA wells and the proposed GSR Project wells. The groundwater model scenarios analyzed in this TM account for the existing irrigation pumping, as shown in Table 10.6-1.

During put periods, the effect of rising groundwater levels and possible induced changes in flow directions in the Primary Production Aquifer would likely occur in the vicinity of the PA wells. This is because of reduced PA pumping with the associated increased use of surface water.

During take periods, both the PA and the SFPUC GSR Project wells would extract water. Thus, declining groundwater levels and induced changes in flow directions can occur around both the PA wells and the GSR Project wells.

It is important to note that the GSR Project would extract water from the Primary Production Aquifer, which is approximately 300 feet or more below the land surface. Therefore, changes in the Basin from in-lieu recharge during put periods and from pumping during take periods are likely and primarily to affect the Primary Production Aquifer.

Given the proposed well screen intervals, the GSR Project wells would extract water from 340 feet to 700 feet bgs, except for CUP-M-1 where the proposed screen is from 240 feet to 410 feet bgs. Cal Water production wells as part of the PA wells have screens from 370 feet to 580 feet bgs; San Bruno production wells have screens from 260 feet to 600 feet bgs; and Daly City production wells have screens from 260 feet to 825 feet bgs.

2.3.2. Mechanisms of Transport

Potential effects of the GSR Project on existing subsurface contamination, other anthropogenic effects, and existing remedial systems (e.g., pump-and-treat) depend greatly on the degree of *physical separation* between the occurrences of perched water bearing zones, unconfined Shallow Aquifer, and the deeper pumping zone in the Primary Production Aquifer. The two mechanisms of transport are explained below. The nature of perched groundwater is further explained in Section 2.6.2.

First, aquifer materials between perched water bearing zones and shallow groundwater can be comprised of thin and discontinuous fine-grain impermeable to low permeable materials. Aquifer materials between the shallow unconfined and deeper production aquifers can be comprised of (1) thick aquifer materials of interstitial clay in sedimentary sands and (2) thick sequences of intervening clay lenses that are considered to be aquitards (i.e., confining units) in some portions of the South Westside Basin. The effect of this hydrostratigraphic arrangement of aquifers and aquitards is that shallow groundwater is shielded from the pumping effects in the deeper production aquifers by thick sequences of fine grained materials at varying depths, which minimizes the movement of downward groundwater flow in the shallow groundwater (including perched water bearing zones) during take periods and dampens the effects of rising water levels during put periods.

Second, and less specific to the GSR Project, the interstitial clays and contiguous confining units between the shallow and deep groundwater zones could retard the transport of highly mobile as well as less-mobile contaminants. Specifically, travel time between the shallow and deep groundwater zones is very long. Furthermore, natural attenuation of dissolved constituents generally occurs due to dispersion and dilution. Hence, the effect of the clay-rich materials is equivalent to a physical barrier that isolates shallow contaminant point sources from the GSR Project effects that occur in the deeper production aquifers. This mechanism is only relevant during take periods, when the drawdown due to the GSR Project wells may induce increased downward gradients and changes in local horizontal gradients and flow directions that might have otherwise resulted in migration of contaminants in shallow groundwater. This secondary mechanism may limit the impact of the cause (i.e., deep aquifer pumping) and effect of reactivating shallow groundwater contamination sources.

In addition to water quality issues in shallow groundwater, the primary nonpoint source constituent of interest is isolated pre-existing nitrate occurrence in the Shallow Aquifer and the upper portion of the Primary Production Aquifer, as described in Section 3.2.2.

2.4. Potential Effects on Groundwater Quality

This section briefly describes the most common issues that are encountered with respect to groundwater quality as a result of variable pumping conditions. The intent of this section is to conceptually introduce the most common issues in broad terms, not with respect to the specific GSR Project operations. Water quality issues that could result from the GSR Project operations are further discussed and evaluated in Sections 4 and 5.

In general, the magnitude of effects would vary depending on pumping implementation (pumping amount, location, frequency, duration, and pumping depth) and the hydrogeologic setting. In many instances, depending on the magnitude of resulting changes in groundwater levels and flow directions, existing and planned beneficial uses of groundwater (for drinking water and/or agricultural use) could be affected. For example, in areas with a shallow water table, the most common effects from reduced pumping (or in the context of this analysis “in-lieu” recharge during put periods of the GSR Project operations) may include a rise in the water table or fluctuations that could potentially reactivate contaminants residing in the unsaturated zone and perched water bearing zones or result in remobilization and potential movement and spread of possible contaminating plumes and activities. This situation is of particular interest in areas with existing active regulated sites with possible contaminant plumes and release activities and in areas where pesticides and fertilizers have been applied on the ground.

In the case of increased pumping (or in the context of this analysis pumping during take periods of the GSR Project operations), conceptually lowered water levels are anticipated within cones of drawdown in the vicinities of the pumping areas (i.e., GSR Project and the PA municipal pumping wells). It is noted that conceptually pump-and-treat systems in areas with a shallow water table could be less effective because lowered water levels would result in decreased yields in remediation wells and, in the extreme case, could cause them to go dry, decreased flow/mass removal, and prolonging time of cleanup. Conversely, pump-and-treat systems could be less effective because of reduced groundwater plume capture as a remediation well’s capture zone is narrowed due to higher groundwater levels and flow.

2.5. Typical Monitoring Procedures

Routine monitoring of groundwater levels and quality at a network of groundwater monitoring wells is essential for planning and implementing strategies to reduce the risk of groundwater quality effects caused by variable pumping conditions. Analysis of data collected from routine monitoring can help investigators to understand the response of the groundwater basin to variable pumping conditions and to identify short-term or long-term potential effects from reduced or increased pumping. Monitoring data can help identify where and when groundwater quality issues may arise. Therefore, it is helpful to implement adequate contingency plans and to streamline decision-making in response to crisis situations.

Depth-discrete multilevel monitoring systems are particularly important to characterize hydraulic head and water quality variations with depth. Groundwater elevation data from multi-level completion wells and aquifer pumping tests can provide evidence for the extent of the hydraulic connection among various aquifer depths. Analysis of measured data can help identify the relative direction of vertical flow between different aquifer units under reduced and increased pumping conditions. Data can be used to assess the horizontal zones of influence of pumping and the vertical effect of deep aquifer pumping on the water table.

Environmental isotopes, such as tritium, deuterium, and oxygen-18, have proven useful in various types of hydrogeologic settings to (1) track the movement of water between different groundwater systems, (2) estimate travel times, (3) determine potential contamination processes, and (4) estimate aquifer vulnerability to groundwater contamination. Groundwater systems that are not in communication with each other often have distinctly different geochemical signatures. On the other hand, groundwater systems that are in hydraulic connection have similar chemical signatures or show a mixing trend. Similar geochemical signatures of groundwater can help characterize the extent of penetration of the same origin water into various groundwater zones.

2.6. Physical Processes Affecting Groundwater Quality

For the purpose of this analysis, potential groundwater quality effects from the GSR Project operations were evaluated conceptually and qualitatively with respect to general hydrogeological conditions and physical processes that can control groundwater flow and quality. The general hydrogeological conditions listed below, and described briefly in the following subsections, may influence the GSR Project's effects on water quality.

- Recharge mechanisms and shallow groundwater contaminants;
- Vadose zone, perched groundwater, and aquifer hydraulic connections; and
- Aquifer types and hydrologic conditions;
- Aquifer hydraulic connections; and
- The occurrence and nature of subsurface contaminants.

2.6.1. Recharge Mechanisms and Shallow Groundwater Contaminants

Groundwater recharge is considered one of the most important factors influencing groundwater vulnerability to contaminating activities on the ground or shallow subsurface because recharge is the primary vehicle by which a contaminant is transported from the ground surface to groundwater. In general, groundwater recharge to an unconfined aquifer is a result of deep percolation into groundwater derived from precipitation and runoff. Recharge to a confined aquifer is complex and dependent on the proximity of the aquifer to the recharge zone, adjacent groundwater zones, confining layers, vertical gradients, and groundwater pumping effects.

From the GSR Project perspective, the predominant inflow component for the Westside Basin (and the South Westside Basin) is from percolating rain and irrigation water, which are the primary recharge mechanisms. Much of the GSR Project area supports commercial and residential land uses and hence surfaces are paved. Direct recharge of precipitation to the ground surface and the shallow unconfined aquifer can be a secondary contributor to the groundwater in the aquifers in developed areas; hence, primary recharging ground waters beneath the GSR Project area flow horizontally from aquifer zones peripheral to the GSR Project area. Due to frequently occurring fine-grained materials separating the upper Shallow Aquifer system from the Primary Production Aquifer (Section 2.3), contaminants in shallow groundwater zones are not likely to affect water quality in the Primary Production and Deep Aquifers. Based on the historical data, there is no evidence for the occurrence of shallow contaminants (i.e., volatile organic compounds, or VOCs) in the drinking water supply aquifers (Primary Production and the Deep Aquifers). If the migration of VOCs were to occur in the future, under natural recharge conditions, it would require a very long time (on the order of decades) for shallow contaminants to migrate if at all down to the Primary Production and the Deep Aquifer at very low concentrations given sufficient time for natural attenuation.

As mentioned above, the GSR Project involves the storage of groundwater through in-lieu recharge into the semi-confined and confined aquifers at depths greater than 300 feet bgs (Section 2.3), which could indirectly lead to higher water levels in the Shallow Aquifer. During put periods, water levels in the Primary Production Aquifer (under confined to semi-confined conditions) would be expected to experience larger fluctuations than would those in the shallow unconfined aquifers. Since groundwater would be recovered from the same Primary Production Aquifer during dry years (take periods), the deeper aquifer system would readily experience declining water levels as a result of pumping by the PA municipal wells and SFPUC GSR Project wells, and the Shallow Aquifer would likely experience negligible water level changes due to their unconfined condition (as suggested by the model results for Model Layer 1 in Section 4). Moreover, the underlying fine grained aquifer materials would minimize the effects of in-lieu recharge on shallow water levels.

2.6.2. Vadose Zone and Perched Groundwater

The lithology of the unsaturated zone and the presence of perched water bearing zones under the land surface are important with respect to groundwater vulnerability to shallow releases of contaminants and plumes. The thickness and soil types in the vadose zone control the degree to which a contaminant can be attenuated prior to reaching groundwater. In general, subsurface media comprised of fine-grained materials (silts, clays) would create lower susceptibility to groundwater contamination while coarse-grained materials (sands and gravels) would create higher susceptibility. The type of soil media in the vadose zone (e.g., clay versus sand) affects the rate at which a contaminant can travel within the vadose zone and from the surface, where most contaminants reside, to groundwater.

The presence of perched groundwater can also control the movement of constituents released into the vadose zone and their continued downward path of migration into groundwater aquifer. By definition, a perched water bearing zone is an unconfined groundwater body supported or underlain by impermeable or slowly permeable materials. The existence of a low-permeability clay layer in a high-permeability sand formation can lead to the formation of a discontinuous saturated lense, with unsaturated conditions existing both above and below (Freeze and Cherry, 1979). The majority of the contaminant release activities canvassed in this evaluation have constituents detected in groundwater in the perched water bearing zones. The depths to perched water bearing zones are on the order of 30 feet to 50 feet bgs beneath which groundwater can be classified as the Shallow Aquifer. The perched water bearing zones and the Shallow Aquifer are separated by low permeability fine-grained materials.

2.6.3. Aquifer Types and Hydrologic Conditions

Aquifer types and conditions play a significant role controlling groundwater occurrence and the effects on the subsurface from potential contaminating activities. It is necessary to understand conceptually the circumstances under which the GSR Project operations would lead to rising or declining water levels and changing groundwater flow directions in the Shallow Aquifer, and how these changes could affect contamination in the unsaturated zone and the Shallow Aquifer.

By definition, unconfined aquifers are directly beneath the unsaturated zone and the water table forms the upper boundary of unconfined aquifers (Freeze and Cherry, 1979). The mechanism that causes rising water levels in unconfined aquifers is the filling of soil porosity with water. In an unconfined aquifer, water released from storage during pumping is derived from the dewatering of these pore spaces. Pumping from an unconfined aquifer lowers the water table (i.e., the hydraulic head) around the wells and produces a water table in the shape of a downward-pointing, curved cone, called the cone of depression or drawdown cone. Drawdown locally alters the general groundwater flow rate and direction, and a contaminant plume in the vicinity of the pumping well can be drawn towards the well. These physical factors make the unconfined aquifer more vulnerable to human activities on the land surface, as water levels in the unconfined aquifer may experience localized fluctuations over a short period of time due to rapid changes in recharge and pumping. Thus, direct recharge to the water table, such as percolating rain during storm events or irrigation, would tend to have direct influence on contaminant plumes.

In confined and semi-confined aquifers, on the other hand, the mechanism of rising groundwater levels during in-lieu recharge (put periods) is different than in the unconfined aquifer. Pressure in the production zone would rebound toward pre-pumping conditions in response to reduced pumping, contrasting with a physical rise in the water table surface in unconfined aquifers. Confined aquifers, by definition, remain saturated during pumping. A volume of water removed from the confined aquifer by a well is released in response to a water-pressure drop that causes aquifer compaction and pore-water expansion, not a dewatering of pore spaces as in the unconfined aquifer.

The aquifer units in the Westside Basin are informally designated as the Shallow Aquifer, the Primary Production Aquifer, and the Deep Aquifer, as described in Section 2.1. In the GSR Project area, both the GSR Project wells and the PA wells would pump from the Merced Formation under confined/semi-confined conditions. Currently, groundwater elevations in the Primary Production Aquifer in the South Westside Basin are substantially lower than water levels in the overlying Shallow Aquifer Colma Formation, suggesting a general downward vertical gradient. The downward gradient is of general interest, as constituents in the upper zone could migrate into the lower production zone. The multilevel monitoring well clusters in the GSR Project area can be used to observe inter-aquifer changes in water quality conditions. However, in regard to the GSR Project, the lack of a downward vertical gradient is also of interest because that could increase the likelihood of a rise in water levels during in-lieu recharge or put periods.

Even though in-lieu recharge is anticipated to increase water levels (pressure heads) in the Primary Production Aquifer, the likelihood of the apparent downward gradient reversing upwards due to the GSR Project operations is uncertain given the anticipated future municipal pumping in the production zone. However, a reduction in vertical gradient by in-lieu recharge would reduce the downward flow of groundwater. With the same argument, reduction of the vertical gradient could potentially cause a rise in the shallow groundwater table.

2.6.4. Aquifer Hydraulic Connections

The degree of hydraulic connection between different aquifer systems (perched, shallow, and deep) is important with respect to groundwater vulnerability to contaminating activities because it controls whether the effects of pumping in the “deep” Primary Production Aquifer can propagate to shallow aquifer systems and cause changes in flow conditions in a manner that would induce groundwater quality effects. The hydraulic connection also defines the possible flow paths a contaminant could travel and the potential for attenuation once it reaches the aquifer.

In the context of hydraulic connections in the subsurface, the presence of fine-grained aquifer materials in the subsurface above pumping zones is critical as these confining materials exert controls on the occurrence and flow of groundwater between the upper and lower aquifer systems. The aggregate occurrences of aquitards and intervening fine grained units could restrict vertical migration of contaminants from the shallow to the deep groundwater zones, and isolate the pumping effects in the deep production aquifer.

The generalized regional cross-sections in the Westside Basin were updated in 2010 based on the new subsurface lithological data obtained from recently installed monitoring wells for the

GSR Project (LSCE, 2010). Based on interpretation of the subsurface, the regional cross-section that extends from north (Golden Gate Park) to south (San Francisco International Airport) and several regional cross-sections that stretch from west to east along the Daly City, South San Francisco, and San Bruno areas provide insight on the presence of fine-grained layers overlying the Primary Production Aquifer and the potential for confined to semi-confined conditions in the Primary Production Aquifer.

Local stratigraphy and recently obtained groundwater level data suggest that in the Daly City, South San Francisco, and San Bruno areas, the Primary Production Aquifer is under semi-confined to confined conditions. In the North Westside Basin area away from Daly City, the presence of the -100 foot clay clearly separates the Primary Production Aquifer from the overlying Shallow Aquifer.

It is noted that the -100 foot clay is no longer present beneath the Daly City area and thus the split between the Shallow Aquifer and deeper Primary Production Aquifer is not formally defined in this portion of the Basin. However, cross-section F-F’ in TM# 1 (LSCE, 2010) oriented north-south through the Basin indicates that from Daly City south to South San Francisco, the Primary Production Aquifer is isolated from shallow groundwater by 50 feet to 100 feet aggregate thickness of intervening clay and sand deposits. The aggregate thicknesses of these materials make up discontinuous low permeability zones that reduce the possibility for vertical migration of contaminants. These relatively low-permeability shallow sediments in the Daly City to South San Francisco area are markedly different than the higher-permeability shallow sands found in the North Westside Basin. South of Daly City, from South San Francisco to San Bruno, the presence of thick surficial Bay Mud deposits of even lower relative permeability likely provides an even greater degree of isolation to the Primary Production Aquifer in that area.

Additional evidence for isolation of the Primary Production Aquifer beneath the cities of Colma and Millbrae is apparent from relative groundwater elevations measured in multilevel GSR Project monitoring well clusters installed in 2008 and 2009. At each monitoring well location, there are three or four separate wells installed at discrete depths. The completion depths for these wells generally correspond to the Primary Production Aquifer and the Deep Aquifer, and an apparent equivalent to the Shallow Aquifer in the North Westside Basin is identified, although it is not formally recognized in this area.

Differences in groundwater levels measured in the GSR Project monitoring wells suggest likely hydraulic separations of these three aquifers in the central and southern portions of the South Westside Basin. For instance, at the monitoring well cluster MW-CUP-18-490 and MW-CUP-18-660 installed in Colma, groundwater levels in the Primary Production Aquifer well (490 feet deep) are typically 31 feet higher than levels in the next deeper well (660 feet deep), installed in the Deep Aquifer. An even greater difference exists in groundwater levels between the 250-foot deep well and the next deepest well, at 500-foot depth, at the monitoring well site CUP-10A. Similar differences in groundwater levels exist for the Shallow Aquifer and Primary Production Aquifer well completions for the other GSR Project monitoring well groupings between Daly City and San Bruno. At the monitoring well MW-CUP-44-1 in northern San Bruno, groundwater levels in the shallowest well completion (190 feet deep) are typically about 10 to 15 feet higher than levels in the intermediate-depth well (300 feet deep). As with conditions in the North Westside Basin, these relative groundwater level differences in the South Westside Basin suggest a similar degree of isolation of the Primary Production Aquifer.

2.6.5. Occurrence and Nature of Contaminants in the Subsurface

For the purpose of this analysis, and consistent with the California Department of Public Health (CDPH) definition, possible contaminating activities (PCAs) are activities, industries, or land uses considered to be potential origins of contamination of the hydrologic environment. These activities may include transporting, storing, manufacturing, producing, using, or disposing of industrial chemical, agricultural chemicals or other potential contaminants. PCAs may include petroleum releases, land disposal of solid wastes, and land-applied chemicals from agricultural practices that may pose a threat to the drinking water supply, by causing the release of contaminants. The locations, status, and groundwater conditions of PCAs were evaluated as part of the water quality assessment to determine potential effects from the GSR Project operations. The inventory of the existing PCAs and their effects on the GSR Project operations are discussed in Section 5.

With respect to the GSR Project operations, potential effects on nitrate conditions may occur, including mobility such as redistribution of nitrate mass in the lower portion of the Shallow Aquifer mainly due to potential changes in flow directions, resulting from the GSR Project pumping conditions.

Nitrate (as NO_3) concentrations historically exceed the drinking water standard primary maximum contaminant level (MCL) of 45 milligrams per liter (mg/l) in some locations (LSCE, 2010), as discussed in Section 3.2.2. Nitrogen, in the form of nitrate, commonly affects water quality beneath agricultural lands (Harter et al., 2012). The extent of nitrate detected in groundwater is mainly attributed to past fertilizer applications and possible confined animal facilities that are not related to the GSR Project conditions. Whether or not the GSR Project is implemented, the occurrence of nitrate in native groundwater is considered a pre-existing condition due to past land use practices. The effect of the GSR Project on nitrate concentrations in the vadose zone or native shallow groundwater depends greatly on the potential for the GSR Project to cause changes in shallow groundwater levels. As explained in Section 2.6.1, fluctuations of shallow groundwater levels due to GSR Project storage and recovery are likely negligible because of the Shallow Aquifer and its hydraulic isolation from the deep aquifers that the GSR Project would extract from.

The primary concern with respect to landfills and other land disposal of solid wastes is leaching by percolating water from rain. Since the GSR Project will use in-lieu recharge rather than surface spreading, it would not directly induce changes in the current conditions of land disposal sites.

In situations where leaks at underground storage tank (UST) sites move through the unsaturated zone, downward movement of hydrocarbons typically ceases when the seepage front reaches the water table. Except for small amounts of hydrocarbons that go into solution, petroleum hydrocarbons do not penetrate below the water table because they are less dense than water and immiscible in water. As a result of this characteristic, oil and gasoline from leaky tanks migrate almost exclusively in the capillary fringe, directly above the water table (Freeze and Cherry, 1979). Dense non-aqueous phase chemicals, on the other hand, can migrate great distances after reaching groundwater, given their densities, which are greater than that of water. However, the downward migration of chemicals denser than water is typically limited by the presence of confining layers.

3. Groundwater Setting

This section provides an overview of the regional geology and hydrogeology of the GSR Project area most relevant to the water quality analysis. The geology and hydrogeology of the Westside Basin have been described previously (LSCE, 2005; DWR, 2003; Yates et al., 1990), and will not be extensively described in this section.

For the assessment of groundwater quality changes from the GSR Project, the South Westside Basin is considered to be the general project area that would be subject to changes in groundwater levels and storage from the GSR Project operations. Contaminant plumes and release activities that are known to be located in the GSR Project area are briefly introduced in this section and further evaluated as part of the empirical analysis in Section 5.

3.1. Westside Groundwater Basin

The groundwater basin beneath the western part of San Francisco from the vicinity of Golden Gate Park and extending southeasterly into San Mateo County is identified in the California Department of Water Resources (DWR) Bulletin 118 as both the Merced Valley Basin and the Westside Basin (DWR, 2003). Since it is more commonly known as the Westside Basin, this designation is used in this TM. Figure 10.6-1 shows the boundary of the Westside Basin and the northern and southern portions of the Basin.

Relevant to this discussion, the Westside Basin has been divided into northern and southern portions at the San Francisco County-San Mateo County line. This subdivision is a political division, which is not representative of a physical boundary, and it is not meant to imply that there is any restriction of groundwater flow between the two areas. The portion of the Basin that lies within San Francisco County is referred to as the North Westside Basin and the portion of the Basin that lies within San Mateo County is referred to as the South Westside Basin. Figure 10.6-1 shows the boundary of the North and South Westside basins. The GSR Project would be located in the South Westside Basin, which has an area of about 25 square miles. The proposed SFGW Project would be located in the North Westside Basin, which has an area of about 15 square miles. Aquifers in the GSR Project area are described earlier in Section 2.1.

3.1.1. Groundwater Flow Conditions

Groundwater levels and general direction of flow vary in the Westside Basin. In the portion of the North Westside Basin north of Lake Merced, groundwater in the Shallow and Primary Production Aquifers tends to flow in a westerly direction towards the Pacific Ocean. Groundwater in this area, from near Lake Merced north to Stern Grove and Golden Gate Park, is encountered at relatively shallow depths, ranging from approximately 5 feet to 60 feet bgs (LSCE, 2006). The Shallow Aquifer beneath Lake Merced also has a generally westward groundwater flow direction.

Near Lake Merced and immediately southward, the groundwater direction in the Primary Production Aquifer is to the south and southeast towards Daly City (the Shallow Aquifer as defined previously is no longer present in the Daly City area). In these areas and further south the depth to piezometric head can exceed 300 feet bgs, due largely to the effects of long-term municipal pumping beneath the Colma and South San Francisco areas. The groundwater depressions caused by concentrated areas of long-term pumping induce flow locally towards those depressions.

In the portion of the Basin from Daly City northward, groundwater elevations have generally exhibited a flat (Shallow Aquifer) to decreasing (Primary Production Aquifer) trend over the past two to three years, as compared to an upward trend from 2002 to 2006. The slight downward trend in the Primary Production Aquifer appears to be caused by resumption of groundwater pumping by Daly City during this period (LSCE, 2010).

From South San Francisco southward to Burlingame in the vicinity of San Francisco Bay (Bay), groundwater within the shallow units overlying the Primary Production Aquifer generally flows east towards the Bay (Rogge, 2003; Yates, 2003). Throughout this portion of the Basin, groundwater flow in the Deep Aquifer is generally east towards the Bay. In the vicinity of San Bruno, groundwater extraction has created a local depression in the water table (City of San Bruno, 2007). A flow divide near the south end of the San Francisco Airport separates the area where groundwater flows toward the pumping depression in San Bruno from the area where groundwater flows toward the Bay (Yates, 2003). The divide trends southwest from near the Millbrae exit on Highway 101, and groundwater northwest of the divide is captured by the San Bruno wells (Yates, 2003).

Groundwater elevations in areas south of South San Francisco are highly variable, depending largely on proximity to pumping wells and depths in the aquifer where water levels are measured. In areas near South San Francisco and San Bruno, the groundwater in the Primary Production Aquifer is typically at elevations ranging from -100 to -200 feet msl (or 130 feet to 230 feet bgs). However, in areas closer to the Bay, groundwater elevations are in the range of approximately 10 to -30 feet msl, with the lower levels corresponding to measurements made in deeper monitoring wells.

3.1.2. Pumping in the Westside Groundwater Basin

Groundwater pumping in the Westside Basin consists primarily of pumping for municipal (potable) supply by Daly City, Cal Water (serving South San Francisco), and San Bruno. Groundwater is also used for irrigation and other non-potable uses, most notably on golf courses around Lake Merced, cemeteries in Colma, at the San Francisco Zoo, and at Golden Gate Park (LSCE, 2006). Groundwater is pumped primarily from deeper, semi-confined portions of the aquifers within the Basin (SFPUC, 2009a). Historical trends and current pumping conditions for municipal and irrigation pumping are described extensively in TM#1 (LSCE, 2010).

3.1.3. Existing Groundwater Quality Monitoring and Reporting Activities

Groundwater quality in the Westside Basin is monitored in a network of production and monitoring wells as part of the semi-annual monitoring program that was initiated throughout the Basin in 2000. Figure 10.6-4 shows the locations of wells monitored by SFPUC in the South Westside Basin. Results of the most recent groundwater quality monitoring were reported in the 2010 Annual Groundwater Monitoring Report Westside Basin, prepared by the SFPUC in coordination with the City of Daly City, San Bruno, and the Cal Water (SFPUC, 2011).

3.2. Groundwater Quality Conditions

This section summarizes general water quality conditions particularly in the South Westside Basin based on the review of available and relevant reports, documents, and data from the ongoing monitoring activities in the Basin, particularly those from sampling events in 2009 (Kennedy/Jenks, 2009 and 2010), and the review of water quality in 2011 (Kennedy/Jenks, 2012a). Since the GSR Project would be implemented in the Daly City, South San Francisco, and San Bruno areas, monitored water quality in these areas is expected to represent the nature of water quality that would be produced during the GSR Project operations. Therefore, water quality conditions are discussed with respect to these general pumping areas based on data at selected key monitoring locations.

Data sources were reviewed for all Title 22 water quality indicators, VOCs, and radiological to note general trends and to identify elevated concentrations and the localized areas where those concentrations exceed the drinking water standards. Data primarily come from four sources listed below:

- Hydrogeologic Conditions in the Westside Basin (LSCE, 2006)
- 2008 and 2010 SFPUC Annual Groundwater Monitoring Reports (SFPUC, 2009a, 2011)
- GSR Phase 1 and 2 Monitoring Well Installation Technical Memoranda (Kennedy/Jenks, 2009 and 2010)
- Review of Water Quality, Treatment, and Operations for Future SFPUC Groundwater Supply Final Draft, October 2011 (Kennedy/Jenks, 2012a).

In addition to these sources, groundwater quality conditions in the Westside Basin are also described as part of TM#1 (LSCE, 2010); thus, references were made to TM#1 as needed for detailed information on basin groundwater quality.

Based on evaluating groundwater quality conditions alone, groundwater quality generally meets the MCLs of the primary and secondary drinking water standards set by the CDPH and SFPUC water quality criteria, with the exception of nitrate in selected areas (see below), fluoride, and other select secondary constituents in selected areas (i.e., pH, color, hardness, turbidity, conductivity, total dissolved solids (TDS), sulfate, chloride, manganese, and iron). For most constituents, SFPUC water quality standards are more stringent than regulatory drinking water standards (i.e., MCLs). Blending analysis of groundwater-surface water was conducted for compliance with the primary and secondary drinking water standards and SFPUC criteria and to determine blending and treatment requirements that will address water quality issues (Kennedy/Jenks, 2012a). Based on the future blended groundwater and surface water supply that will be delivered to SFPUC drinking water customers, predicted blended water quality for the SFPUC GSR Project wells meets regulatory and SFPUC criteria for the constituents listed above, except for hardness, iron, manganese, turbidity, and fluoride (Kennedy/Jenks, 2012a). Turbidity levels are anticipated to be addressed by well operations. Exceedances for iron and manganese indicate that treatment will be required. Fluoride and hardness will be addressed by blending. While there are localized areas with naturally occurring manganese and iron concentrations that exceed the secondary drinking water standards, these issues will be addressed by treatments during the GSR Project implementation. It should also be noted that this TM primarily focuses on the potential effects the GSR Project on existing anthropogenic pollution, not water quality issues associated with naturally occurring conditions.

Other water quality parameters are not necessarily of concern, but are noted below based on long-term data available at key locations in the South Westside Basin. All water quality parameters vary by locations and depths of groundwater. The GSR Project proposes locations and aquifers that are expected to provide the best available water quality for groundwater production.

3.2.1. General Minerals

Data from recently installed monitoring wells by SFPUC as part of the GSR Project showed several sites with elevated levels for the following constituents: hardness, specific conductance (EC), TDS, turbidity, color, iron, manganese, sulfate, and aluminum. In addition, pH for groundwater is in the range of 7-8 units and will have to be raised to meet water quality standard through treatment and/or blending (Kennedy/Jenks 2012a). Concentrations of these constituents may need to be lowered to meet the primary and secondary MCLs, and/or water quality targets developed by SFPUC and the PAs. It is anticipated that potential blending/treatment may be necessary to reduce concentrations. In terms of the relevance of monitoring data collected from the monitoring wells, it is important to note that these results are informative but not fully representative of the raw water quality that would be pumped from the GSR Project production wells. As reported in the Phase 1 and 2 Monitoring Well Installation Technical Memoranda, recommendations were made for design and construction of the 16 GSR Project production wells with potential test well design parameters and noted water quality effects (Kennedy/Jenks, 2009 and 2010). Groundwater quality conditions with respect to general minerals are further described below by the general pumping areas in Daly City, South San Francisco, and San Bruno.

Daly City Area - Long-term historical data extending back to the mid-1970s (DC-2 Westlake) suggest an increase in mineral concentrations (EC, TDS, and chloride) as of 2000, but data are too sporadic to conclude that there are any current trends or changes. More recent data (since 2000) show that TDS has fluctuated, but EC and chloride concentrations are similar to 2000 conditions (Figure 21 in TM#1, LSCE, 2010).

South San Francisco Area - A Cal Water well (SS1-14) has the longest period of record in the Basin, dating back to the 1950s (Figure 22 in TM#1, LSCE, 2010). Chloride concentrations have remained around 120 mg/l to 130 mg/l for the entire period. Concentrations of EC and TDS fluctuated more than chloride and appeared to exhibit a generally upward trend since the 2000 monitoring event. During the 2008 sampling event, total and dissolved manganese concentrations exceeded the secondary MCL of 0.05 mg/l at the South San Francisco Linear Park wells (MW-120, 220, 220, 440, and 520). At this well cluster, detected concentrations ranged from 0.147 mg/l to 0.825 mg/l for total manganese.

San Bruno Area - Available data extending back to 2000 suggest fairly constant conditions and generally lower concentrations than elsewhere in the Basin. TDS concentrations have been around 300 mg/l, and chloride concentrations are consistently low at around 60 mg/l. The 2008 sampling results remained within historical ranges for EC, TDS, and chloride (Figure 23 in TM#1, LSCE, 2010). As part of the City of San Bruno's Bay monitoring program, the two well clusters installed in 2006 (Burlingame-S, M, D and SFO-S-D) show chloride concentrations less than 350 mg/l in the shallow well Burlingame-S, and less than 140 mg/l in both the medium (Burlingame-M) and deep well (Burlingame-D).

3.2.2. Nitrate

Among the general water quality parameters, trends in nitrate in the GSR Project area are discussed separately due to elevated concentrations that exceed drinking water standards in localized areas. Historical data are available at the selected key monitoring locations in the PA pumping areas, as summarized below (Figure 24 in TM#1, LSCE, 2010). In this analysis, observed nitrate is described in terms of nitrate as nitrate (NO_3) and all nitrate values are reported in terms of nitrate (as NO_3). Data are compared relative to the primary MCL of 45 mg/l for nitrate as NO_3 (the primary MCL for nitrate as nitrogen (N) is 10 mg/l).

Nitrate (as NO_3) concentrations reported in groundwater sampled in 2008 and 2009 are shown in Figure 10.6-5 based on observed data from the PA wells and the GSR Project monitoring wells. The following is a description of nitrate distribution by the general areas of Daly City, Colma, South San Francisco, Golden Gate National Cemetery, and San Bruno. In general, data indicate isolated occurrences of elevated nitrate levels above the primary MCL of 45 mg/l for nitrate in portions of Daly City and South San Francisco. Ongoing monitoring will continue to examine trends and help delineate whether the recent data are indicative of changing, temporary, or anomalous conditions with respect to nitrate in the Daly City and South San Francisco areas.

Daly City Area – During the spring 2008 sampling, detected nitrate concentrations in four wells sampled ranged from 10 mg/l in the Jefferson to 131 mg/l in inactive Daly City A Street well, which exceeds the primary MCL of 45 mg/l. Historical data available since 2000 from DC 2 and Vale wells show nitrate concentrations ranging mostly from 20 to 40 mg/l. Detected nitrate concentrations in three of the four wells sampled in 2008 decreased slightly compared to 2007, with the exception of the Jefferson well, which remained relatively the same (9.4 mg/l in 2007 and 10 mg/l in 2008).

Nitrate concentrations reported at the GSR Project monitoring well MW-10A in Daly City were elevated, ranging from about 36 mg/l from MW-10A-160 and MW-10A-250 to 49.5 mg/l from MW-10A-500. Nitrate from the 645-foot screen in MW-CUP-10A-710 was about 0.9 mg/l. The Park Plaza monitoring well had nitrate concentrations of 26.5 mg/l in the primary production zone depth (i.e., Primary Production Aquifer) and a much lower concentration of 0.6 mg/l in the deeper zone (i.e., Deep Aquifer).

City of Colma Area – The GSR Project monitoring well MW-CUP-18 located in Colma had nitrate concentrations ranging from 6.6 mg/l from MW-CUP-18-230 to 14.85 mg/l from MW-CUP-18-425 mg/l and a much lower concentration of 0.63 mg/l from MW-CUP-18-660 in the deeper zone. Nitrate was not detected from the GSR Project monitoring well MW-CUP-19 sampled at three different depths (475 feet, 600 feet, and 690 feet bgs).

South San Francisco Area – Detected nitrate concentrations in raw groundwater during the 2008 sampling were 47 mg/l in SS1-19, which is slightly above the primary MCL of 45 mg/l, and 35 mg/l in SS1-20 (Note that groundwater from these Cal Water wells is blended with SFPUC surface water prior to distribution and the resulting blend fully meets all drinking water standards). The inactive SS1-14 well, with historical data dating back to the late 1950s, was offline during the 2008 sampling; data show concentrations increased slightly from the 1950s to 1990s, while remaining below 40 mg/l. Nitrate concentrations from 2000 to 2007 in SS1-14 fluctuated considerably with the highest concentration of 120 mg/l measured in spring 2001. Recent measurements since 2004 have been approximately 80 mg/l. Since 2001, nitrate concentrations remained near 80 mg/l, based on the data reported in the SFPUC's 2010 Annual Groundwater Monitoring Reports (SFPUC, 2011). Detected nitrate concentration was 0.5 mg/l in the SSF Linear Park MW-220 and non-detect at other depths.

Data are also available from three multi-level monitoring wells installed by SFPUC in the South San Francisco as part of the GSR Project. Nitrate from the GSR Project monitoring well MW-CUP-22A-290 was about 43 mg/l, which is close to the primary MCL of 45 mg/l. At greater depths, nitrate concentrations at this location were much lower, about 1.1 mg/l from MW-CUP-22A-440 and 2.4 mg/l from MW-CUP-22A-545. Nitrate concentration of 64.9 mg/l was reported at the GSR Project monitoring well MW-CUP-23-230 in September 2009. Nitrate concentrations in MW-CUP-23 from deeper depths were lower and below the primary MCL: 29 mg/l in MW-CUP-23-600, 21.3 mg/l in MW-CUP-23-440, and non-detect in MW-CUP-23-515. MW-CUP-36 had nitrate concentration of about 32 mg/l at the shallowest depth (160 feet bgs) and much lower concentration of about 6.8 mg/l at the 270-foot screen and no nitrate detections from deeper depths.

Golden Gate National Cemetery – Nitrate concentrations reported at the GSR Project monitoring well MW-CUP-44-1-190 and MW-CUP-44-1-300 were 37 and 32.8 mg/l, respectively. Nitrate was not detected in MW-CUP-44-1-460 and MW-CUP-44-1-580.

San Bruno Area – Nitrate concentrations reported in 2008 were 5.5 mg/l in SB-17 and 1 mg/l in SB-20. Historical data available for SB-17 since 2000 show measured nitrate concentrations of 3.5 mg/l to 6 mg/l, which are well below the primary MCL of 45 mg/l. Similarly, data from SB-20 since 2004 showed very low nitrate concentrations, less than 2 mg/l, at this location. MW-CUP-M-1 located in Millbrae had relatively low nitrate at 12.1 mg/l.

3.2.3. Organic Compounds

A few trace organic compounds were detected in the monitoring wells for the GSR Project during sampling in 2008 and 2009, but these are not necessarily of concern because detected concentrations were near their respective reporting limits, which are well below the respective MCLs.

During the December 2008 and January 2009 sampling, acetone was detected in low concentrations in groundwater samples from the Phase 1 wells, including the existing SFPUC Park Plaza monitoring well cluster (MW135, MW195, MW460, and MW620). To assess the validity of acetone presence in the native groundwater, Phase 1 wells MW-CUP-18-230 and MW-CUP-18-490 were re-sampled in October 2009 and acetone was not detected. The previously detected acetone concentrations were not repeatable and are not considered to be representative of regional water quality conditions (Kennedy/Jenks, 2009 and 2010).

As found in numerous studies in the State and in particular the “California Aquifer Susceptibility” study by the Lawrence Livermore National Laboratory (Moran et al., 2004), the Westside Basin wells with deeper screens draw an older groundwater component, and are free of VOCs and other contaminants residence in the shallow groundwater zones. In this Basin, vulnerability of groundwater is largely controlled by depth, and wells that tap deeper aquifers are apparently protected from VOC contamination that may be present in shallow groundwater zones.

3.2.4. Groundwater Quality Near Cemeteries

Cemeteries in the GSR Project area were evaluated by SFPUC for potential groundwater quality concerns. Based on the recent groundwater sampling conducted by SFPUC from five monitoring wells (MW-CUP-18, MW-CUP-19, MW-CUP-22A, MW-CUP-44-1, and the Linear Park monitoring well) located in the vicinity of the cemeteries, there is no apparent groundwater contamination from cemeteries (Kennedy/Jenks, 2010, see also Section 5.4). The ongoing SFPUC monitoring at the monitoring wells for the GSR Project will continue to evaluate groundwater quality conditions in the vicinity of the cemeteries.

The initial samples were taken in September, October, and November 2009 at three different monitoring locations near the cemeteries. Samples were analyzed for aldehydes, including formaldehyde (a chemical used for embalming) and acetaldehyde (most likely a natural microbial degradation byproduct in the aquifer sediments and unrelated to cemeteries or embalming). Locations sampled included a multi-level monitoring well MW-CUP-44-1 (screened at five depths from 190 feet to 580 feet bgs and each depth sampled) located in the Golden Gate National Cemetery, MW-CUP-18 (two depths sampled at 230 feet and 490 feet bgs) located near Cypress Lawn Cemetery, and the Linear Park multi-level monitoring wells (screened at four depths from 120 feet to 530 feet bgs and each depth sampled). All samples had concentrations of non-detect below the reporting limit for formaldehyde (less than 5 micrograms per liter(μg/l)), with the exception of the reported concentration of 26 μg/l measured from the Linear Park monitoring well at 440 feet bgs (Kennedy/Jenks, 2009 and 2010). This detection is below the notification level of 100 μg/l for formaldehyde. It is important to note that this detection was flagged by the laboratory as being received past the holding time and not considered acceptable for regulatory compliance. The 2009 samples were also analyzed for acetaldehyde (most likely a natural microbial degradation byproduct). For acetaldehyde, only two samples were reported to be 1.0 and 2.0 μg/l, which are slightly above the reporting limit of 1.0 μg/l (no reported MCL or notification level for acetaldehyde). It is possible that the acetaldehyde detections are due to natural background or sample contamination.

SFPUC conducted a subsequent re-sampling for formaldehyde in 2010 at five monitoring well locations including the Linear Park well and re-sampling did not confirm the presence of formaldehyde where the samples were all below the detection limit (less than 5 μg/l). The subsequent sampling was conducted in May, October, and December 2010 and included the following well locations: MW-CUP-18 (three depths sampled at 230 feet, 425 feet, and 490 feet bgs) and MW-CUP-22A (two depths sampled at 290 feet and 545 feet bgs), MW-CUP-19 (sampled at 475 feet bgs) and the Linear Park monitoring well (re-sampled at four depths from 120 feet to 520 feet bgs).

3.3. Existing Regulated Sites

Possible groundwater contamination from human activities at the ground surface is an important aspect of groundwater quality assessment. The PCAs from existing regulated sites warrant special considerations because of their potential to pose notable risk to groundwater quality during the GSR Project operations. Records of known PCAs were compiled from the following sources. Locations of these sites were mapped and are further discussed in Section 5.2.4. The inventory of the existing PCAs was previously compiled and evaluated as part of the CDPH Drinking Water Source Assessment Program (DWSAP) documentation as discussed in Section 5.2.3.

- **State Water Resources Control Board (SWRCB) GeoTracker Database** – The GeoTracker database (compiled in March 2012 at http://geotracker.swrcb.ca.gov/), contains a total of 1,560 regulated sites within San Mateo County (SWRCB, 2012). Each of these sites is identified with a status of “closed” or “open”2. Among these, the majority of them (1,155) were closed under regulatory oversight. Among the 405 open sites, 49 were reported to be inactive and the remaining 356 sites are leaking underground storage tank (LUST) sites or other cleanup sites currently undergoing active investigation, monitoring, and/or soil/groundwater remediation. There is no military LUST site (closed or open) in the South Westside Basin. There is one Military cleanup site listed in San Mateo County located in Half Moon Bay, but the site was reported to be inactive.

- **California Solid Waste Information System (SWIS) Database** – This contains solid waste facilities, operations, and disposal sites (compiled in January 2010 at http://www.calrecycle.ca.gov/SWFacilities/). According to the SWIS database, among 33 land disposal sites/transfer stations in San Mateo County, 14 sites were located in the general GSR Project area (CalRecycle, 2010). Among the 14 sites, one (1) site is closed, one (1) site in the process of closing, and 12 sites were reported to be active.

- **San Francisco Bay Regional Water Quality Control (RWQCB) Board Spills, Leaks, Investigations, and Cleanup (SLIC) Database** – According to the SLIC database, there are 145 sites reported in the San Mateo County (compiled in May 2010 at http://www.waterboards.ca.gov/sanfranciscobay/publications_forms/avail_doc.shtml). Among these, 15 sites are reported in the general area of the GSR Project in the South Westside Basin (RWQCB, 2010).

- **California Department of Toxic Substances Control (DTSC) Database** – Facilities and sites that are regulated by the California Department of Toxic Substances Control (DTSC) were searched through the Envirostor database website (compiled in May 2010 at http://www.envirostor.dtsc.ca.gov/public/) that allows a search for properties where extensive investigation and/or cleanup actions are planned or have been completed at permitted facilities and clean-up sites (DTSC, 2010). In the compiled database, 15 sites were reported in the general area of the GSR Project in the South Westside Basin.

[2] Open sites include sites that are currently active with site assessments or remediation activities. These sites are likely to have verification monitoring requirements. Closed sites have a status of completed closed cases. A case closed site qualifies to receive a "no further action" (closure) letter once the owner or operator meets all appropriate corrective action requirements. After this occurs, a closure letter or other formal closure decision document is issued for the site to indicate no further work is required.

4. Groundwater Model Analysis

Groundwater models are useful tools that can help quantify the changes in groundwater conditions associated with future project activities. This section presents the current modeling analysis conducted to evaluate the GSR Project effects on groundwater quality using the latest Westside Basin Groundwater Flow Model (HydroFocus, 2011). Presented in this section is a summary of the modeling scenario results related specifically to the potential effects on groundwater quality from Scenario 2 for the GSR Project and Scenario 4 for the Cumulative Scenario.

4.1. MODFLOW Model

The existing Westside Basin Groundwater Flow Model was developed over a period of time from 2002 to 2011 by HydroFocus (HydroFocus, 2007, 2009, and 2011). The model development has been a collaborative effort sponsored by Daly City with review by SFPUC, Cal Water, San Bruno, and their respective consultants.

The existing Westside Basin Groundwater Flow Model was used to simulate future model scenarios to evaluate potential effects from the GSR Project. The model scenario development and assumptions, including modifications made to the existing model, are discussed in Task 10.1 TM (Kennedy/Jenks, 2012b).

For the assessment of groundwater quality effects from the GSR Project, the model results were used to demonstrate general trends as they pertain to changes in groundwater levels at the regional-scale. The assessment also identifies general areas with a shallow water table that might be susceptible to remobilization of existing contaminants and/or plumes as a result of fluctuation in the water levels in the shallow water bearing zones.

4.2. Model Scenario Summary

The numerical groundwater model discussed in the Task 10.1 TM was used as a predictive tool for simulating the basin conditions under various management scenarios associated with the GSR Project. A detailed description of the model setup and assumptions of these scenarios, including amounts and distribution of pumping, is provided in the Task 10.1 TM (Kennedy/Jenks, 2012b). Among the five modeling scenarios developed, the following three scenarios are applicable to analyzing the GSR Project effects on groundwater quality:

- **Scenario 1 – Existing Conditions** – Scenario 1 represents the Existing Conditions and does not include the SFPUC Projects. Groundwater pumping by the PAs and irrigation pumping are representative of the existing pumping conditions (as of June 2009).
- **Scenario 2 – GSR Project** – Scenario 2 represents the implementation of the GSR Project and the PA pumping rates as designated by the GSR Project operations. The PA

and GSR Project pumping occur according to the put/take/hold sequence described in TM 10.1. Irrigation pumping remains the same as in Scenario 1.

- **Scenario 4 – Cumulative Scenario** – Scenario 4 represents the implementation of both the GSR Project (Scenario 2) and the SFGW Project (Scenario 3b) along with other foreseeable projects, such as the Daly City Vista Grande Drainage Area Improvements Project (which increases stormwater diversions into Lake Merced). Irrigation pumping remains the same as Scenario 1, except with minor variations such as the planned build-out at Holy Cross cemetery.

4.3. Use of Model Results

The results of modeling scenarios are analyzed to determine general areas in the South Westside Basin where the GSR Project could affect groundwater quality. This analysis was conducted at the regional scale and was by necessity, fairly qualitative. The assessment focused on the Full SFPUC Storage Account and the Design Drought. This is because these aspects of the GSR Project may play an important role in the GSR Project's possible effects on groundwater levels and storage. All of the model scenarios start with the initial condition of June 2009 groundwater levels. The June 2009 SFPUC Storage Account value is approximately 20,000 af. In order to achieve a "Full" SFPUC Storage Account value of 60,500 af in both Scenarios 2 and 4, the first 6.5 years of the model simulation are put years. The 60,500 af that represents the Full SFPUC Storage Account is 40,500 af larger than the June 2009 initial condition of 20,000 af. It is therefore very likely that groundwater levels in the South Westside Basin are higher under the Full SFPUC Storage Account than under the Existing Conditions of Scenario 1.

For the GSR Project water quality assessment, the results of the modeling analysis are presented as model estimated basin-wide change in groundwater storage (Section 4.3.1 and Figure 10.6-6), water level hydrographs at selected locations (Section 4.3.2 and Attachment 10.6-A), estimated basin-wide depth to water contour maps (Section 4.3.3 and Figures 10.6-7 through 10.6-11), and groundwater flow directions in the shallow groundwater (Section 4.3.4 and Figures 10.6-12 through 10.6.17).

HydroFocus (2007) suggests the strongest predictive ability of the model is in relative changes over time rather than the absolute predictions of water levels. However, in this analysis, it is also important to assess the estimated absolute depths to water table. Therefore, the results are presented for Scenarios 1, 2 and 4 for both the absolute and relative differences from Scenario 1.

4.3.1. Change in Groundwater Basin Storage

Model estimated change in groundwater basin storage is presented in Figure 10.6-6 for each of the five scenarios separately over the simulation period. Unlike groundwater levels, the model-simulated groundwater storage values are not relied upon in this analysis. Instead, the results of the Full SFPUC Storage Account condition are assumed to represent the highest water levels and are used as a reference for the water quality assessment.

4.3.2. Water Levels

Model-simulated water levels for each of the five model scenarios and relative to the Existing Conditions are presented in Attachment 10.6-A. However, as described previously, only Scenarios 1, 2 and 4 are considered in this TM.

The existing groundwater model includes the capability of monitoring head at 125 different monitoring points. This section examines the results for 11 selected monitoring points (Figure 10.6-2). These well locations were selected within the general extent of the pumping areas in the South Westside Basin and within the vicinity of the GSR Project wells and the PA production wells. As discussed previously, historical groundwater pumping has been relatively intense and focused within the South Westside Basin. Furthermore, most GSR Project wells would be located in these general pumping areas, with one GSR Project well (CUP-M-1) planned to the south, in the City of Millbrae. Therefore, the model-simulated effects on groundwater levels would be most evident in the PA pumping areas and the GSR Project pumping areas.

As per TM 10.1, in this analysis, hydrograph representations for each of the monitoring points are presented for Model Layer 1 (which includes the shallow unconfined aquifer) and for Model Layer 4 (which represents the Primary Production Aquifer). TM 10.1 also presents groundwater model-simulated hydrographs for selected locations from all five model layers. The results for Model Layer 1 are of particular interest for assessing water quality effects associated with rising water levels (such as the potential mobilization of contaminants).

In each hydrograph in Attachment 10.6-A, the model-simulated water levels are expressed as feet of elevation (datum NGVD29) and the time axis is in scenario years. The total duration of each hydrograph corresponds to the total length of time for each model simulation (47.25 years).

4.3.3. Depth to Water

Depth to water contour maps were generated for Scenarios 1, 2, and 4 based on the model-simulated water levels in Model Layer 1 as a representation of the shallow aquifer conditions (Figures 10.6-7, 10.6-8, and 10.6-10). For the purpose of evaluating the GSR Project effects, the changes in depth to water for Scenarios 2 and 4 were also contoured relative to the Existing Conditions (Figures 10.6-9 and 10.6-11). On Figures 10.6-9 and 10.6-11, a positive sign indicates a rise in water table elevation relative to Scenario 1. In this analysis, the relative difference contour maps were used to identify general areas that would be most susceptible to rising water levels as a result of the GSR Project operations under Scenarios 2 and 4. The absolute depth-to-water contour maps were used to identify areas that might be within the 70-foot depth threshold (Section 1.1) from the ground surface under the Existing Conditions and therefore might be most susceptible to groundwater quality effects. This approach was taken because, generally speaking, areas with a shallow water table (less than 70 feet bgs) are considered most sensitive to changes in water quality. As discussed in Section 1.1, in this water quality assessment, the 70-foot depth threshold is considered conservative and was determined by canvassing the reported depths of contaminants in lists of active regulated sites from several State and local data sources. As a conservative approach, all depth to water table contours were prepared and evaluated at the time period that corresponds to the Full SFPUC Storage Account condition (or Scenario year 7).

4.3.4. Groundwater Flow Directions

During the GSR Project recharge and recovery periods, changes in groundwater flow directions would be anticipated to occur as a result of changes in the Production Aquifer zone pumping conditions. If the response to deeper pumping propagates to the unconfined Shallow Aquifer, this may result in changes in flow directions due to changes in the shallow aquifer hydraulic gradient.

Model estimated flow directions in Model Layer 1 were used to evaluate general basin-wide flow directions and to identify areas that may be subject to changes in flow directions due to the GSR Project operations. This is a qualitative comparison performed at the basin scale. Maps with arrows indicating flow directions (Figures 10.6-12 through 10.6-17) were prepared for Scenarios 1, 2 and 4 and the results of Scenarios 2 and 4 were compared to those of Scenario 1 visually in order to identify potential changes relative to the Existing Conditions.

For the purpose of comparative analysis, the model estimated flow directions were mapped at the simulation periods that would represent the most conservative conditions. In Scenarios 2 and 4, these conditions are associated with the Full SFPUC Storage Account (for the maximum rise in water levels) and at the end of the Design Drought (for the maximum drawdown).

4.4. Scenario 2 - GSR Project Analysis

The possible effects of the GSR Project upon groundwater levels and associated groundwater quality issues are considered in this section for Scenario 2.

4.4.1. Water Levels

In the South Westside Basin, the groundwater model results for water levels are evaluated for the following 11 locations: DC-A St, DC-3, DC-8, DC-2-Westlake, Cypress Lawn No. 02, SSF-2, SSF-18, SB-12, SB-13, SB-15, and SB-16. Hydrographs corresponding to these locations for Model Layer 1 and Model Layer 4 are presented in Attachment 10.6-A, both based on the absolute water levels and relative to the Existing Conditions (Scenario 1).

Scenario 2 typically produces groundwater levels higher than Scenario 1 in the South Westside Basin. The Full SFPUC Storage Account generally reflects the maximum rise in groundwater levels. The maximum drawdown in groundwater levels generally corresponds to the end of the

Design Drought. This is mainly due to the aggregate effects of pumping by the PAs, GSR Project and the background irrigation pumping.

For the water quality assessment, Model Layer 1 results are of particular interest as they represent changes in water table conditions in response to the GSR Project operations. Among the major pumping areas, the changes in groundwater level in Model Layer 1 associated with the GSR Project vary from the largest changes in the Daly City and Colma areas, to somewhat medium changes in South San Francisco, and minor changes in the San Bruno area. The largest changes in water table conditions (both declines and increases) in the Daly City area appear to coincide with areas with large depth to water table under the Existing Conditions. In the Daly City area, water levels in Model Layer 1 generally remain above Scenario 1 conditions, ranging from a net increase of 80 feet at the Full SFPUC Storage Account to a net decline of about 55 feet at the end of the Design Drought. In the South San Francisco area, the model-simulated water levels are higher in Scenario 2 relative to Scenario 1, except at the end of the simulation period, but the relative changes remain within 20 feet of Scenario 1. In the San Bruno area, the water levels in Scenario 2 are consistently higher than in Scenario 1 throughout the entire simulation period. However, the maximum increase is about 8 feet, which represents a smaller effect compared to the Daly City and Cal Water pumping areas.

Results from Model Layer 4 for Scenario 2 relative to the Existing Conditions are briefly discussed, as they represent conditions in the Primary Production Aquifer and are not directly related to the assessment of water quality in the Shallow Aquifer. In Model Layer 4, water levels show large fluctuations controlled mainly by the GSR Project put/take/hold sequence. These particular trends in predicted groundwater levels for Scenario 2 are clearly evident on all of the hydrographs. At the end of the Design Drought, groundwater levels under Scenario 2 are projected to decline, relative to Scenario 1 levels from approximately 60 feet to 120 feet in the Daly City and Colma pumping areas (DC-2-Westlake, DC-3, DC-8, DC-A-St, and Cypress Lawn No.2), about 130 feet in the Cal Water area (SSF-2 and SSF-18), and from about 80 feet to 100 feet in the San Bruno area (SB-12, SB-13, SB-15, and SB-16).

4.4.2. Depth to Water

Figures 10.6-7 and 10.6-8 show depth to water contour maps for Scenario 1 and 2, respectively, at the time period corresponding to the Full SFPUC Storage Account. Based on the Existing Conditions, the estimated depth to the water table is largest near Daly City and becomes shallow further south toward San Bruno and Millbrae. Overall, the depth to water table ranges from 200 feet to 300 feet bgs in the Daly City area, within 50 feet to 100 feet in the Cal Water area, and mostly within 50 feet in the San Bruno area (Figure 10.6-7). In general, both Scenario 1 and Scenario 2 show similar ranges of depth to water tables in these major pumping areas, but each scenario shows different spatial variations.

Figure 10.6-8 shows the difference in depth to water table conditions from Scenario 2 relative to Scenario 1. Consistent with the results from the water level hydrographs in Model Layer 1, the largest rise in water table resulting from the GSR Project is seen in the vicinity of the Daly City area, ranging from 40 feet to 80 feet (Figure 10.6-8). While the overall rise in water table is large, the resulting depth to water table from the GSR Project would be well below the 70-foot depth threshold, given the large depth to water table (200 feet to 300 feet bgs) without the GSR Project. At the Full SFPUC Storage Account, increase in water table would be around 5 feet in the South San Francisco area and less than 3 feet in the San Bruno area. In the San Bruno and South San Francisco areas, the maximum increase in depth to water table from the GSR Project is estimated to be less than 10 feet. While the existing depths to water table in these areas are shallower compared to Daly City, the overall rise in water table resulting from the GSR Project is relatively small.

4.4.3. Groundwater Flow Directions

Model estimated groundwater flow directions are presented for Scenarios 1, 2, and 4 in Figures 10.6-12 through 10.6-17. Groundwater flow directions are presented in Model Layer 1 at two selected time periods that correspond to the Full SFPUC Storage Account and the end of the Design Drought.

At the Full SFPUC Storage Account, flow directions in Scenario 2 tend to follow trends similar to Scenario 1, with the most notable changes apparent in the Daly City area (as shown by comparing Figures 10.6-12 and 10.6-14). Scenario 1 demonstrates flow directions in the Daly City area that are primarily towards the pumping center around the Daly City municipal wells; while Scenarios 2 shows continued flow to slightly further south of Day City towards the Colma area, as a result of the large rise in water table conditions from the GSR Project. San Bruno and Cal Water pumping areas show no appreciable changes in flow directions relative to Scenario 1, both at the Full SFPUC Storage Account and the end of the Design Drought.

In light of the large depth to water table conditions in the Daly City area, changes in flow conditions resulting from the GSR Project would occur well below the 70-foot depth threshold. Therefore, these changes are not anticipated to affect the conditions of contaminants and plumes residing in the soil above 70 feet bgs. See also discussion on nitrate in Section 5.6.5.

4.4.4. Evaluation

The groundwater model results show that at the regional scale, groundwater levels and storage at the Full SFPUC Storage Account represent the highest water levels. However, the increase in water levels and storage as a result of the Full SFPUC Storage Account relative to Scenario 1 does not appear to be sufficient to result in a substantial rise in the water table (or shallow aquifer water levels) above the 70-foot depth threshold associated with the potential mobilization of shallow contaminants.

In general, Model Layer 1 results show that the maximum rise in water table (40 feet to 80 feet rise) would occur primarily in the Daly City area, where large depths to the water table (200 feet to 300 feet bgs) exist before the GSR Project. Therefore, the rise in the water table of up to 80 feet from the GSR Project would not cause water levels to rise to within the 70 feet bgs threshold and would not be anticipated to cause mobilization of contaminants in soil or shallow aquifer conditions.

At the Full SFPUC Storage Account condition, the overall rise in water tables resulting from the GSR Project is less than 5 feet in the South San Francisco and San Bruno areas. However, as shown in Attachment 10.6-A, the maximum rise in water table could reach locally to about 20 feet in the South San Francisco area and 10 feet in the San Bruno area. These changes are smaller compared to those in the Daly City area and should be viewed in the context of the shallow depth to water table conditions (less than 100 feet bgs) and the locations of the PCAs, which are pre-existing conditions. As further discussed in Section 5, the maximum rise in water tables resulting from the GSR Project does not appear to affect areas with existing contaminants that are located in the soil and/or in the shallow depths of water. Therefore, this small increase in water levels from the GSR Project operations in these areas does not appear to be an issue with respect to the mobilization of contaminants.

Changes in flow directions in Model Layer 1 are apparent in response to the GSR Project. However, the effect of change in flow directions is not anticipated to affect the existing contaminants and plumes because of their geographic locations and/or depths (e.g., Model Layer 1 groundwater levels in the Daly City area are projected to remain well below 70 feet bgs threshold depth under Scenario 2) (Section 5).

4.5. Scenario 4 - Cumulative Scenario Analysis

Scenario 4 includes the proposed operation of both the GSR and SFGW Projects, projected pumping for the PAs and third party pumpers such as irrigation pumping, and other foreseeable projects. Reasonably foreseeable projects that are considered under the cumulative scenarios include Daly City's Vista Grande Drainage Area Improvements Project and Holy Cross cemetery future build-out. A detailed description of the model assumptions used for Scenario 4 is presented in the Task 10.1 TM (Kennedy/Jenks, 2012b).

4.5.1. Water Levels

Hydrographs corresponding to the selected 11 locations for Model Layer 1 and Model Layer 4 are presented in Appendix 10.6-A. Results from Scenario 4 in the South Westside Basin are similar to those from Scenario 2. The combined effects of the two SFPUC Projects are most notable in the Daly City area due to the proximity to SFGW Project operations in the North Westside Basin. In the South San Francisco and San Bruno areas, there is no appreciable difference between Scenario 4 and Scenario 2 with the GSR Project. Therefore, the findings presented in Section 4.4 for Scenario 2 are applicable to Scenario 4.

Similar to Scenario 2, the lowest groundwater levels predicted in the South Westside Basin for Scenario 4 correspond to the Design Drought. Recovery of groundwater levels, relative to simulated Scenario 1 conditions, is expected to be similarly discrete during the GSR Project put periods, as shown in hydrographs in Attachment 10.6-A. During hold periods, the PAs would return to their designated pumping, which is essentially the same as the pumping under Scenario 1. The trends seen in groundwater levels during hold periods in Scenario 4 therefore tend to follow trends seen in Scenario 1.

4.5.2. Depth to Water

Figure 10.6-10 shows the depth to water contour map generated for Scenario 4 to represent conditions at the Full SFPUC Storage Account. Under Scenario 4, the combined effects of the GSR and the SFGW Projects in the northern portions of the South Westside Basin result in depth to water table conditions very similar to Scenario 2 at the Full SFPUC Storage Account condition (Scenario Year 7). However, there are slight spatial variations in the depth to water between Scenario 4 and Scenario 2. These can be attributed to the effects of the SFGW Project and very minor modifications in the PA pumping assumptions, primarily for the Daly City and Cal Water municipal wells. In general, the Scenario 2 results are more conservative than the Scenario 4 results with respect to rising water table conditions. This is because the SFGW Project is absent from Scenario 2. Under Scenario 4, only slightly higher depths to water table are experienced than in Scenario 2. These are located primarily in the Daly City area and occur as a result of shifting a portion of the Daly City pumping under the Existing Conditions to the proposed DC-A Replacement well under the Cumulative Scenario (which is located on the west side of Daly City, further away from the well locations under the Existing Conditions).

4.5.3. Groundwater Flow Directions

Model estimated groundwater flow directions in Model Layer 1 for Scenarios 1 and 4 are presented in Figures 10.6-12 and 10.6-16 for the Full SFPUC Storage Account and in Figures 10.6.13 and 10.6-17 at the end of the Design Drought. The effects of the Cumulative Scenario in the South Westside Basin are very similar to those of Scenario 2 for the GSR Project because the SFGW Project under the Cumulative Scenario is concentrated in the North Westside Basin.

At the end of the Design Drought, Scenarios 1 and 4 show strong flow directions towards the Daly City, Colma and South San Francisco areas of the Basin where the majority of pumping would occur (Figures 10.6-13 and 10.6-17). Similar to Scenario 2, the most notable difference for Scenario 4 compared to Scenario 1 is the increased pumping in the Daly City area. As a result of this change, the overall flow direction south of Daly City appears to be primarily towards Daly City.

At the Full SFPUC Storage Account, the flow directions in Scenario 4 tend to be similar to those of Scenario 1, but slight changes are apparent in the Daly City area where the flow direction changes from toward the pumping area under Scenario 1 to a more southwesterly flow direction under Scenario 4.

4.5.4. Evaluation

The effects of Scenario 4 in the South Westside Basin are similar to those of Scenario 2. Because the SFGW Project operates solely in the North Westside Basin, the majority of the SFGW Project effects are limited to the general extent of that area. Therefore, the general model findings for Scenario 2 are also applicable for the Cumulative Scenario with respect to water quality effects.

In summary, the model analysis results suggest that the Cumulative Scenario would not cause mobilization of contaminants in soil or shallow aquifer zones as a result of increases in groundwater levels and storage in the South Westside Basin. The model results show that at the regional scale, the groundwater levels and storage associated with the Full SFPUC Storage Account condition represent the highest levels. However, the increase in water levels and storage as a result of the Full SFPUC Storage Account under the Cumulative Scenario relative to Scenario 1 does not appear to result in a substantial rise in the water table (or the water levels in the shallow aquifer) (Figure 10.6-10). Therefore, increases in water levels and storage from the Cumulative Scenario do not appear to be an issue with respect to the mobilization of shallow contaminants and plumes. Changes in flow directions in Model Layer 1 are apparent under Scenario 4 and similar to those conditions anticipated for Scenario 2. Therefore, general findings presented in Section 4.4.4 for Scenario 2 would be applicable for the Cumulative Scenario with respect to the effects of changes in flow directions on water quality.

5. Empirical Analysis

This section describes the empirical analysis for evaluating the effects of potential changes in groundwater quality as a result of the possible changes in groundwater levels and storage associated with the GSR Project operations. The focus is on existing and open regulated cleanup sites, referred to as possible contaminating activities or PCAs. Records of known PCAs were compiled from the following sources and relevant sites were included in Preliminary DWSAPs submitted to the CDPH. These sites were mapped and are further discussed in Section 5.2.3 as part of the CDPH DWSAP documentation and analysis of groundwater protection zones.

The main criterion to be addressed with respect to groundwater quality is the potential mobilization of contaminants in groundwater and soil as a result of possible increases in shallow groundwater levels from the GSR Project operations. In addition, the potential change to the shallow groundwater flow direction is also considered as this may influence existing contaminant plumes. This assessment also evaluates groundwater quality effects based on historical land use such as localized nitrate distribution and assessment of potential contamination from cemeteries.

5.1. Data Sources

As noted in Section 3.3, data sources listed below were compiled and evaluated at the basin-wide scale and in the vicinity of the pumping areas for the GSR Project.

- Records of known contaminating activities from GeoTracker (SWRCB, 2012);
- Records of known historical land disposal sites (SWIS, 2010);
- Records of DTSC sites (California DTSC, 2010);
- Records of SLIC sites (San Francisco Bay RWQCB Spills, Leaks, Investigations, and Cleanup, 2010); and
- Recent 2008 nitrate measurements in the South Westside Basin.

The databases used for the analysis were mapped in a Geographic Information System (GIS). Data compiled for the existing regulated sites, including the GeoTracker, SWIS, DTSC, and SLIC databases, are available in electronic format and can be provided upon request.

5.2. Approach and Methodology

An inspection level assessment was conducted using a comprehensive mapping of listed PCAs in the GSR Project area. It was the main intent of this qualitative assessment to investigate basin-wide soil and groundwater contamination activities. The approach included a basin-wide compilation and review of known contaminant sites at the regional scale. First, a basin-wide screening was applied to identify known existing open regulated sites across the entire GSR Project area in the South Westside Basin. Figure 10.6-18 is an index figure to Figures 10.6-19 through 10.6-23 that show the open regulated site locations and recorded depths to groundwater (also in Plate B-1). Listings of open and closed sites are included in Table B-1 in Attachment 10.6-B. Table B-1 lists open and closed regulated sites within the 2,000 feet groundwater protection zones and the South Westside Basin boundary. The relevant databases were sorted based on salient themes such as the type of cleanup site, regulatory status (e.g., open or closed), and the potential media affected (e.g., soil, drinking water aquifer). GIS maps were created to show locations of the existing PCAs with respect to these themes over the entire South Westside Basin. These maps are represented as Figures 10.6-19 through 10.6-23 for the open regulated sites.

To assess the potential for water quality changes related to rising groundwater levels associated with the GSR Project, the areas that may be most susceptible to groundwater quality effects were identified. This identification was based on four key components that were evaluated jointly in order to determine the vulnerability of specific portions of the groundwater basin. The four key components are:

1. Depth to water in the perched water bearing zone or in the Shallow Aquifer;
2. Presence of confining layers in the subsurface;
3. Groundwater protection zones around the GSR Project pumping centers; and
4. Status and spatial distributions of PCAs in the GSR Project area.

5.2.1. Depth to Water

Depth to water is considered an important parameter with respect to groundwater vulnerability, because it represents the distance a contaminant must travel through the unsaturated zone before reaching the water table (or top of the Shallow Aquifer) and affecting quality of water supply. It is noted that perched water bearing zones occur and are considered to be overlying the Shallow Aquifer in the Basin. According to the GeoTracker database, contaminants from PCAs in the GSR Project area are mostly characterized as occurring in soil and in the perched zones above the primary or drinking water supply aquifers.

In general, shallow contaminants below ground are more likely to affect unsaturated and perched water bearing zones in areas with a shallow water table in the Shallow Aquifer. Hence, areas with shallow water levels have a higher risk of groundwater contamination, while areas with a deep water table would present a lower risk to groundwater quality. Thus, depth to water table was analyzed in conjunction with the locations and status of the existing PCAs.

Based on groundwater model results, the depth to water contour maps for Scenario 1 (Figure 10.6-7) and Scenarios 2 and 4 (Figures 10.6-8 and 10.6-10) are compared to evaluate the potential for higher water levels in the Shallow Aquifer (Model Layer 1) due to the GSR Project in-lieu recharge operations. For the GSR Project, the Full SFPUC Storage Account, which represents 60,500 af of in-lieu recharge, generally has the highest water levels in the South Westside Basin. Therefore, the depths to water contour maps for Scenarios 1, 2 and 4 were prepared at the time period that corresponds to the Full SFPUC Storage Account (Scenario Year 7).

Depths to the water table in Model Layer 1 in Scenarios 2 and 4 were compared relative to Scenario 1 to demonstrate the effect of GSR Project operations on water levels, as shown in Figure 10.6-9 for Scenario 2 and Figure 10.6-11 for Scenario 4. Results of the modeling analysis presented in Section 4 demonstrate that GSR Project operations in the production depths (Primary Production Aquifer) would result in about 80 feet of water level rise in Model Layer 1, which generally represents conditions in the Shallow Aquifer. The largest rise in water levels is naturally centered on the portion of the groundwater basin with the historically lowest water levels under pre-GSR Project conditions – i.e., beneath Daly City (Figures 10.6-9 and 10.6-11). Water depths in the Shallow Aquifer are further evaluated in Section 5.6.1.

5.2.2. Presence of Confining Layers In the Subsurface

The presence of confining layers comprised of fine grained sediments above the GSR Project pumping zones is critical for assessing potential groundwater quality changes from the GSR Project operations. Confining layers exert controls on the groundwater flow and direction. Confining strata of fine grained aquifer material, when encountered in the subsurface between the PCAs and the deep pumping aquifer, could restrict flow from the shallow zone to the production zone (Primary Production Aquifer) and isolate the pumping effects in the deep production aquifer. The following describes the main geographic areas of significance in the Westside Basin:

- In the North Westside Basin away from Daly City, the presence of the -100-foot clay clearly separates the Primary Production Aquifer from the overlying Shallow Aquifer.
- The -100-foot clay is not encountered beneath Golden Gate Park and differences in groundwater levels between the two aquifers indicate that the Shallow Aquifer is unconfined and the Primary Production Aquifer is semi-confined, with a downward component of groundwater flow.
- Local stratigraphy and recently-obtained groundwater level data suggest that in the Daly City, South San Francisco, and San Bruno areas, the Primary Production Aquifer is confined to semi-confined. The -100-foot clay is no longer present beginning in the Daly City area, and thus the Shallow Aquifer is also not formally defined for this area.

- Nonetheless, from South San Francisco to San Bruno, the presence of thick surficial Bay Mud deposits of even lower relative permeability likely provides an even greater degree of confinement to the Primary Production Aquifer in that area.

5.2.3. Groundwater Protection Zones

The concept of groundwater protection zones that was developed by the CDPH, formerly Department of Health Services, for the DWSAP was applied in this analysis as the basis for defining the anticipated area of influence around each pumping (existing or proposed) well. The overall objective of the DWSAP is to ensure the quality of drinking water sources is protected. Permitting of a new water supply well requires that a DWSAP assessment be completed as part of the permit process and submitted to CDPH. Compliance with the CDPH requirements is a key part of groundwater quality protection.

Groundwater protection zones as defined by the CDPH for DWSAP represent approximate areas from which groundwater may be withdrawn by the pumping well in two, five, and ten years of pumping. Groundwater protection zones associated with two, five, and ten years of travel time for groundwater are known as Zone A, Zone B5, and Zone B10, respectively. These zones also represent the area in which contaminants released to groundwater could migrate and potentially affect the groundwater extracted by wells located within the designated zones. The size of each zone is determined by the pumping rate of the well, interval of pumping, and local hydrogeologic conditions. The CDPH requires a minimum radius for each protection zone: 600 feet for Zone A, 1,000 feet for Zone B5, and 1,500 feet for Zone B10. If the calculated radii of the protection zones are less than the CDPH minimums, the minimum values are used instead. DWSAP includes the preparation of an inventory of PCAs that can show the release of contaminants within the protection zones, similar to the empirical analysis presented in this section.

For this analysis, 2,000-foot groundwater protection zones delineated by the DWSAP as illustrated in Figure 10.6-18 (also in Plate B-1) were considered as areas of influence around a pumping well(s) during take period pumping by the GSR Project and PAs. The 10-year time period, or Zone B10, was considered to represent a conservative groundwater protection zone around the pumping wells - given that the take period pumping during the Design Drought would occur over 7.5 years for Scenarios 2 and 4.

For the GSR Project, preliminary DWSAP groundwater protection zones were prepared for the 16 proposed production well sites (Figure 10.6-2). Estimated groundwater protection zone for the 10-year travel time for these well sites ranged from the minimum CDPH requirement of 1,500 feet to approximately 1,900 feet. For this analysis, a more conservative approach was taken, assigning a groundwater protection zone of 2,000 feet around each of the PA wells and the GSR Project wells. Consistent with DWSAP, the assigned groundwater protection zone serves as a search radius around the wells to identify PCAs that may be most affected by the GSR Project operations. Based on the above, contaminants released to groundwater could migrate downward and potentially affect groundwater extracted by the GSR Project wells. Additionally, contaminants within or in proximity to the GSR Project anticipated areas of influence can also be affected but may not be captured by groundwater extraction.

The inventory of PCAs was evaluated for all 16 proposed GSR Project well sites and included in the Preliminary DWSAPs. DWSAPs for seven of the 16 proposed wells were submitted to the CDPH in 2009. SFPUC received a letter from the CDPH for the approval of the seven well sites and CDPH did not place any restrictions or special conditions on well design or construction (CDPH, 2009). DWSAP documentation for the remaining nine well sites has not been submitted to CDPH since these wells will not be constructed until 2014.

5.2.4. Possible Contaminating Activities (PCAs) Analysis

For this study, PCAs are defined as human activities at the ground surface that are actual or possible sources of contamination for groundwater. PCAs include sources of chemical contaminants that could have adverse effects upon human health. Risk of groundwater contamination is directly related to specific land uses that entail handling of hazardous materials or waste (e.g., dry cleaners, solid waste facilities, gas stations and other facilities with underground tanks storing hazardous materials).

The objective of the PCA analysis is to compile a comprehensive database of PCAs in the GSR Project area and to develop a technically-sound and scientifically-defensible methodology to identify areas with PCAs that may be affected by the GSR Project due to rising water levels or change of flow directions. The PCA analysis was conducted at different scales, beginning from a regional scale to a more local scale in the vicinity of the PA municipal wells and GSR Project wells. A basin-wide map of the locations of known existing regulated sites was prepared to evaluate spatial distribution of all PCAs. PCAs were tabulated, grouped, and reviewed in appropriate categories (e.g., case status, case types, potential media affected) to characterize their status.

In the next level of inspection, the primary focus was on areas in the vicinity of the existing PA municipal wells and GSR Project wells. Locations of reported PCAs were mapped within the groundwater protection zones identified around the wells.

At the local scale, GIS maps were prepared to illustrate areas that would be most vulnerable with respect to groundwater quality because of the presence of PCAs within groundwater protection zones. This analysis focused only on open sites within the groundwater protection zones. PCA sites that are reported to be closed under regulatory oversight were screened out because the presence of closed sites is not anticipated to pose a groundwater quality risk. At this scale, PCAs were tabulated and grouped with their identification to further characterize the open PCAs with respect to their risk to groundwater quality. These sites were considered a risk to groundwater quality and their status was analyzed with respect to the potential affected media (soil, groundwater, or drinking water aquifer). Within each groundwater protection zone, pertinent information relating to the type of PCA record, type of land use activity, leaking underground storage tank information and other hazardous material information at the existing regulated site was noted and tabulated in summary tables. Sites with notable or possible contamination concerns were highlighted for further discussion in Sections 5.5.1 and 5.6.4.

5.3. Nitrate

As part of the groundwater quality assessment, the current condition of nitrate in the South Westside Basin was reviewed to identify general areas that may be affected by nitrate from historical land use applications. As discussed in Section 3, elevated nitrate concentrations, exceeding the drinking water standards, are known to exist in certain areas in the Basin such as Daly City. The nitrate measurements taken between April 2008 and September 2008 from the existing monitoring wells and the multiple nested monitoring wells installed by the SFPUC as part of the GSR Project (SFPUC, 2009a; Kennedy/Jenks, 2010) were compiled. Nitrate data are sampled in wells screened in the Shallow, Primary Production, and Deep Aquifers. Figure 10.6-5 presents data collected from groundwater wells at different aquifer depths and depicts the overall nitrate distribution in the Basin. To differentiate a nitrate-depth relationship and to identify localized areas with high nitrate levels, nitrate data measured at different depths were plotted together at the multi-level monitoring well locations.

5.4. Cemeteries

As discussed in Section 3.2.4, cemeteries in the GSR Project area were evaluated by SFPUC for potential groundwater quality concerns because cemeteries are in the vicinity of some of the GSR Project monitoring wells and the GSR Project production wells. Data were used to address potential regulatory issues and support the Preliminary DWSAP submittal to the CDPH.

Based on the recent groundwater sampling conducted in 2009 and 2010 by SFPUC, there is no apparent groundwater contamination from cemeteries (Kennedy/Jenks, 2010), supported by data from five monitoring wells (MW-CUP-18, MW-CUP-19, MW-CUP-22A, MW-CUP-44-1, and the Linear Park monitoring well) located in the vicinity of the cemeteries.

In a study of six cemetery sites in Ontario, Canada (Soo et al., 1992), the analysis of groundwater samples collected at wells located downgradient of the cemeteries indicated that the cemeteries are not a significant source of groundwater contamination. In the same study, the calculated loading estimates for formaldehyde and nitrates being released from cemeteries supports a low potential for groundwater contamination. For comparison to the existing PCAs, the CDPH considers cemeteries as a “medium” risk with respect to water quality concerns as compared to auto service stations, which are assigned a risk ranking of “very high”.

It is also important to note that the GSR Project wells will draw groundwater from the deep Primary Production Aquifer, typically below 350 feet to 600 feet bgs and are generally protected from shallow aquifer contaminants such as possible releases from cemeteries. The upper portion of the GSR Project wells will be sealed to a depth of at least 300 feet to prevent shallow surface pollution from entering the well. This exceeds the state well sealing requirement of 50 feet.

The GSR Project is not anticipated to mobilize related constituents in groundwater because of the depth of pumping. Because of the very shallow nature of constituents from the existing cemeteries, the rise in water levels in the lower portion of the Shallow Aquifer during GSR Project put periods is not likely to mobilize these shallow constituents in the soil. Moreover, groundwater quality effects from cemeteries are controlled by land use activities unrelated to GSR Project operations. In addition, the ongoing SFPUC monitoring at the monitoring wells for the GSR Project will continue to evaluate groundwater quality conditions in the vicinity of the cemeteries.

5.5. Results of Empirical Analysis

The complete PCA database that includes maps and PCA site inventory-listing is presented in Figures 10.6-19 through 10.6-23. Attachment 10.6-B shows the locations of the reported PCAs in the GeoTracker (Plate B-1), SWIS (Figure B-1), DTSC (Figure B-2), and SLIC (Figure B-3) databases. Plate B-1 shows locations of open regulated PCA sites based on the GeoTracker database. The inventory of the GeoTracker database for closed and open sites is listed in Table B-1 in Attachment 10.6-B.

5.5.1. GeoTracker Database

Regulated sites reported in the GeoTracker database were mapped based on case status, case type, and potential media affected, as shown on the GISs maps on Figures 10.6-19 through 10.6-23 and in Plate B-1 in Attachment 10.6-B. General findings based on the evaluation of the sites are as follows:

- Among the 1,560 sites reported in the GeoTracker database in San Mateo County, 514 sites are located in the GSR Project Area while the remaining are located outside of the GSR Project area (see the inventory list in Attachment 10.6-B, Table B-1).

- Out of the 514 sites identified in the GSR Project Area, 135 sites are identified with a status of open.

- A total of 153 sites closed and open are identified within the groundwater protection zones around the pumping wells. These are evaluated in Section 5.6.

- Out of the 153 sites located within the groundwater protection zones, 51 sites are reported to be open and the remaining 102 sites are reported closed under regulatory oversight.

An inventory is presented in Attachment 10.6-B with a listing of 514 closed and open sites located in the South Westside Basin. Figure 10.6-18 and Plate B-1 (Attachment 10.6-B) illustrate the locations of regulated sites classified as open and within the South Westside Basin and the vicinity. Figures 10.6-19 through 10.6-23 present small scale site maps with the locations of PCAs for the general pumping areas (e.g., Daly City, Colma, South San Francisco, San Bruno, and Millbrae) based on the reported potential media affected for each PCA. For clarity, PCA sites are posted with only their global ID numbers and recorded depths to water based on records from the GeoTracker. They can be cross referenced with site names listed in Table B-1.

Among the 51 sites identified within the groundwater protection zones in the GSR Project area (Figures 10.6-19 through 10.6-23), several PCA sites are reported to have affected soil with no groundwater contamination or plume. The majority of the remaining sites are LUST cleanup sites related to soil and shallow groundwater contamination.

Five sites in the GeoTracker database are identified in the groundwater protection zones and characterized in GeoTracker with the "*potential media affected as aquifer used for drinking water supply*", with the exception of one site (Olympic Service Station) that is not identified as affecting the drinking water, but included and briefly discussed below due to its proximity to the proposed GSR Project well CUP-M-1. Two of the five sites are recently listed as case closed. One of the five sites is located in the San Bruno area, three sites are located in the Daly City area, and one site is in the Millbrae area. Based on the review of the most recent information available at the GeoTracker database, general findings for these five sites are summarized as follows:

- **Arco #0465 (T0608100027)** – This is an active ARCO gasoline station with underlying soil and shallow/perched groundwater affected with petroleum hydrocarbons. This site is located on the southern corner of the intersection of Southgate Avenue and Lake Merced Boulevard in Daly City. The site is about 700 feet northeast of the Daly City Westlake production well and about 1,000 feet northwest of the GSR Project well cluster site (CUP-05, CUP-06, and CUP-07) (Figure 10.6-19). Based on the 2009 monitoring report available at GeoTracker website, on-site monitoring wells were screened from 39 feet to 70 feet bgs. Data available at the GeoTracker website indicate a shallow depth to water table at approximately 56 feet bgs (Figure 10.6-19), based on data measured in 2002, as reported by the GeoTracker records.

  A deep on-site monitoring well installed to a depth of 220 feet bgs (below an approximate 10-foot-thick clayey silt to silt clay zone) observes water levels at much lower depths at approximately 154 feet bgs, which may represent the intermediate regional drinking water aquifer. (i.e., Primary Production Aquifer). Groundwater sampling conducted in 2009 at the intermediate on-site monitoring well and off-site shallow monitoring well (screened from 39 feet to 49 feet bgs) detected no petroleum hydrocarbons. On-site shallow monitoring wells showed plume concentrations to be either stable or declining over time, with the contaminant plumes being contained on site.

- **Chevron 9-5584 (T0608179897)** – This was a former Chevron station. Currently, a strip mall and parking lot occupy the site. It is located on the northeastern corner of the intersection of El Camino Real and San Benito Avenue, about 1,700 feet south of the San Bruno production well No.17 (Figure 10.6-22). Site monitoring data indicate shallow depth to water, with water levels ranging from about 20 feet to 60 feet bgs. This is consistent with data available at the GeoTracker website indicating a shallow depth to water table at approximately 34 feet bgs (Figure 10.6-22), based on data measured in 2003, as reported by the GeoTracker records. The site has both soil vapor and groundwater extraction wells. The most recent monitoring event in March 2010 shows a benzene and TPH plume mostly contained on site.

- **Olympic Service Station (T0608121993)** – This is an existing service station located about 980 feet upgradient of the GSR Project proposed well CUP-M-1 (Figure 10.6-23). During the course of aquifer tests at monitoring well MW-CUP-M-1, the water level in a shallow monitoring well (Olympian MW-3, located at the Olympic Service Station) about 950 feet west of MW-CUP-M-1 was monitored. This was done to determine whether the pumping at MW-CUP-M-1 would affect any surrounding wells in the Shallow Aquifer. The pumping at M-1 resulted in no discernible effects on the water levels at the Olympic Service Station monitoring wells even after the removal of barometric pressure.

  Based on the review of the Pangea Environmental Services, Inc. 2008 Groundwater Monitoring Report (Pangea Environmental Services, Inc., 2008) (downloaded from the GeoTracker website), concentrations of total petroleum hydrocarbons as gasoline (TPHg) and benzene detected in on-site monitoring wells are on long-term declining trends, while total petroleum hydrocarbons as diesel (TPHd) have been generally stable. No MTBE was detected in the easternmost downgradient monitoring well (MW-3), which is the closest well, at a distance of 950 feet from CUP-M-1. Soil grab sampling indicates that MTBE attenuated to a concentration of ~0.88 parts per billion (ppb) with depth. An abstract of this conclusion is also included in the Categorical Exemption for the proposed GSR Project well CUP-M-1 (SFPUC, 2009b).

  The compounds detected at the Olympic Service Station release are isolated in the shallow groundwater zones, based on data from the well log CUP-M-1 and cross-section H-H' in the TM#1 (LSCE, 2010). This is also supported by depth to water data available at the GeoTracker website indicating shallow depth to water table conditions at approximately 17.5 feet bgs (Figure 10.6-23), based on data measured in 2003. The shallow water bearing zone is underlain by clay/Bay Deposits (Qbd) from about 100 feet to 170 feet bgs.

- **Gas and Wash Partners (T10000003031)** – This is a LUST cleanup site. Contamination at this site was discovered in February 2011, when the current property owner conducted sampling beneath three underground storage tanks that were proposed to be converted to use for storage of recycled water (TEC, 2011). Sampling indicated a historical release of gasoline, benzene, toluene and xylene from two of the three storage tanks and one of the fuel dispensers. Based on the particular contaminants encountered in the sampling, TEC (2011) speculated that the petroleum hydrocarbon release occurred before the introduction of oxygenated gasoline in the late 1970s to late 1980s; the fuel storage tanks were lined in early 1999. The investigation was limited to soil sampling, and did not sample deeper than just below the USTs; groundwater was not encountered or sampled. The detected concentrations of petroleum hydrocarbons were above the Environmental Screening Levels (ESLs) mandated for shallow soil at a commercial property over a potential drinking water source. TEC (2011) noted that a nearby LUST site (approximately 500 feet to the east) had groundwater depths no shallower than 160 feet below the ground surface. Based on the current information available from the site investigation report, there is no supporting data indicating this site has affected the drinking water supply aquifer.

  As of May 20, 2011, the Gas and Wash Partners site is listed as open-site assessment for the site characterization and investigation. The site is located east of well cluster CUP-05, CUP-06 and CUP-07, and north of Daly City Well No. 4 (Figure 10.6-19). This site is approximately 1,900 feet from CUP-07 and 470 feet from Daly City No.4.

- **Chevron 9-6982 (T0608100148) Classified as "Completed - Case Closed" 12/27/2011** – This is a Chevron service station with underlying soil and shallow/perched groundwater affected with gasoline. The site is located on the north side of John Daly Boulevard, about 2,000 feet north of the Daly City Westlake production well (Attachment 10.6-B, Table B-1). This site is just outside of the 2,000-foot search radius around the Daly City Westlake well, but due to its proximity, it was considered for evaluation.

  The site contains an underlying aquitard at a depth of approximately 30 feet bgs, as reported by the GeoTracker website and three different shallow water bearing zones to depths at 80 feet bgs. Based on the 2010 monitoring report available at the GeoTracker website, depth to the water table ranges from 26 feet to 35 feet bgs in the shallowest zone and at approximately 74 feet bgs in the deep zone. No total petroleum hydrocarbons as diesel (TPHd) were detected in soil samples collected during monitoring well installation to a depth of 35 feet bgs.

  Depth to water table at the site is relatively shallow, ranging from 63 feet to 74 feet bgs. The site is closed given that the extent of hydrocarbons in soil and groundwater are adequately defined, the sources of MTBE were removed in 1997, and the soil has residual hydrocarbon concentrations below the ESL.

5.5.2. SWIS Database

Locations of reported land disposal sites are shown in Attachment 10.6-B, Figure B-1 based on grouping by case type (i.e., closed, closing, and active) and facility type (i.e., disposal, composting, and transfer station). Fourteen (14) disposal/composting/transfer sites were identified in northern San Mateo County; of these, six sites are located in the South Westside Basin. However, as shown in Figure B-1, five sites out of the six are too far away from the GSR Project pumping areas and located near the Bay or the Pacific Ocean.

Based on the above analysis, there is only one land disposal site within the vicinity of the GSR Project wells. This site is the closed Junipero Serra Solid Waste Disposal Site, located in Colma about 1,700 feet southwest of CUP-18 and 2,500 feet west of CUP-19. This landfill was a solid waste disposal site that began operations in the year 1956 and accepted primarily commercial solid wastes. After site closure in 1983, the site was ultimately developed for commercial land uses, collectively known as the Metro Center. There are no current water quality issues reported on this closed landfill site.

5.5.3. DTSC Database

Locations of the sites reported by California DTSC are shown in Attachment 10.6-B, Figure B-2. Fifteen (15) sites were reported in the South Westside Basin and the majority of these sites are concentrated in South San Francisco, Daly City, and City of Brisbane away from the general pumping areas.

5.5.4. SLIC Database

Locations of the reported SLIC sites are shown in Attachment 10.6-B, Figure B-3 based on status type (i.e., inactive and active). Fifteen (15) sites were reported in the South Westside Basin. Similar to the findings with the DTSC database, the majority of these SLIC sites are located in South San Francisco away from the general pumping areas. The closest distance of existing SLIC site is approximately 1,100 feet to the proposed Cal Water municipal well SSF1-24 (shown as 41S0154 on Figure B-3) and 1,400 feet to the proposed GSR Project well CUP-41-4 (shown as 41S0048 on Figure B-3). As noted in TM 10.1, the Cal Water proposed well SSF1-24 is considered redundant and no pumping was assigned to this well in the groundwater modeling analysis.

5.6. Evaluation

The following evaluation is based on the approach introduced in Section 5.2 of combining the four key components of the GSR Project conditions and supporting data.

5.6.1. Depth to Water in the Shallow Aquifer

Based on the evaluation of the regulated PCAs reported in the GeoTracker database (Section 5.5.1), GSR Project operations under Scenarios 2 and 4 are not anticipated to influence sites with soil contamination located within the anticipated area of influence of the GSR Project. This is based on comparing the depth to water contours of Scenario 1 to Scenarios 2 and 4 (Figures 10.6-7, 10.6-8, and 10.6-10).

The intent of Figures 10.6-7, 10.6-8, and 10.6-10 is simply to show that shallow depths - of less than 70 feet - to groundwater as predicted in Model Layer 1 for the Shallow Aquifer primarily occur on the fringes of the GSR Project area, both with and without the GSR Project operations. It is noted that depths to water estimated by the groundwater model for Model Layer 1 do not distinguish multiple water bearing zones such as perched groundwater.

Scenarios 1, 2 and 4 show that the shallowest estimated occurrence of groundwater is beneath the City of Millbrae, San Francisco International Airport, and vicinity. The model results suggest that groundwater detected at and east of the GSR Project well CUP-M-1 could occur at depths of less than 50 feet (green and blue contours). However, the PCAs mapped for this particular area are all reported to have depths to water at less than 10 feet south of CUP-M-1 and depths of less than 17.3 feet between CUP-M-1 and north to SB No.16, as shown in Figures 10.6-22 and 10.6-23, which depict measured depth to water at the PCA sites based on the GeoTracker database. Therefore, rising water levels in Model Layer 1 during the GSR Project operations would not pose a risk of remobilizing existing contamination in the soil and/or shallow groundwater systems.

Other shallow depths to groundwater simulated by Scenarios 1 and 2 are beneath the east side of the City of South San Francisco. PCA sites mapped for this particular area have reported depths to water between 6 feet to 45 feet within the anticipated groundwater protection zones of CUP-36-1 and CUP-41-4 in this area (Figures 10.6-21). The PCAs located east the GSR Project well CUP-41-4 are all reported to have depths to water of less than 13 feet. Beneath the areas of Daly City and Colma, groundwater model estimated water levels are maintained low between 200 feet to 300 feet bgs. This can be generalized to the entire GSR Project area with water levels estimated to be at 200 feet to 400 feet bgs under the Full SFPUC Storage Account.

The lack of notable changes in water levels is apparent on the fringes of the GSR Project area (dark colored contours on Figures 10.6-7, 10.6-8, and 10.6-10). It is concluded that the shallow water levels encountered in these areas represent pre-project conditions and hence are not subject to further evaluation in regards to the GSR Project and its effect on existing shallow PCA releases.

Relative Changes in Water Levels

To further illustrate the model-simulated rise in water levels as related to PCA sites, the changes in shallow depth to water levels relative to Scenario 1 are quantified and illustrated as contours in Figure 10.6-9 for Scenario 2 with the GSR Project and Figure 10.6-11 for Scenario 4 with the combined GSR and SFGW Projects under the Cumulative Scenario. The greatest change in water levels is anticipated to be in the historically deepest ground waters in the South

Westside Basin – i.e., City of Daly City. However, the changes in water levels from the GSR Project operations under Scenarios 2 and 4 did not produce notable rise of water levels in the Shallow Aquifer that could influence the remobilization of shallow contaminants above the 70 feet bgs. This is shown by the relative changes in depth to water contours in Figure 10.6-9 for Scenario 2 and in Figure 10.6-11 for Scenario 4.

Changes in water level contours for Scenarios 2 and 4 are also shown in close-up views with PCA sites and their reported depths to water in Figures 10.6-19 to 10.6-23. These figures illustrate that the model simulated rise in water levels from Scenarios 2 and 4 relative to Scenario 1 are similar, with minor to no variations between the two model scenarios; thus, the findings for the effects of Scenarios 2 and 4 with respect to rise in water levels, and resulting effects on the existing PCA sites are essentially the same.

5.6.2. Presence of Confining Layers In the Subsurface

The aggregate occurrences of aquitards and intervening fine grained units between shallow contaminants and the groundwater production zones could restrict vertical migration of contaminants to the deep groundwater zones; hence, isolating the pumping effects in the Primary Production Aquifer.

As discussed in Section 2.6.4, additional evidence of the confinement of the Primary Production Aquifer beneath the cities of Colma and Millbrae is apparent from relative groundwater elevations measured in the multilevel GSR Project monitoring well clusters installed by SFPUC in 2008 and 2009 (Kennedy/Jenks, 2009 and 2010). At each monitoring well location, there are three or four separate wells installed at discrete depths. The completion depths for these wells generally correspond to the Primary Production Aquifer and the Deep Aquifer, and although it is not formally recognized in this area, an apparent equivalent to the Shallow Aquifer as defined in the North Westside Basin. Differences in groundwater levels measured in the GSR Project monitoring wells – or the lack of neutral vertical gradients – suggest likely hydraulic separations of these three aquifers in the central and south basin area.

5.6.3. Groundwater Protection Zones around GSR Project and PA Municipal Wells

The intent of this discussion is to characterize potential groundwater effects of the 51 PCA sites that are listed as open and that are located within the groundwater protection zones of the GSR Project and the PA municipal wells (See Section 5.2.3). The focus is to evaluate the likelihood of the GSR Project operations to draw down contaminants from PCA sites in the shallow zone into the Primary Production Aquifer and into the supply wells.

Contaminants as reported in PCA sites in soil, shallow or perched groundwater zones within the GSR Project area (Figures 10.6-19 to 10.6-23) are not anticipated to be mobilized due to the GSR Project operations. This conclusion is based on the reported shallow nature of these cleanup sites (Section 5.6.4) and intervening clay and other fine grained aquifer materials, suggesting varying degree of hydraulic separation between PCAs and the Primary Production Aquifer (Section 5.6.2).

5.6.4. PCA Status and Spatial Distribution of PCAs in the GSR Project Area

Out of the 51 PCAs identified in the GSR Project groundwater protection zones, four PCA sites (Arco #0465, Chevron 9-5584, Gas and Wash Partners, and Chevron 9-6982), were reported to have listed potential media affected as *"aquifer used for drinking water supply*" within the groundwater protection zone of 2,000 feet (see Figure 10.6-18 for the basin-wide view and Figures 10.6-19 through 10.6-23 for the small scale site maps). Only two open PCAs are within the GSR Project groundwater protection zones: Arco #0465 and Gas and Wash Partners are within the GSR Project well cluster CUP-5, 6, and 7 (Figure 10.6-19). Only one open PCA (Chevron 9-5584) is within the PA groundwater protection zones (Figure 10.6-23). The remaining PCA site Chevron 9-6982 is case closed (see Section 5.5.1 for details).

Given the current status of these sites with contained, stable, or declining concentrations over time, and the shallow nature of the contaminant plumes and the ongoing cleanup activities, the GSR Project is not anticipated to mobilize contaminants at the three open sites (Arco #0465, Chevron 9-5584, and Gas and Wash Partners). Therefore, the potential for the GSR Project to cause water quality effects at these PCA sites is low, further supported by the underlying fine grained deposits including the Bay-Mud.

5.6.5. Nitrate

Occurrence of elevated nitrate levels in the Basin is localized and present in the Shallow Aquifer and the upper part of the Primary Production Zone. Elevated nitrate concentrations in the Primary Production Aquifer are limited in extent to isolated areas of groundwater beneath Daly City, such as the inactive Daly City A Street production well and the nearby GSR Project monitoring well MW-CUP-10A-500 (Figure 10.6-5).

The GSR Project monitoring well MW-CUP-23-230 located in South San Francisco has a reported nitrate concentration of 64.9 mg/l. Also in South San Francisco where Cal Water pumping occurs, the detected nitrate concentration was 47 mg/l in SS1-19, which is slightly above the primary MCL of 45 mg/l, and 35 mg/l in SS1-20 (Note that groundwater from these Cal Water wells is blended with SFPUC surface water prior to distribution and the resulting blend fully meets all drinking water standards).

In light of findings from the modeling analysis, as suggested by the model results presented in Section 4, the GSR Project operations could have an effect on the current elevated nitrate conditions reported at depths in the Basin, mainly as a result of the potential rise in water levels in the lower portions of the South Westside Basin and changes in flow directions. The potential rise in water levels in the lower portions of the Shallow Aquifer could mobilize nitrate in groundwater. Conversely, it is likely that an increase in groundwater volume could result in a decrease in overall nitrate concentrations in the Primary Production Aquifer as a function of dilution – see Section 6.1 for more discussion.

5.6.6. Cemeteries

The recent groundwater sampling conducted by the SFPUC from five monitoring wells located in the vicinity of the cemeteries demonstrated no groundwater contamination from cemeteries. The GSR Project is not anticipated to mobilize related constituents in groundwater because of the depth of pumping. Because of the very shallow sources, the rise in water levels in the lower portion of the Shallow Aquifer during GSR put periods is not likely to mobilize these shallow constituents in the soil; moreover, groundwater quality effects from cemeteries are controlled by land use activities unrelated to the GRS Project operations.

6. Summary

This section summarizes the findings from the numerical groundwater model and empirical analyses.

6.1. Scenario 2 - GSR Project

The MODFLOW model results indicate that most of the changes relevant to the GSR Project are in the South Westside Basin. Changes in groundwater levels are most notable in the vicinity of the GSR Project wells (Figures 10.6-9 and 10.6-11), including the wells operated by the SFPUC and the PAs. This is because of in-lieu recharge during put periods and extraction of groundwater during take periods. More specifically for the GSR Project, the issues evaluated in this TM focused on the potential mobilization of contaminants in groundwater as a result of pumping or increase in groundwater levels and storage in the South Westside Basin. These higher water levels could occur under the Full SFPUC Storage Account of 60,500 af. This value represents an additional 40,500 af above the initial (June 2009) condition of 20,000 af.

The model results show that water levels are generally higher at the Full SFPUC Storage Account than at other times during the 47.25 years of simulation. In other words, at the basin-scale, the Full SFPUC Storage Account would be the most conservative with respect to higher groundwater levels that may occur due to the GSR Project operation. The modeling analysis further demonstrates that the GSR Project would generally produce higher groundwater levels in the South Westside Basin relative to Scenario 1 during the majority of the 47.25 year simulation period. Simulated water levels for the GSR Project tend to rise during the long put periods and decline during the long take periods (e.g., during the Design Drought) compared to Scenario 1. As shown by the model estimates, the water levels during the hold periods tend to follow the trends seen in Scenario 1. This occurs because during the hold periods both Scenarios 1 and 2 have similar pumping for the PA municipal wells (6.84 million gallons per day (mgd) under Scenario 1 and 6.9 mgd under Scenario 2). Trends vary by locations and show negligible to moderate declining water levels in response to the continued PA pumping during the hold periods.

However, the simulated depth to water (represented by water levels in Model Layer 1) in Scenario 2 during the Full SFPUC Storage Account condition shows deep water levels in most portions of the Basin. This suggests that the response of Model Layer 1 to changes in pumping conditions in deeper layers (e.g., Model Layer 4) is small, especially relative to the substantial depth to water in the Shallow Aquifer in the center of the Basin (Figures 10.6-7, 10.6-8, and 10.6-10). Therefore, rising water levels in Model Layer 1 during the GSR Project operations are expected to stay between 200 feet to 300 feet deep and are not anticipated to rise near the 70-foot threshold depth that is the indicator for risk of remobilization of existing contamination in the soil and/or shallow groundwater systems.

Based on the location and status of regulated existing cleanup sites in the GSR Project area, it is anticipated that the reported sites with contaminated soil and/or shallow unconfined/perched water bearing zones within the anticipated area of influence of the GSR Project would not be affected by the GSR Project pumping operations. Furthermore, the GSR Project is not expected to have an effect on existing groundwater remediation projects. This conclusion is based on the shallow nature of these reported cleanup sites and the aggregate thicknesses of intervening clay and sand layers between the shallow aquifer and deep pumping aquifer, from which the GSR Project would pump.

In light of the findings from the modeling analysis, as suggested by the model results presented in Section 4, the GSR Project operations could have an effect on the current isolated nitrate conditions reported at depths in the Basin, mainly as a result of the potential rise in water table in the lower portions of the Shallow Aquifer and changes in flow directions. It is likely that an increase in groundwater volume could result in the decrease in overall isolated nitrate concentrations in the Primary Production Aquifer as a function of dilution. While the occurrence and extent of nitrate in groundwater are mainly due to historical land use and natural recharge processes that are not related to the GSR Project operations, the effect of the GSR Project on nitrate distribution (lateral or vertical extents by spreading of nitrate in groundwater) is uncertain and the location of reported nitrate detections may change as more extraction wells come online. Therefore, the GSR Project effect on pre-Project nitrate conditions will require continued water quality monitoring to assess changes in nitrate distribution and concentration trends when the GSR Project production wells are commissioned.

With respect to water quality concerns near the cemeteries, the recent groundwater sampling conducted by the SFPUC from five monitoring wells located in the vicinity of the cemeteries demonstrates no existing groundwater contamination from cemeteries.

6.2. Scenario 4 - Cumulative Scenario

The Cumulative Scenario assumes the combined operations of the GSR Project and SFGW Project and other future projects that can operate concurrently. The MODFLOW simulation results under Scenario 4 show that groundwater levels in the South Westside Basin are similar to Scenario 2. Because the SFGW Project is focused in the North Westside Basin, the overall effect of the SFGW Project on the South Westside Basin is minimal. Model-simulated groundwater levels for the combined GSR and SFGW Projects south of Lake Merced and near Daly City primarily show the effects of the GSR Project, but show slightly lower water levels than the GSR Project due to the combined pumping effects of the two projects. This difference is attributed to the SFGW Project extracting and intercepting groundwater that would otherwise flow from the North Westside Basin south into the Daly City area. Groundwater levels from the Cumulative Scenario mimic the trends seen in the GSR Project in the remainder of the South Westside Basin. Near South San Francisco and San Bruno, the effects of the SFGW Project are minimal; the groundwater levels reflect conditions similar to the GSR Project Scenario.

Overall, with respect to changes in groundwater levels, depths to water, and groundwater storage, the effects of the Cumulative Scenario on the South Westside Basin are similar to Scenario 2. Therefore, the general findings discussed above for the GSR Project Scenario are essentially the same for the Cumulative Scenario.

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Figure List

Table List

Attachment List

Figures

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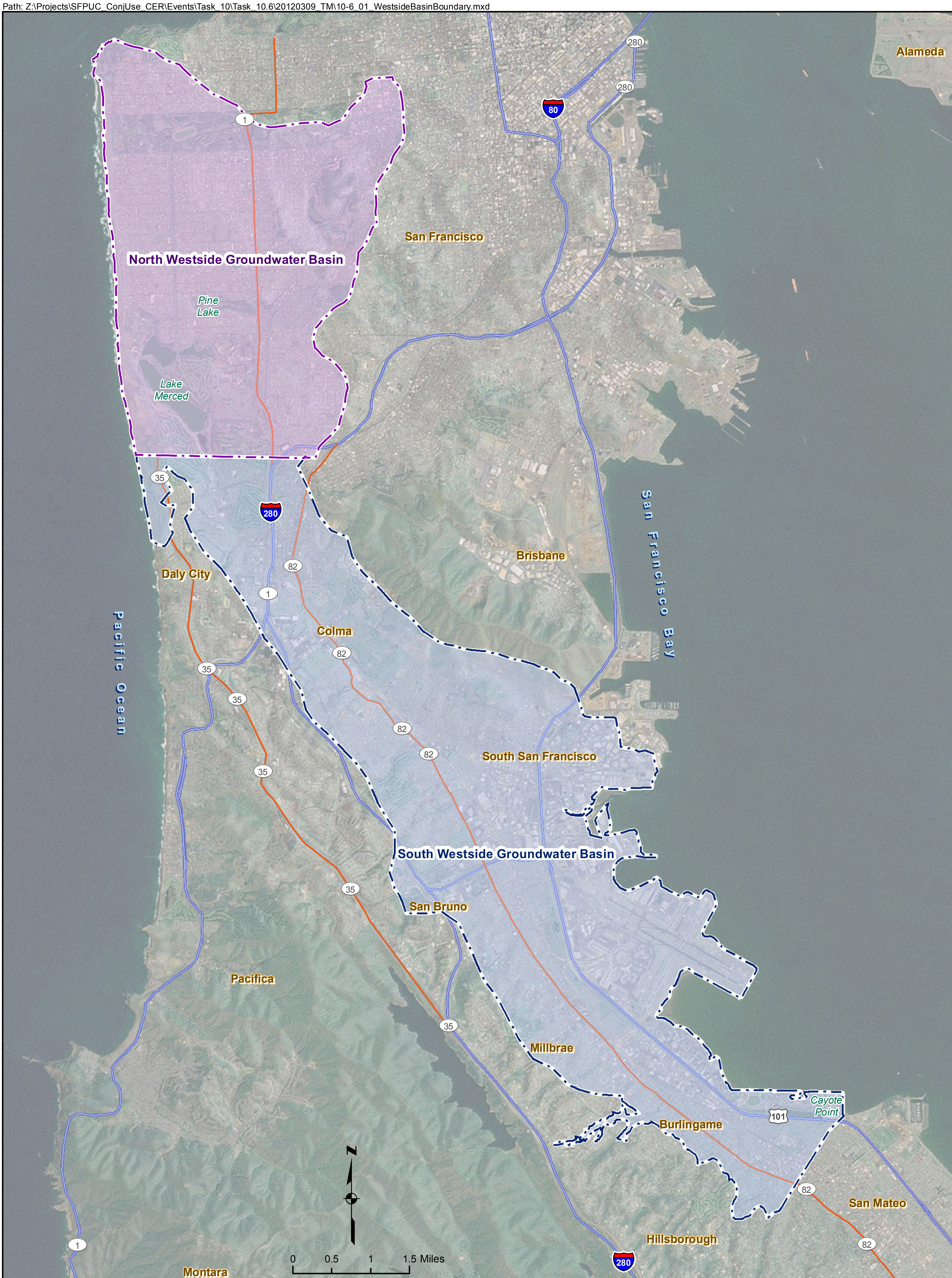

Aerial Photo Source: World Imagery from ESRI. Copyright:© 2009 ESRI, AND, TANA, UNEP-WCMC

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WESTSIDE GROUNDWATER BASIN BOUNDARY
NORTH AND SOUTH WESTSIDE BASINS

Kennedy/Jenks Consultants 303 Second Street, Suite 300 South San Francisco, CA 94107	Figure 10.6-1
Regional Groundwater Storage and Recovery Project	Date April 2012

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Legend

- GSR Project Proposed Municipal Wells
- Cal Water Municipal Wells
- Daly City Municipal Wells
- San Bruno Municipal Wells
- Selected Monitoring Wells with Model Results
- South Westside Groundwater Basin
- North Westside Groundwater Basin

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LOCATIONS OF PARTNER AGENCY WELLS, PROPOSED GSR PROJECT WELLS, AND SELECTED REPRESENTATIVE MONITORING WELLS

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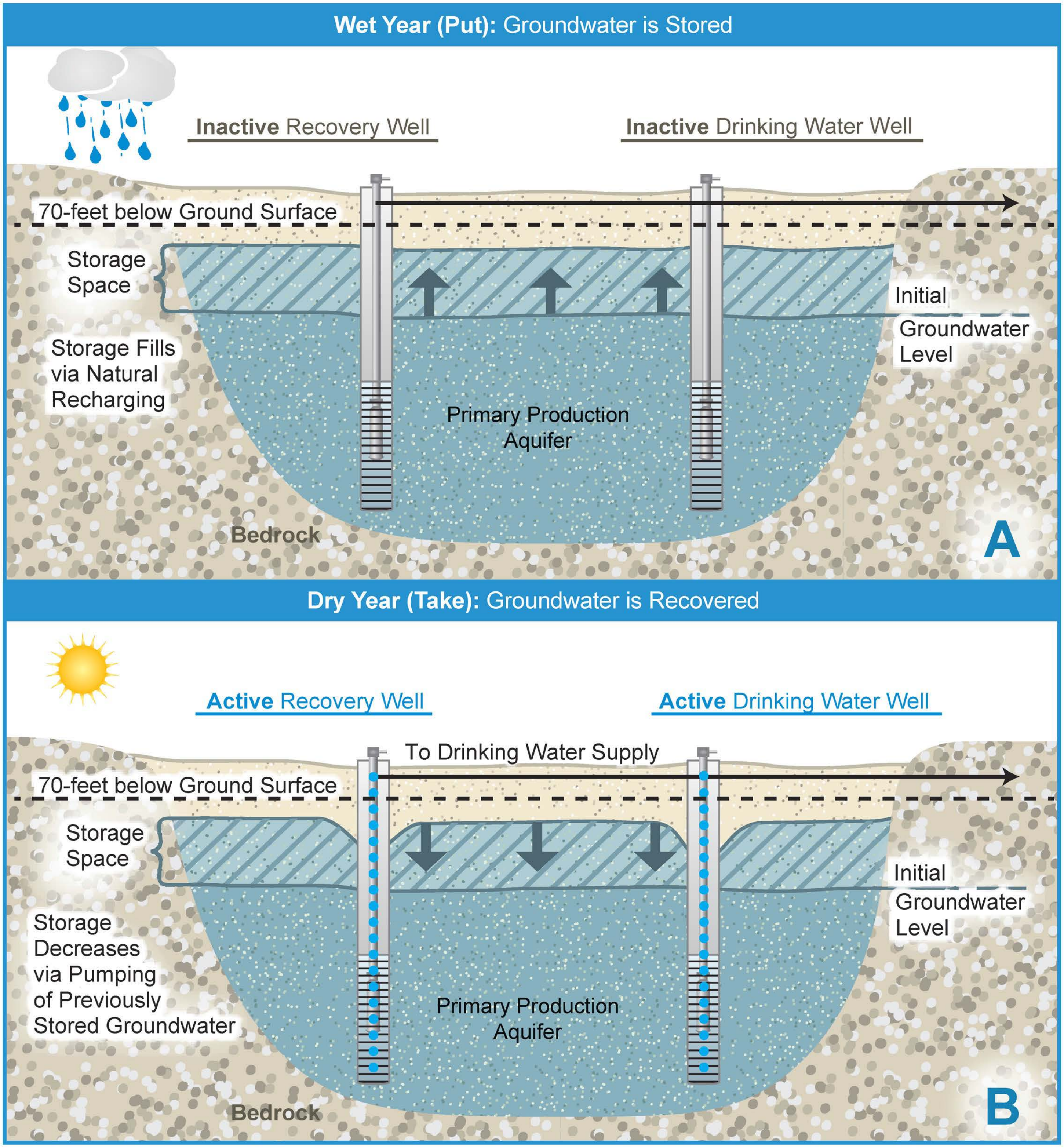
Regional Groundwater Storage and Recovery Project

Figure 10.6-2

Date April 2012



Note:

In illustration (A), the upward arrows represent the filling of the storage space with groundwater during wet years; while in illustration (B) the downward arrows represent the decline in stored water during dry years.

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Regional Groundwater Storage and Recovery Project

San Francisco Public Utilities Commission
Engineering Management Bureau

Conceptualization of Changing Water Levels
GSR Project Operations

K/J 0864001
April 2012
Figure 10.6-3

Source:
Hetch Hetchy Regional Water System - Services of the San Francisco Public Utilities Commission
Regional Groundwater Storage and Recovery Project
Water System Improvement Program, Winter 2012

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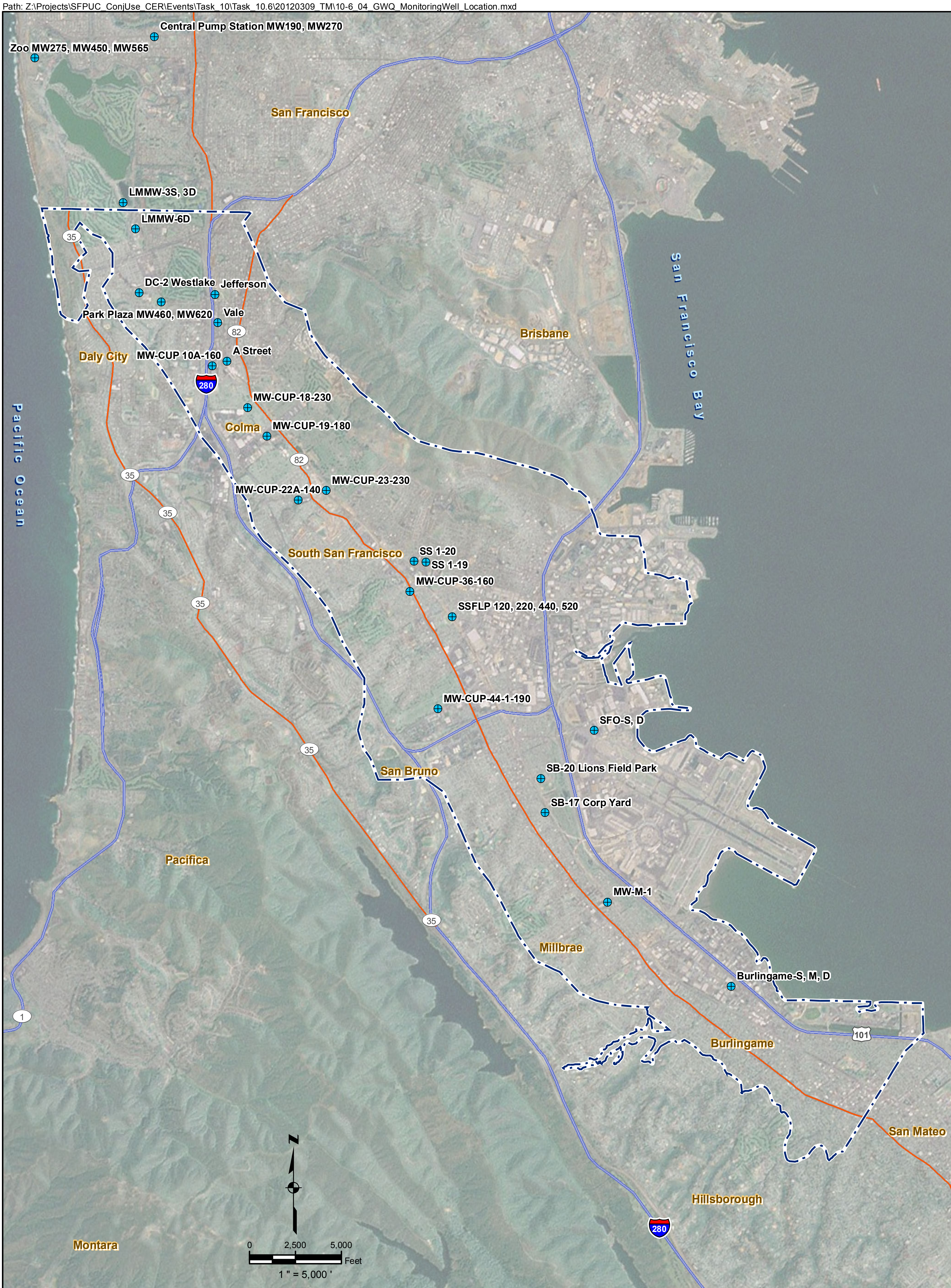

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Ground Water Quality Monitoring Well

South Westside Groundwater Basin

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GROUNDWATER QUALITY MONITORING WELL NETWORK

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Regional Groundwater Storage and Recovery Project

Figure **10.6-4**

Date April 2012

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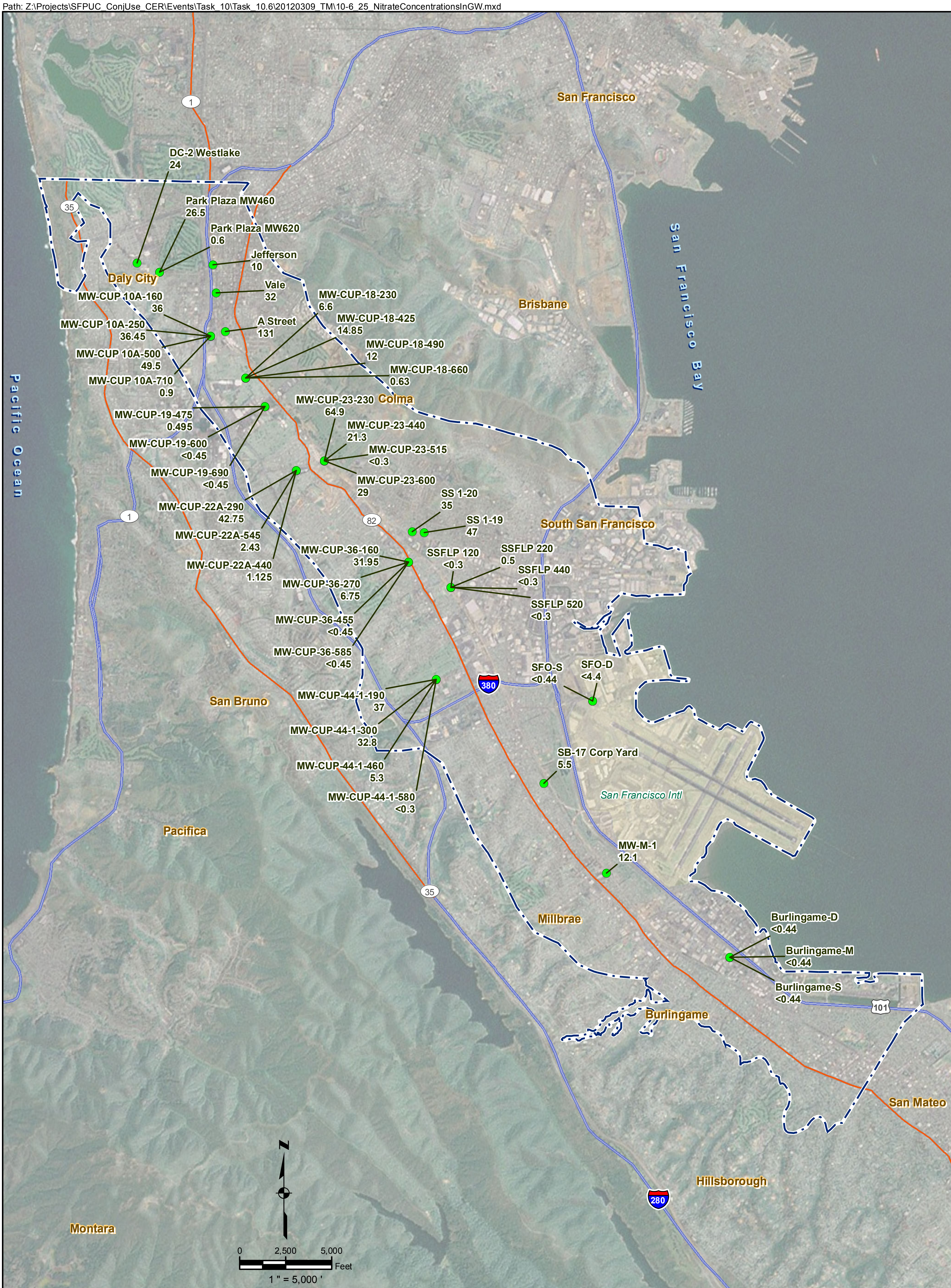

Legend

DC-2 Westlake = Monitoring Well Name
24: = Nitrate as NO3 (mg/l)

South Westside Groundwater Basin

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Nitrate Concentrations in Groundwater (as NO3, mg/l)

April 2008 and September 2009

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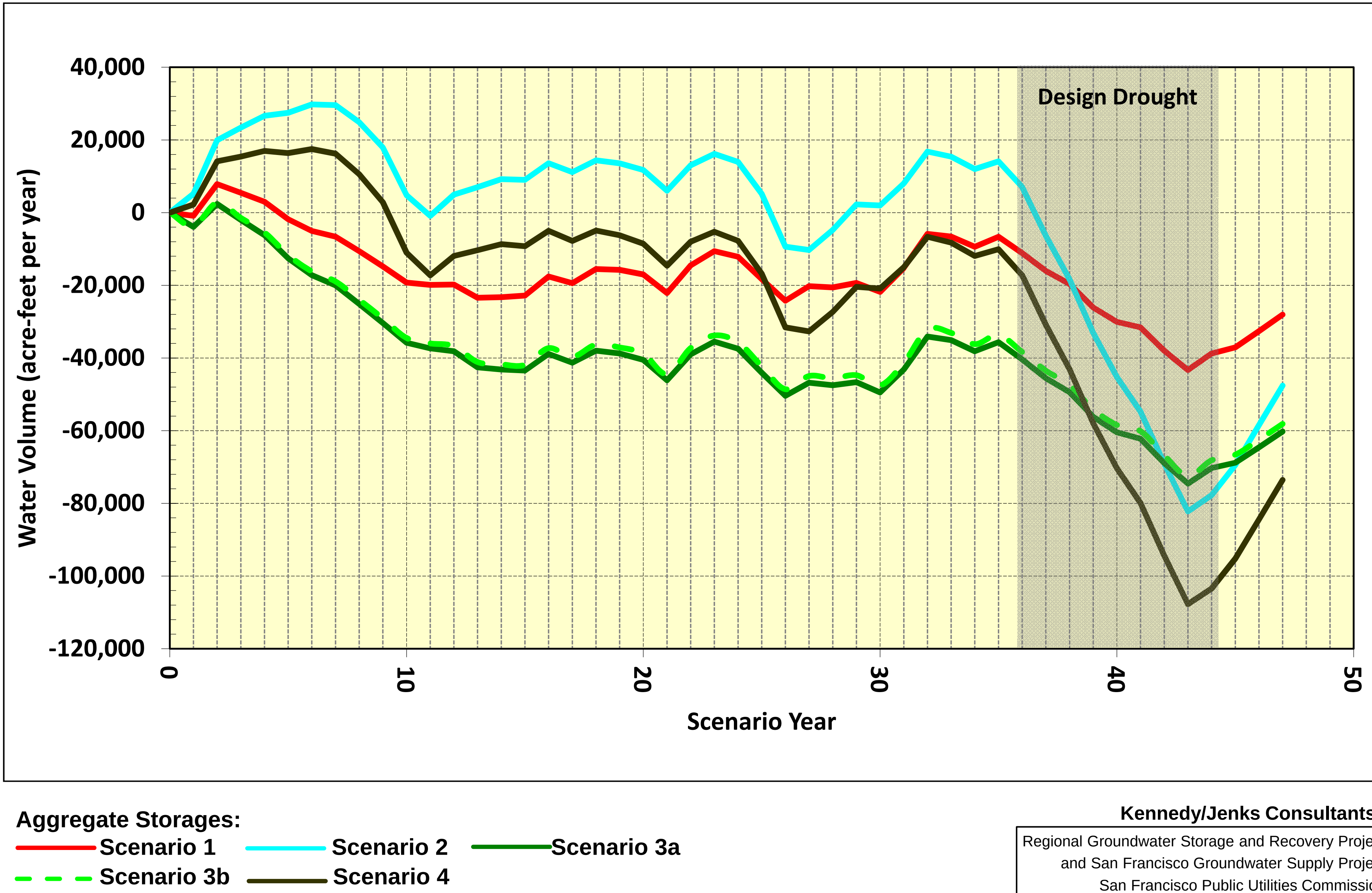
Regional Groundwater Storage and Recovery Project

Figure **10.6-5**

Date April 2012



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Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Groundwater Model-Simulated Aggregate Change in Groundwater Storage

K/J 0864001
April 2012

Figure 10.6-6

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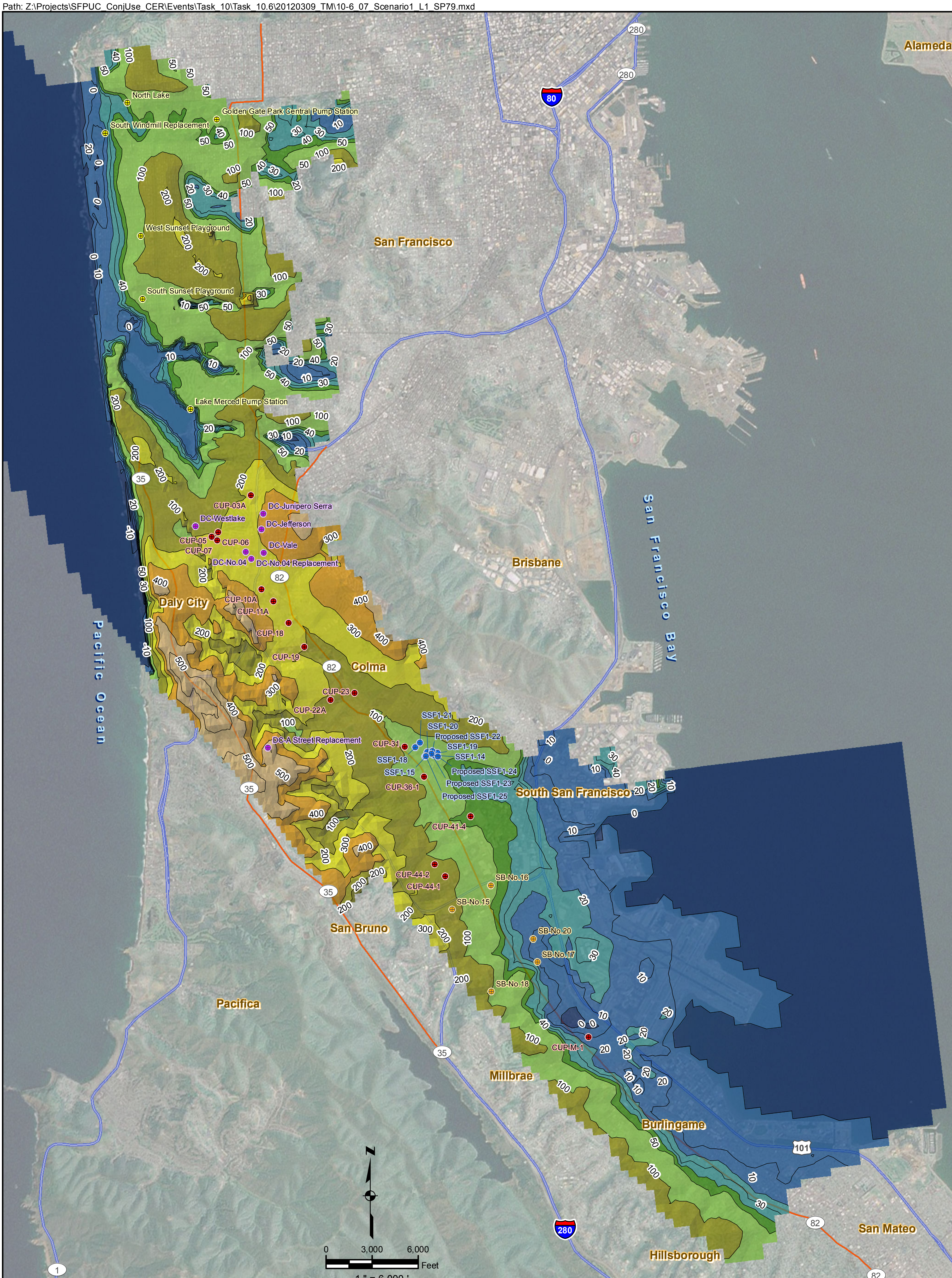

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Depth To Water (feet)

Model Simulated Depth To Water (feet)

- 400 - 594
- 300 - 400
- 200 - 300
- 100 - 200
- 50 - 100
- 40 - 50
- 20 - 40
- 0 - 20
- -22 - 0

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SCENARIO 1, LAYER 1
Model Simulated Depth to Water Contour Map

(Model Scenario Year 7)

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Regional Groundwater Storage and Recovery Project

Figure **10.6-7**

Date April 2012

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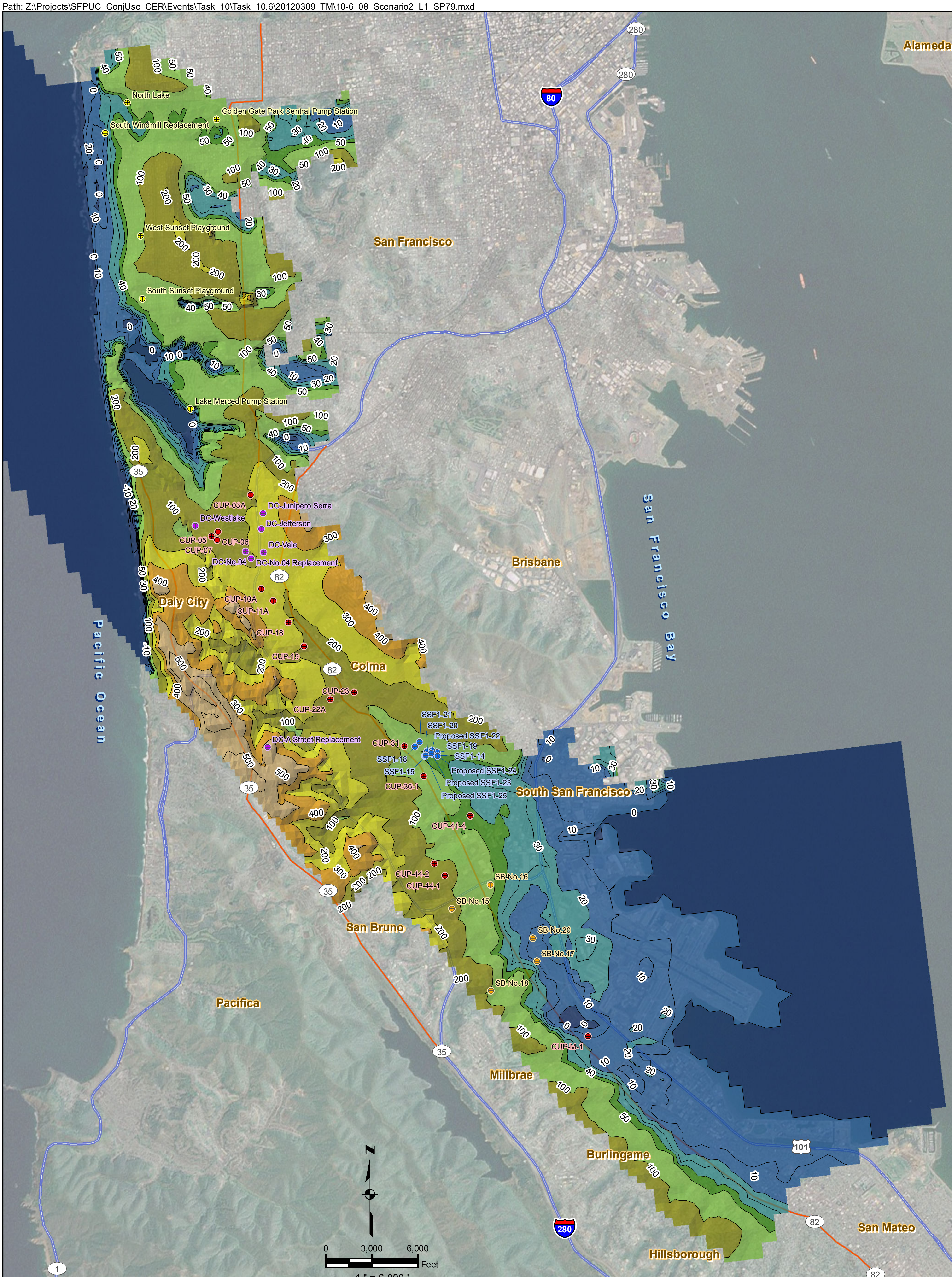

Legend

● GSR Project Proposed Municipal Wells

⊕ SFGW Project Proposed Municipal Wells

⊕ San Bruno Municipal Wells

● Daly City Municipal Wells

● Cal Water Municipal Wells

Depth To Water (feet)

Model Simulated Depth To Water (feet)

- 400 - 651
- 300 - 400
- 200 - 300
- 100 - 200
- 50 - 100
- 40 - 50
- 20 - 40
- 0 - 20
- -22 - 0

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SCENARIO 2, LAYER 1
Model Simulated Depth to Water Contour Map
Full SFPUC Storage Account

(Model Scenario Year 7)

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Regional Groundwater Storage and Recovery Project

Figure **10.6-8**

Date April 2012

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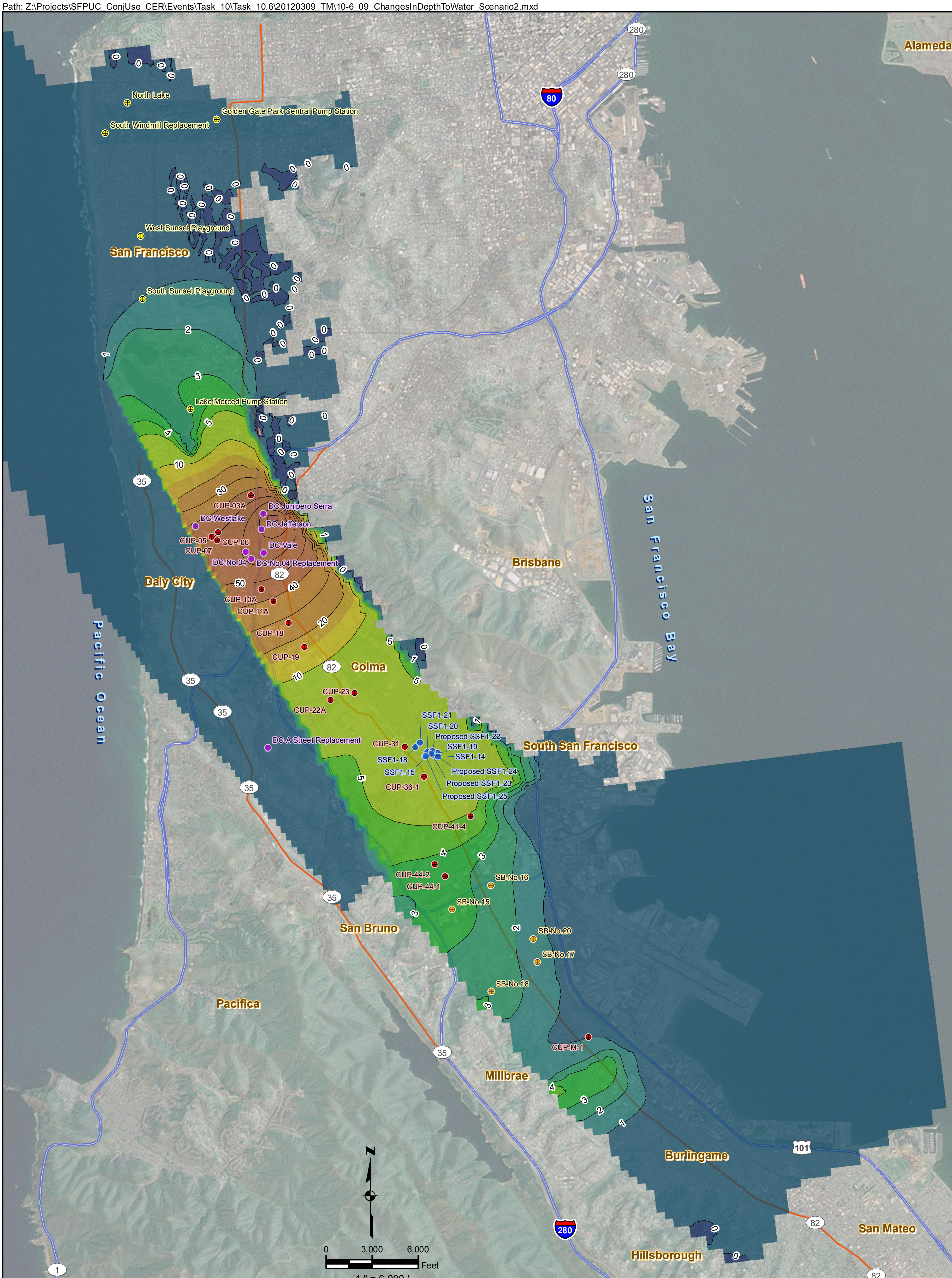

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Changes in Depth to Water (feet)

Model Simulated Depth To Water (Feet)

0 - -0.5	3 - 2	20 - 15	
1 - 0	4 - 3	40 - 20	
2 - 1	5 - 4	80 - 40	
	10 - 5	84 - 80	
	15 - 10		

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SCENARIO 2, LAYER 1
Model Simulated Changes in Depth to Water Relative to Scenario 1 Full SFPUC Storage Account

(Model Scenario Year 7)

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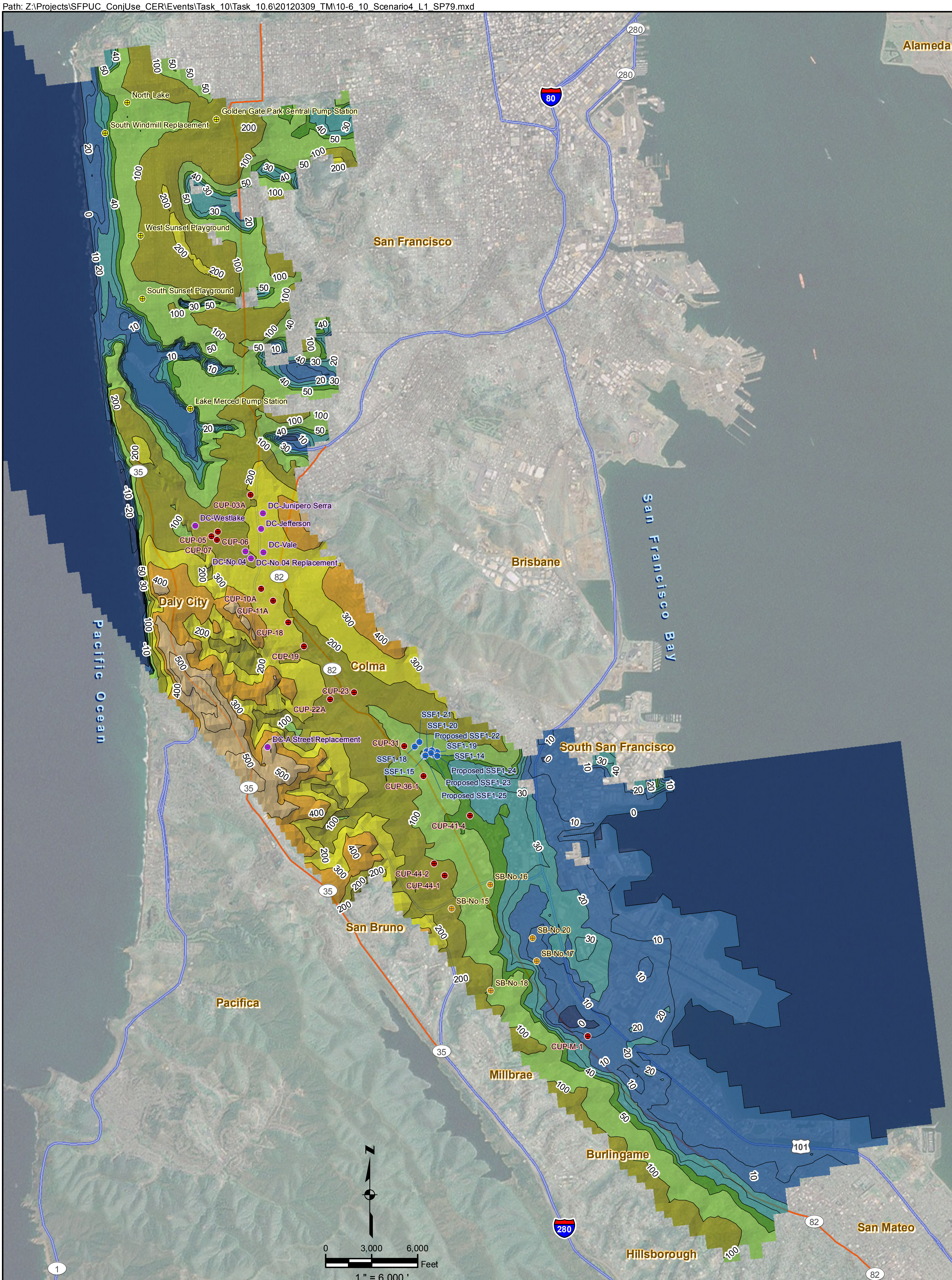
Figure **10.6-9**

Regional Groundwater Storage and Recovery Project

Date April 2012

Path: Z:\Projects\SFPUC_ConjUse_CER\Events\Task_10\Task_10.6\20120309_TM\10-6_10_Scenario4_L1_SP79.mxd



Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Depth To Water (feet)

Model Simulated Depth To Water (feet)

- 400 - 594
- 300 - 400
- 200 - 300
- 100 - 200
- 50 - 100
- 40 - 50
- 20 - 40
- 0 - 20
- -22 - 0

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SCENARIO 4, LAYER 1
Model Simulated Depth to Water Contour Map
Full SFPUC Storage Account

(Model Scenario Year 7)

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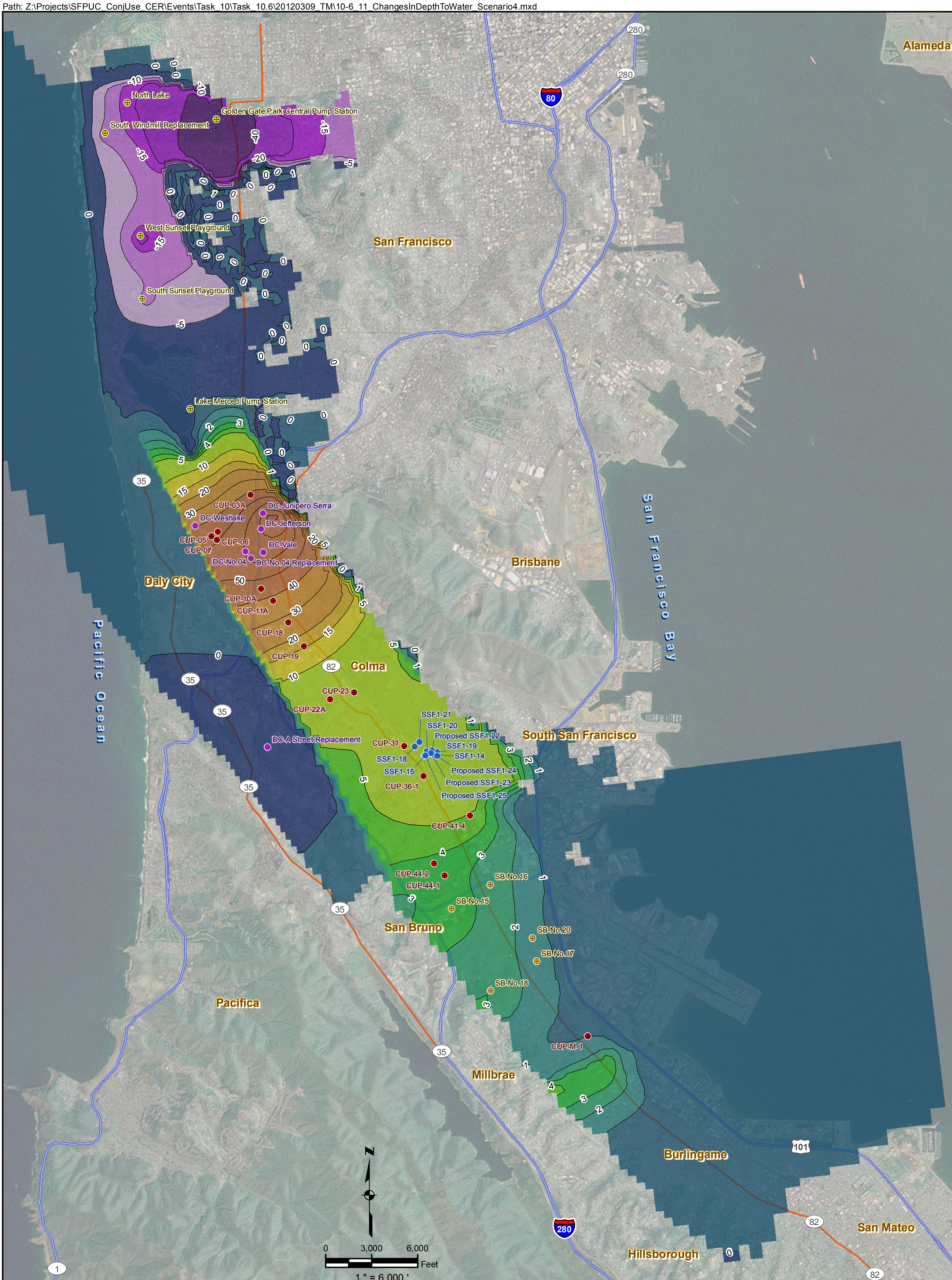
Regional Groundwater Storage and Recovery Project

Figure **10.6-10**

Date April 2012

Path: Z:\Projects\SFPUC_ConjUse_CER\Events\Task_10\Task_10.6\20120309_TM\10-6_11_ChangesInDepthToWater_Scenario4.mxd



Legend

● (red)	GSR Project Proposed Municipal Wells
⊕ (yellow)	SFGW Project Proposed Municipal Wells
⊕ (orange)	San Bruno Municipal Wells
● (purple)	Daly City Municipal Wells
● (blue)	Cal Water Municipal Wells
∼ (line)	Changes in Depth to Water (feet)

Model Simulated Depth To Water (Feet)

-40 - -80	-5 - -10	4 - 3	40 - 20
-20 - -40	0 - -5	5 - 4	80 - 40
-15 - -20	1 - 0	10 - 5	84 - 80
-10 - -15	2 - 1	15 - 10	
	3 - 2	20 - 15	

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SCENARIO 4, LAYER 1
Model Simulated Changes in Depth to Water Relative to Scenario 1 Full SFPUC Storage Account

(Model Scenario Year 7)

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Figure
10.6-11

Regional Groundwater Storage and Recovery Project

Date
April 2012

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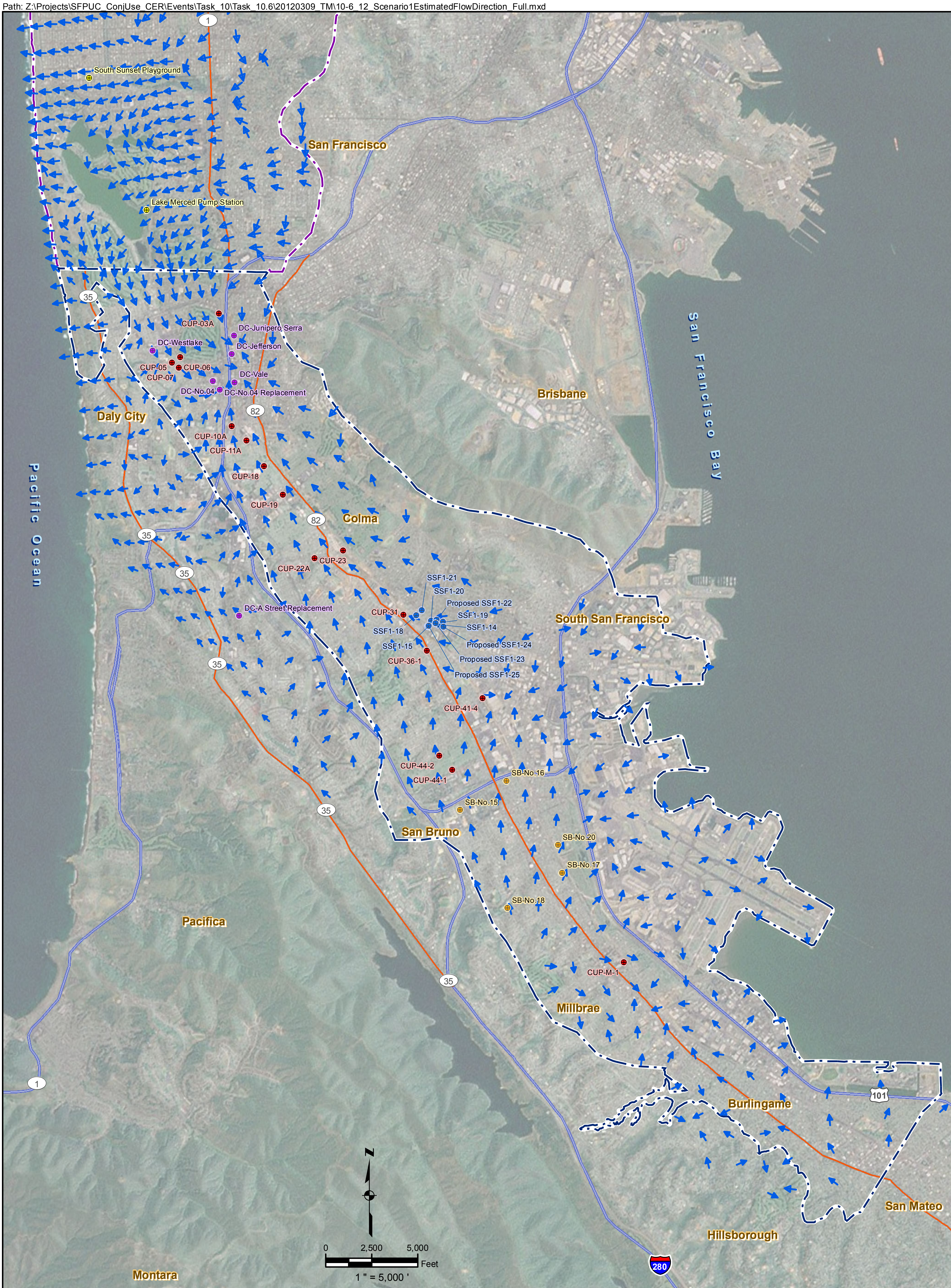

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Model Estimated Flow Direction
- South Westside Groundwater Basin
- North Westside Groundwater Basin

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SCENARIO 1, LAYER 1
Model Estimated Flow Directions
Full SFPUC Storage Account

(Model Scenario Year 7)

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Regional Groundwater Storage
and Recovery Project

Figure
10.6-12

Date
April 2012

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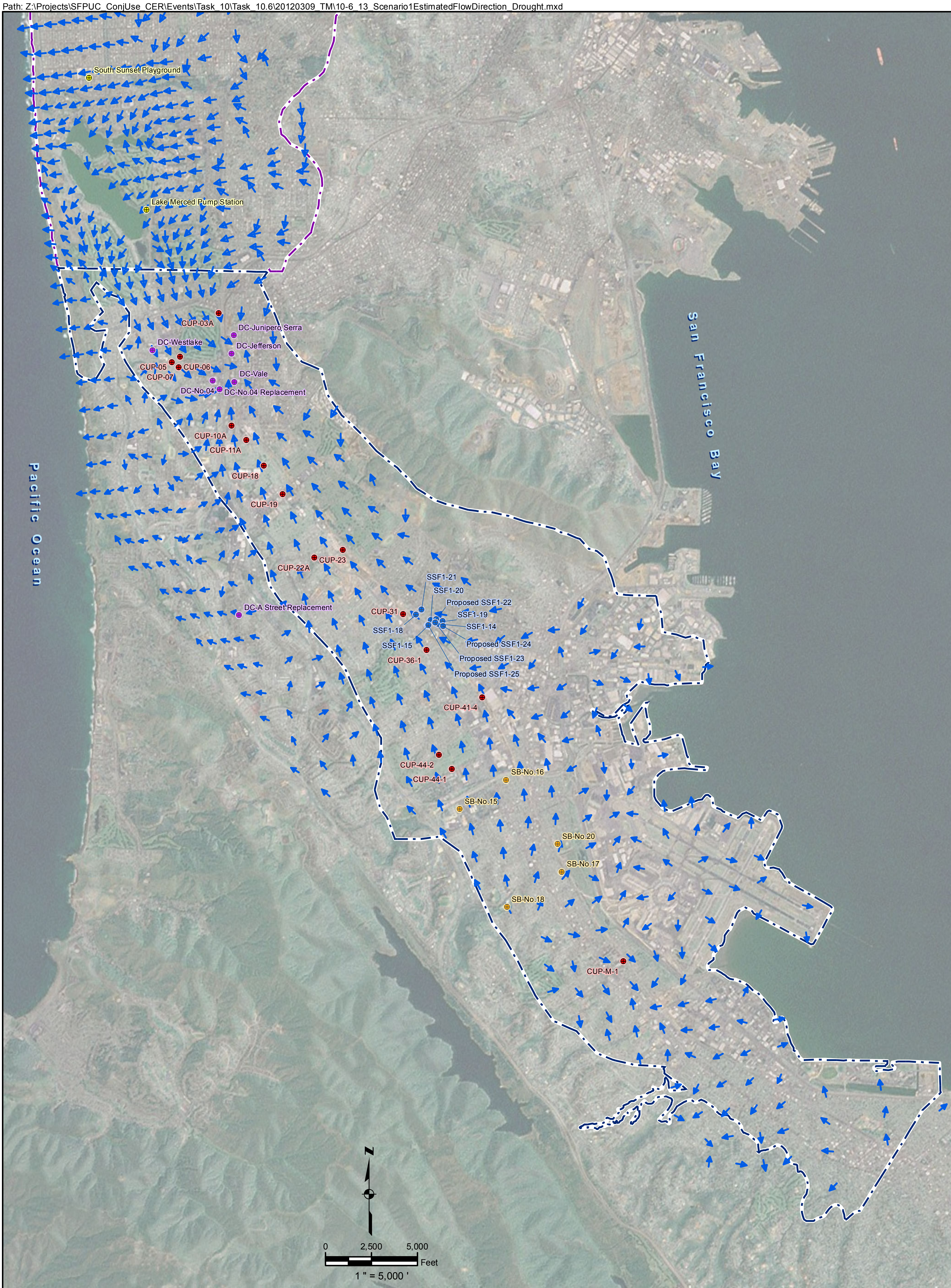

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Model Estimated Flow Direction
- South Westside Groundwater Basin
- North Westside Groundwater Basin

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SCENARIO 1, LAYER 1
Model Estimated Flow Directions
End of Design Drought

(Model Scenario Year 44)

Kennedy/Jenks Consultants 303 Second Street, Suite 300 South San Francisco, CA 94107	Figure **10.6-13**
Regional Groundwater Storage and Recovery Project	Date April 2012

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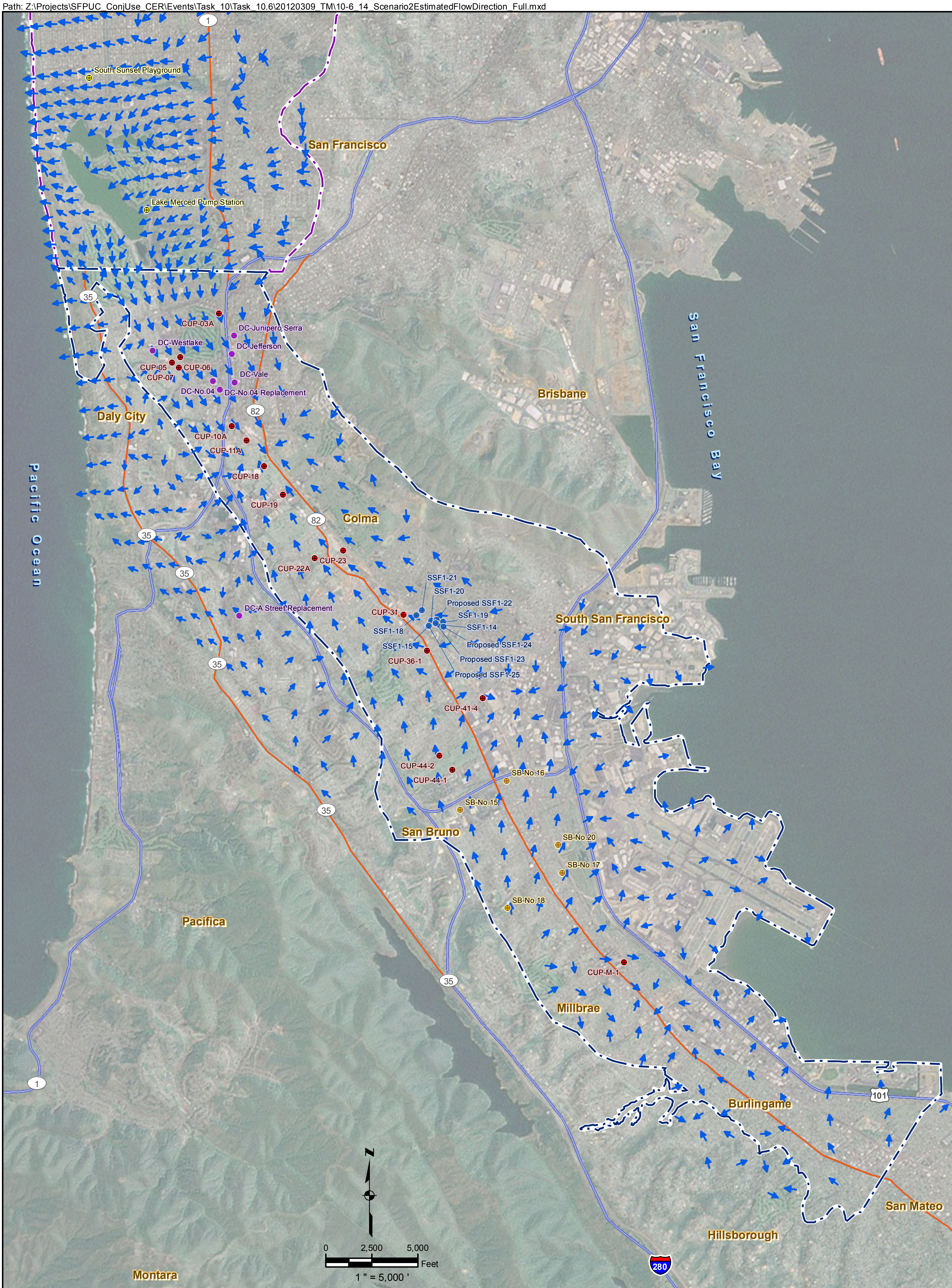

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Model Estimated Flow Direction
- South Westside Groundwater Basin
- North Westside Groundwater Basin

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SCENARIO 2, LAYER 1
Model Estimated Flow Directions
Full SFPUC Storage Account

(Model Scenario Year 7)

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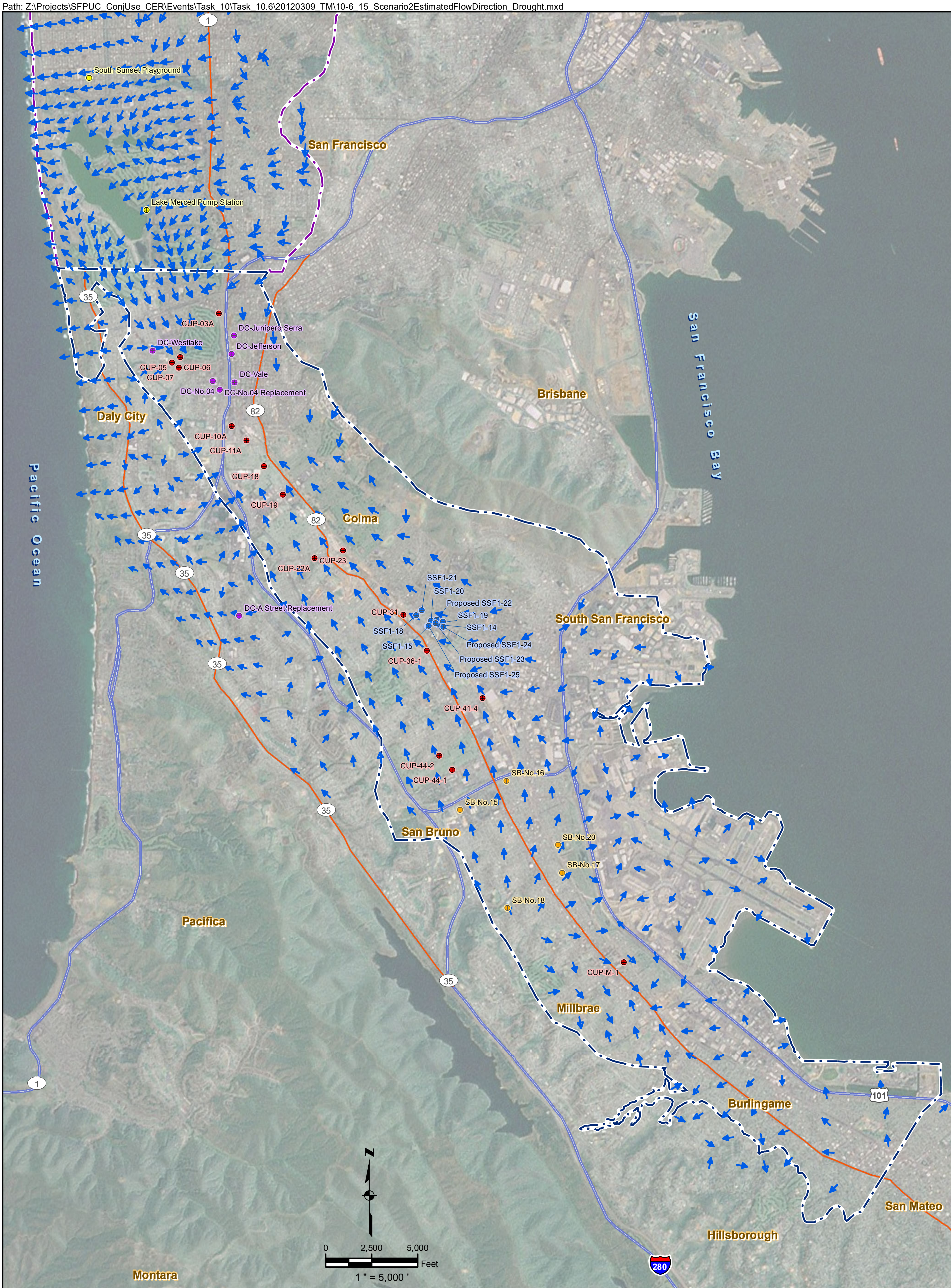
Regional Groundwater Storage and Recovery Project

Figure
10.6-14

Date
April 2012

Path: Z:\Projects\SFPUC_ConjUse_CER\Events\Task_10\Task_10.6\20120309_TM\10-6_15_Scenario2EstimatedFlowDirection_Drought.mxd



Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Model Estimated Flow Direction
- South Westside Groundwater Basin
- North Westside Groundwater Basin

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SCENARIO 2, LAYER 1
Model Estimated Flow Directions
End of Design Drought

(Model Scenario Year 44)

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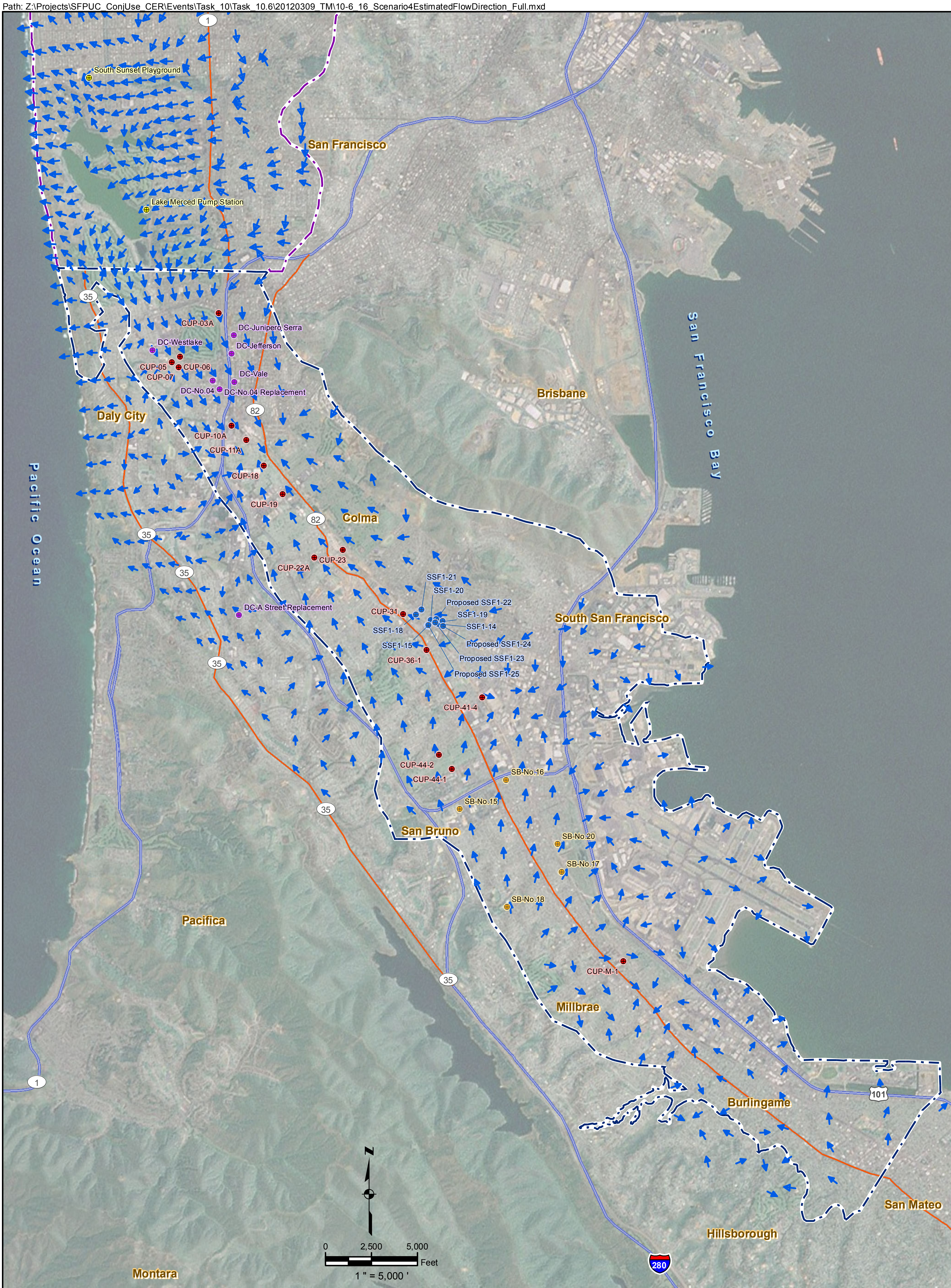
Figure
10.6-15

Regional Groundwater Storage and Recovery Project

Date
April 2012

Path: Z:\Projects\SFPUC_ConjUse_CER\Events\Task_10\Task_10.6\20120309_TM\10-6_16_Scenario4EstimatedFlowDirection_Full.mxd



Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Model Estimated Flow Direction
- South Westside Groundwater Basin
- North Westside Groundwater Basin

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SCENARIO 4, LAYER 1
Model Estimated Flow Directions
Full SFPUC Storage Account

(Model Scenario Year 7)

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Regional Groundwater Storage and Recovery Project	Date April 2012

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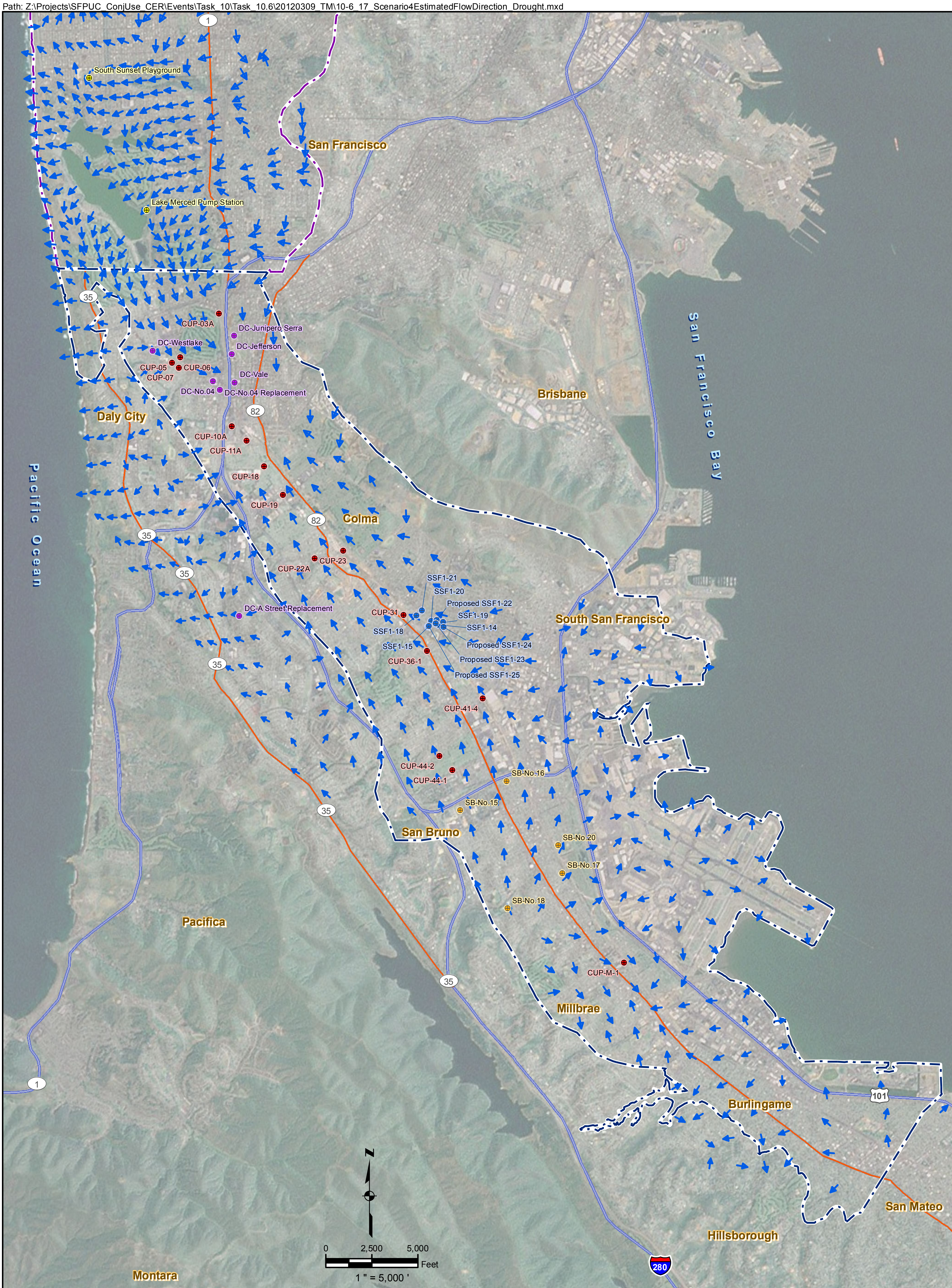

Legend

- GSR Project Proposed Municipal Wells
- SFGW Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Model Estimated Flow Direction
- South Westside Groundwater Basin
- North Westside Groundwater Basin

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SCENARIO 4, LAYER 1
Model Estimated Flow Directions
End of Design Drought

(Model Scenario Year 44)

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Regional Groundwater Storage and Recovery Project

Figure **10.6-17**

Date April 2012

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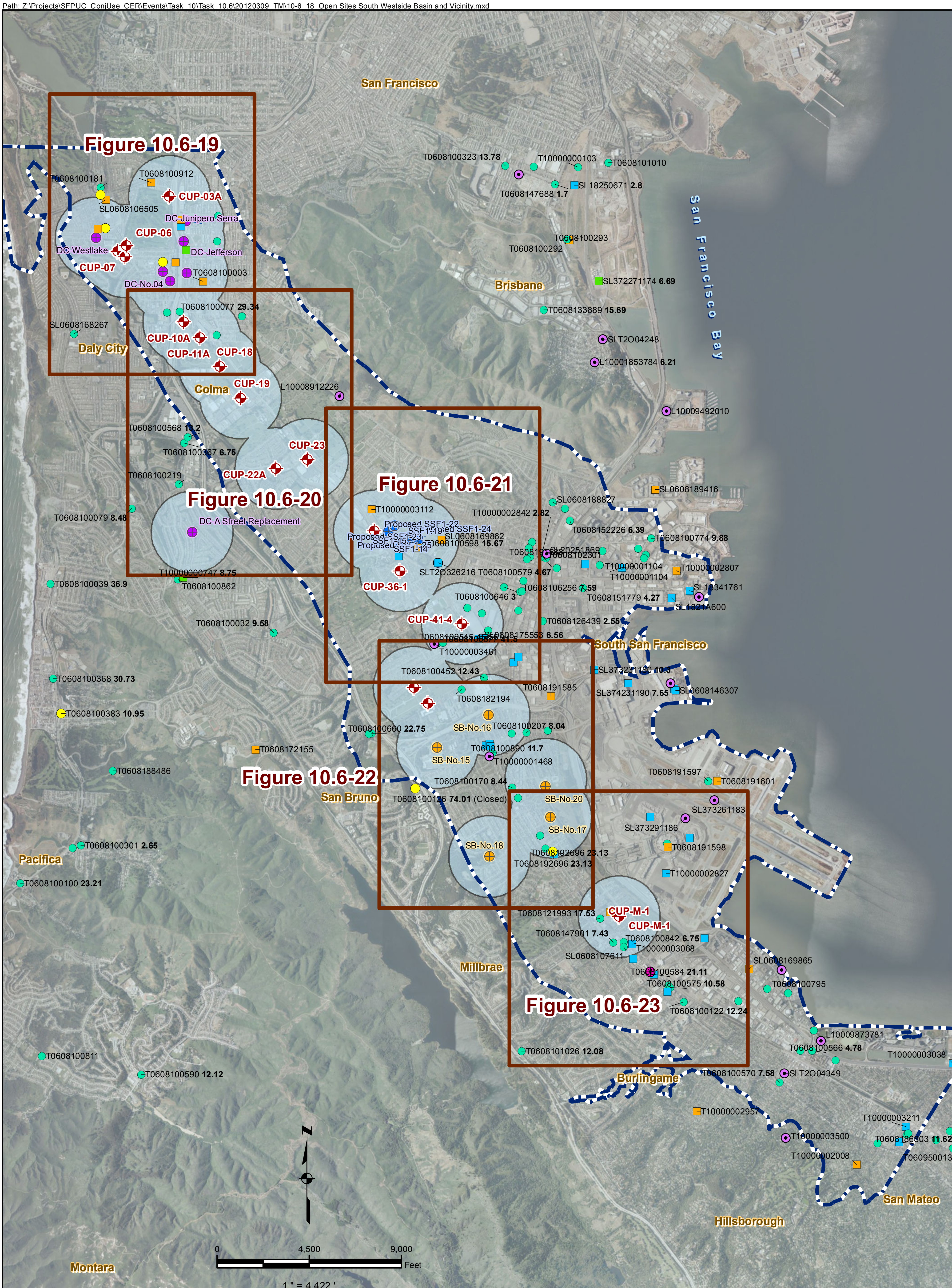

Legend

Potential Media Affected Near Project Area

- Other Groundwater (uses other than drinking water)
- Soil
- Soil/Other Groundwater (uses other than drinking water)
- Soil/Other Groundwater (uses other than drinking water)/Aquifer or Well used for drinking water supply
- Soil/Aquifer used for drinking water supply
- Well used for drinking water supply
- Aquifer used for drinking water supply
- Under Investigation
- Unknown

T0608194016 | 21.8
Global ID | Depth to Water (feet)

- GSR Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- South Westside Groundwater Basin
- 2000 feet Radius Buffer

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"OPEN" REGULATED SITES IN THE SOUTH WESTSIDE BASIN AND VICINITY WITH RECORDED DEPTHS TO WATER (See Also Plate B-1)

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Regional Groundwater Storage and Recovery Project

Figure
10.6-18

Date
April 2012

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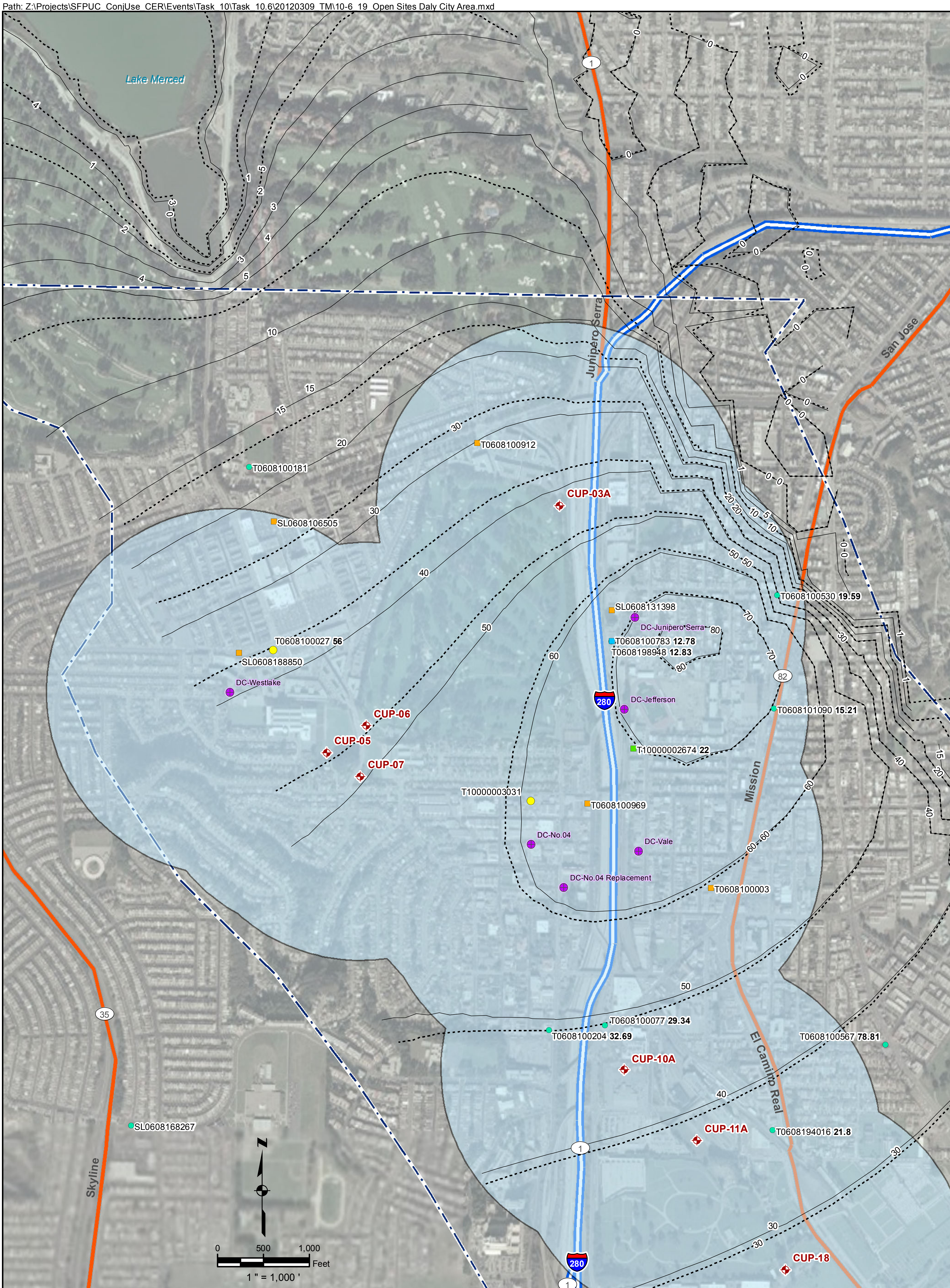

Legend

Potential Media Affected Near Project Area

- Other Groundwater (uses other than drinking water)
- Soil
- Soil/Other Groundwater (uses other than drinking water)
- Soil/Other Groundwater (uses other than drinking water)/Aquifer or Well used for drinking water supply
- Soil/Aquifer used for drinking water supply
- Aquifer used for drinking water supply
- Well used for drinking water supply
- Under Investigation
- Unknown

T0608194016 | 21.8
Global ID | Depth to Water (feet)

- GSR Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Changes in Depth to Water (feet) Scenario 2
- Changes in Depth to Water (feet) Scenario 4
- 2000 feet Radius Buffer
- South Westside Groundwater Basin

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"OPEN" REGULATED SITES WITH RECORDED DEPTHS TO WATER NEAR PUMPING WELLS IN THE DALY CITY AREA

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Regional Groundwater Storage and Recovery Project

Figure
10.6-19

Date
April 2012

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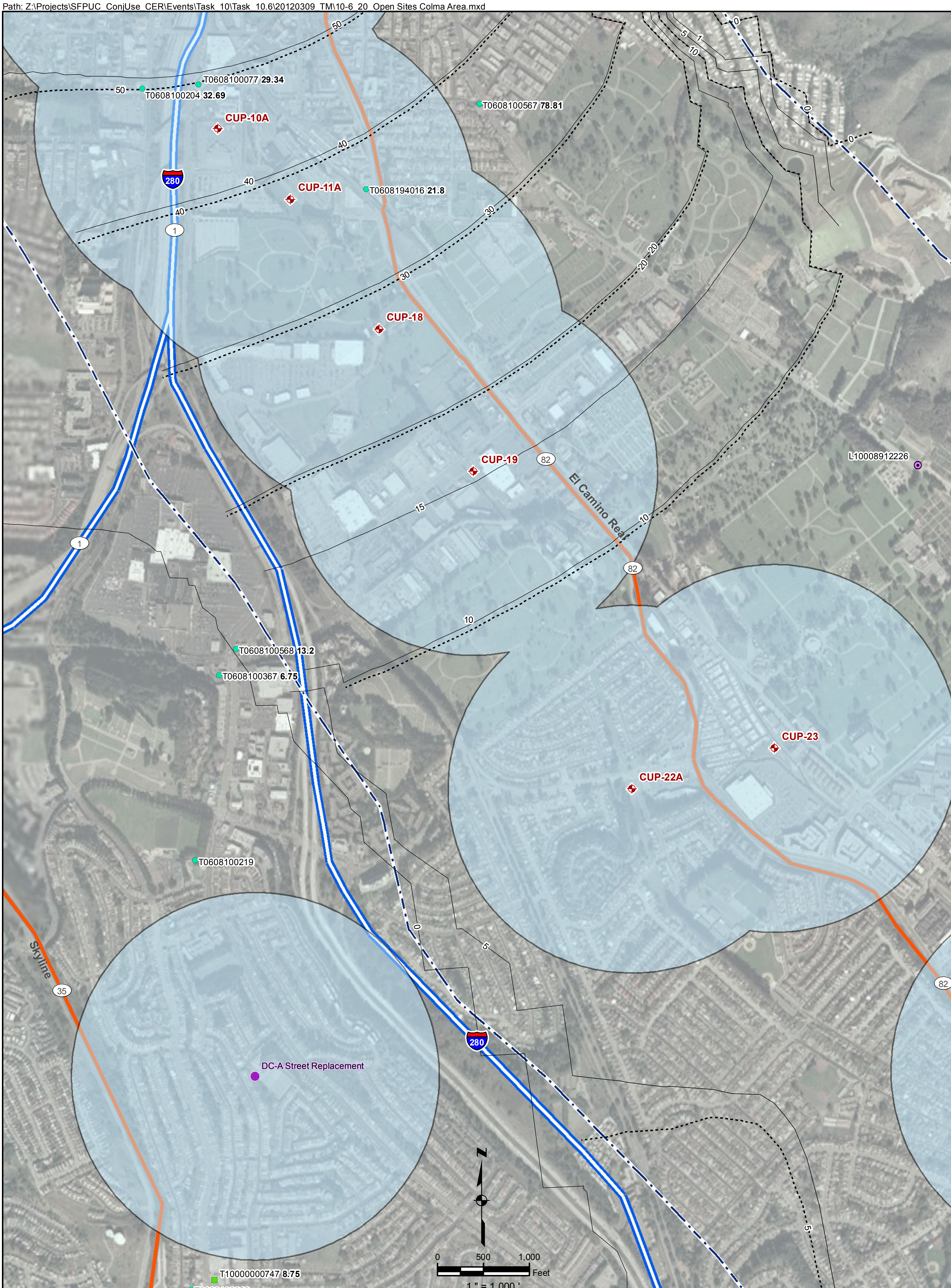

Legend

Potential Media Affected Near Project Area

- Other Groundwater (uses other than drinking water)
- Soil
- Soil/Other Groundwater (uses other than drinking water)
- Soil/Other Groundwater (uses other than drinking water)/Aquifer or Well used for drinking water supply
- Soil/Aquifer used for drinking water supply
- Aquifer used for drinking water supply
- Well used for drinking water supply
- Under Investigation
- Unknown

T0608194016 | 21.8
Global ID | Depth to Water (feet)

- GSR Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Changes in Depth to Water (feet) Scenario 2
- Changes in Depth to Water (feet) Scenario 4
- 2000 feet Radius Buffer
- South Westside Groundwater Basin

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"OPEN" REGULATED SITES WITH RECORDED DEPTHS TO WATER NEAR PUMPING WELLS IN THE COLMA AREA

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Regional Groundwater Storage and Recovery Project

Figure
10.6-20

Date
April 2012

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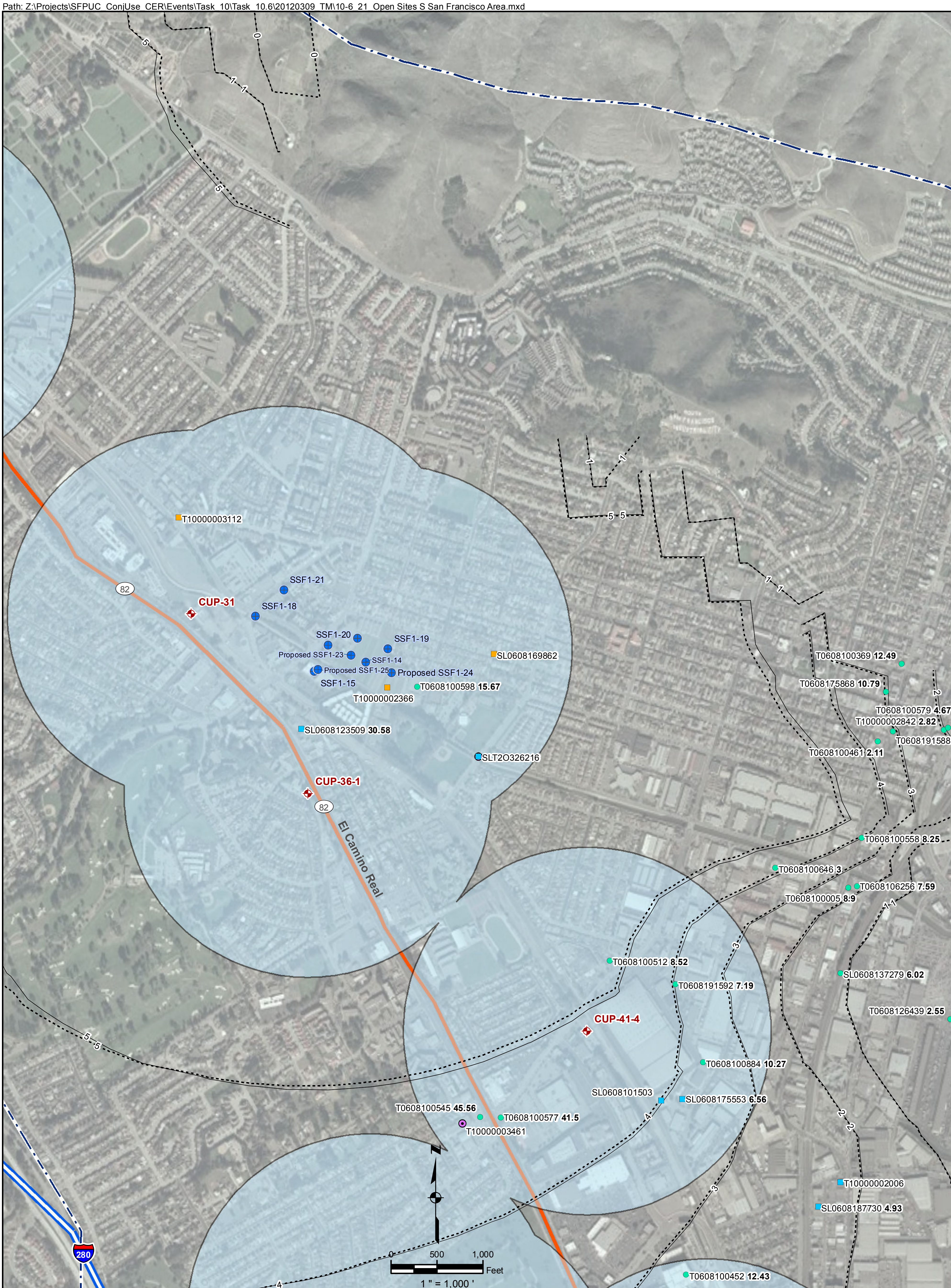

Legend

Potential Media Affected Near Project Area

- Other Groundwater (uses other than drinking water)
- Soil
- Soil/Other Groundwater (uses other than drinking water)
- Soil/Other Groundwater (uses other than drinking water)/Aquifer or Well used for drinking water supply
- Soil/Aquifer used for drinking water supply
- Aquifer used for drinking water supply
- Well used for drinking water supply
- Under Investigation
- Unknown

T0608194016 | 21.8
Global ID | Depth to Water (feet)

- GSR Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Changes in Depth to Water (feet) Scenario 2
- Changes in Depth to Water (feet) Scenario 4
- 2000 feet Radius Buffer
- South Westside Groundwater Basin

CITY AND COUNTY OF SAN FRANCISCO
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"OPEN" REGULATED SITES WITH RECORDED DEPTHS TO WATER NEAR PUMPING WELLS IN THE SOUTH SAN FRANCISCO AREA

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Regional Groundwater Storage and Recovery Project

Figure **10.6-21**

Date April 2012

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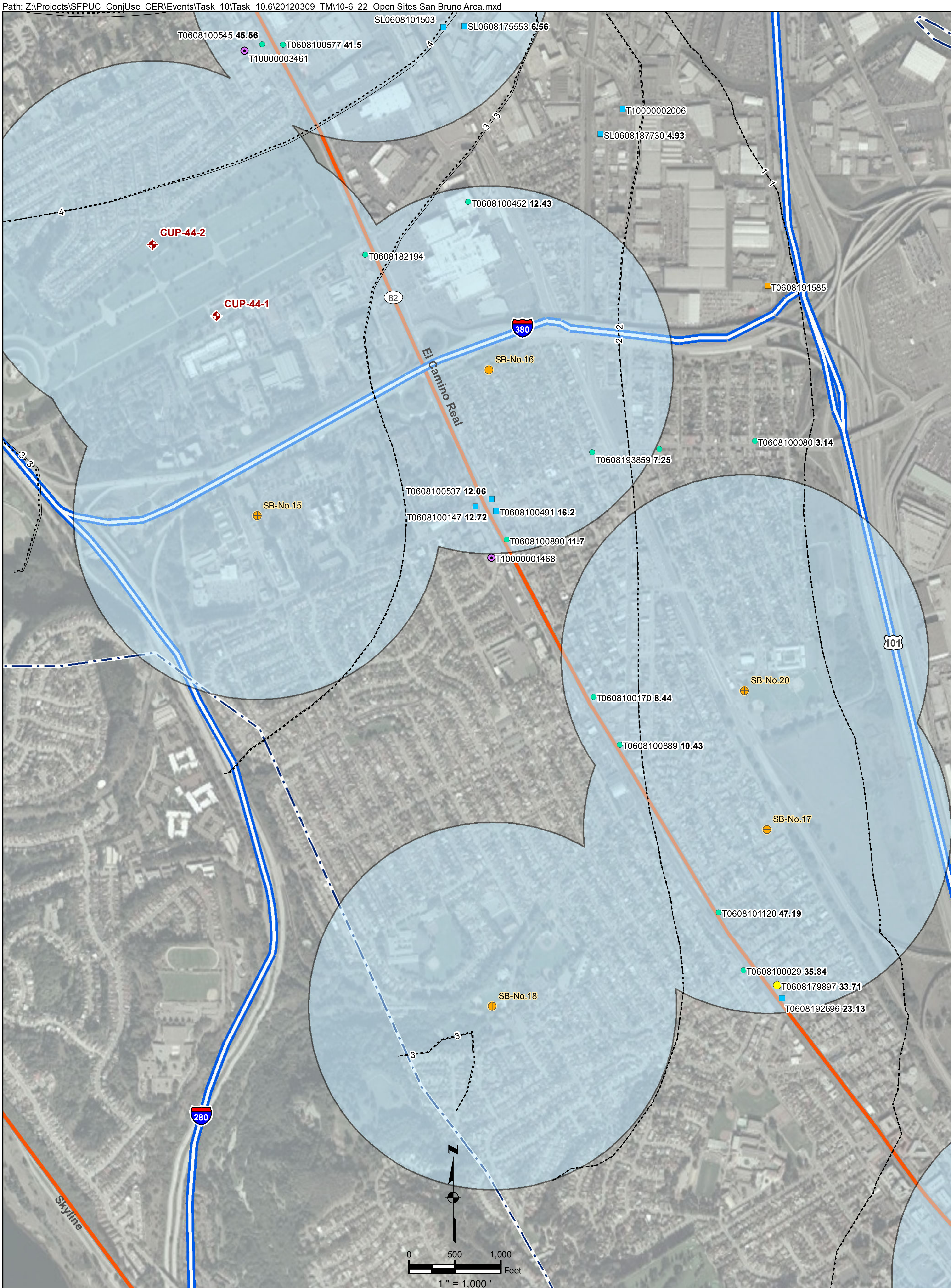

Legend

Potential Media Affected Near Project Area

- Other Groundwater (uses other than drinking water)
- Soil
- Soil/Other Groundwater (uses other than drinking water)
- Soil/Other Groundwater (uses other than drinking water)/Aquifer or Well used for drinking water supply
- Soil/Aquifer used for drinking water supply
- Aquifer used for drinking water supply
- Well used for drinking water supply
- Under Investigation
- Unknown

T0608194016 | 21.8
Global ID Depth to Water (feet)

- GSR Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Changes in Depth to Water (feet) Scenario 2
- Changes in Depth to Water (feet) Scenario 4
- 2000 feet Radius Buffer
- South Westside Groundwater Basin

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"OPEN" REGULATED SITES WITH RECORDED DEPTHS TO WATER NEAR PUMPING WELLS IN THE SAN BRUNO AREA

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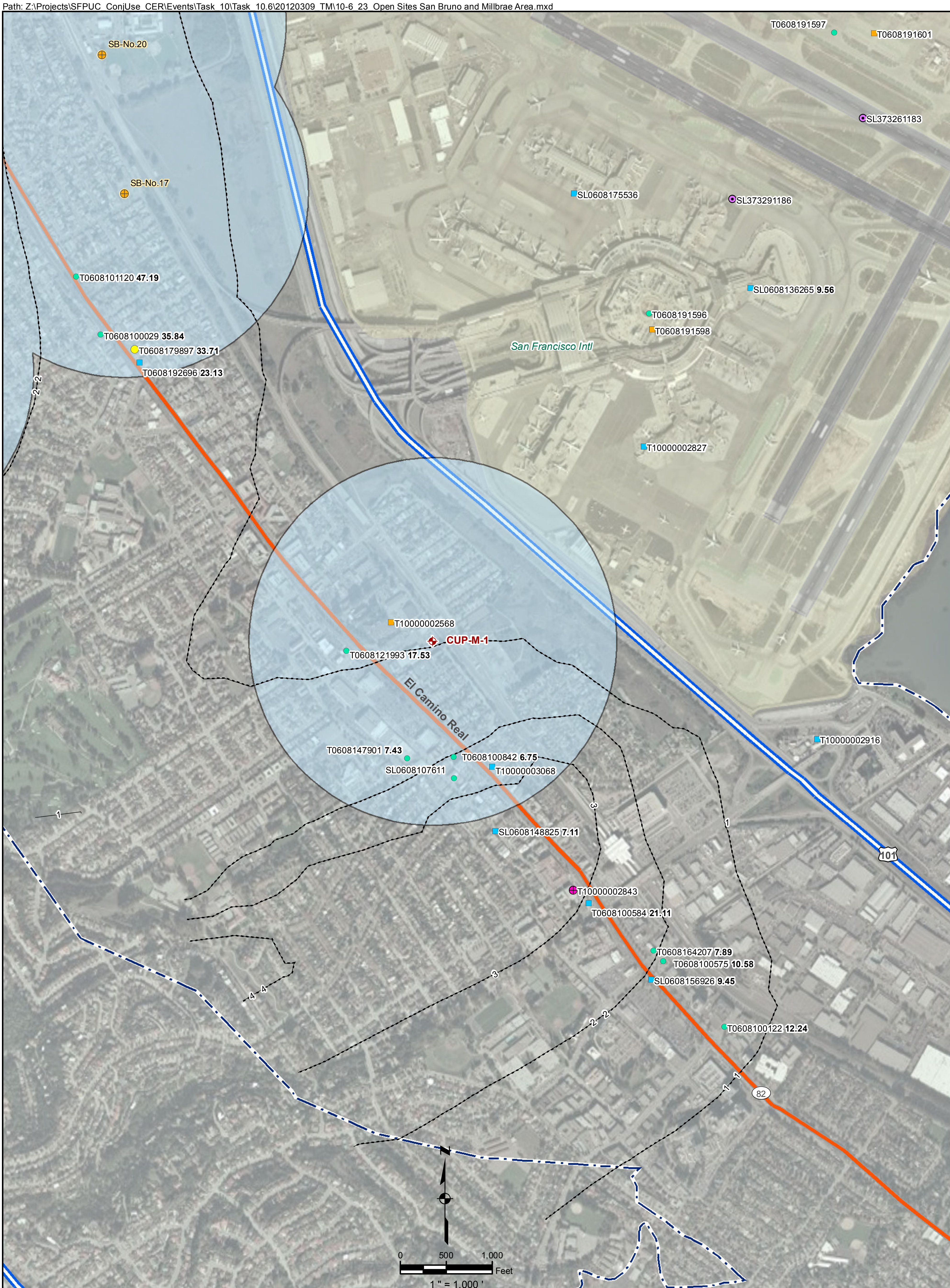
Regional Groundwater Storage and Recovery Project

Figure **10.6-22**

Date April 2012

Path: Z:\Projects\SFPUC_ConjUse_CER\Events\Task_10\Task_10.6\20120309_TM\10-6_23_Open Sites San Bruno and Millbrae Area.mxd



Legend

Potential Media Affected Near Project Area

- Other Groundwater (uses other than drinking water)
- Soil
- Soil/Other Groundwater (uses other than drinking water)
- Soil/Other Groundwater (uses other than drinking water)/Aquifer or Well used for drinking water supply
- Soil/Aquifer used for drinking water supply
- Aquifer used for drinking water supply
- Well used for drinking water supply
- Under Investigation
- Unknown

T0608194016 | 21.8
Global ID | Depth to Water (feet)

- GSR Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- Changes in Depth to Water (feet) Scenario 2
- Changes in Depth to Water (feet) Scenario 4
- 2000 feet Radius Buffer
- South Westside Groundwater Basin

CITY AND COUNTY OF SAN FRANCISCO
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"OPEN" REGULATED SITES WITH RECORDED DEPTHS TO WATER NEAR PUMPING WELLS IN THE SAN BRUNO/MILLBRAE AREA

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Regional Groundwater Storage and Recovery Project

Figure **10.6-23**

Date April 2012

Table

Table 10.6-1: Summary of Model Scenario Pumping Assumptions

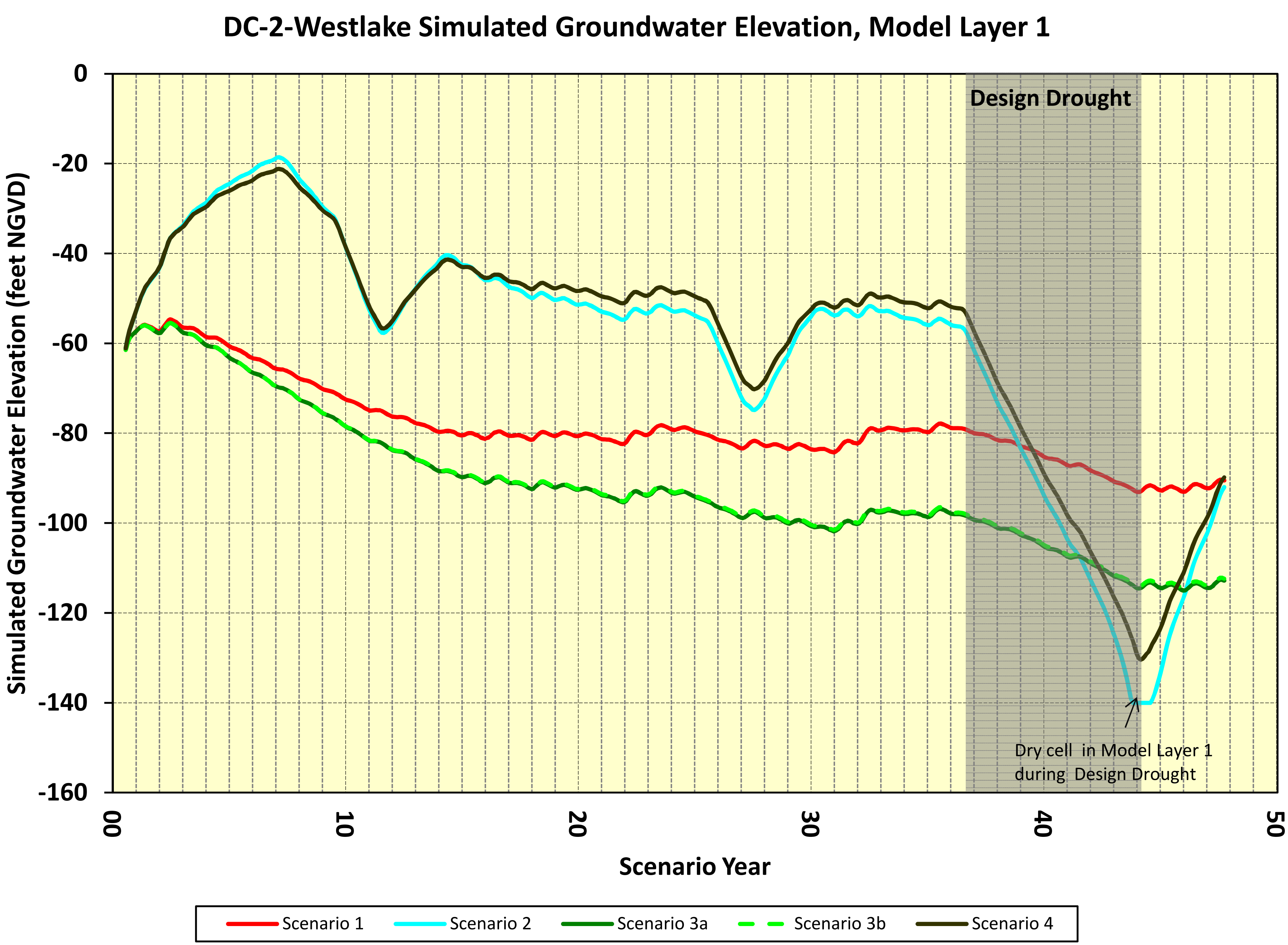
		Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4
Model Scenarios		**Existing Conditions**	**GSR**	**SFGW**	**SFGW**	**Cumulative**
Establish Initial Conditions		Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence	Hydrologic Sequence
	June 2009 Condition	√	√	√	√	√
Model Scenario Simulation Period						
	47.25 years (including Design Drought) Hydrologic Sequence: July 1996 to September 2003 -> October 1958 to November 1992 -> December 1975 to June 1978 -> July 2003 - September 2006		√	√	√	√
Pumping Assumptions for Municipal Use						
PA Municipal Wells (mgd)						
	"Take" Periods	6.84	6.90	6.84	6.84	6.90
	"Put" Periods	6.84	1.38	6.84	6.84	1.38
	"Hold" Periods	6.84	6.90	6.84	6.84	6.90
GSR Project Proposed Municipal Wells (mgd)						
	"Take" Periods	0.0	7.23	0.0	0.0	7.23
	"Put" Periods	0.0	0.04	0.0	0.0	0.04
	"Hold" Periods	0.0	0.04	0.0	0.0	0.04
SFGW Project Proposed Municipal Wells (mgd)						
	Year-Round Pumping	0.0	0.0	3.0	4.0	4.0
Total Municipal Pumping (PA + GSR + SFGW)						
	"Take" Periods	***6.84***	***14.13***	***9.84***	***10.84***	***18.13***
	"Put" Periods	***6.84***	***1.42***	***9.84***	***10.84***	***5.42***
	"Hold" Periods	***6.84***	***6.94***	***9.84***	***10.84***	***10.94***
Irrigation and Other Non-Potable Pumping Assumptions (mgd)(1)						
Golden Gate Park	Elk Glen (GGP)	0.081	0.081	0.081	0.000	0.000
	South Windmill (GGP)	0.498	0.498	0.498	0.000	0.000
	North Lake (GGP)	0.563	0.563	0.563	0.000	0.000
	Sub-Total	***1.142***	***1.142***	***1.142***	***0.000***	***0.000***
Golf Courses	Burlingame Golf Club	0.150	0.150	0.150	0.150	0.150
	California Golf No. 02	0.192	0.192	0.192	0.192	0.192
	Green Hills No. 05	0.099	0.099	0.099	0.099	0.099
	Lake Merced Golf No. 01	0.004	0.004	0.004	0.004	0.004
	Lake Merced Golf No. 02	0.004	0.004	0.004	0.004	0.004
	Lake Merced Golf No. 03	0.010	0.010	0.010	0.010	0.010
	Olympic Club No. 09(2)	0.002	0.002	0.002	0.002	0.002
	SF Golf West	0.035	0.035	0.035	0.035	0.035
	Sub-Total	***0.495***	***0.495***	***0.495***	***0.495***	***0.495***
Cemeteries	Cypress Lawn No. 02	0.020	0.020	0.020	0.020	0.020
	Cypress Lawn No. 03	0.144	0.144	0.144	0.144	0.144
	Eternal Home	0.013	0.013	0.013	0.013	0.013
	Hills of Eternity No. 02	0.020	0.020	0.020	0.020	0.020
	Holy Cross No. 03(3)	0.190	0.190	0.190	0.190	0.230
	Home of Peace No. 02	0.039	0.039	0.039	0.039	0.039
	Italian Cemetery	0.033	0.033	0.033	0.033	0.033
	Olivet	0.098	0.098	0.098	0.098	0.098
	Woodlawn No. 02	0.085	0.085	0.085	0.085	0.085
	Sub-Total	***0.641***	***0.641***	***0.641***	***0.641***	***0.681***
Other	Hillsborough Residents No. 1-12	0.291	0.291	0.291	0.291	0.291
	Edgewood Development Ctr.	0.009	0.009	0.009	0.009	0.009
	Zoo No.05	0.321	0.321	0.321	0.321	0.321
	Stern Grove	0.004	0.004	0.012	0.013	0.013
	Sub-Total	***0.626***	***0.626***	***0.634***	***0.635***	***0.635***
Total Irrigation and Other Non-Potable Pumping		***2.90***	***2.90***	***2.91***	***1.77***	***1.81***

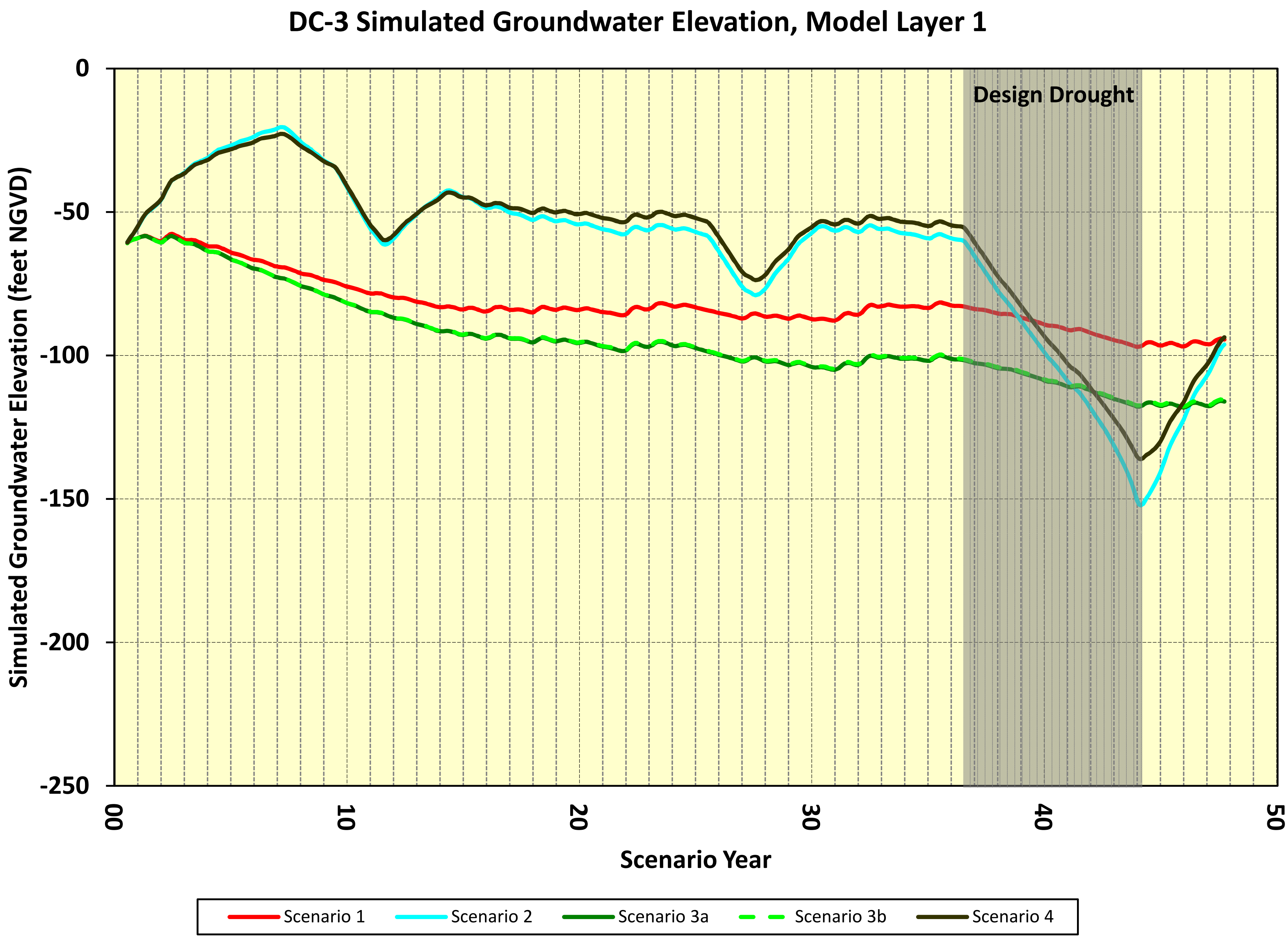
Key:
afy - acre-feet per year
mgd - million gallons per day
PA - Partner Agencies
GGP - Golden Gate Park
GSR - Regional Groundwater Storage and Recovery
SFGW - San Francisco Groundwater Supply
SFPUC - San Francisco Public Utilities Commission

Notes:
(1) Pumping wells that are listed identify the wells in the model scenarios whose pumping assumptions were modified compared to the 2008 No-Project Scenario by HydroFocus (May, 2011, ver. 3.1), as a result of revised Soil Moisture Budget (SMB). Pumping rates for the three wells in the GGP, California Golf No. 02, Edgewood Development Center, Zoo No. 05, and Stern Grove wells were further modified compared to the results of revised SMB.
(2) Olympic Club No. 09 values include pumping for both Olympic Golf Club wells.
(3) Holy Cross No. 3 well irrigation pumping for Scenarios 1, 2, 3a, and 3b is based on the results of revised SMB. Based on the projected future build-out at the Holy Cross cemetery, an additional pumping of 0.04 mgd (45 afy) was estimated to occur under Scenario 4 (Cumulative).

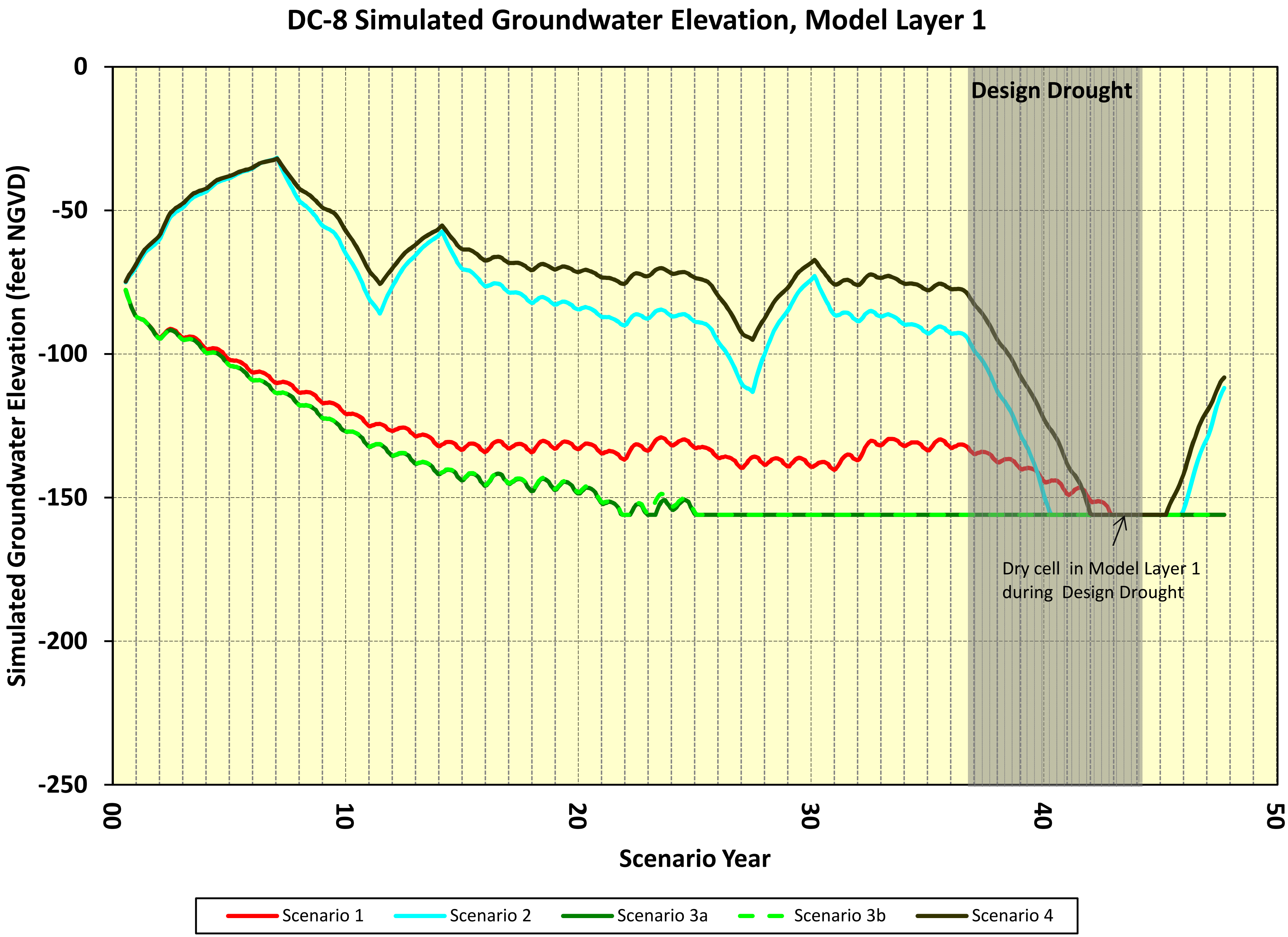
Attachment 10.6-A

Model Scenario Hydrographs for Selected Locations

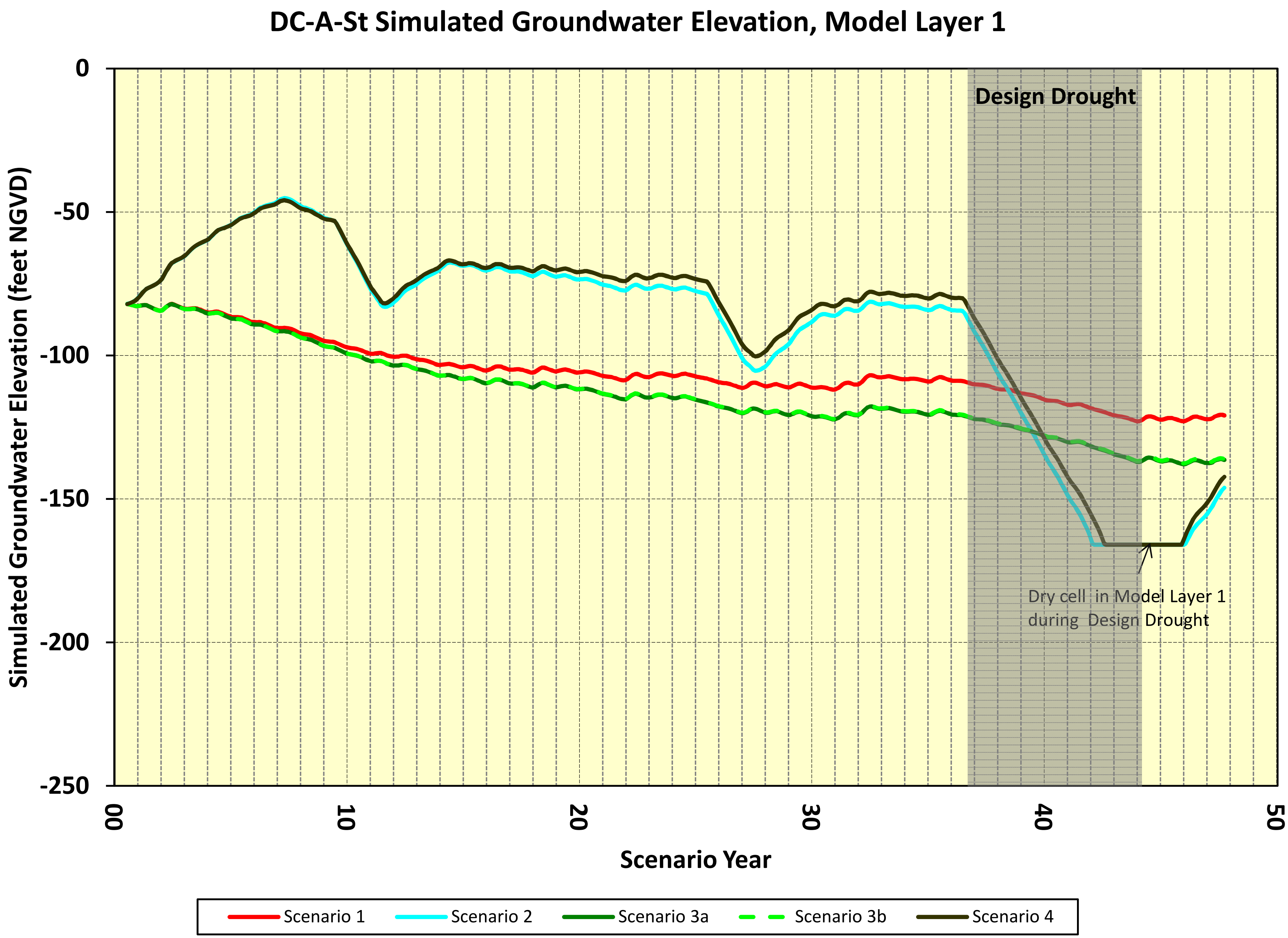

DC-2-Westlake Simulated Groundwater Elevation, Model Layer 1
Simulated Groundwater Elevation (feet NGVD)
0
-20
-40
-60
-80
-100
-120
-140
-160
Design Drought
Dry cell in Model Layer 1
during Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

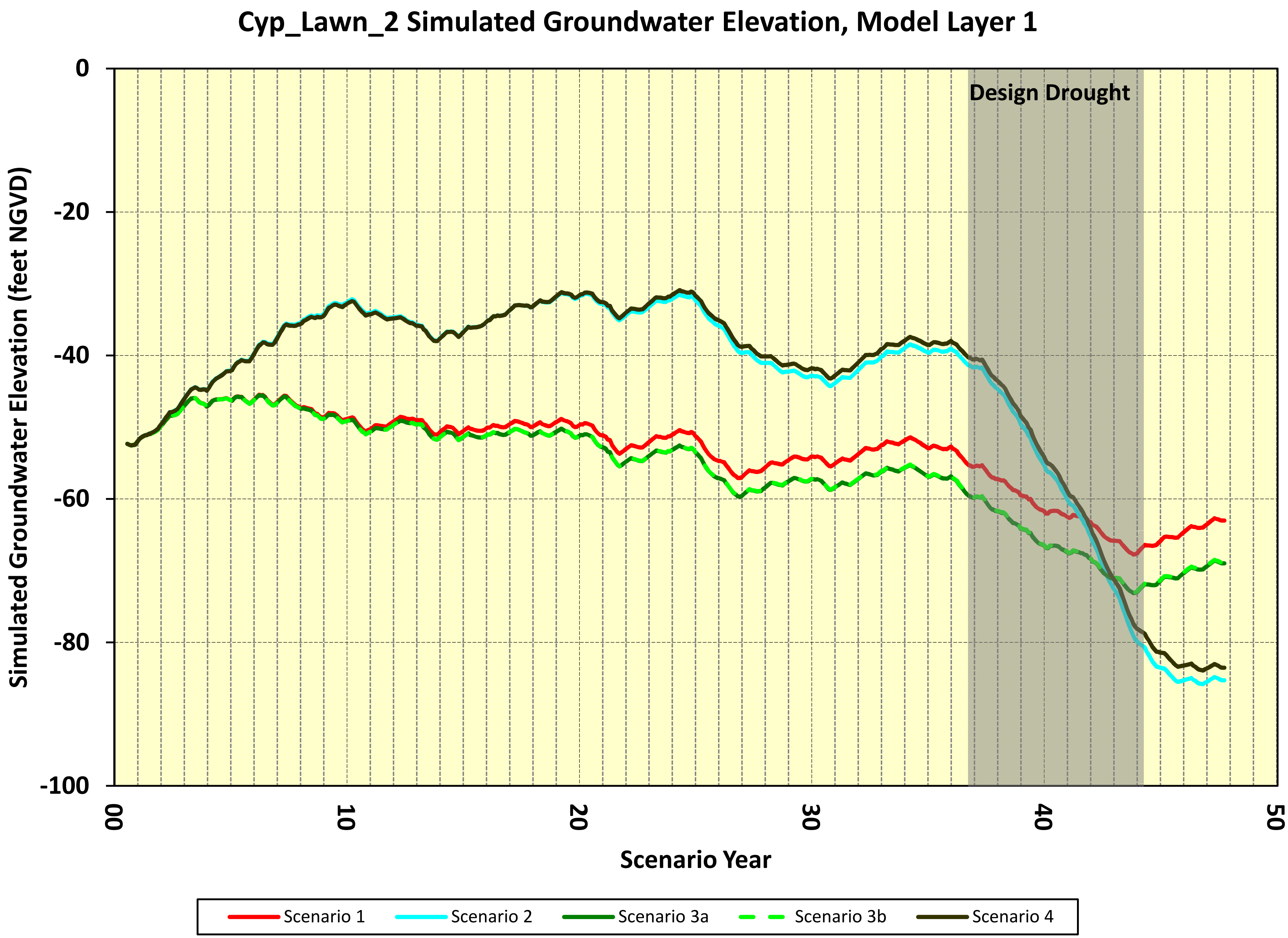


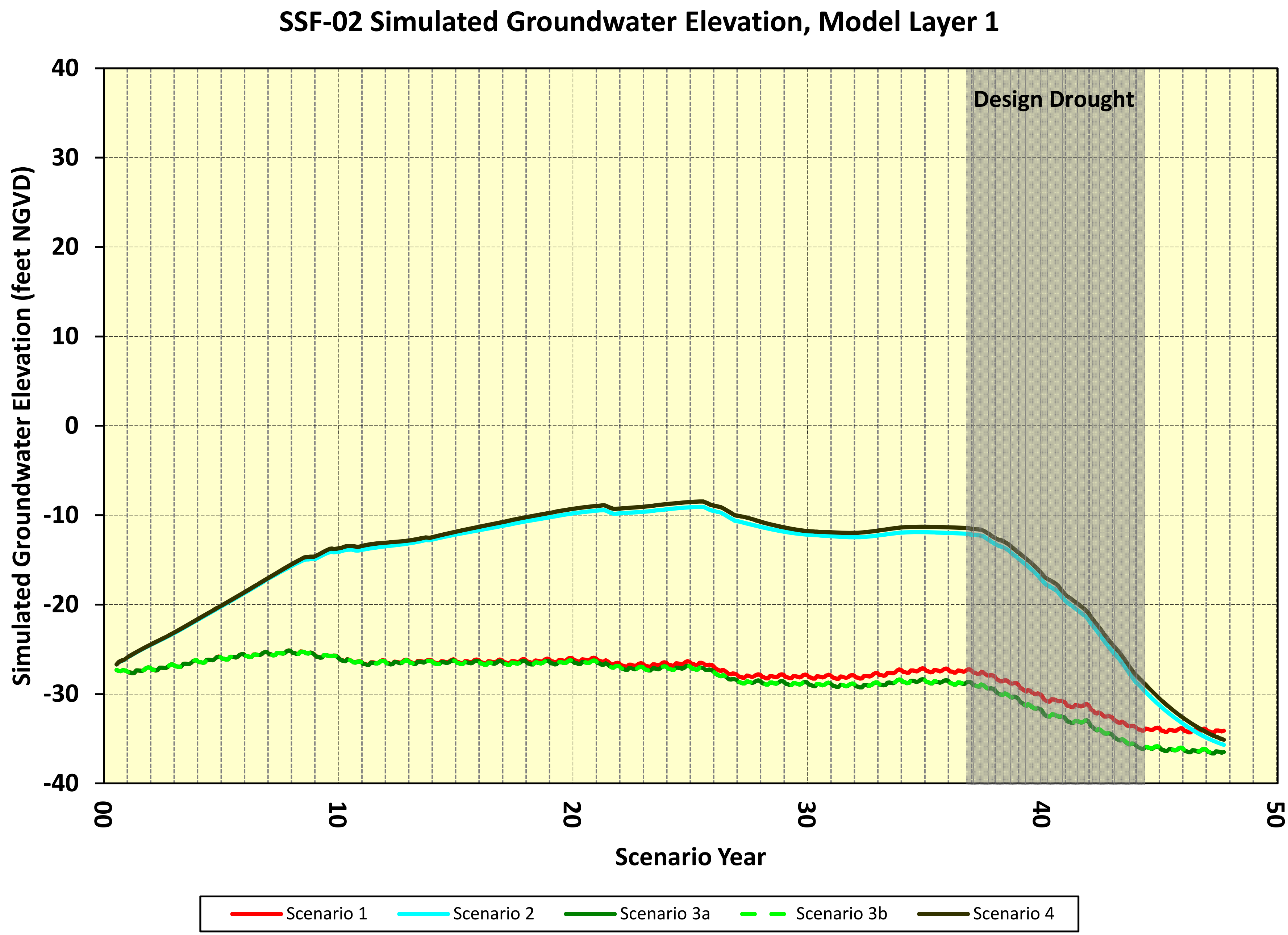
DC-3 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

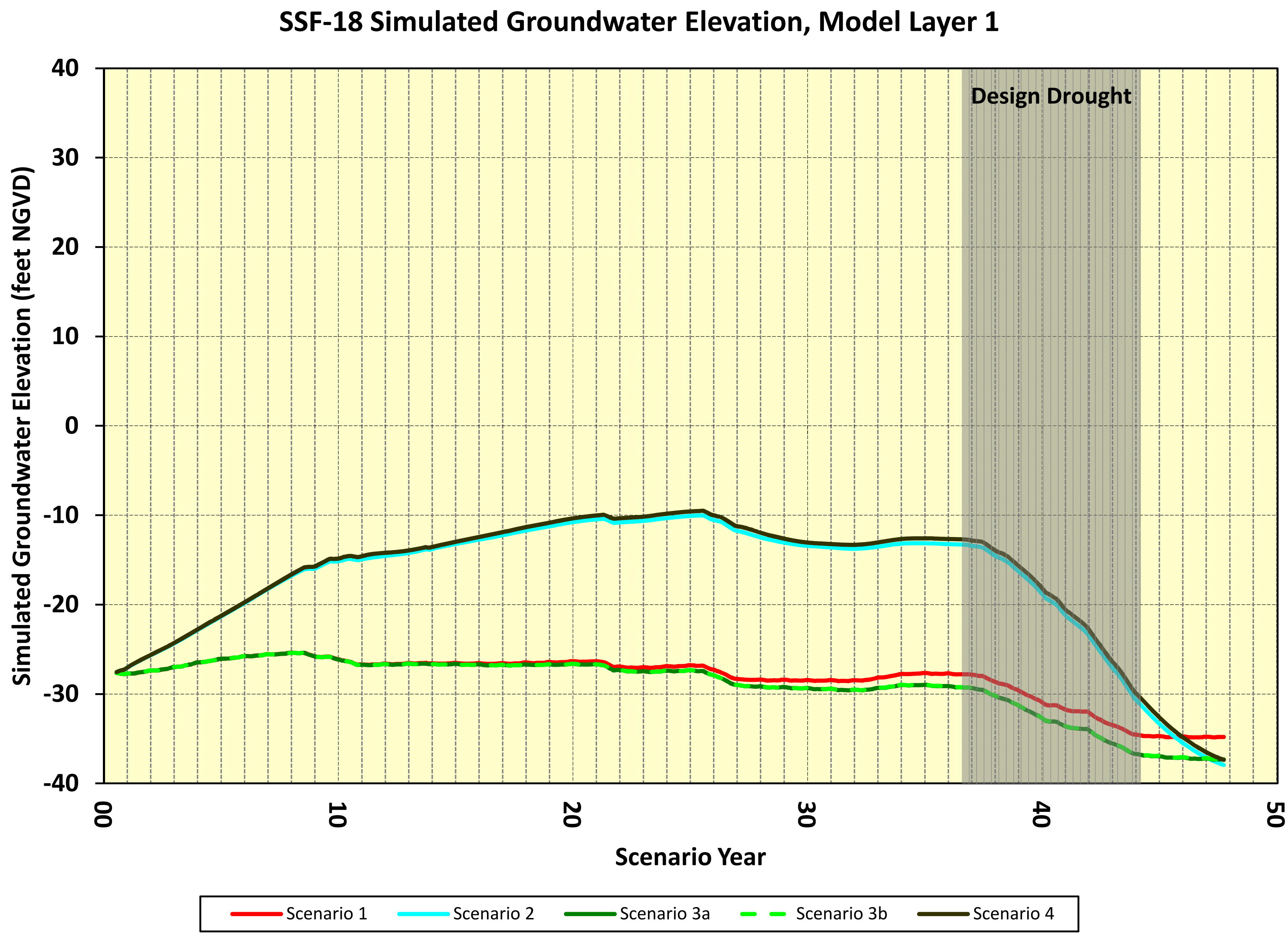


DC-8 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Dry cell in Model Layer 1
during Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

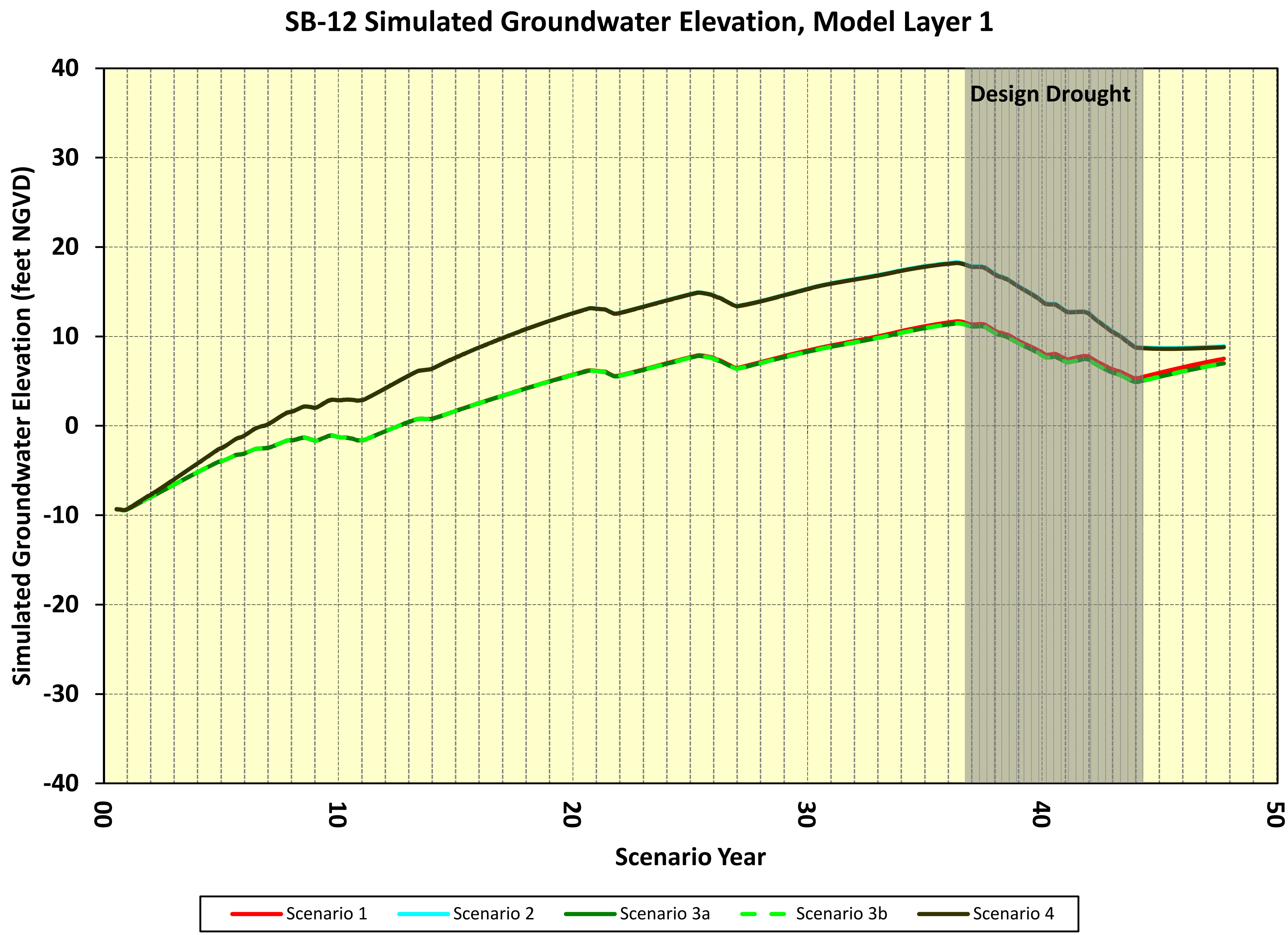

DC-A-St Simulated Groundwater Elevation, Model Layer 1
Design Drought
Dry cell in Model Layer 1
during Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


Cyp_Lawn_2 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-20
-40
-60
-80
-100
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

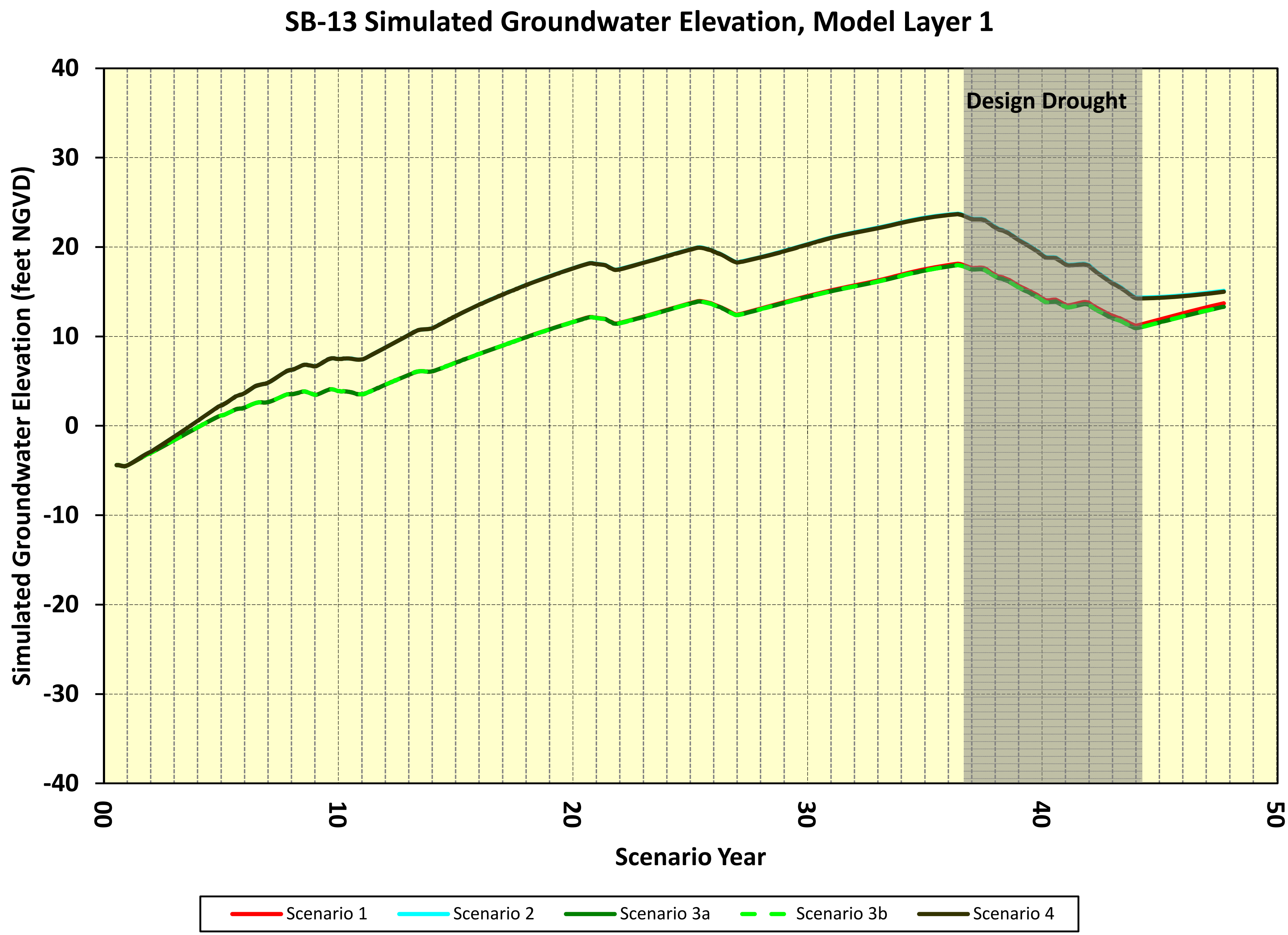

SSF-02 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
30
20
10
0
-10
-20
-30
-40
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

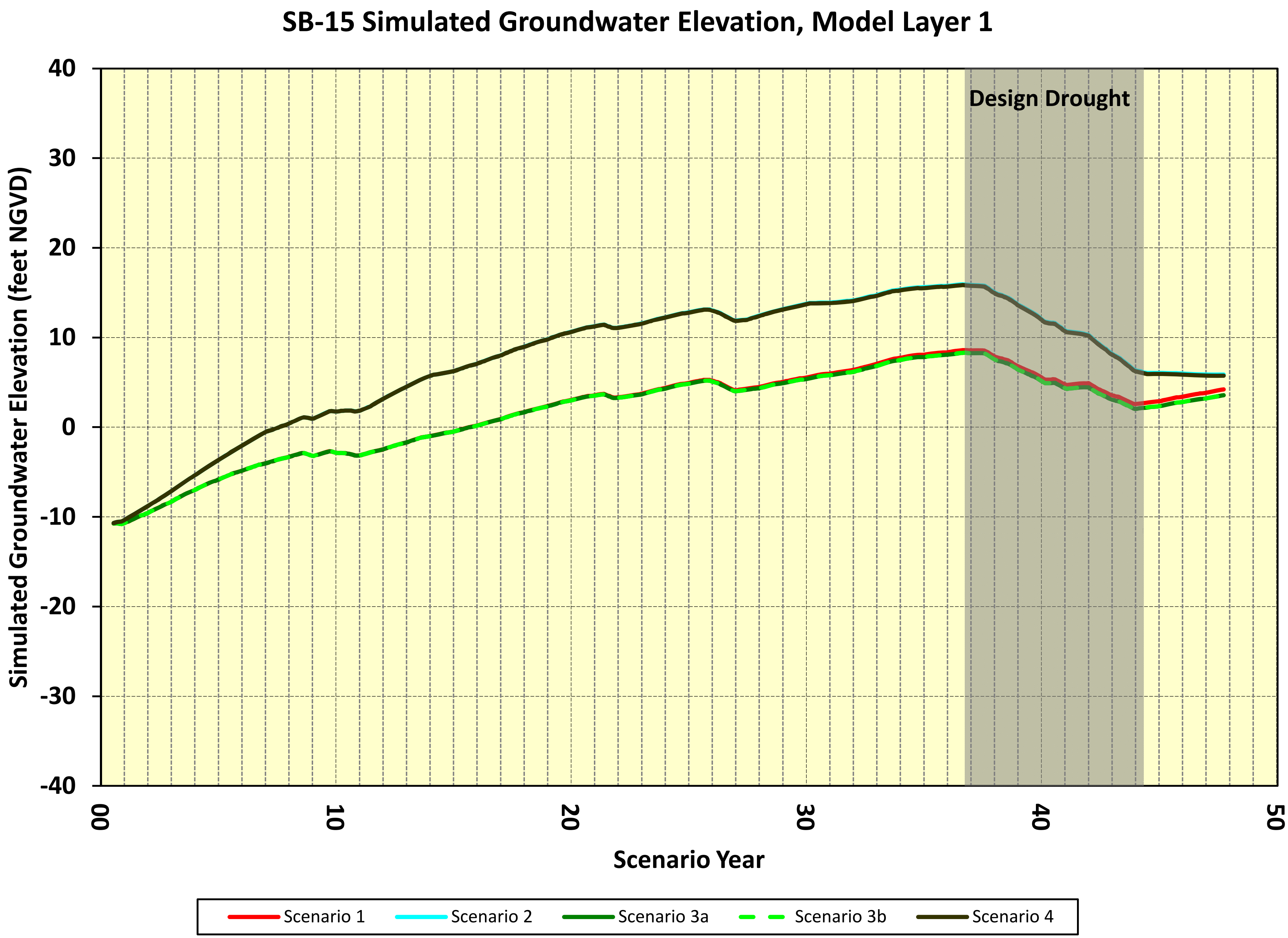


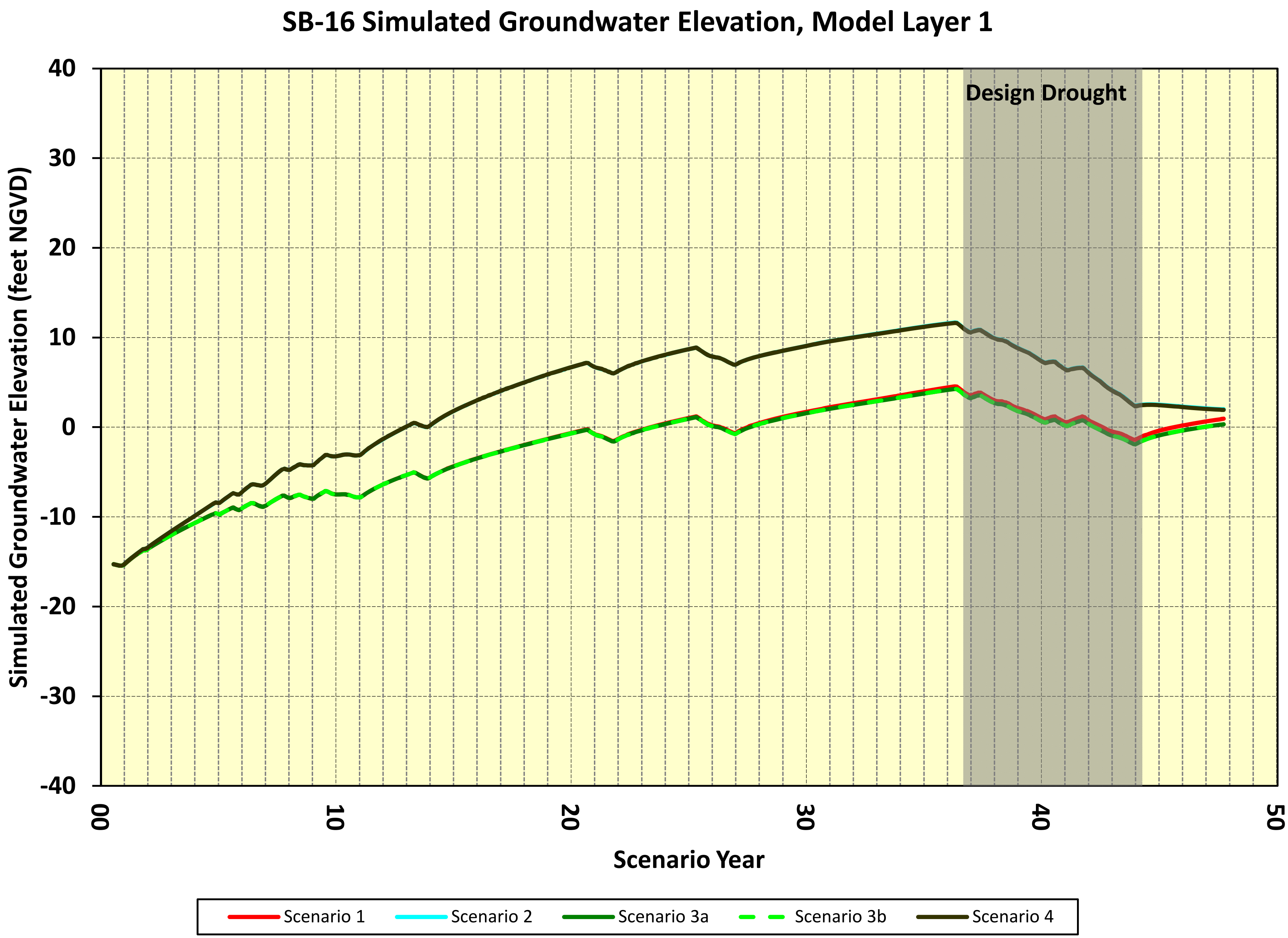
SSF-18 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
30
20
10
0
-10
-20
-30
-40
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

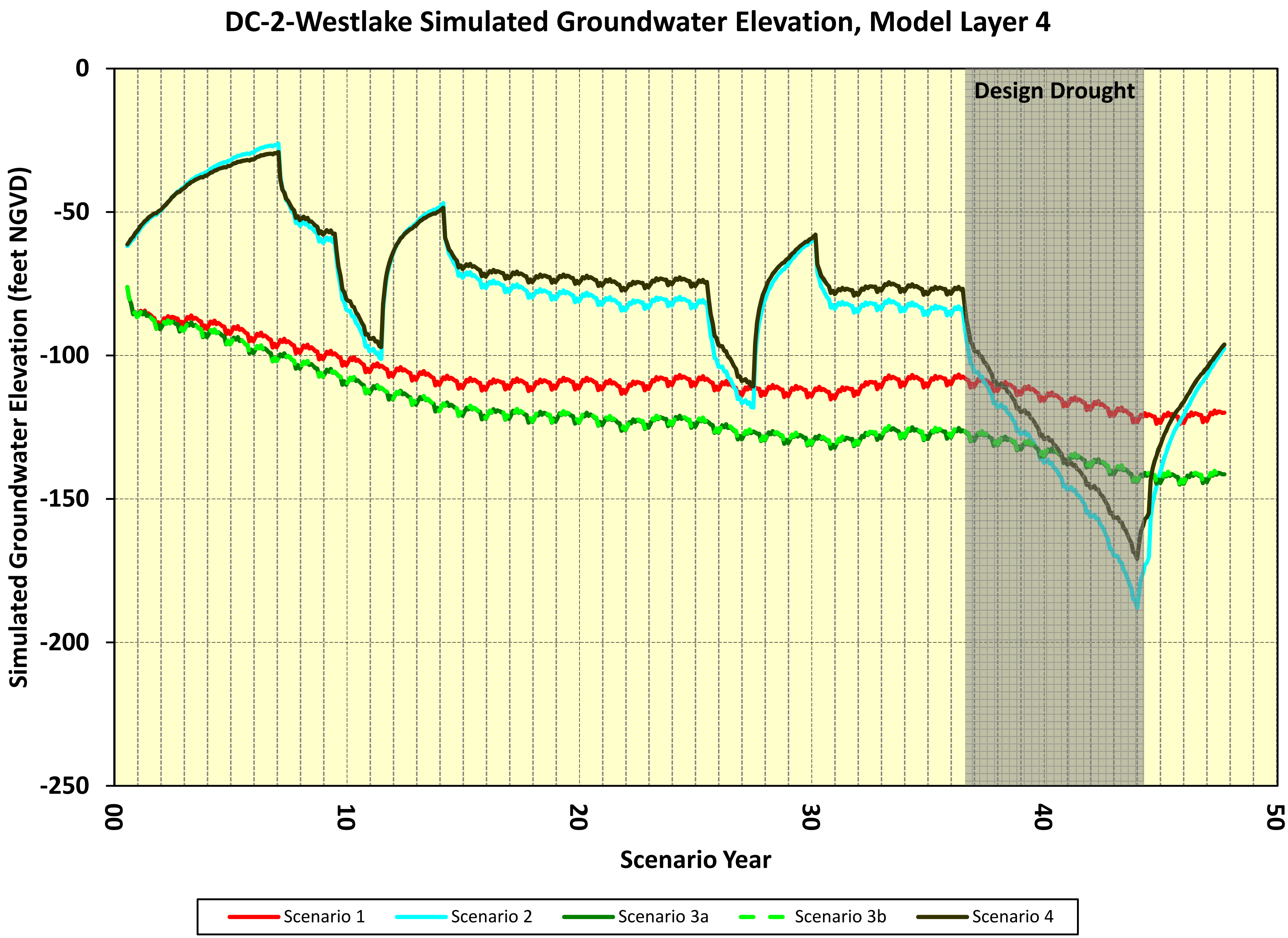


SB-12 Simulated Groundwater Elevation, Model Layer 1
Simulated Groundwater Elevation (feet NGVD)
40
30
20
10
0
-10
-20
-30
-40
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

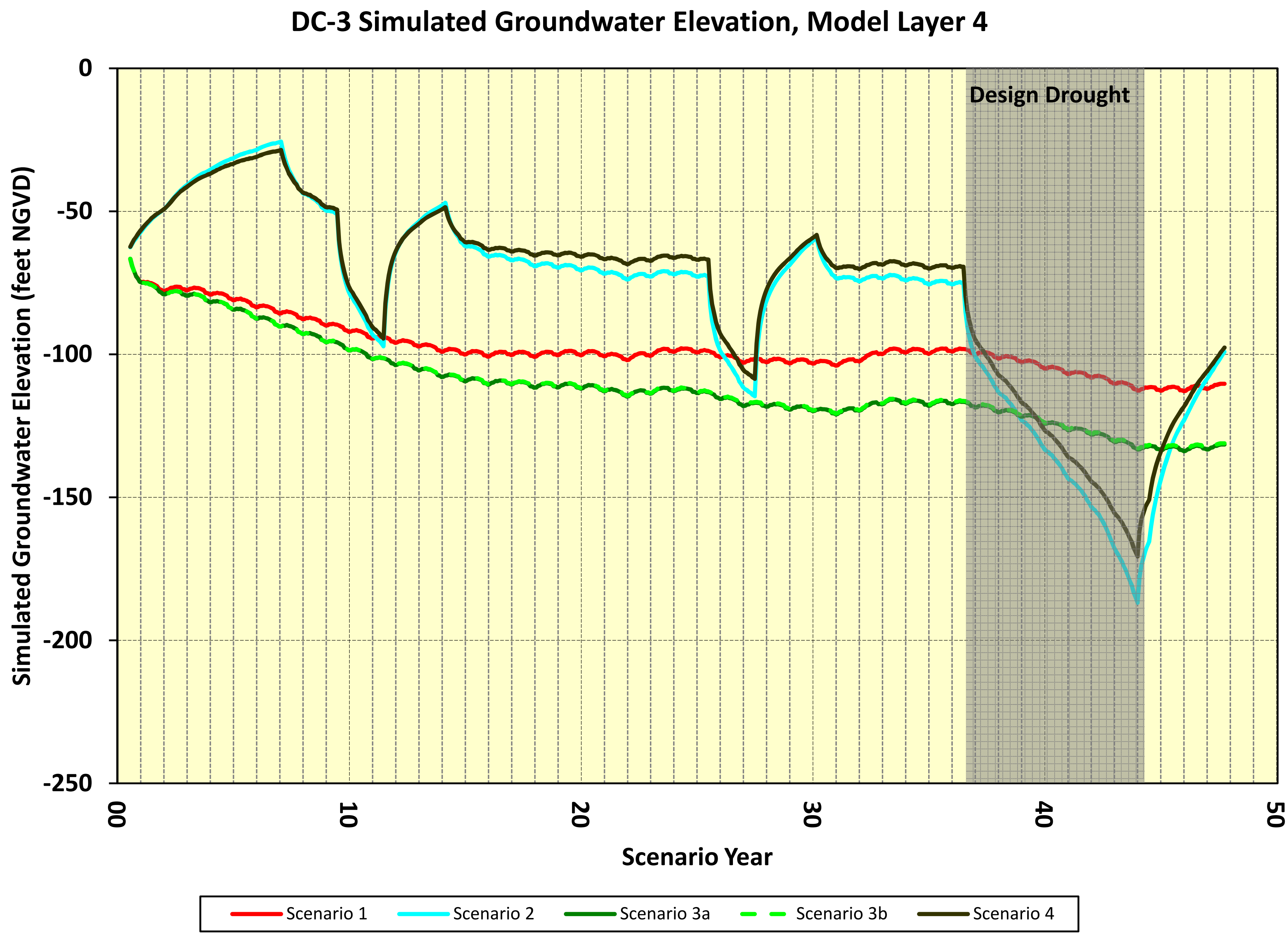

SB-13 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
30
20
10
0
-10
-20
-30
-40
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


SB-15 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
30
20
10
0
-10
-20
-30
-40
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

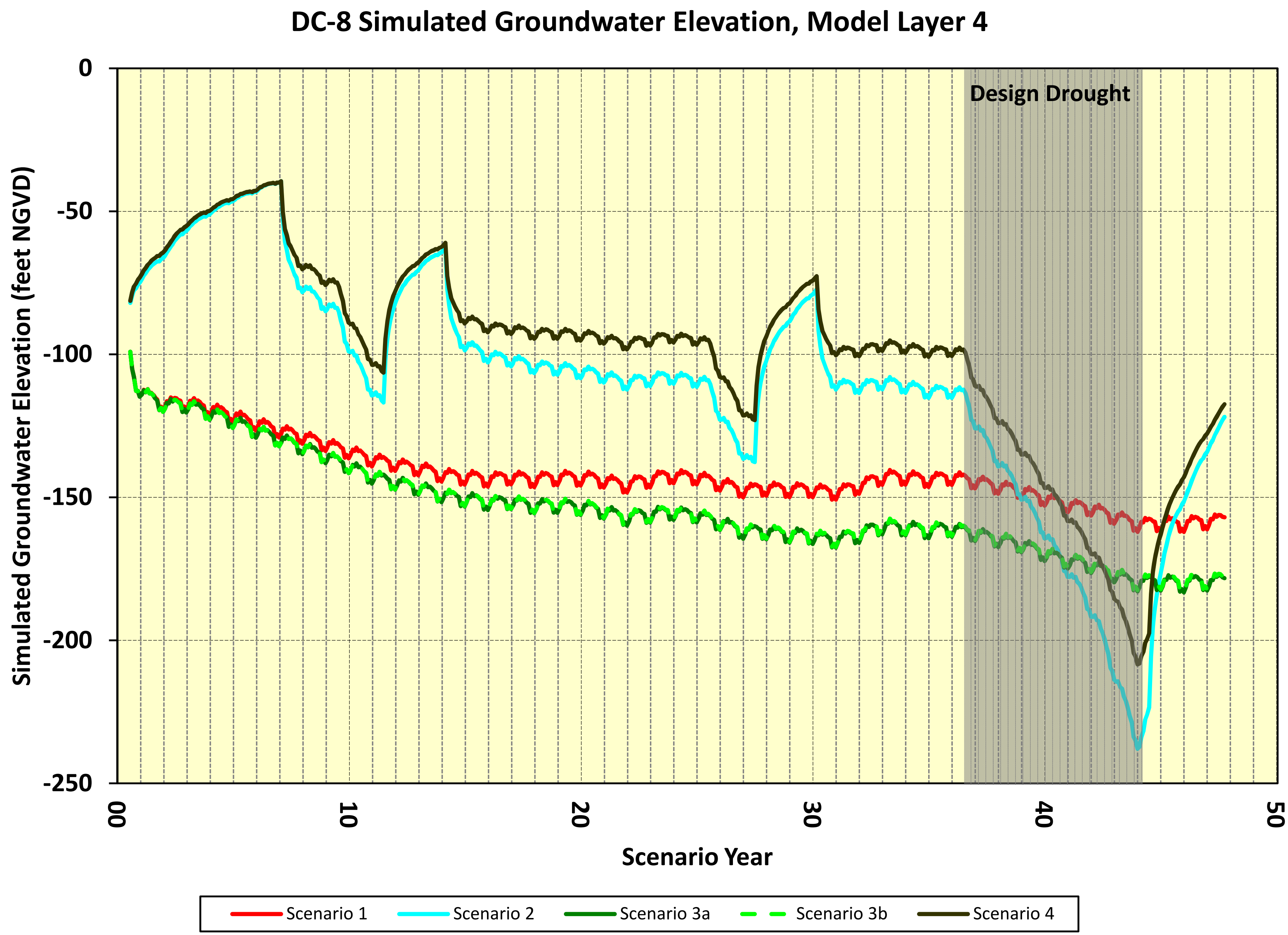

SB-16 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
30
20
10
0
-10
-20
-30
-40
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



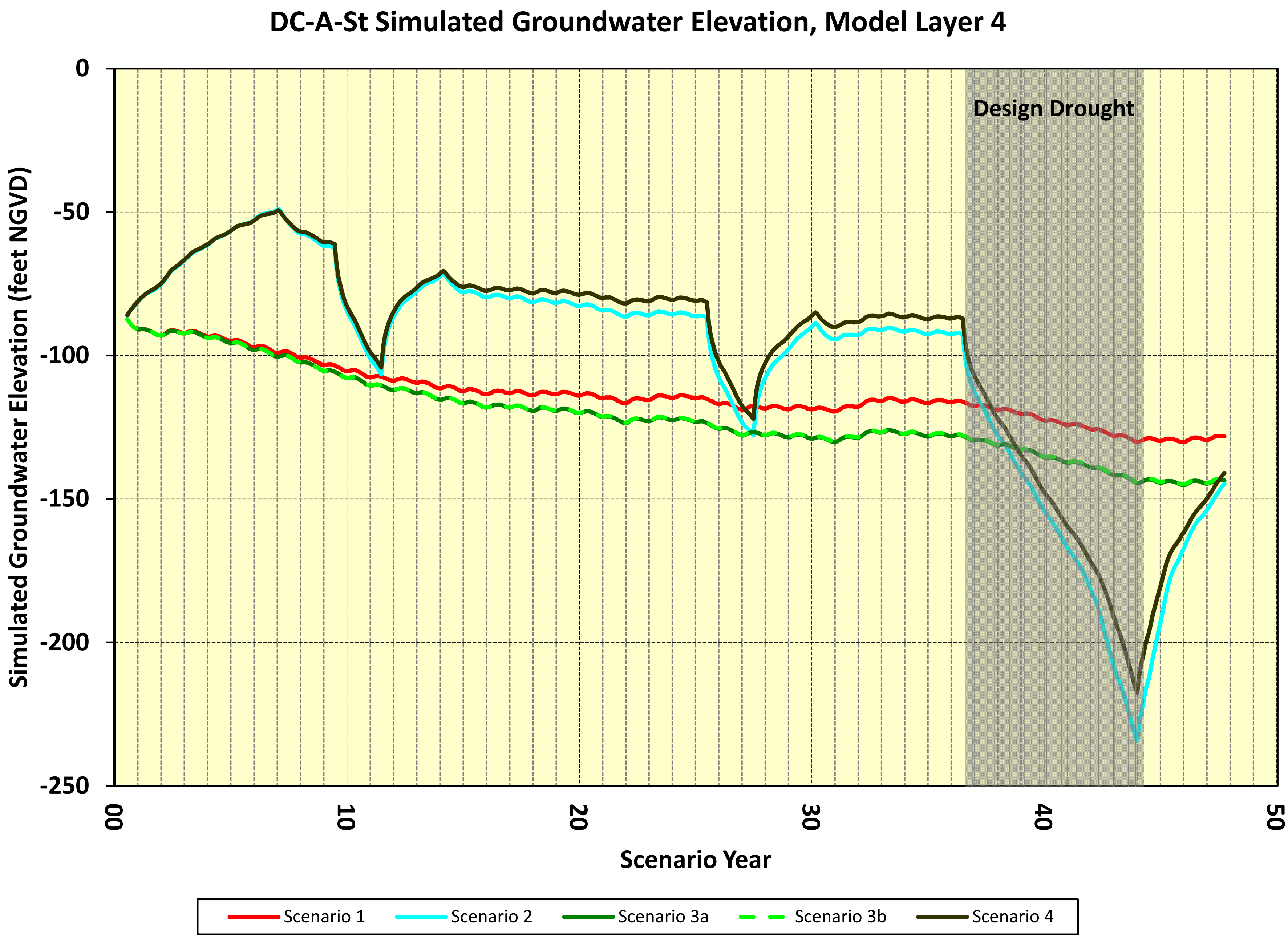
DC-2-Westlake Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



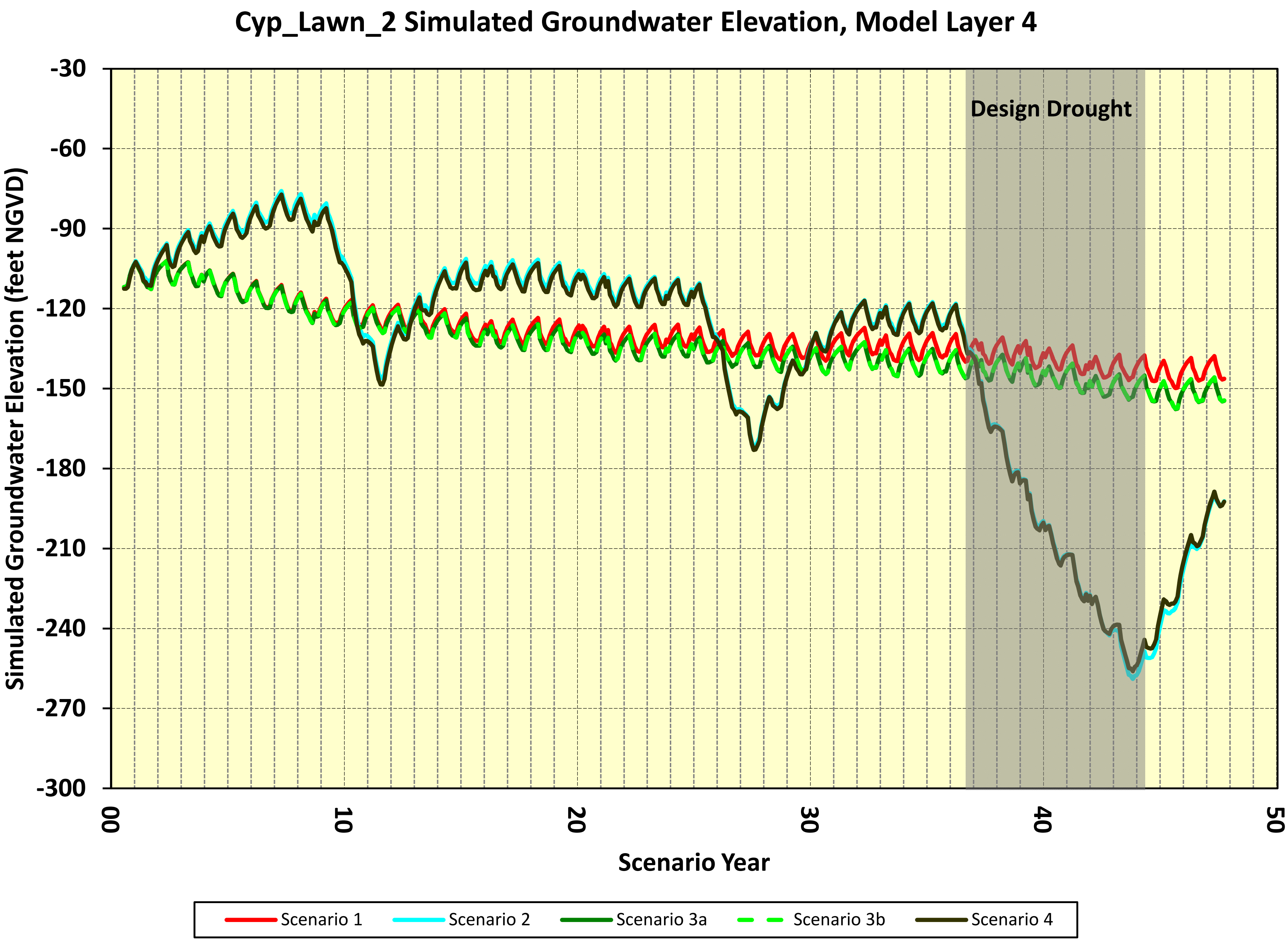
DC-3 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

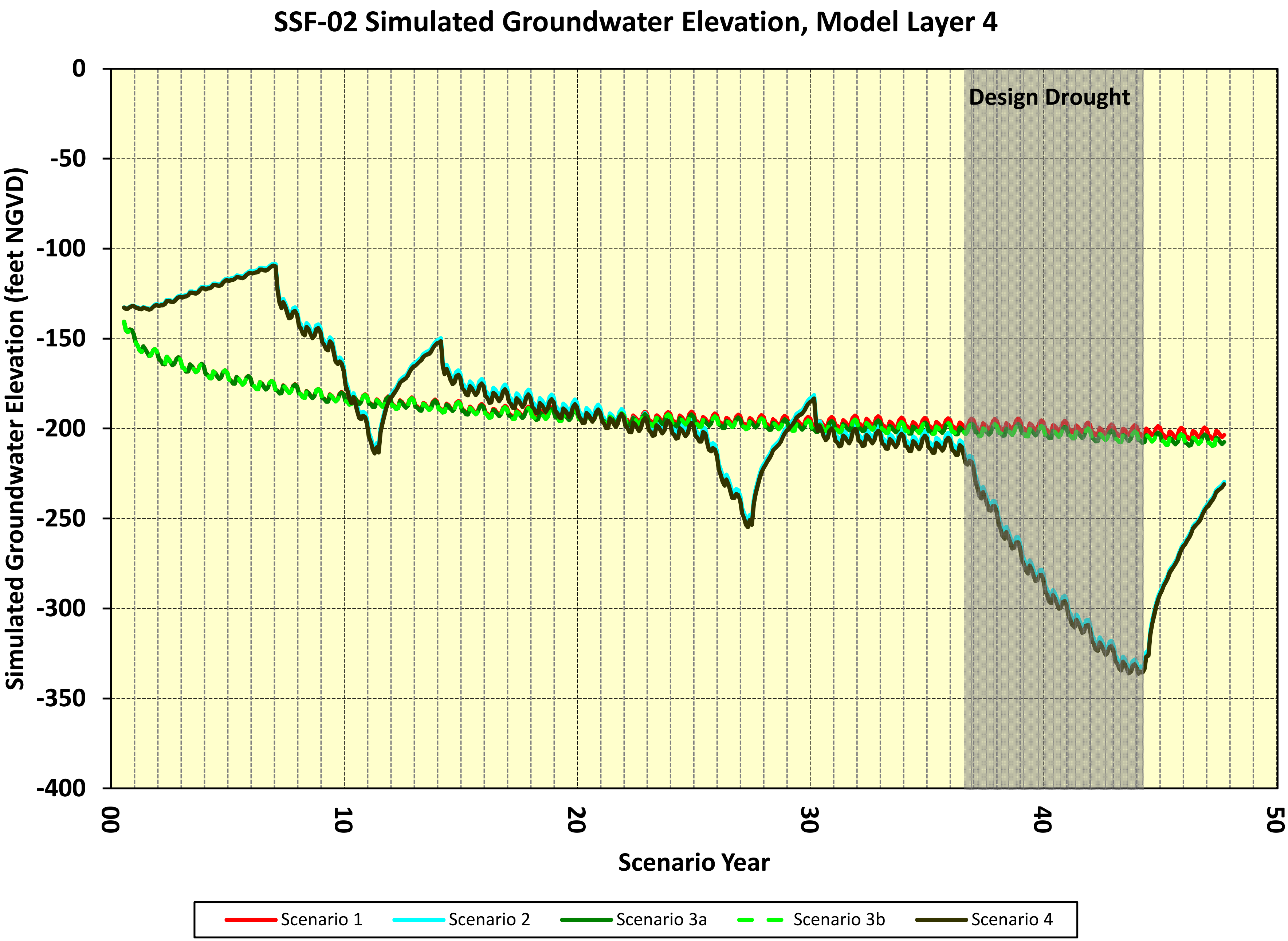


DC-8 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

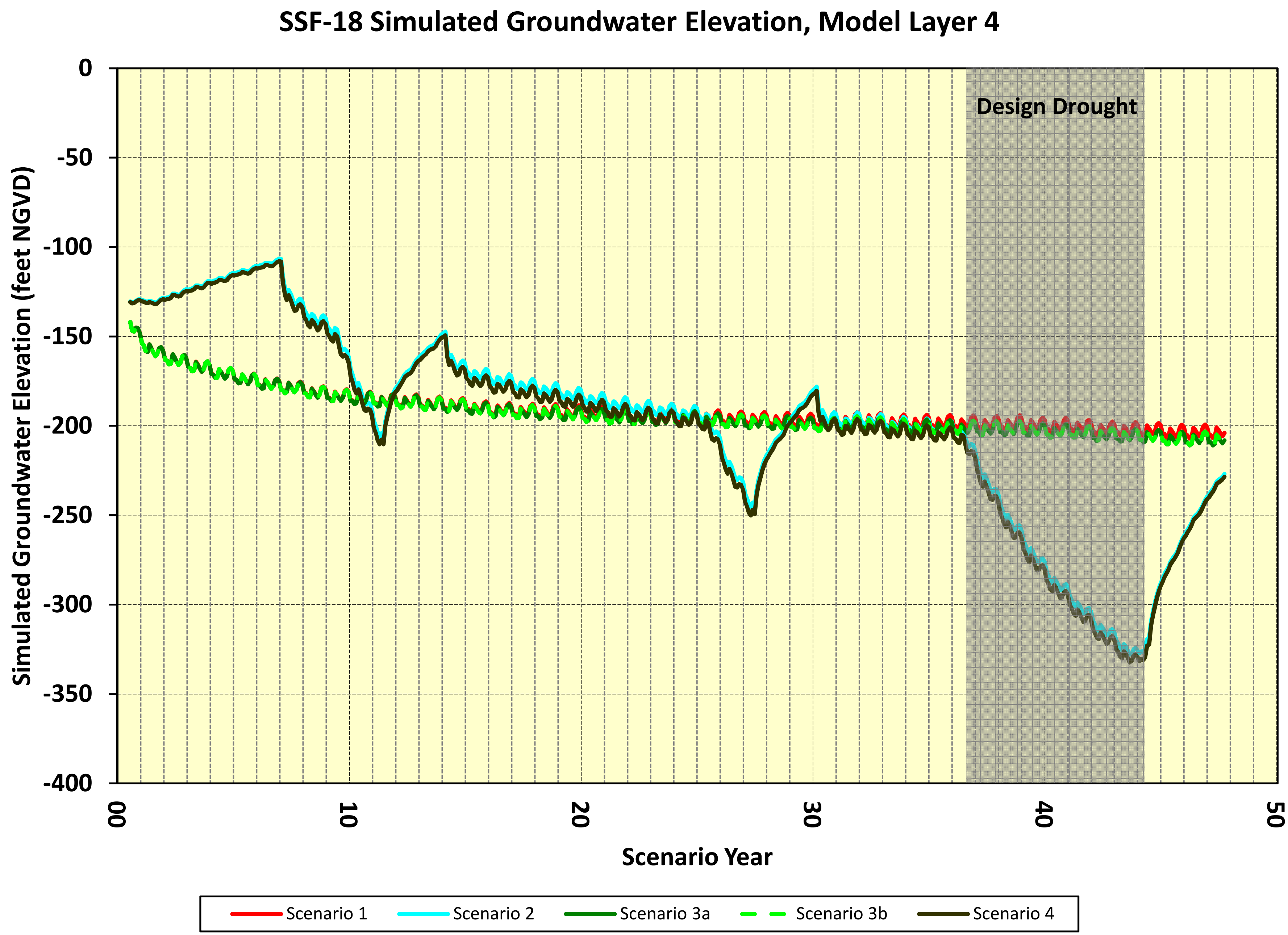


DC-A-St Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

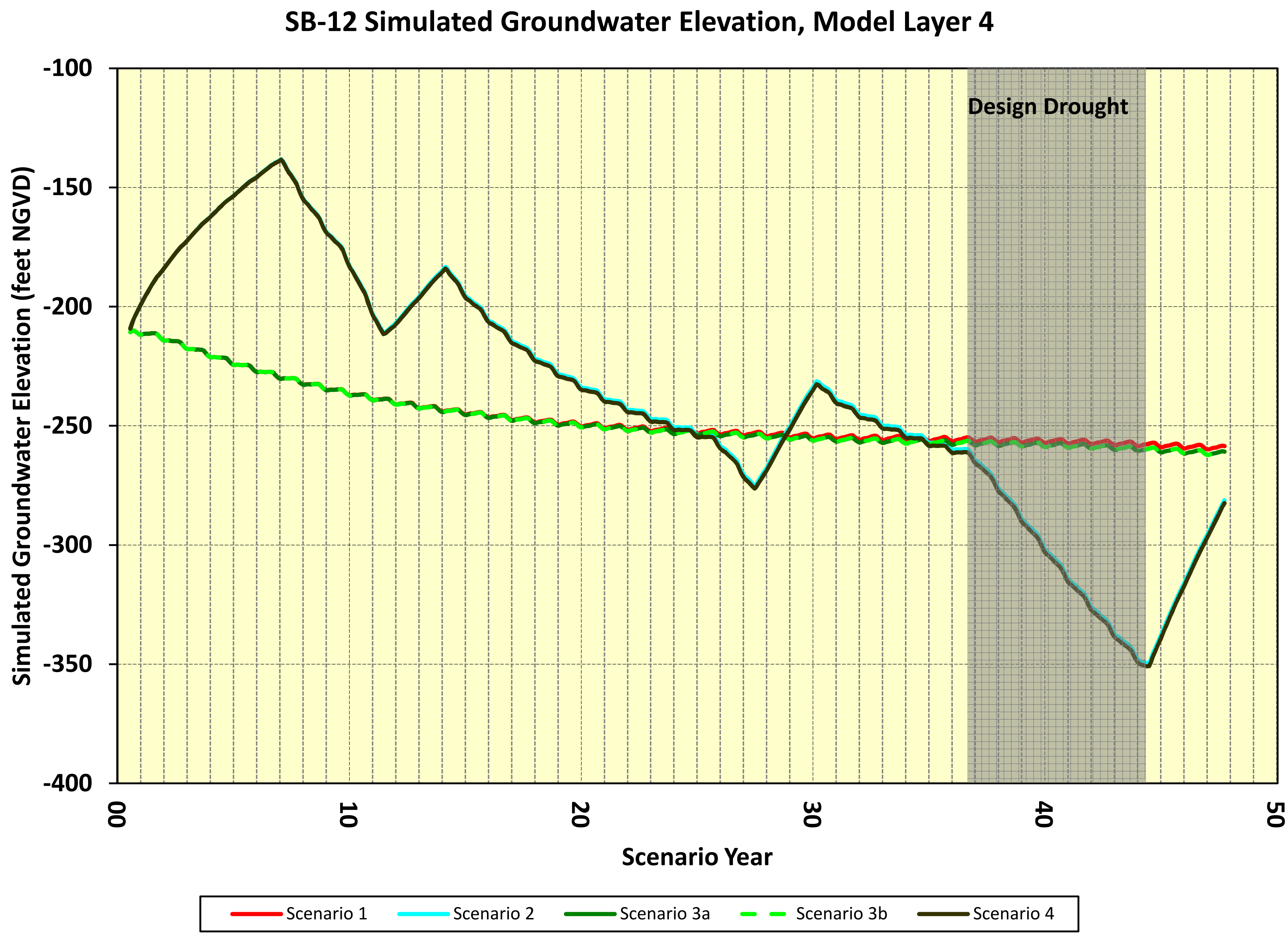

Cyp_Lawn_2 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
-30
-60
-90
-120
-150
-180
-210
-240
-270
-300
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



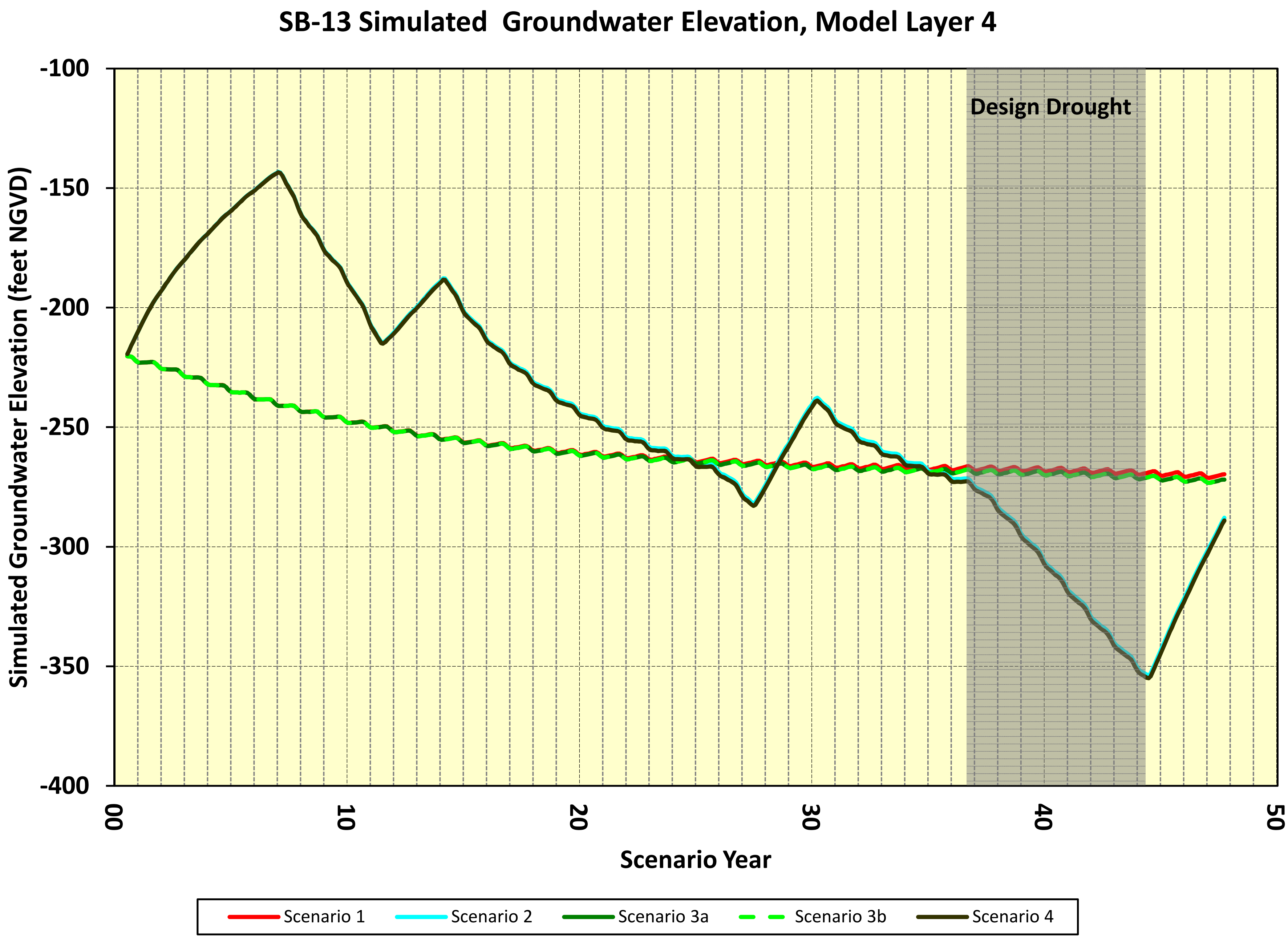
SSF-02 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

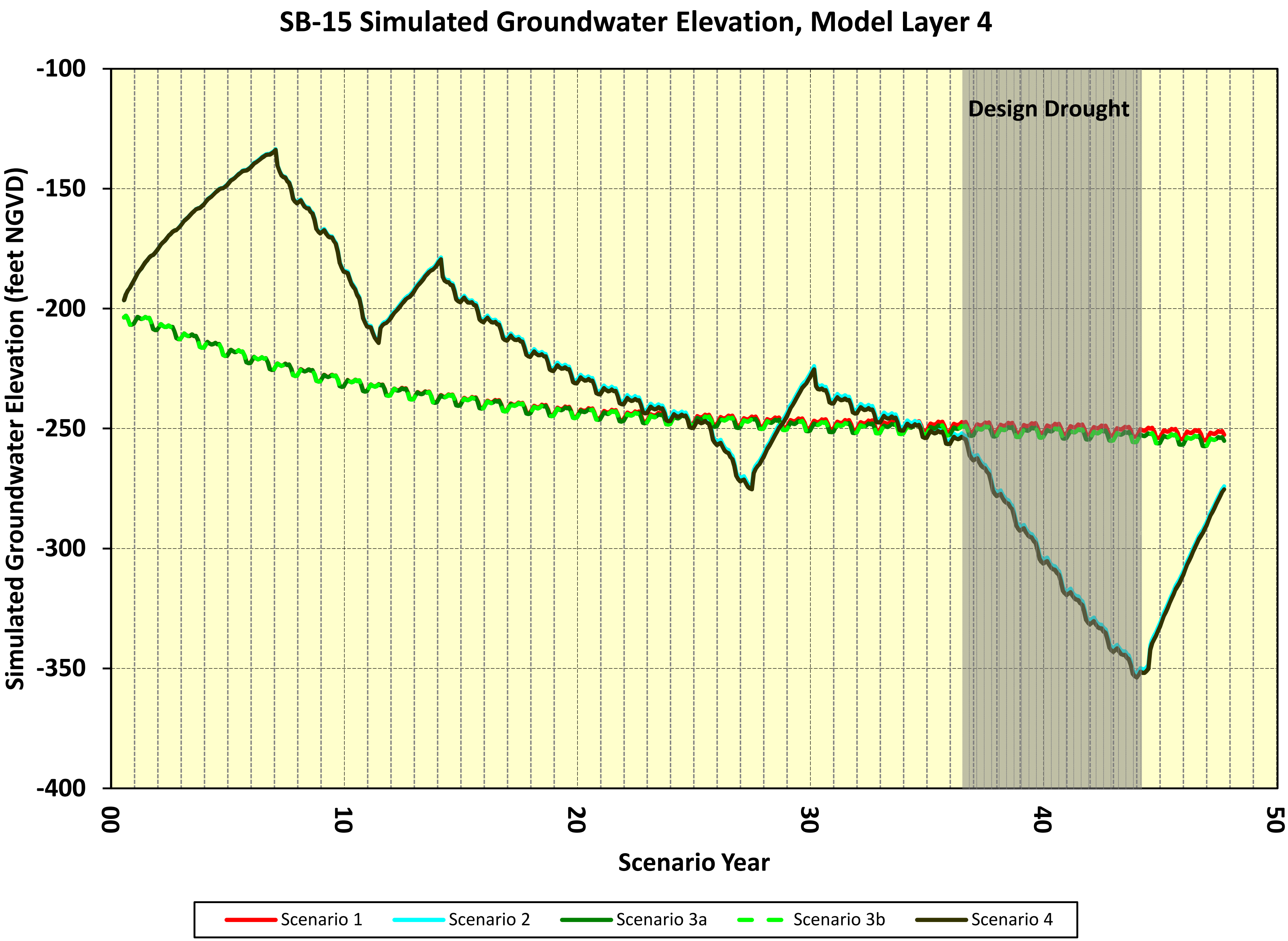


SSF-18 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

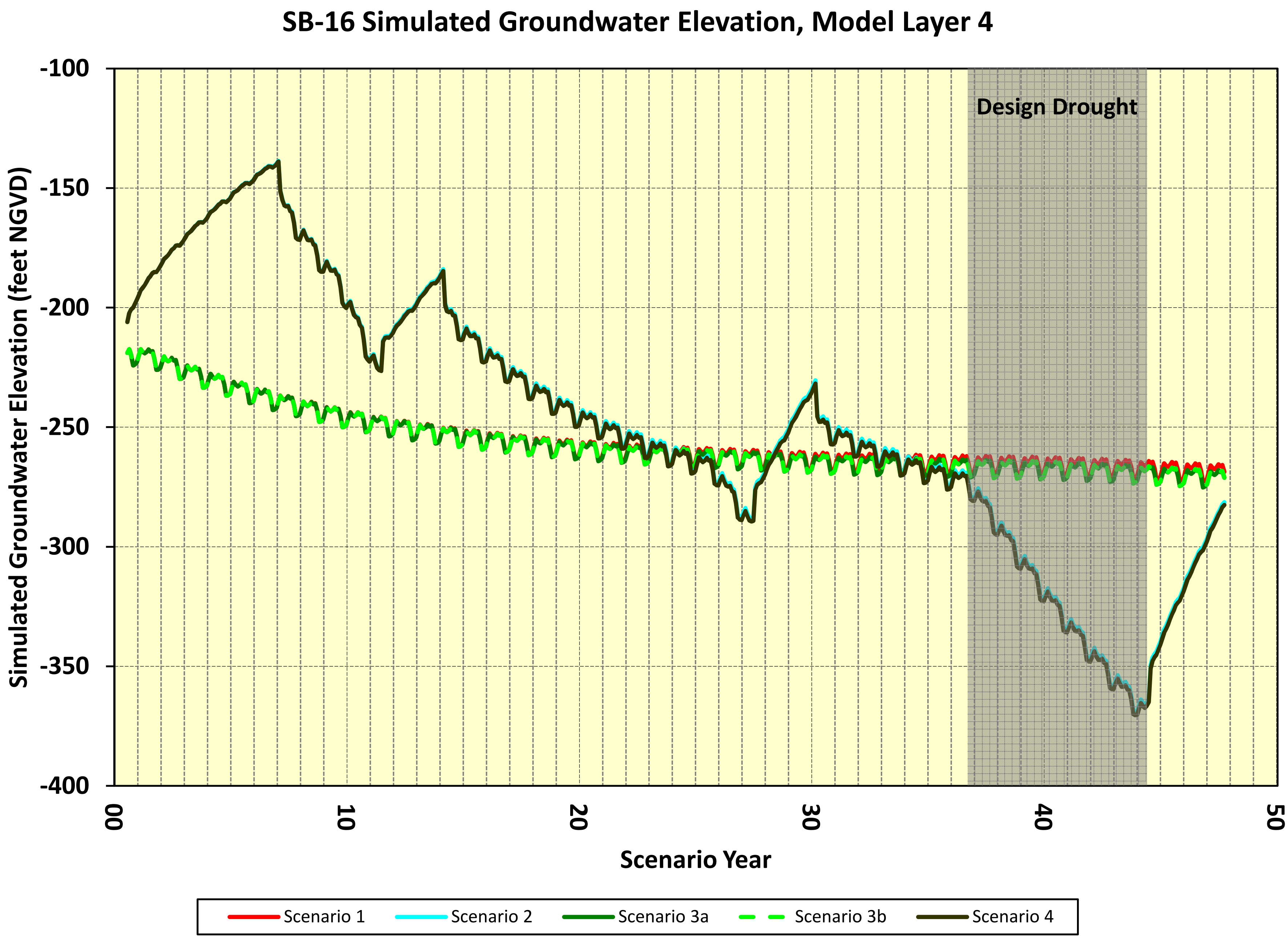


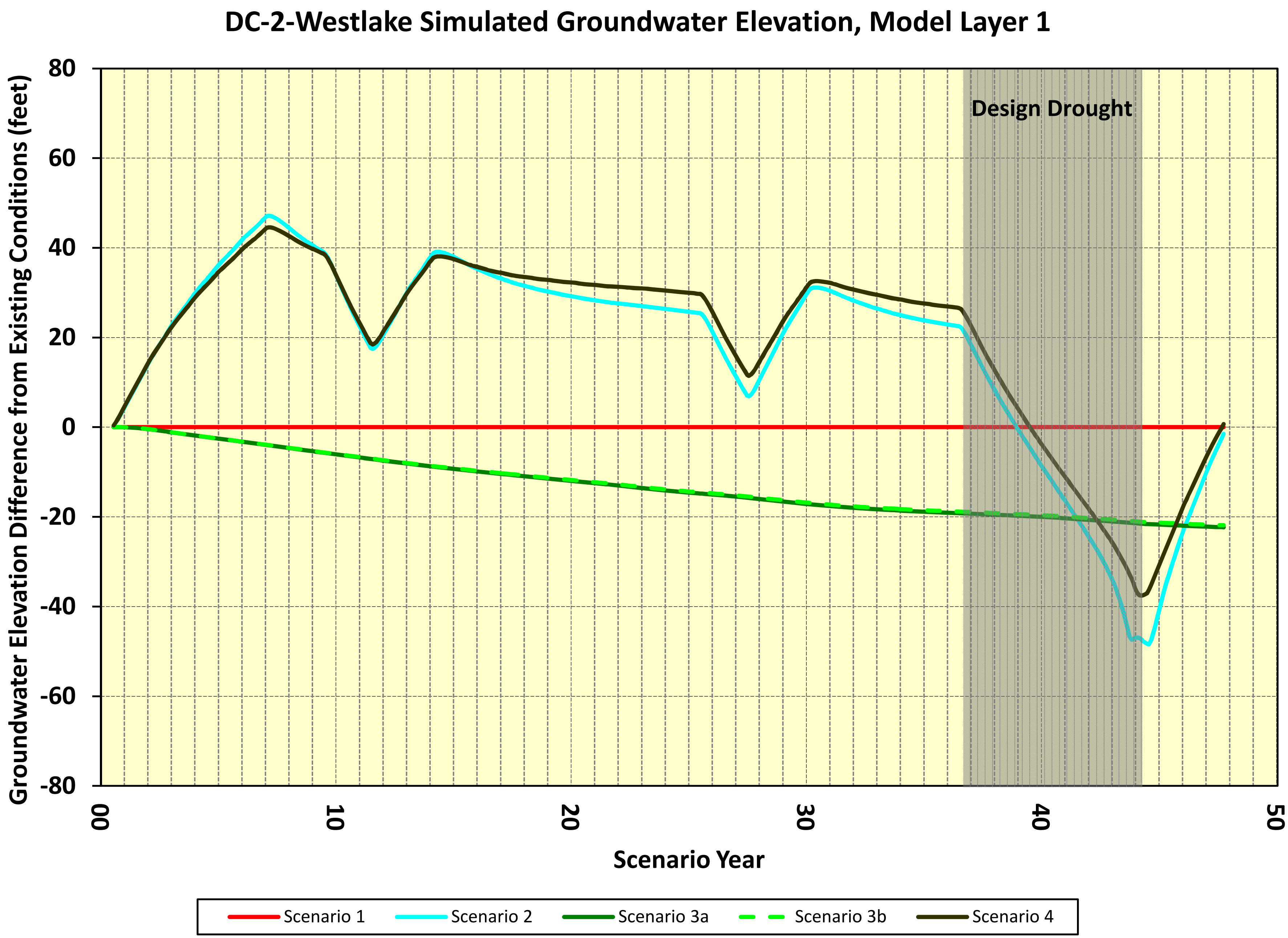
SB-12 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


SB-13 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

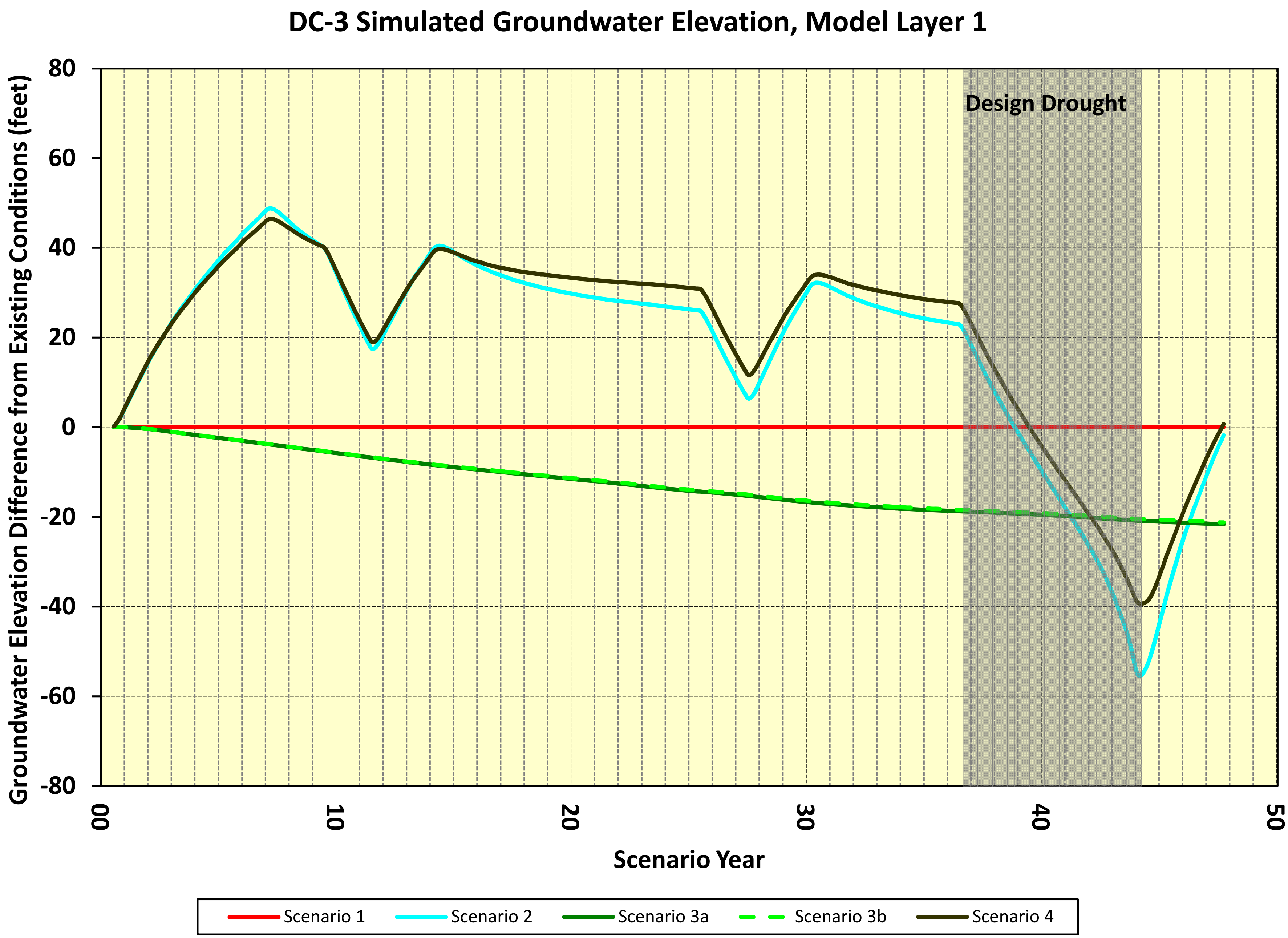


SB-15 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

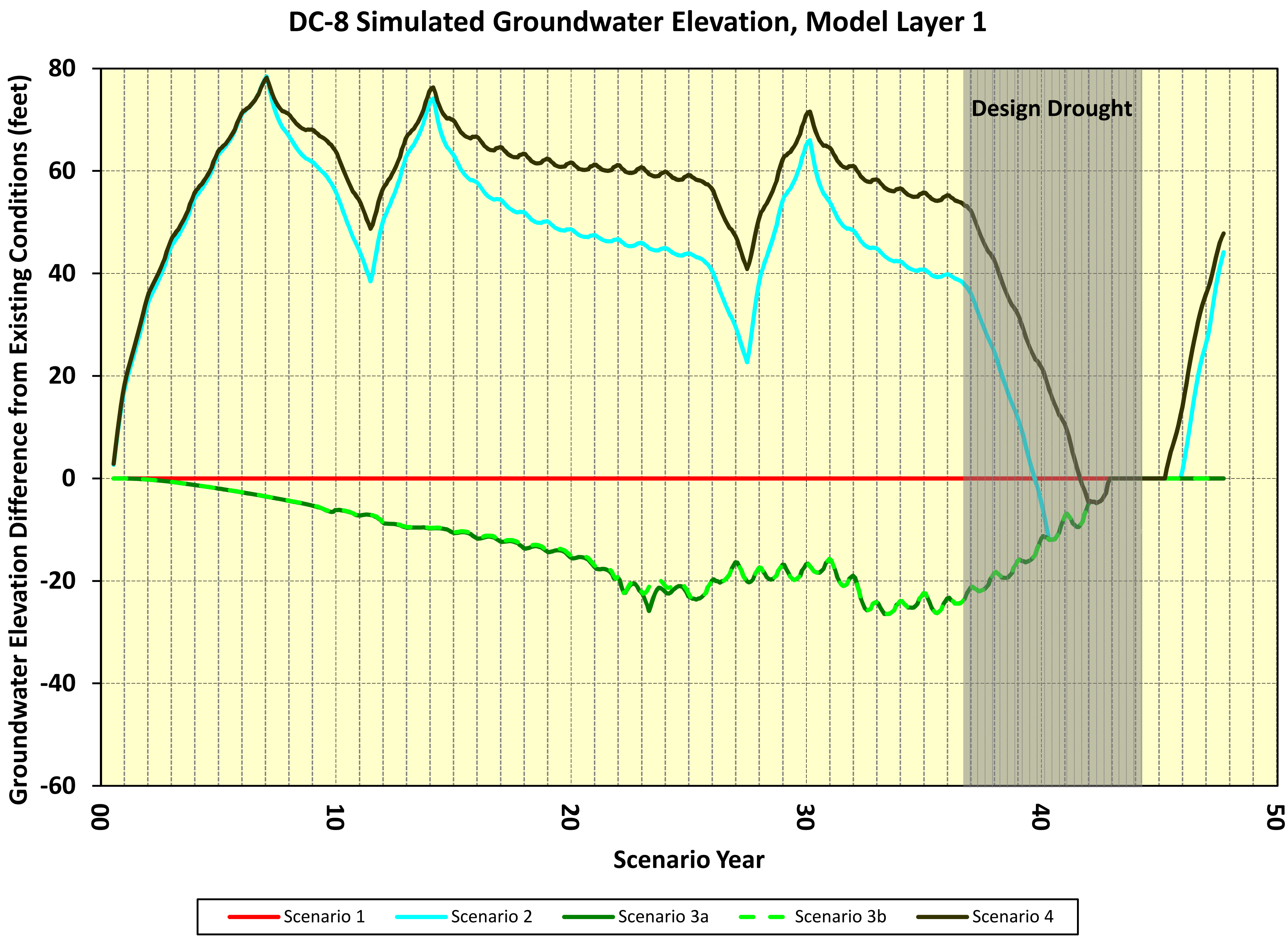

SB-16 Simulated Groundwater Elevation, Model Layer 4
Simulated Groundwater Elevation (feet NGVD)
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Design Drought
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

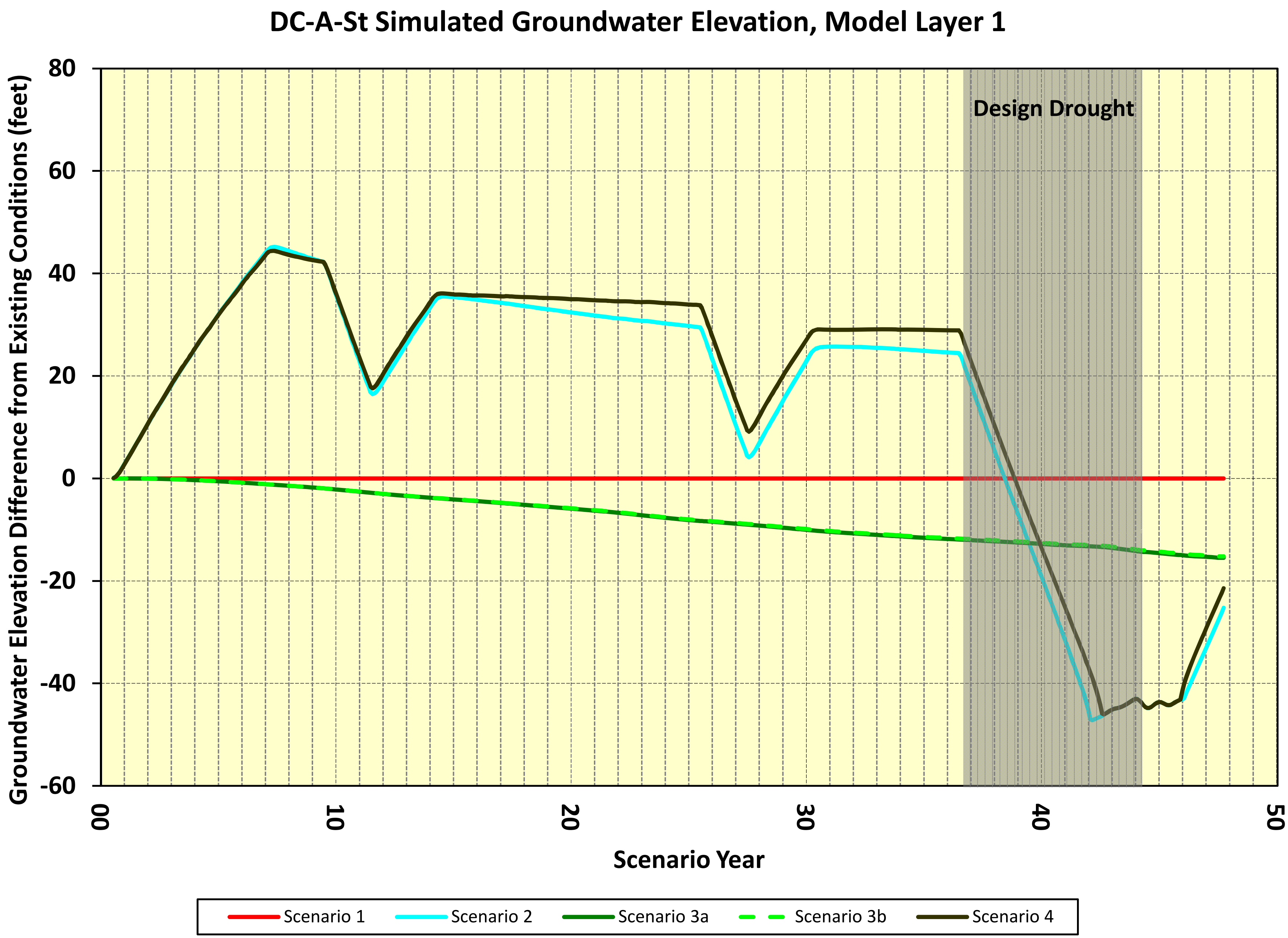


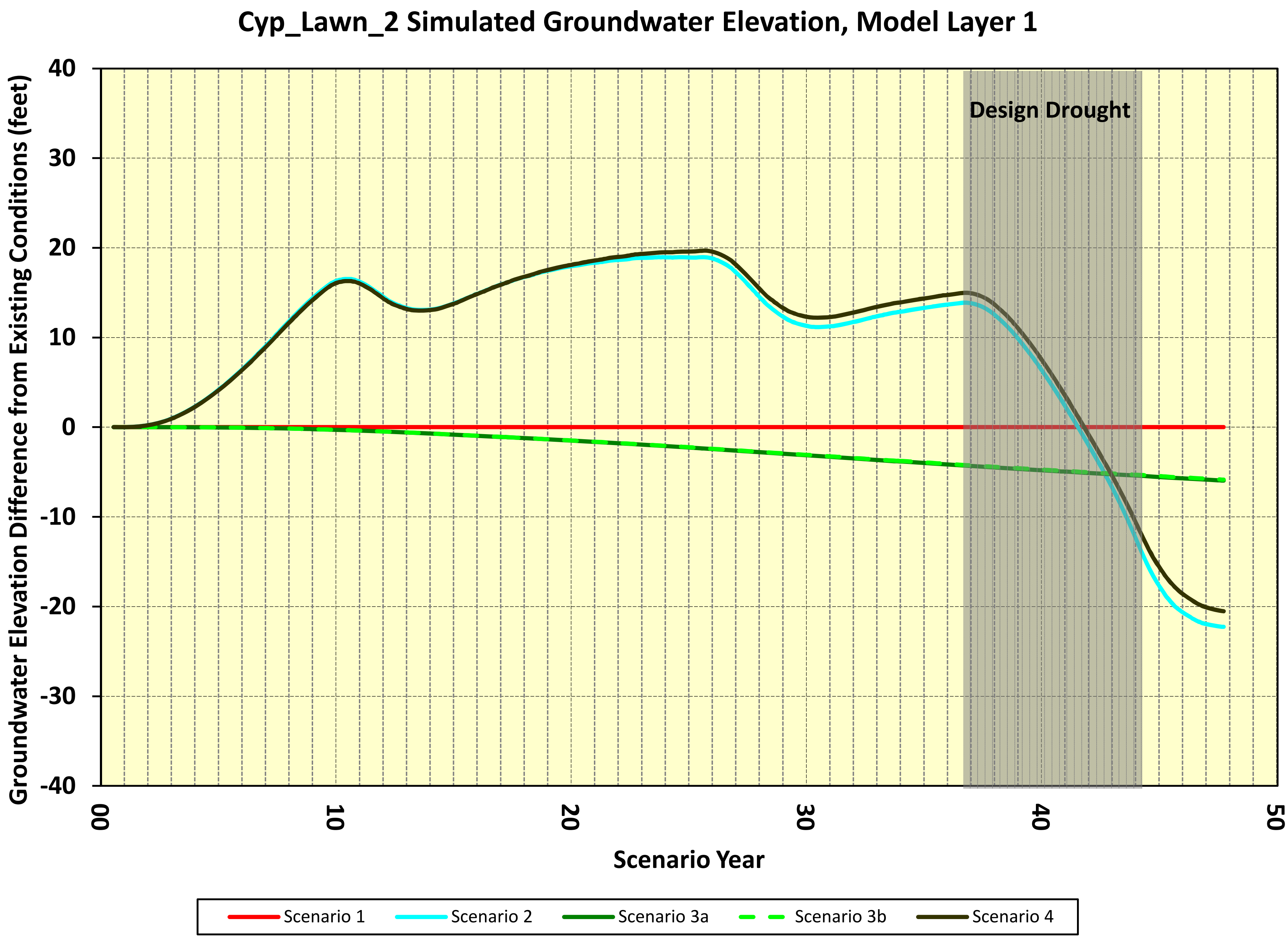
DC-2-Westlake Simulated Groundwater Elevation, Model Layer 1
Groundwater Elevation Difference from Existing Conditions (feet)
80
60
40
20
0
-20
-40
-60
-80
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



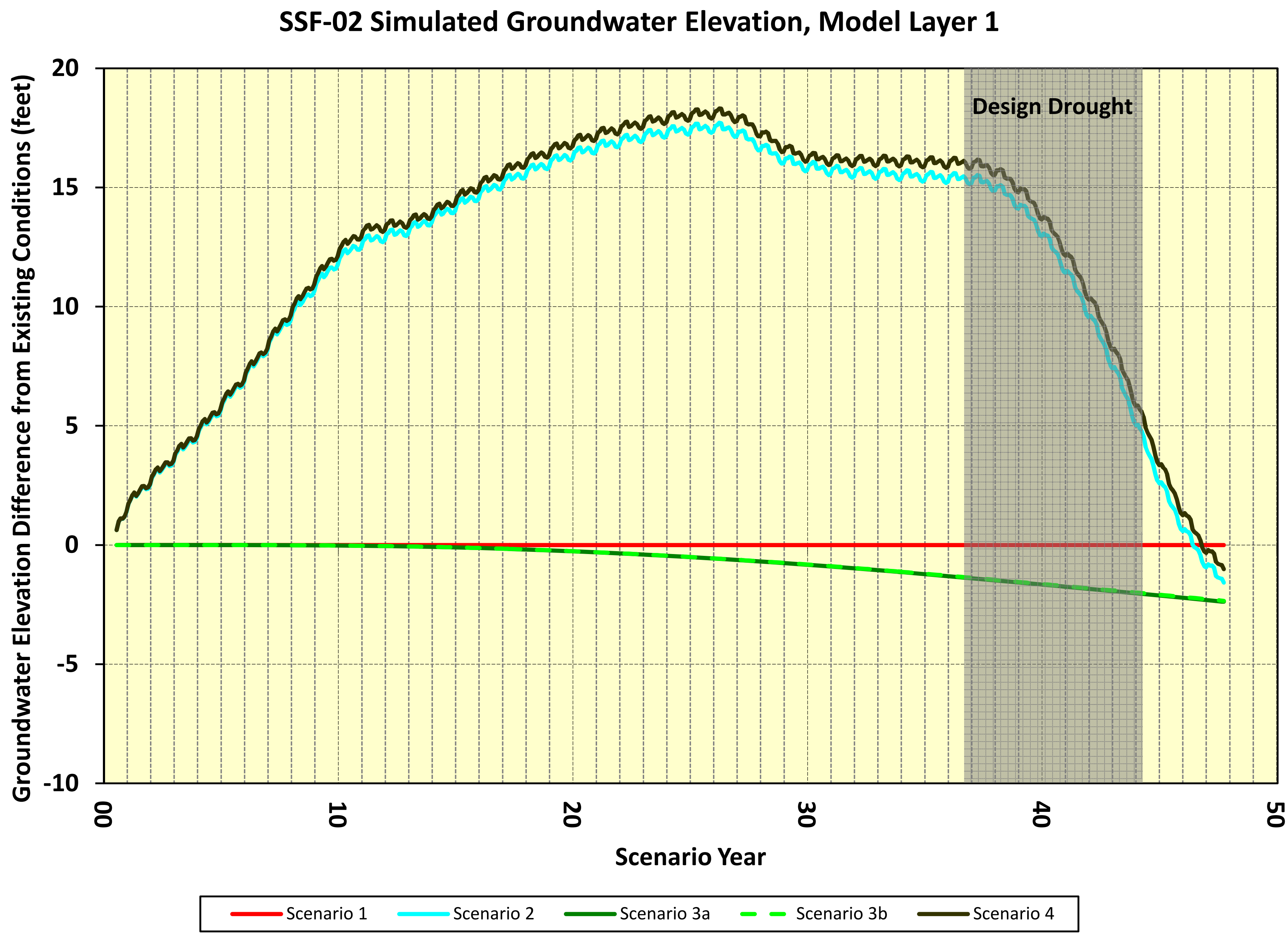
DC-3 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Groundwater Elevation Difference from Existing Conditions (feet)
80
60
40
20
0
-20
-40
-60
-80
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


DC-8 Simulated Groundwater Elevation, Model Layer 1
Groundwater Elevation Difference from Existing Conditions (feet)
80
60
40
20
0
-20
-40
-60
00
10
20
30
40
50
Scenario Year
Design Drought
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

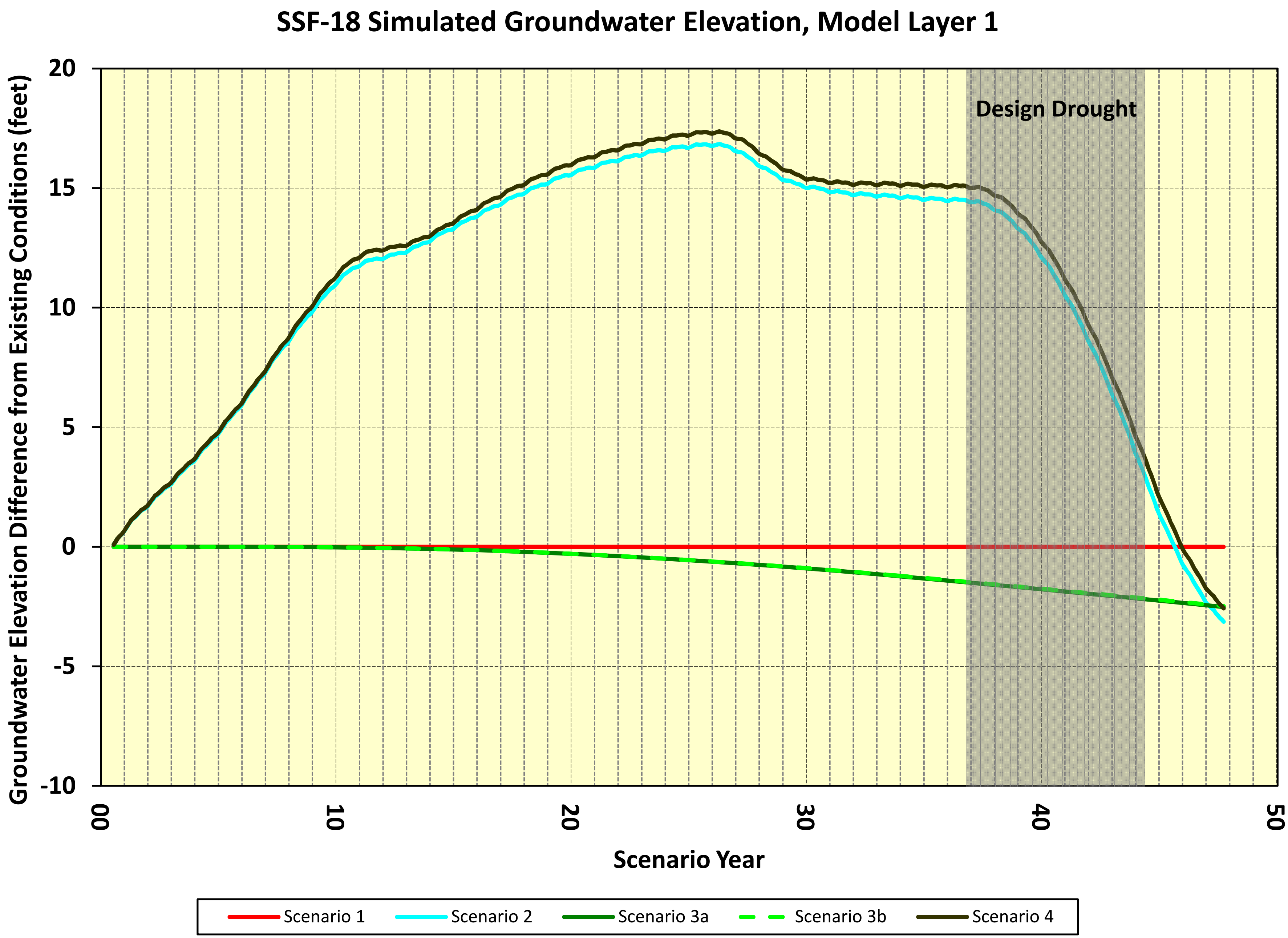

DC-A-St Simulated Groundwater Elevation, Model Layer 1
Groundwater Elevation Difference from Existing Conditions (feet)
80
60
40
20
0
-20
-40
-60
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



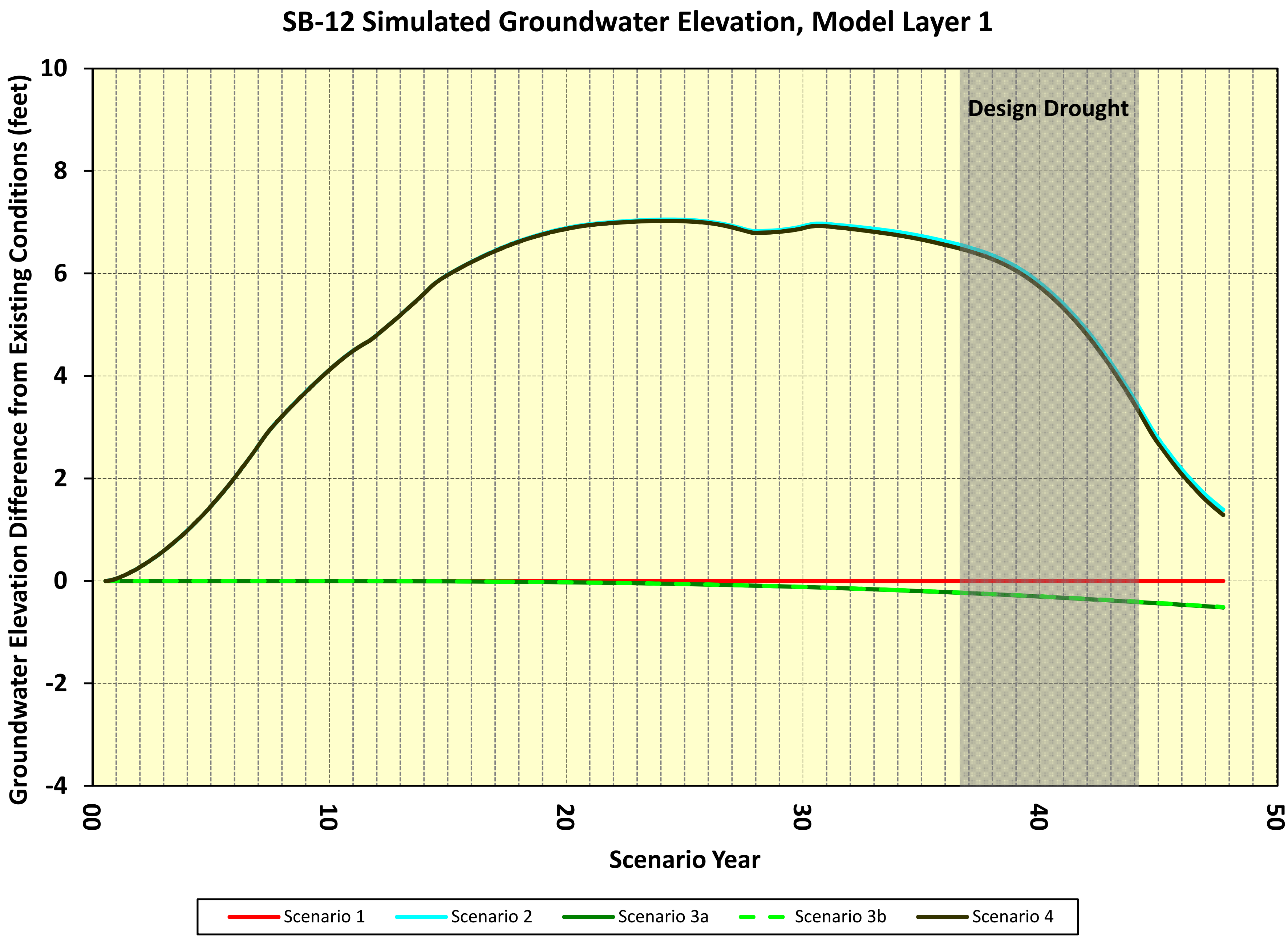
Cyp_Lawn_2 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Groundwater Elevation Difference from Existing Conditions (feet)
40
30
20
10
0
-10
-20
-30
-40
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

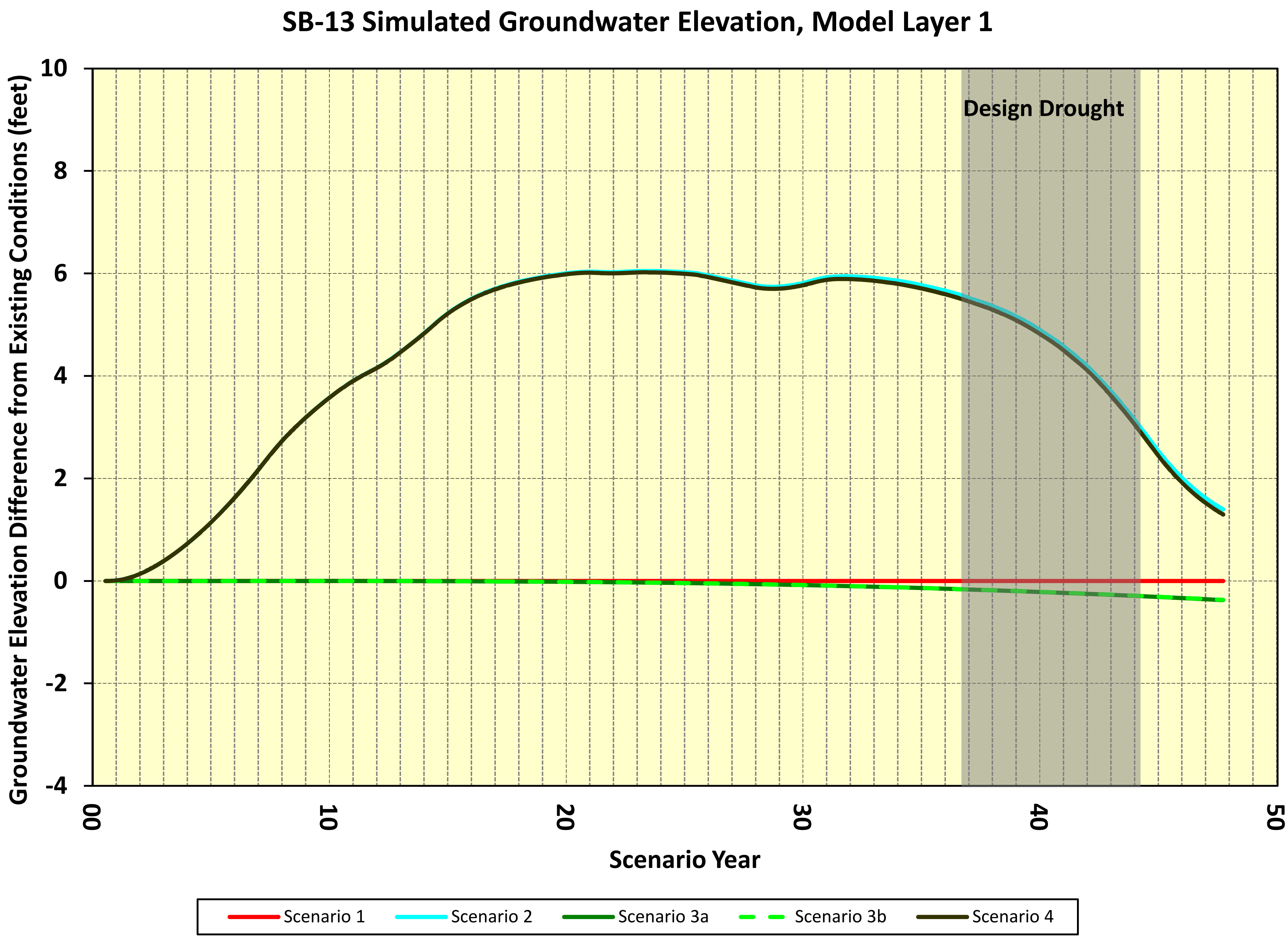


SSF-02 Simulated Groundwater Elevation, Model Layer 1
Groundwater Elevation Difference from Existing Conditions (feet)
20
15
10
5
0
-5
-10
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

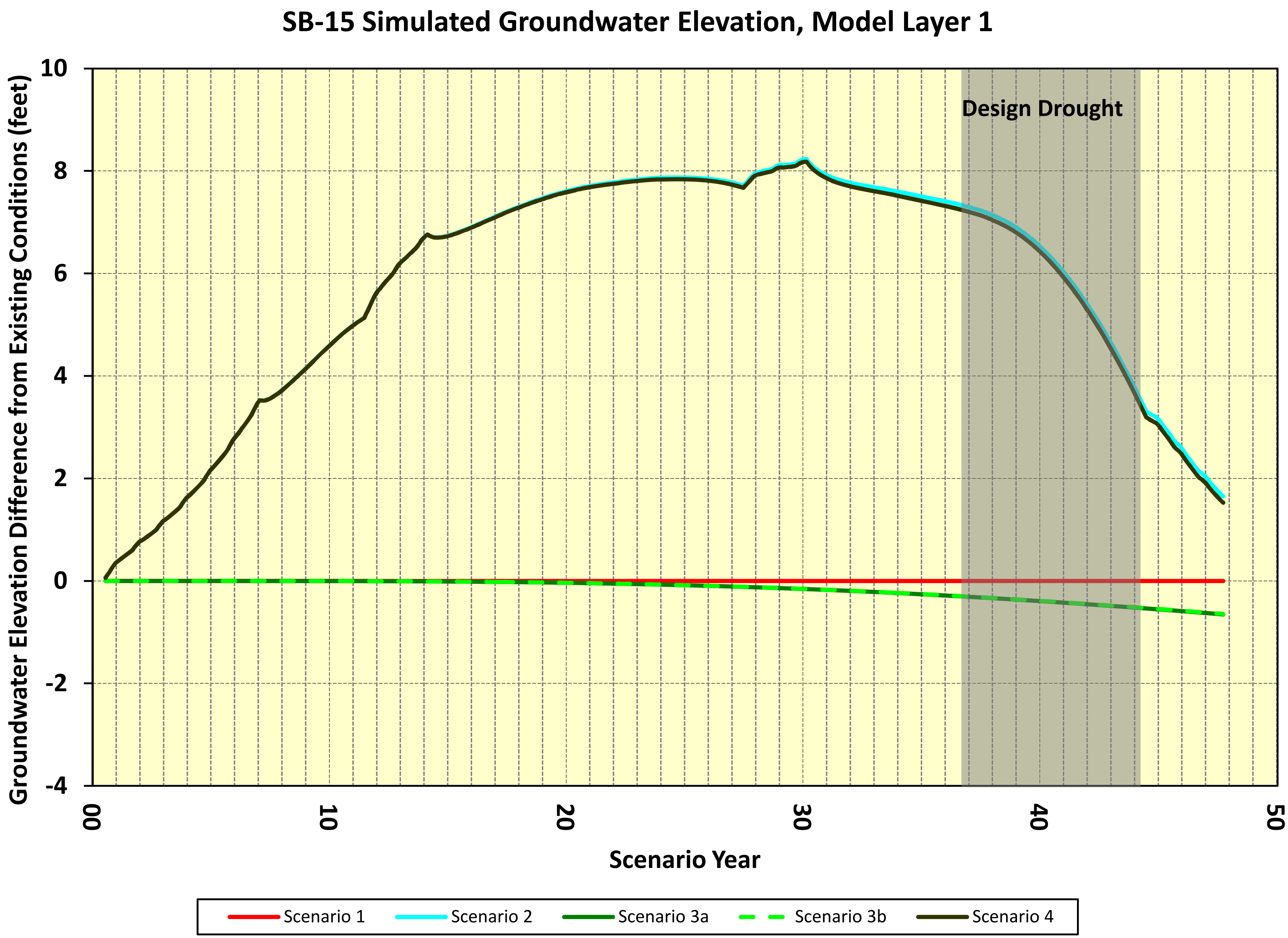


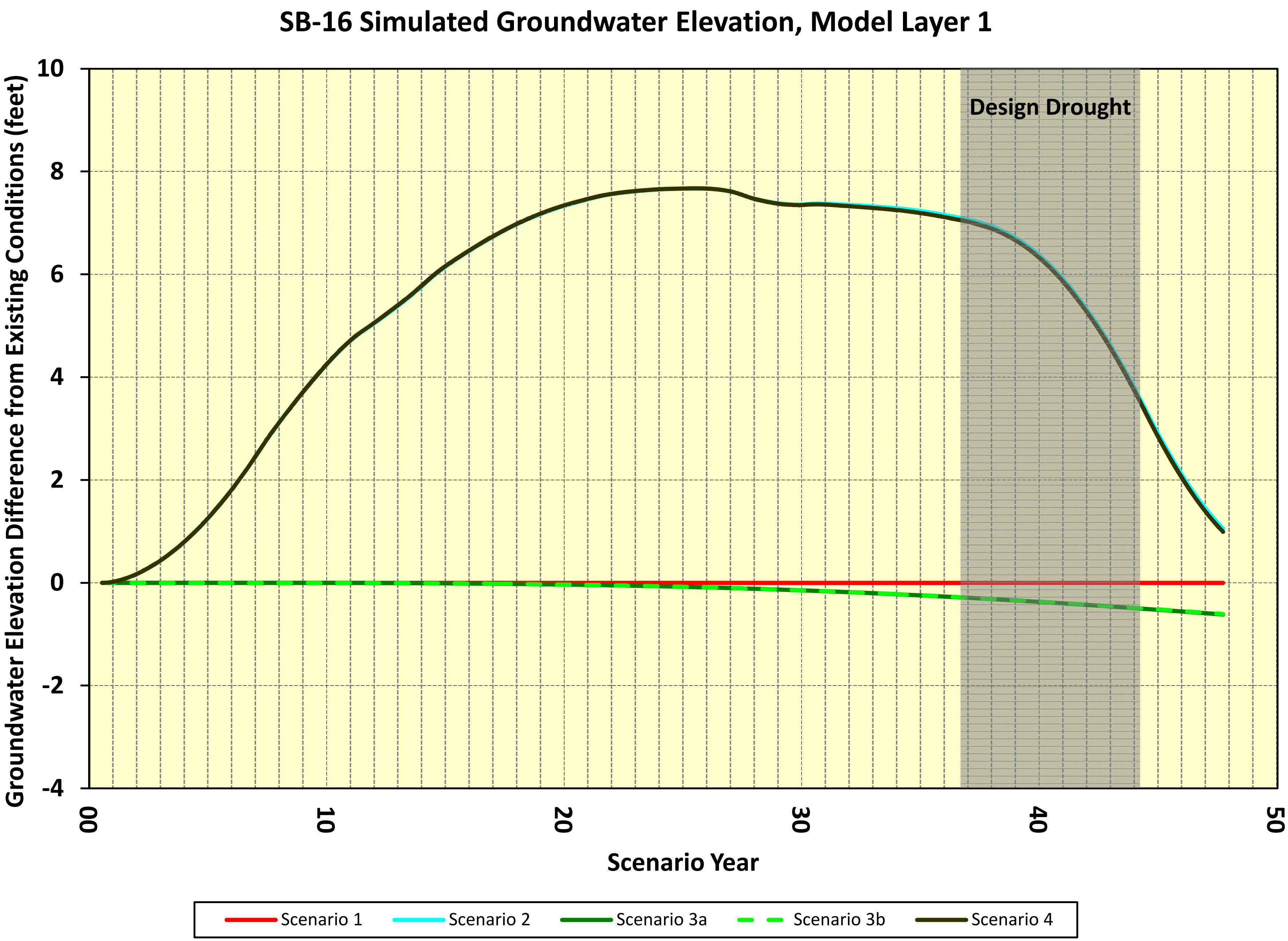
SSF-18 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Groundwater Elevation Difference from Existing Conditions (feet)
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

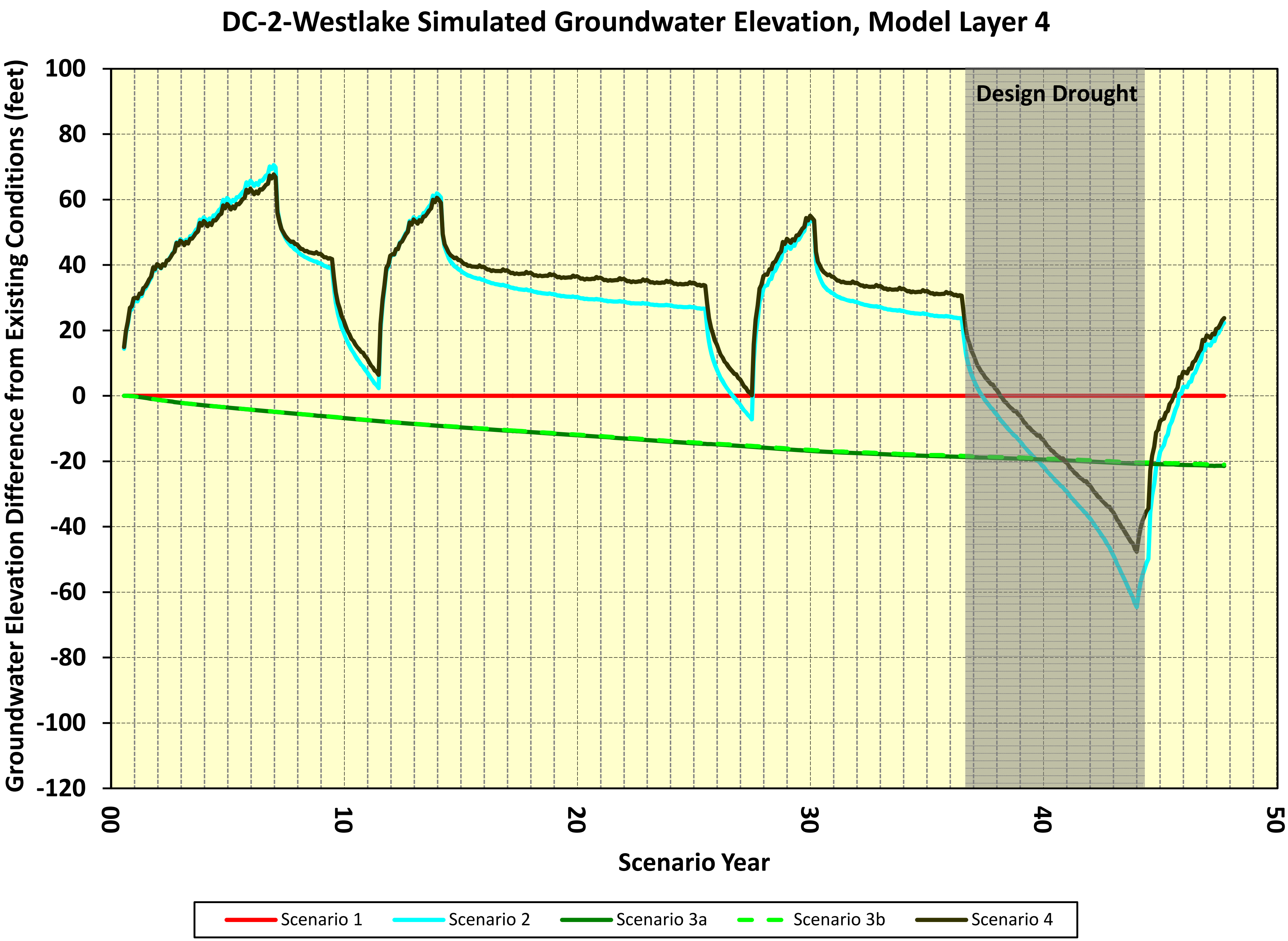

SB-12 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Groundwater Elevation Difference from Existing Conditions (feet)
10
8
6
4
2
0
-2
-4
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

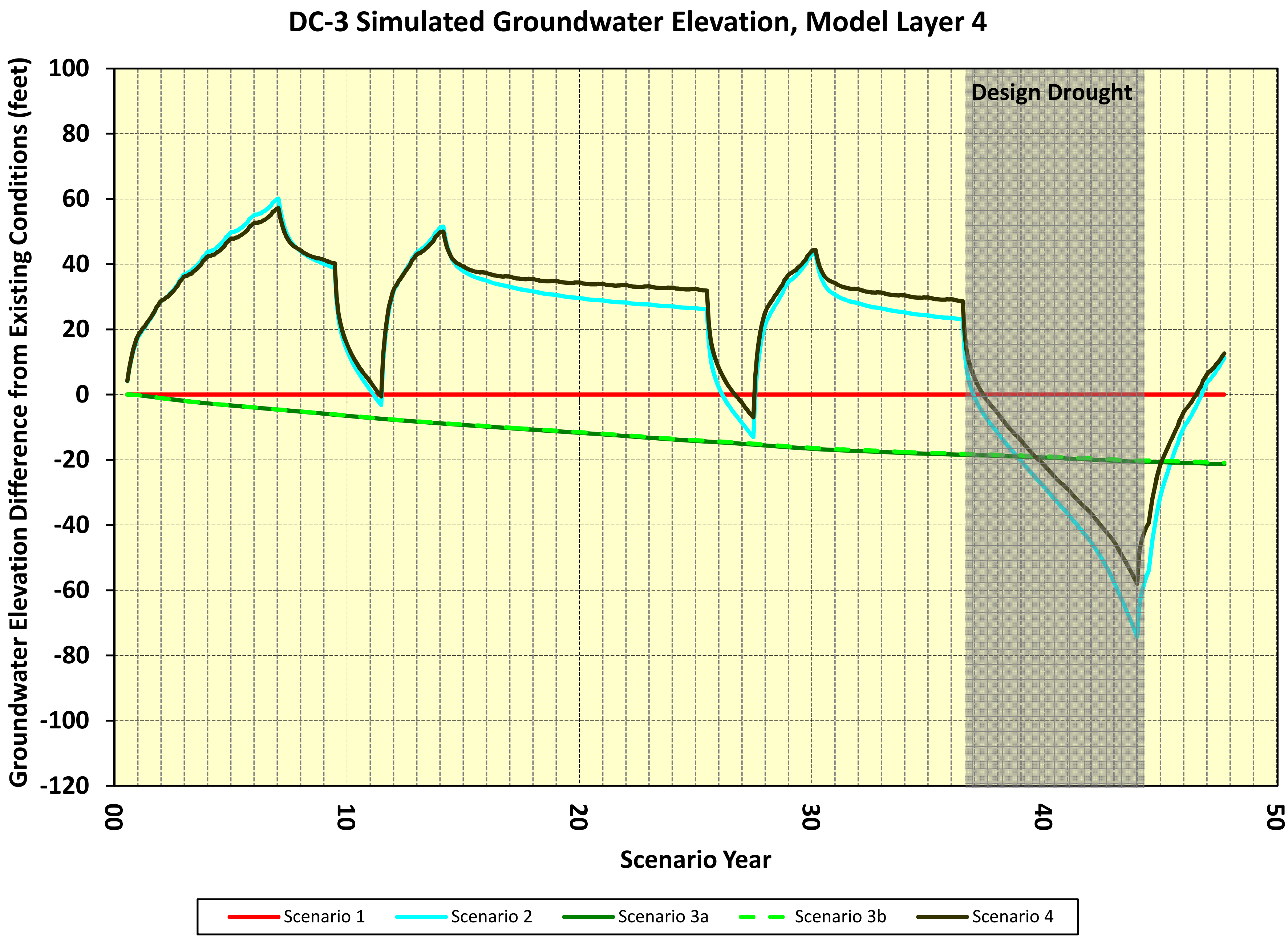


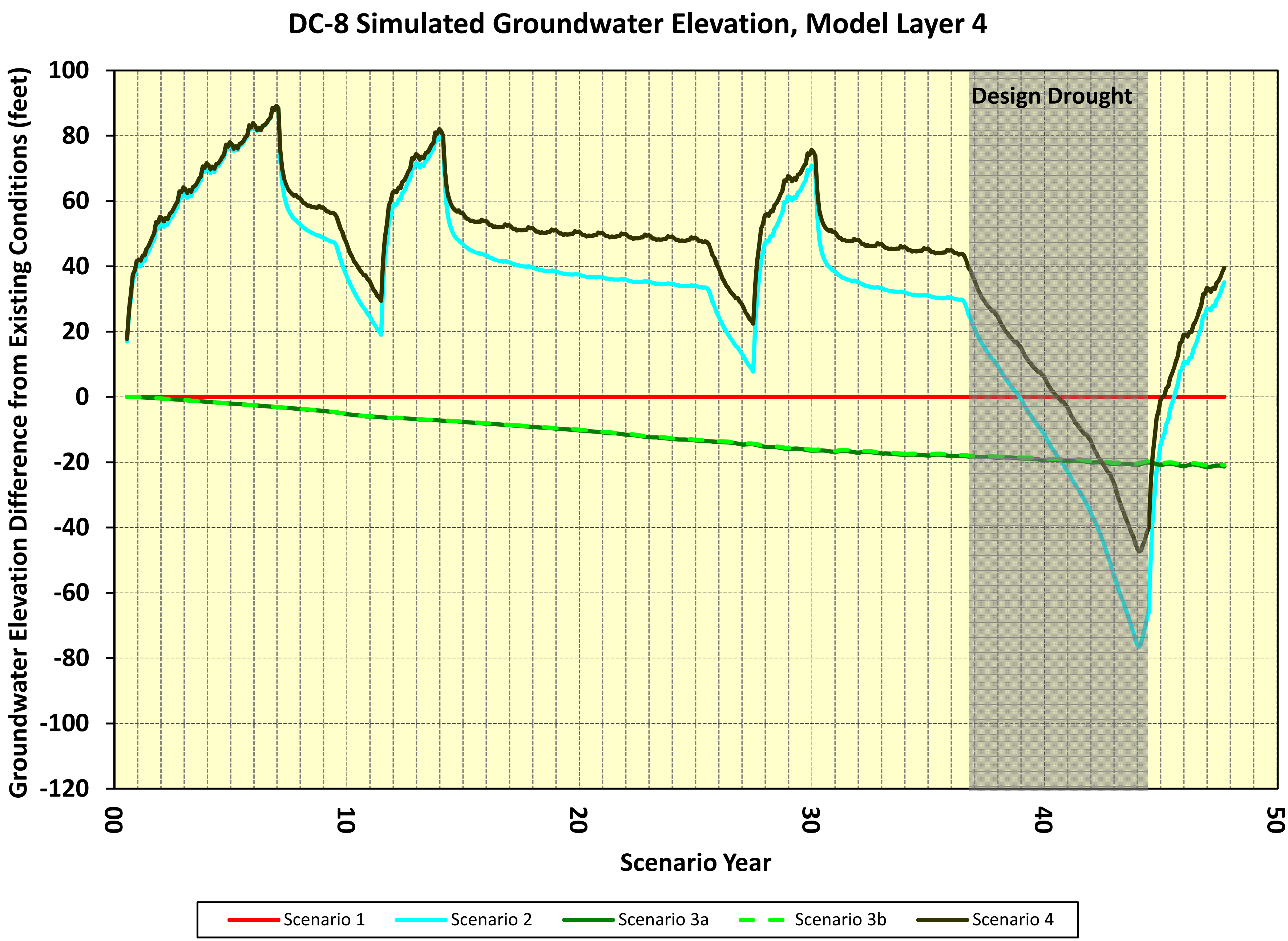
SB-13 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Groundwater Elevation Difference from Existing Conditions (feet)
10
8
6
4
2
0
-2
-4
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


SB-15 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Groundwater Elevation Difference from Existing Conditions (feet)
10
8
6
4
2
0
-2
-4
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

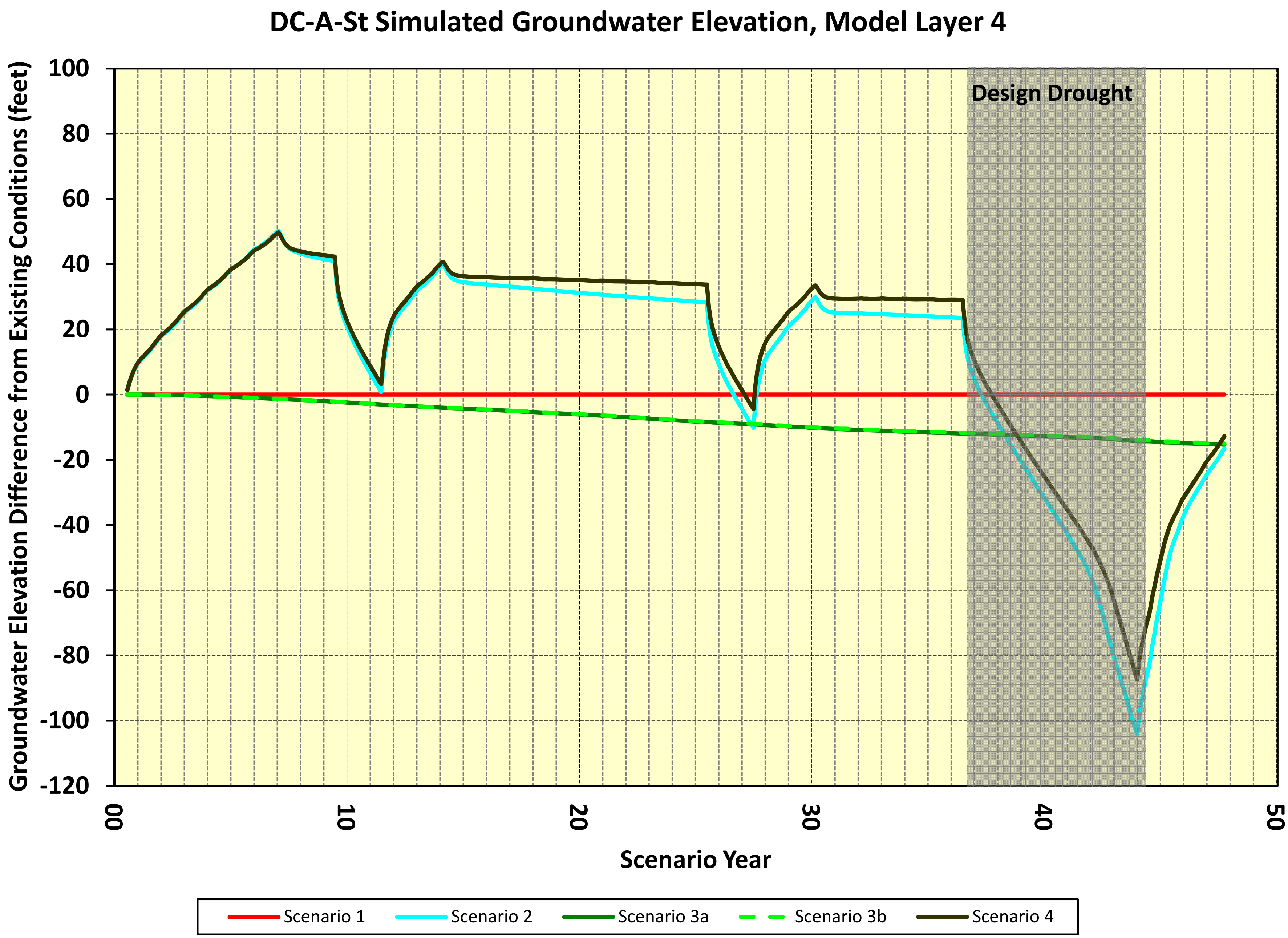

SB-16 Simulated Groundwater Elevation, Model Layer 1
Groundwater Elevation Difference from Existing Conditions (feet)
10
8
6
4
2
0
-2
-4
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

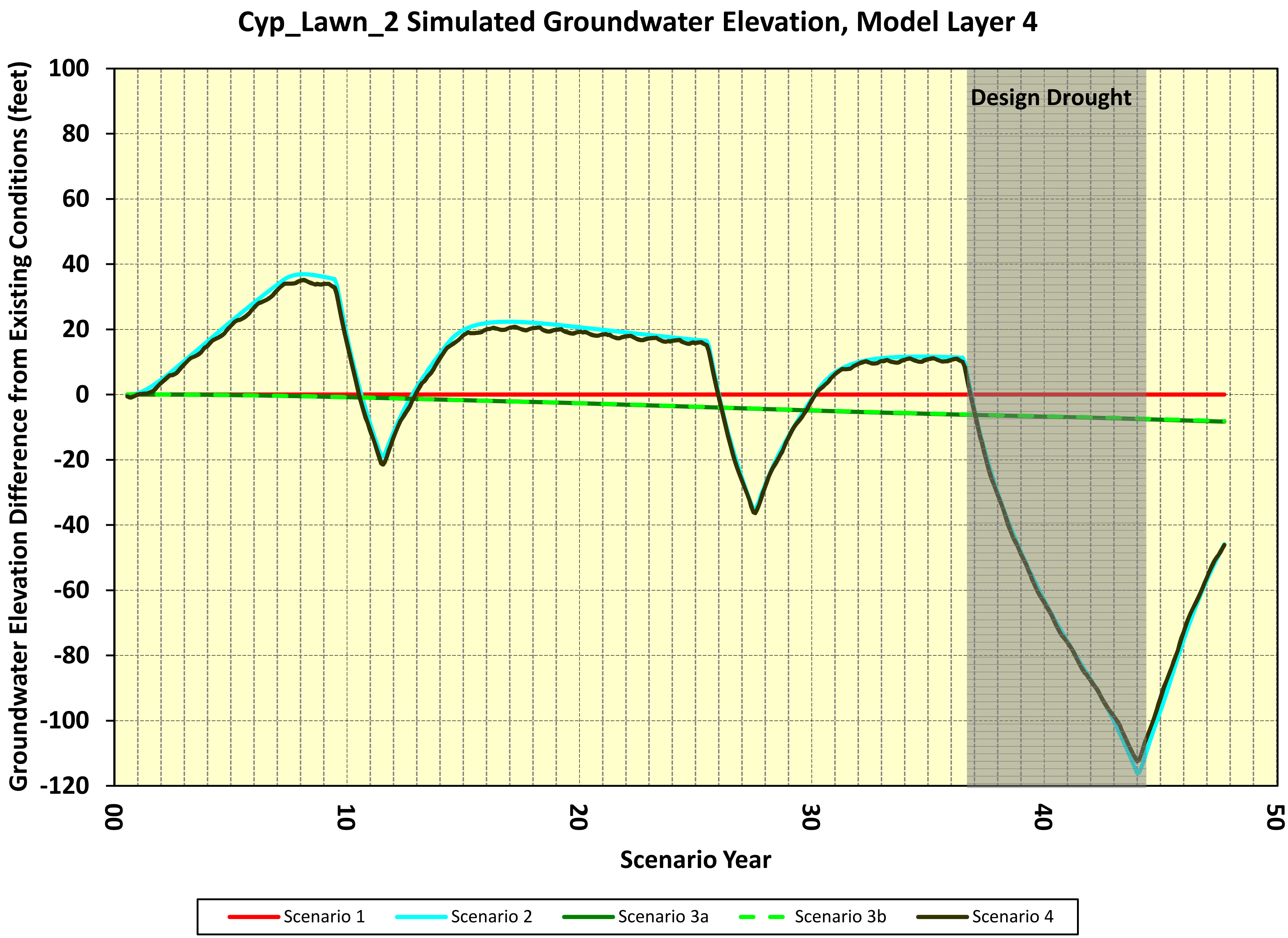

DC-2-Westlake Simulated Groundwater Elevation, Model Layer 4
Groundwater Elevation Difference from Existing Conditions (feet)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


DC-3 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Groundwater Elevation Difference from Existing Conditions (feet)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

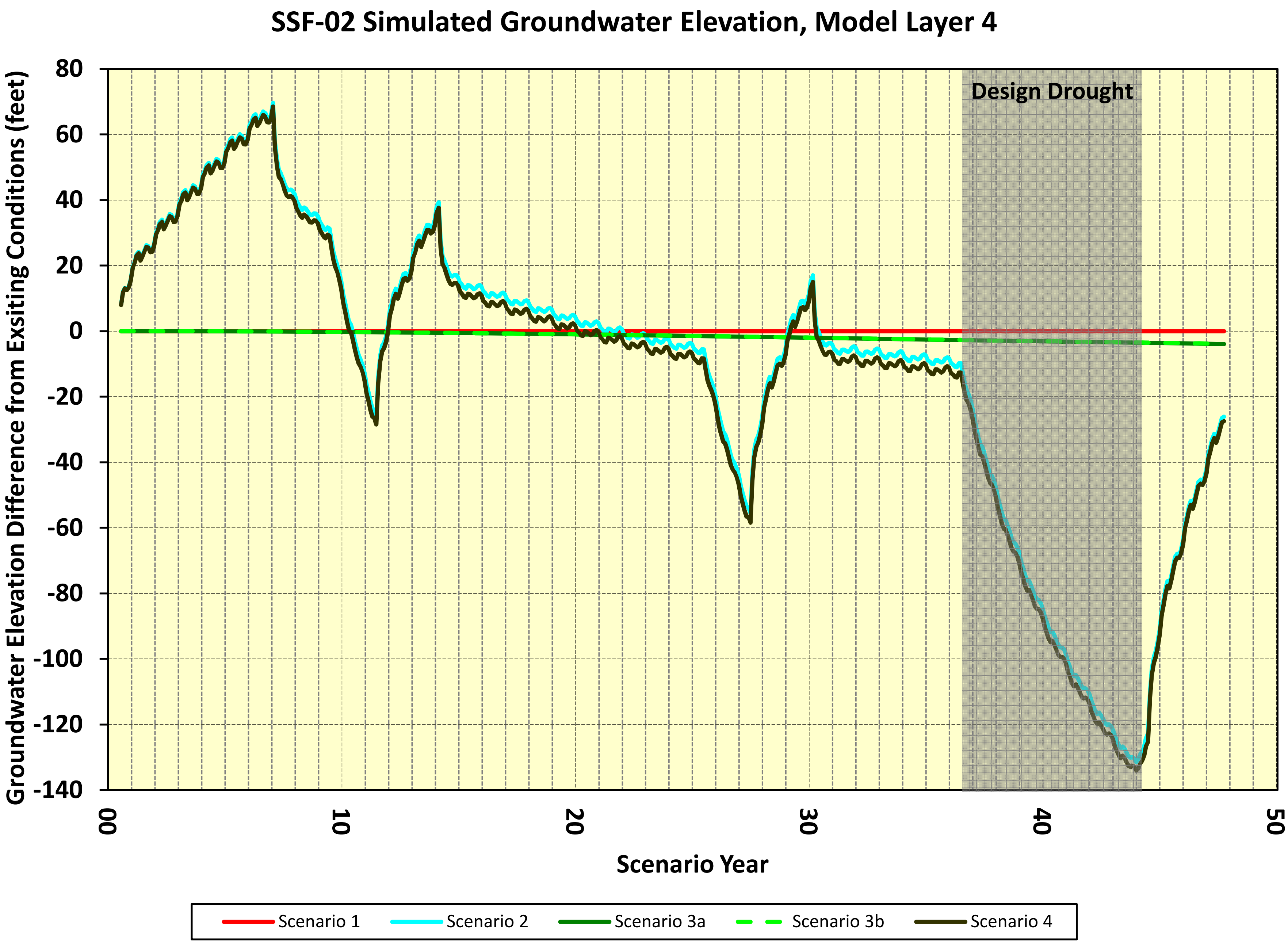


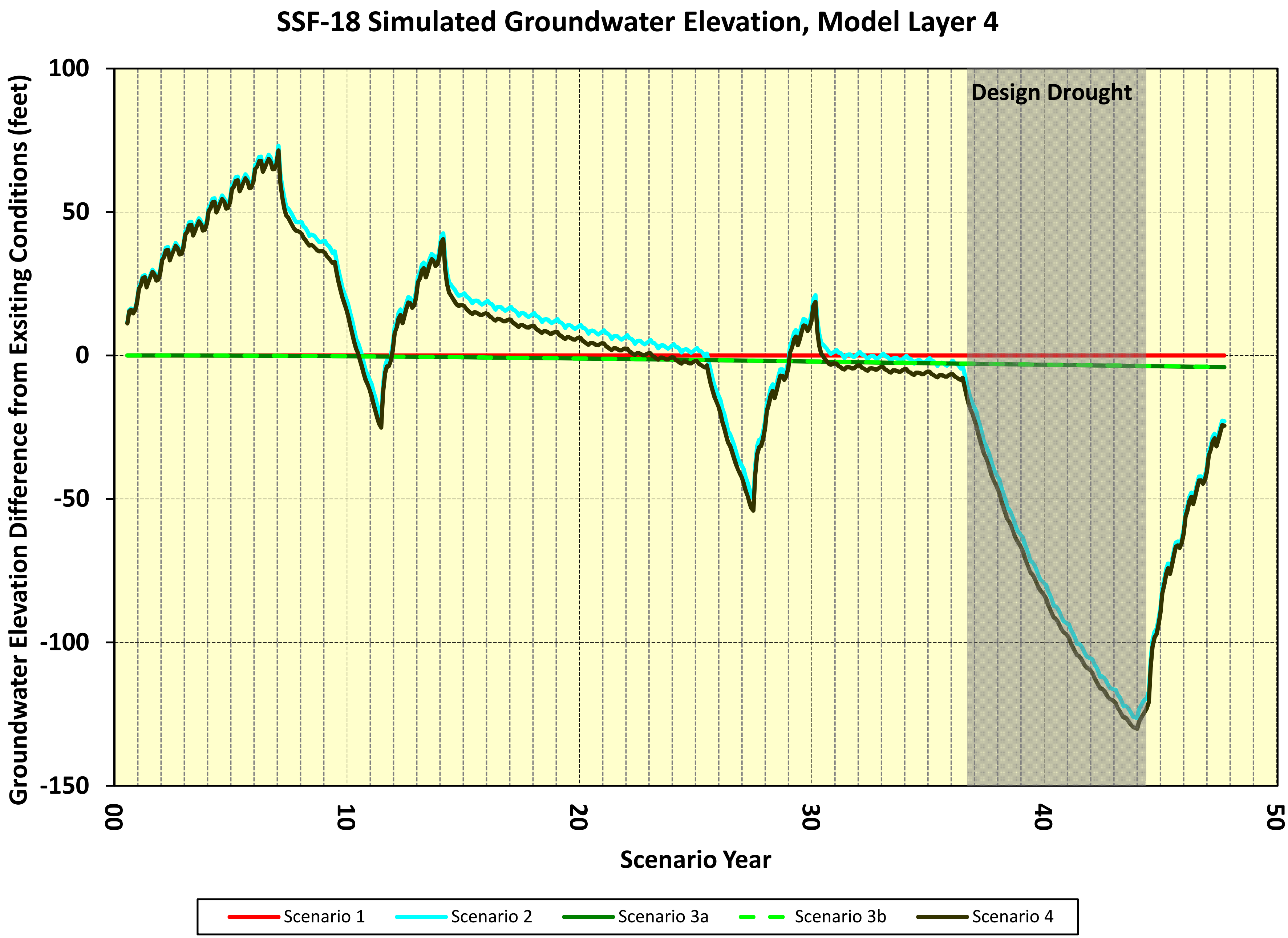
DC-8 Simulated Groundwater Elevation, Model Layer 4
Groundwater Elevation Difference from Existing Conditions (feet)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


DC-A-St Simulated Groundwater Elevation, Model Layer 4
Groundwater Elevation Difference from Existing Conditions (feet)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

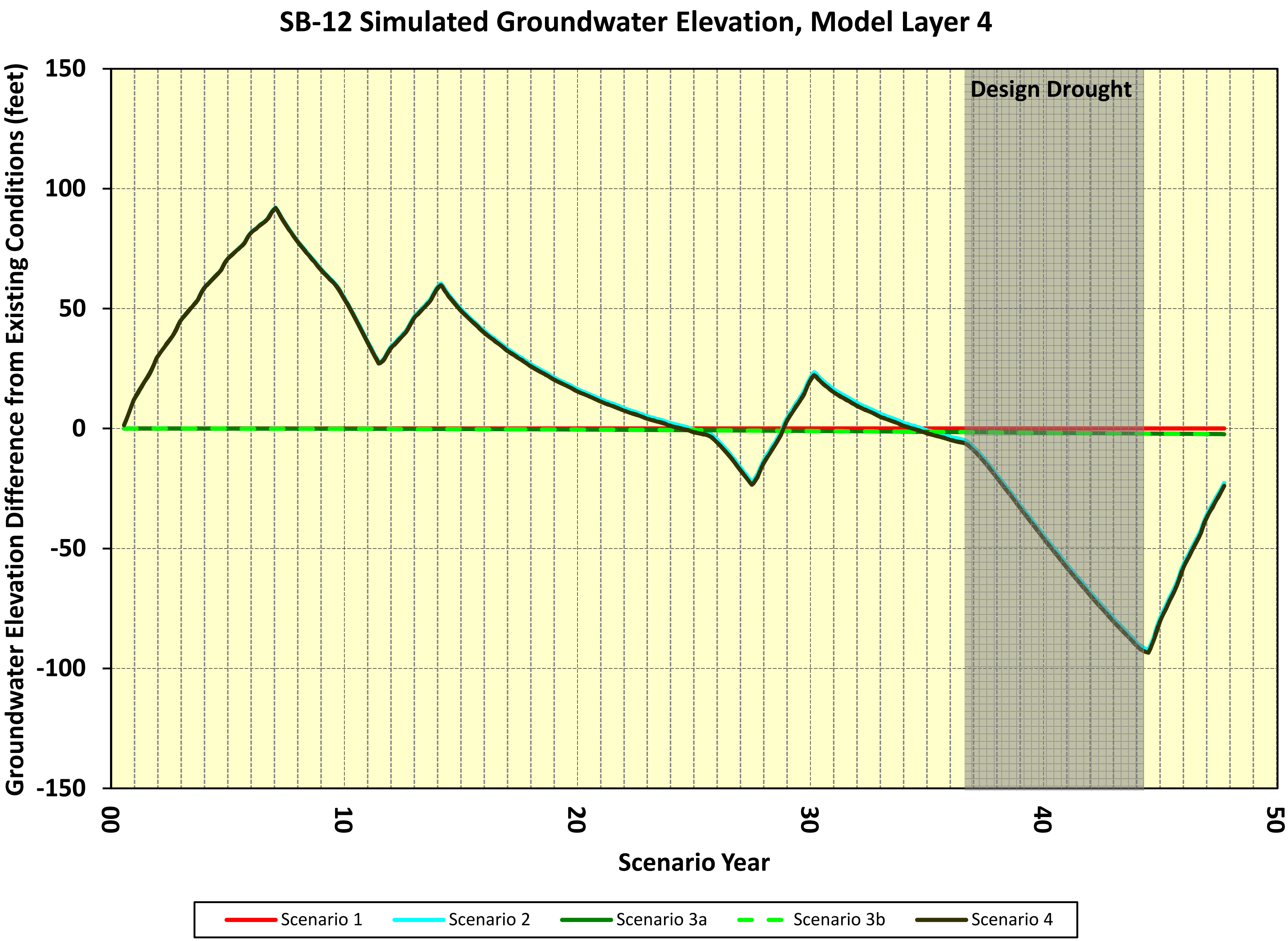


Cyp_Lawn_2 Simulated Groundwater Elevation, Model Layer 4
Groundwater Elevation Difference from Existing Conditions (feet)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

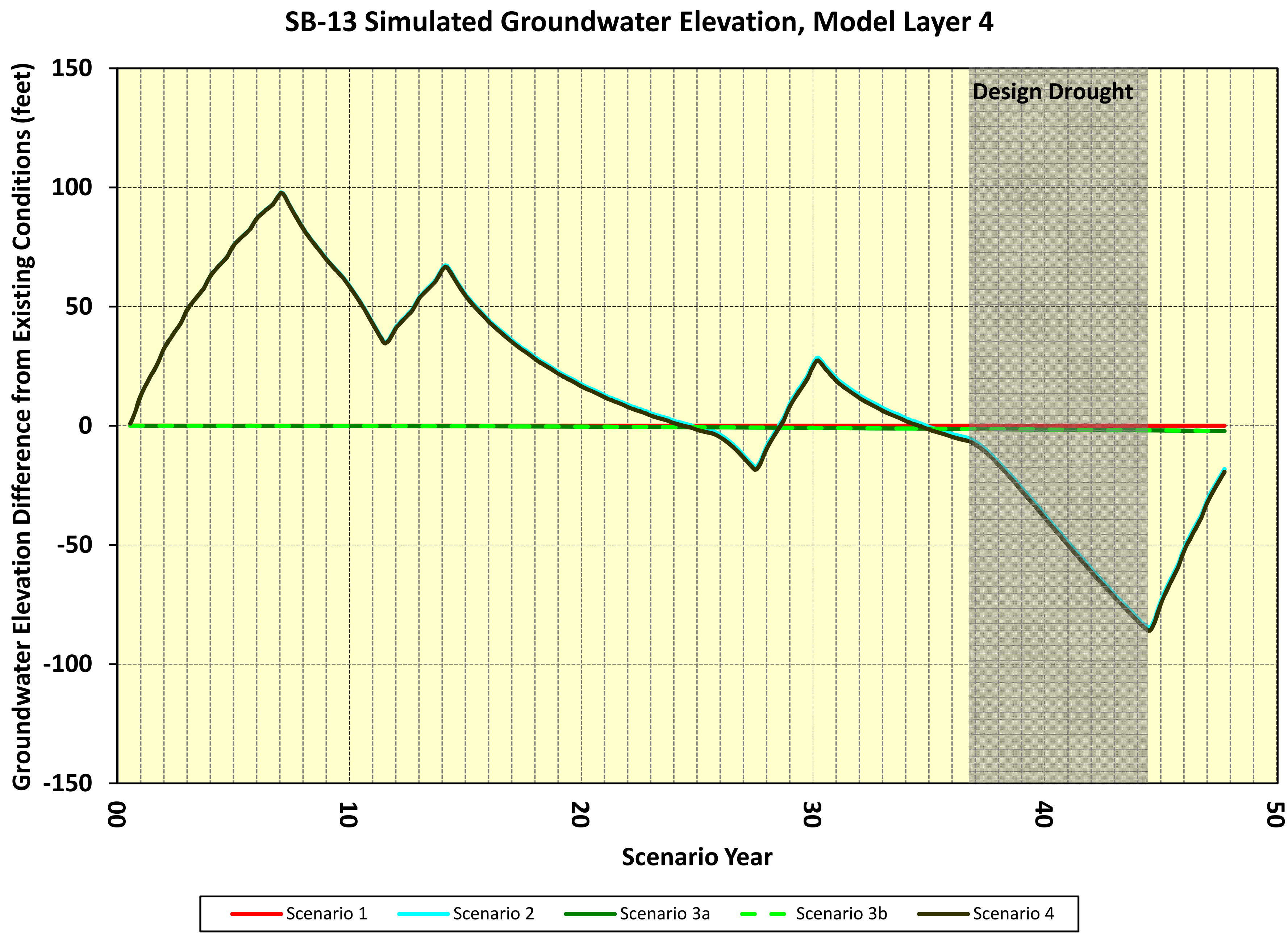

SSF-02 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Groundwater Elevation Difference from Exsiting Conditions (feet)
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

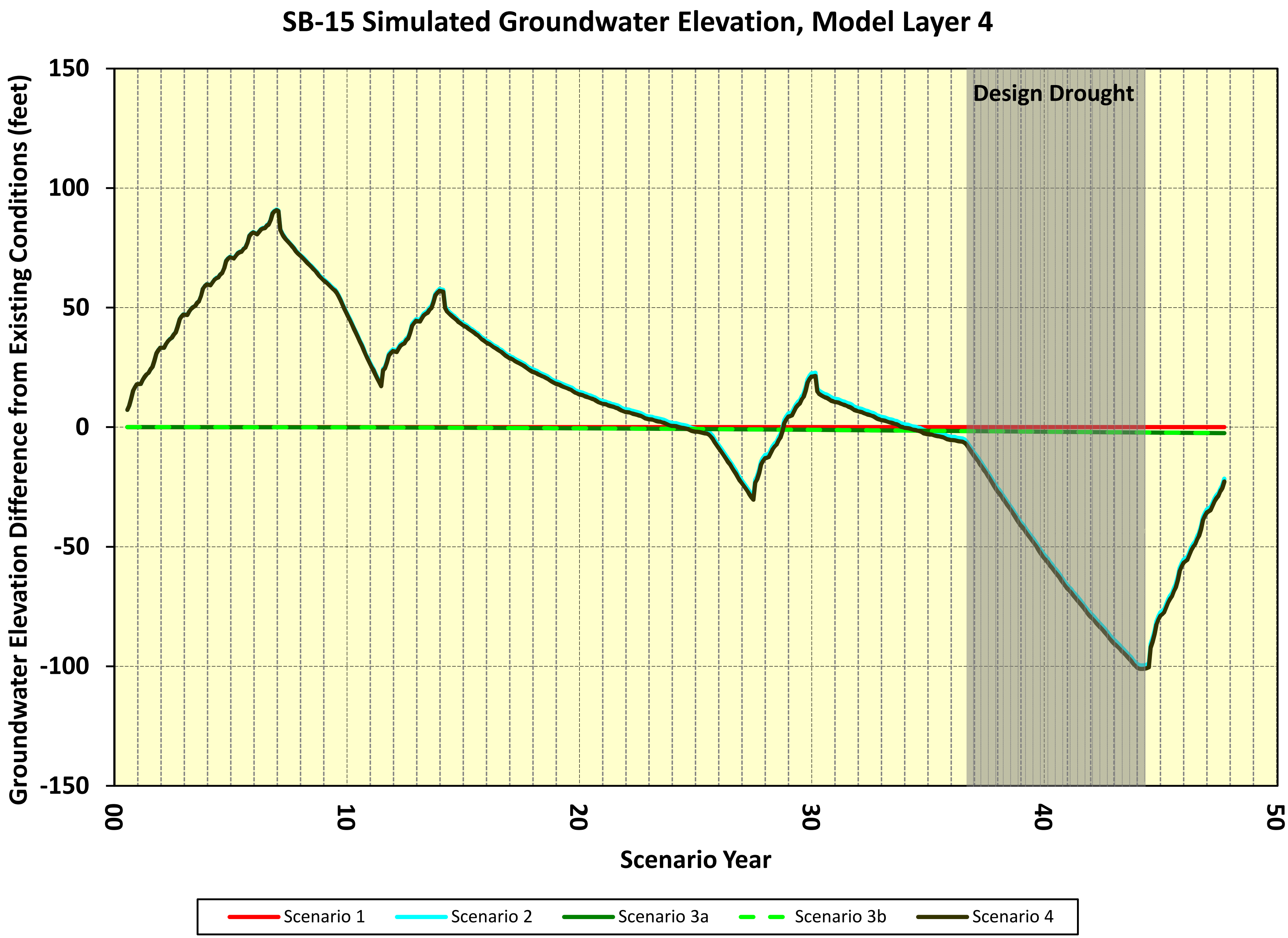


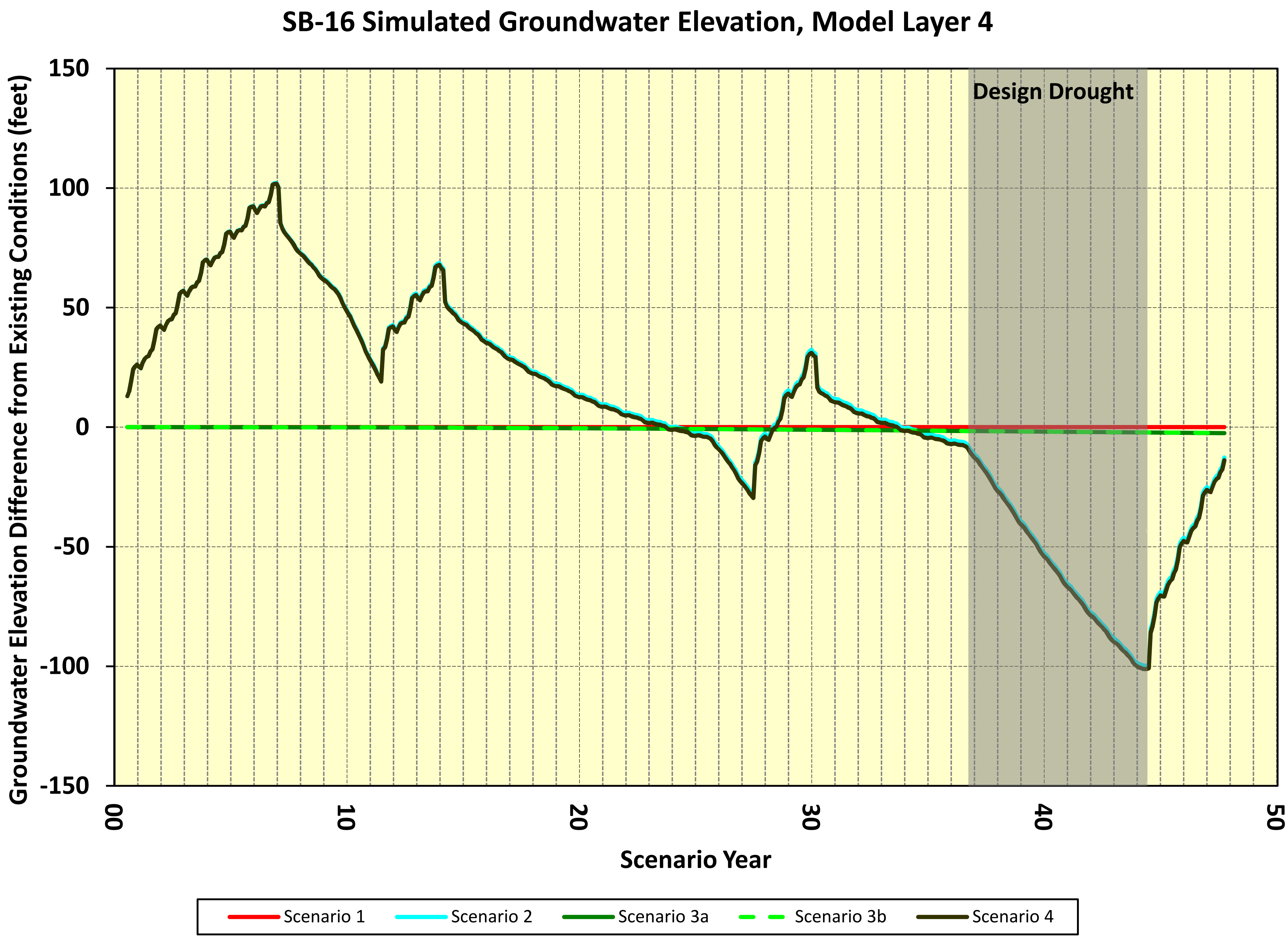
SSF-18 Simulated Groundwater Elevation, Model Layer 4
Groundwater Elevation Difference from Exsiting Conditions (feet)
100
50
0
-50
-100
-150
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



SB-12 Simulated Groundwater Elevation, Model Layer 4
Groundwater Elevation Difference from Existing Conditions (feet)
150
100
50
0
-50
-100
-150
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


SB-13 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Groundwater Elevation Difference from Existing Conditions (feet)
150
100
50
0
-50
-100
-150
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


SB-15 Simulated Groundwater Elevation, Model Layer 4
Groundwater Elevation Difference from Existing Conditions (feet)
150
100
50
0
-50
-100
-150
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

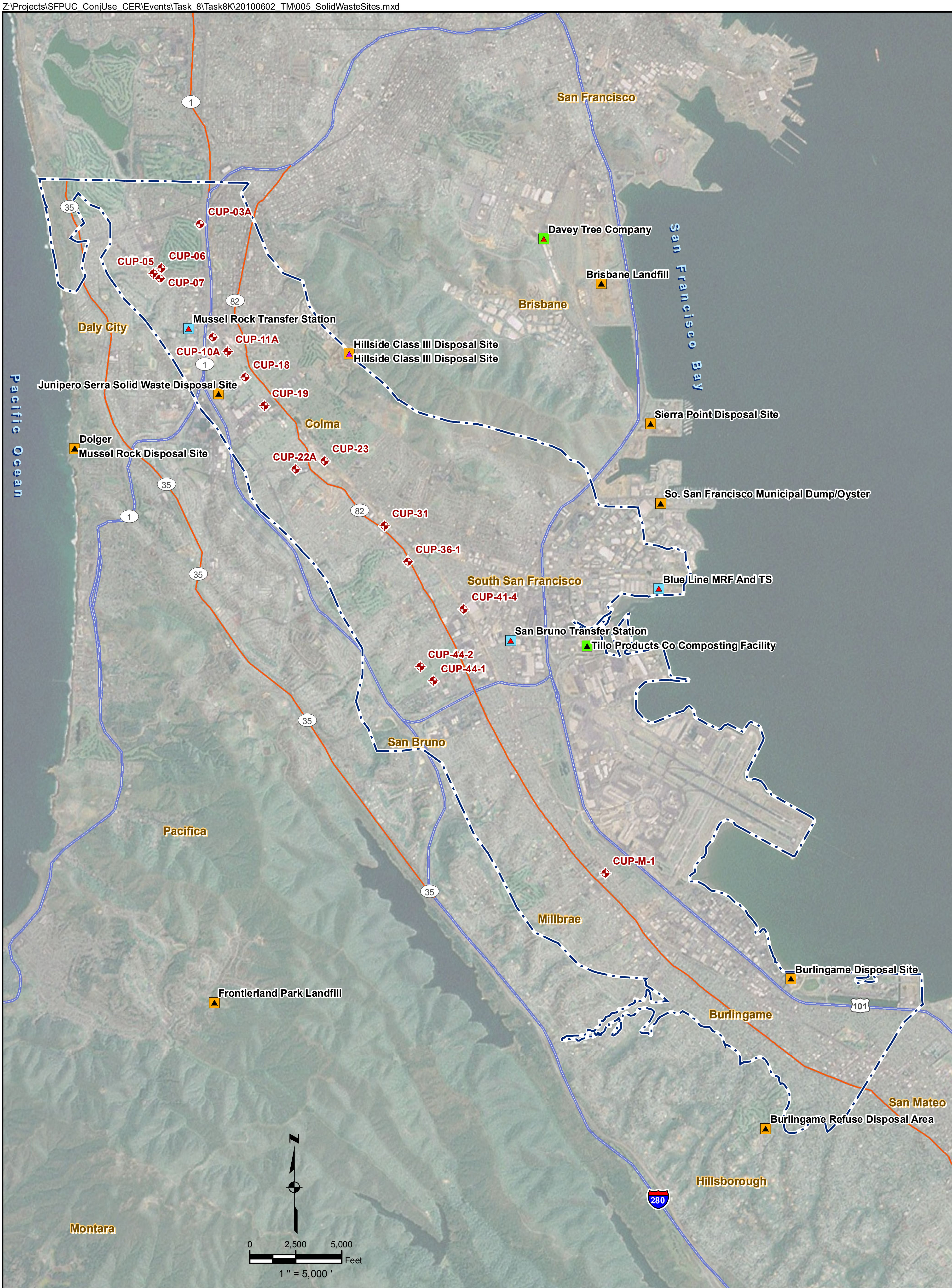


SB-16 Simulated Groundwater Elevation, Model Layer 4
Groundwater Elevation Difference from Existing Conditions (feet)
150
100
50
0
-50
-100
-150
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

Attachment 10.6-B

Existing Regulated Sites – GeoTracker, SWIS, DTSC, and SLIC

Z:\Projects\SFPUC_ConjUse_CER\Events\Task_8\Task8K\20100602_TM\005_SolidWasteSites.mxd



Legend

Solid Waste Facility Status
- Active
- Closed
- Closing

Solid Waste Facility Category
- Composting
- Disposal
- Transfer/Processing

- GSR Proposed Municipal Wells
- South Westside Groundwater Basin

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
ENGINEERING MANAGEMENT BUREAU

SOLID WASTE FACILITY LOCATION

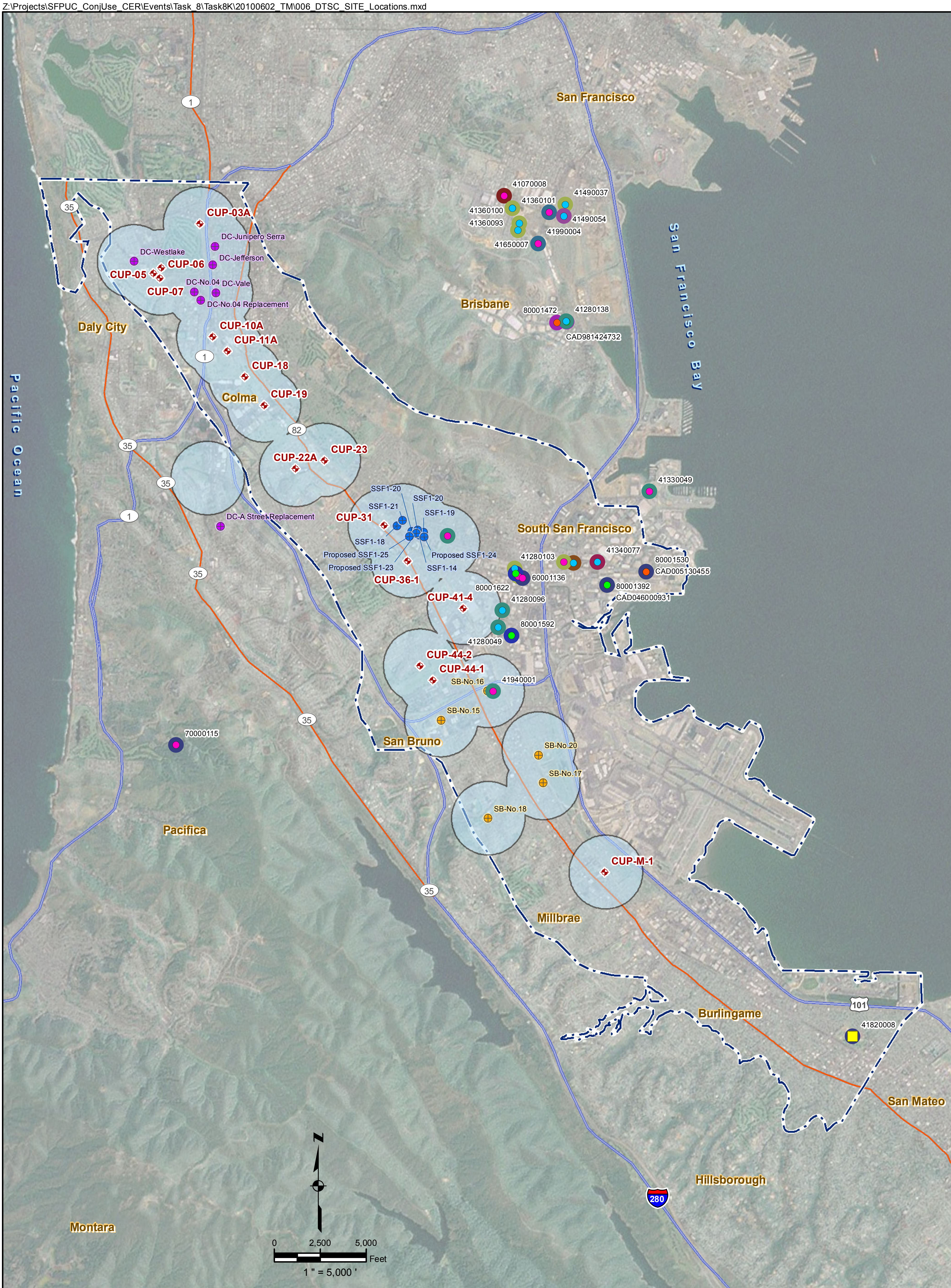
Kennedy/Jenks Consultants
303 Second Street, Suite 300 South
San Francisco, CA 94107

Regional Groundwater Storage and Recovery Project

Figure **B-1**

Date April 2012

Z:\Projects\SFPUC_ConjUse_CER\Events\Task_8\Task8K\20100602_TM\006_DTSC_SITE_Locations.mxd



Legend

DTSC Site/Facility Type

- CORRECTIVE ACTION
- HAZ WASTE - NON-OPERATING
- SCHOOL CLEANUP
- STATE RESPONSE
- VOLUNTARY CLEANUP

DTSC CLEANUP_STATUS

- ACTIVE
- ACTIVE - LAND USE RESTRICTIONS
- BACKLOG
- CERTIFIED
- CERTIFIED / OPERATION & MAINTENANCE
- CERTIFIED/OP & MAINT-LAND USE RESTRIC
- COMPLETED
- INACTIVE
- INACTIVE - NEEDS EVALUATION
- NO FURTHER ACTION
- REFER: LOCAL AGENCY
- REFER: RWQCB

- GSR Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- 2000 feet Radius Buffer
- South Westside Groundwater Basin

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
ENGINEERING MANAGEMENT BUREAU

DTSC SITE LOCATIONS

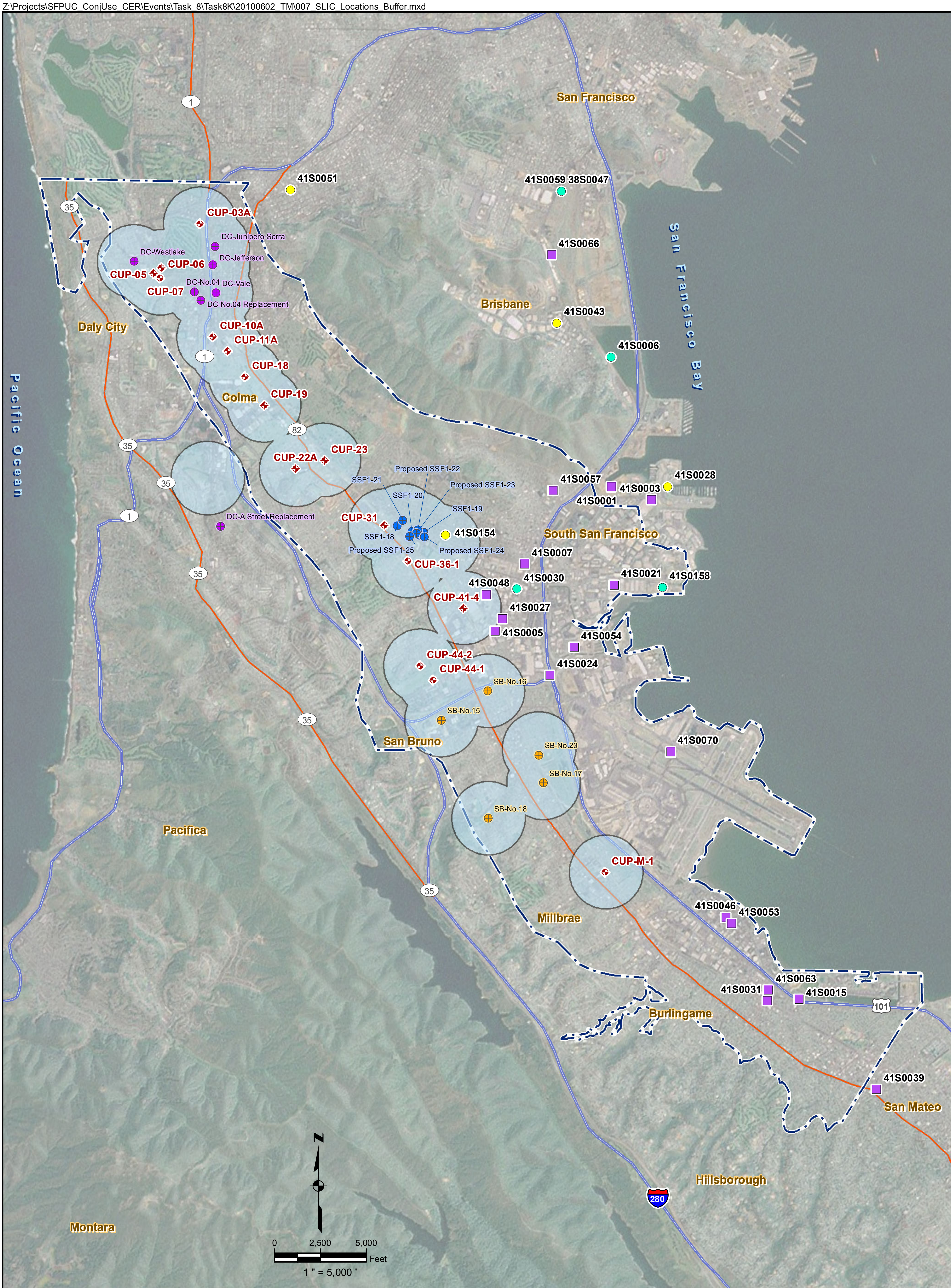
Kennedy/Jenks Consultants
303 Second Street, Suite 300 South
San Francisco, CA 94107

Regional Groundwater Storage and Recovery Project

Figure **B-2**

Date April 2012

Z:\Projects\SFPUC_ConjUse_CER\Events\Task_8\Task8K\20100602_TM\007_SLIC_Locations_Buffer.mxd



Legend

SLIC (Spills, Leaks, Investigations, and Cleanup Database) Locations and Site Number

- Active (3)
- Inactive (18)
- Refered to Others Agency (4)

- GSR Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- 2000 feet Radius Buffer
- South Westside Groundwater Basin

CITY AND COUNTY OF SAN FRANCISCO
PUBLIC UTILITIES COMMISSION
ENGINEERING MANAGEMENT BUREAU

PRODUCTION WELLS AND CLEANUP SITES

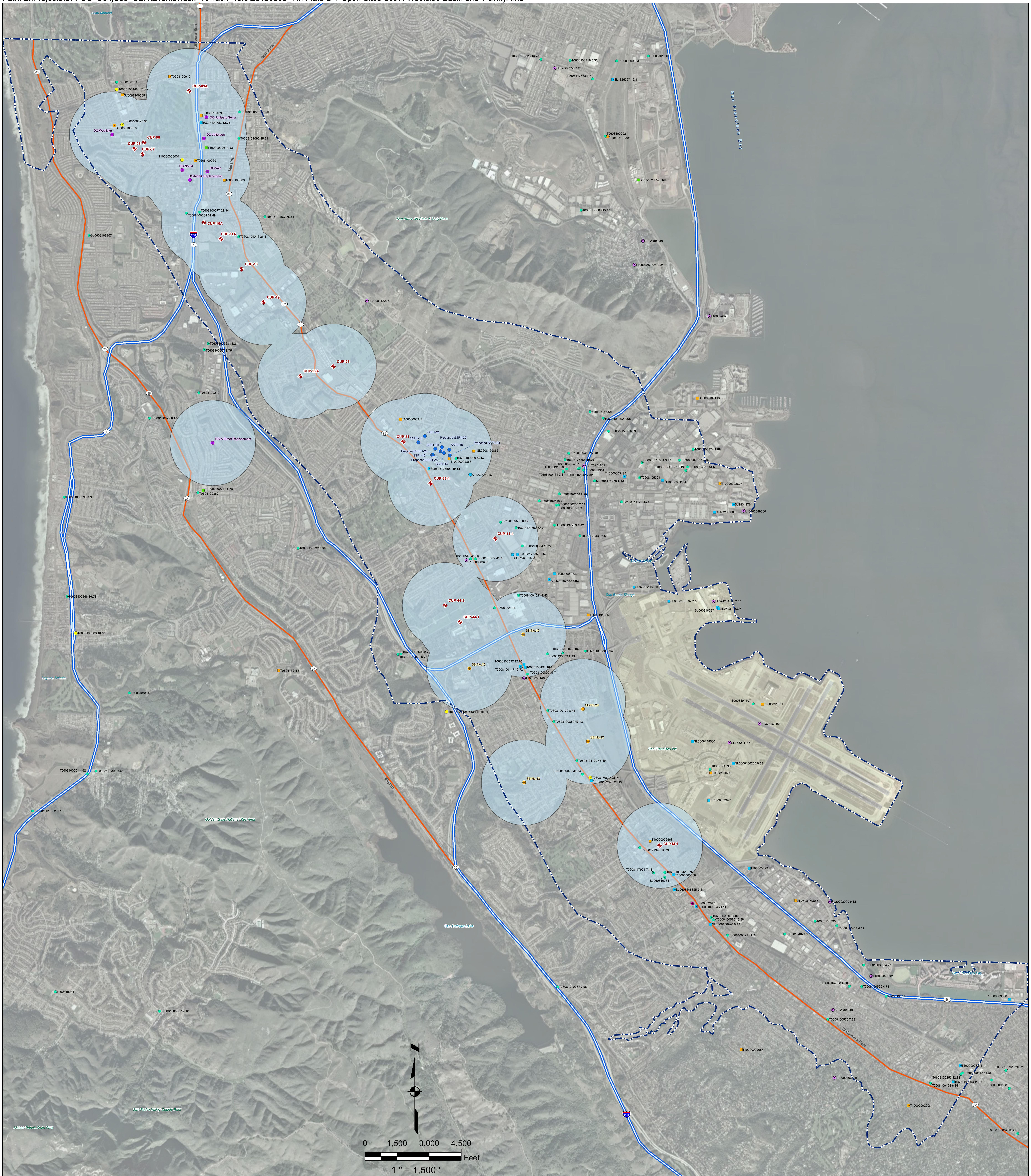
Kennedy/Jenks Consultants
303 Second Street, Suite 300 South
San Francisco, CA 94107

Regional Groundwater Storage and Recovery Project

Figure
B-3

Date
April 2012

Path: Z:\Projects\SFPUC_ConjUse_CER\Events\Task_10\Task_10.6\20120309_TM\Plate B-1 Open Sites South Westside Basin and Vicinity.mxd



Legend

Potential Media Affected Near Project Area

- Other Groundwater (uses other than drinking water)
- Soil
- Soil/Other Groundwater (uses other than drinking water)
- Soil/Other Groundwater (uses other than drinking water)/Aquifer or Well used for drinking water supply
- Soil/Aquifer used for drinking water supply
- Well used for drinking water supply
- Aquifer used for drinking water supply
- Under Investigation
- Unknown

T0608194016 | 21.8

Global ID Depth to Water (feet)

- GSR Project Proposed Municipal Wells
- San Bruno Municipal Wells
- Daly City Municipal Wells
- Cal Water Municipal Wells
- South Westside Groundwater Basin
- 2000 feet Radius Buffer

CITY AND COUNTY OF SAN FRANCISCO

PUBLIC UTILITIES COMMISSION

ENGINEERING MANAGEMENT BUREAU

"OPEN" REGULATED SITES IN THE SOUTH WESTSIDE BASIN AND VICINITY AND RECORDED DEPTHS TO WATER

Kennedy/Jenks Consultants
303 Second Street, Suite 300 South
San Francisco, CA 94107

Figure
Plate B-1

Regional Groundwater Storage and Recovery Project

Date
April 2012

GLOBAL_ID	BUSINESS NAME	CASE TYPE	STATUS	STATUS DATE	POTENTIAL	POTENTIAL 1	PROTECTION ZONE	FIELD_POIN	STATUS_1	GW_MEAS_DA	DTW
L10002089336	O'BRIEN-HASKINS FORMER SAN BRUNO CHANNEL	Land Disposal Site	Open	1/9/2008							
L10008912226	HILLSIDE LNDFL COLMA DUMP	Land Disposal Site	Open	1/1/1965							
L10009873781	BURLINGAME LANDFILL	Land Disposal Site	Open - Verification Monitoring	9/25/2009							
SL0002020085	SHELL OIL SFO SATELLITE PLANT, SOUTH SF (former)	Cleanup Program Site	Open - Assessment & Interim Remedial Action	12/29/2009			Inside 2000ft Protection Zone				
SL0608101503	416 Browning (fmr Goss-Jewett facility)	Cleanup Program Site	Open - Site Assessment	9/17/2007	Tetrachloroethylene (PCE)	Other Groundwater (uses other than drinking water), Soil, Soil Vapor, Under	Inside 2000ft Protection Zone				
SL0608104752	SOFOS PROPERTY	Cleanup Program Site	Completed - Case Closed	6/23/2010	Nickel	Aquifer used for drinking water supply, Other Groundwater (uses other than					
SL0608106162	SFIA - UNITED AIRLINES MAINTENANCE CENTER AT SF AIRPORT	Cleanup Program Site	Open - Remediation	1/1/2007	* Solvents, Aviation	Other Groundwater (uses other than drinking water), Soil, Well used for drinking		MW-3C	ACT	8/8/2005	7.3
SL0608106505	WESTLAKE FRENCH CLEANERS	Cleanup Program Site	Open - Site Assessment	6/4/2008	Tetrachloroethylene (PCE)	Soil	Inside 2000ft Protection Zone				
SL0608107611	CITIBANK/BETTY-BRITE CLEANERS (FORMER)	Cleanup Program Site	Open - Site Assessment	4/28/2004	Tetrachloroethylene (PCE)	Other Groundwater (uses other than	Inside 2000ft Protection Zone				
SL0608111084	GRAND ROEBLING PROPERTY	Cleanup Program Site	Open - Site Assessment	10/5/2005	Tetrachloroethylene (PCE)	Other Groundwater (uses other than		MW-3	ACT	10/25/2006	5.95
SL0608115344	COEN COMPANY	Cleanup Program Site	Completed - Case Closed	11/20/2006	Diesel	Other Groundwater (uses other than					
SL0608116110	MATTISON & SHIDLER	Cleanup Program Site	Completed - Case Closed	11/29/1995		Soil					
SL0608123509	CHEVRON, FORMER STANDARD OIL SUBSTATION	LUST Cleanup Site	Open - Verification Monitoring	3/9/2010	Gasoline	Other Groundwater (uses other than drinking water), Soil	Inside 2000ft Protection Zone	MW-1	ACT	2/2/2010	30.58
SL0608127237	SFIA - SAN FRANCISCO AIRPORT BOARDING AREA E	Cleanup Program Site	Open - Remediation	1/1/2004	Aviation	Other Groundwater (uses other than drinking water), Soil					
SL0608128898	GEORGIA PACIFIC	Cleanup Program Site	Completed - Case Closed	12/22/2009	Tetrachloroethylene (PCE)	Other Groundwater (uses other than		MW-1S	ACT	3/20/2007	7
SL0608131398	PACIFIC PLAZA III	Cleanup Program Site	Open - Remediation	7/6/2009	Arsenic	Soil	Inside 2000ft Protection Zone				
SL0608136265	SFIA - SF AIRPORT BOARDING AREA D	Cleanup Program Site	Open - Remediation	1/1/2005	Aviation	Other Groundwater (uses other than drinking water), Soil		BM-4	ACT	12/5/2005	9.56
SL0608137279	UNION PACIFIC	Cleanup Program Site	Open - Site Assessment	2/14/2007	* Solvents	Other Groundwater (uses other than		MW-1	ACT	2/23/2009	6.02
SL0608146307	SFIA - CHEVRON BULK FUEL TERMINAL @ S.F. INT' AIRPORT	Cleanup Program Site	Open - Verification Monitoring	1/1/1999	Diesel, Aviation, Gasoline	Other Groundwater (uses other than drinking water), Soil		2	NOACC	3/16/2006	
SL0608147763	STANDARD ELECTRIC	Cleanup Program Site	Completed - Case Closed	8/15/2006	* Solvents	Other Groundwater (uses other than drinking water)					
SL0608148825	former PENINSULA CLEANERS - offsite	Cleanup Program Site	Open - Assessment & Interim Remedial Action	12/6/2010	Tetrachloroethylene (PCE)	Other Groundwater (uses other than drinking water), Soil, Soil Vapor, Under		MW-1	ACT	3/2/2004	7.11
SL0608156926	HOLIDAY CLEANERS	Cleanup Program Site	Open - Site Assessment	11/8/2007	Tetrachloroethylene (PCE), Trichloroethylene (TCE), Vinyl chloride	Indoor Air, Other Groundwater (uses other than drinking water), Soil		MW-1	ACT	6/15/2009	9.45
SL0608164408	BAYHILL 7 FACILITY	Cleanup Program Site	Completed - Case Closed	6/16/2009	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
SL0608165957	OTTOBONI NURSERY	Cleanup Program Site	Completed - Case Closed	12/4/2003		Soil					
SL0608169862	735 COMMERCIAL	Cleanup Program Site	Open - Site Assessment	7/10/2003	* Pesticides/Herbicides	Soil	Inside 2000ft Protection Zone				
SL0608169865	855 MALCOLM ROAD	Cleanup Program Site	Open - Verification Monitoring	12/29/2009	Tetrachloroethylene (PCE)	Soil					
SL0608174279	ASSOCIATED ROAD PARCEL	Cleanup Program Site	Open - Site Assessment	10/26/2007	* Solvents	Other Groundwater (uses other than drinking water)		MW-1	ACT	10/14/2009	5.62
SL0608175536	SFIA - SAN FRANCISCO AIRPORT BOARDING AREA F	Cleanup Program Site	Open - Remediation	1/1/2004	Aviation	Other Groundwater (uses other than drinking water), Soil					
SL0608175553	290 South Maple	Cleanup Program Site	Open - Assessment & Interim Remedial Action	4/14/2008	Tetrachloroethylene (PCE)	Other Groundwater (uses other than drinking water), Soil	Inside 2000ft Protection Zone	MW-2	ACT	5/20/2008	6.56
SL0608182371	SFIA - PS TRADING BULK TERMINAL AT SFIA	Cleanup Program Site	Open - Verification Monitoring	10/30/2009	Aviation	Other Groundwater (uses other than drinking water), Soil		P-4	DRY	9/6/2005	
SL0608187305	PARKING CORPORATION OF AMERICA	Cleanup Program Site	Completed - Case Closed	5/26/2010	Gasoline	Other Groundwater (uses other than drinking water)		MW-2	ACT	9/16/2005	1.99
SL0608187730	1245 MONTGOMERY AVE	Cleanup Program Site	Open - Remediation	10/31/2007	Benzene, Other Solvent or Non-Petroleum Hydrocarbon, Trichloroethylene (TCE)	Other Groundwater (uses other than drinking water), Soil, Soil Vapor		MW-7	ACT	6/29/2005	4.93
SL0608188827	Rollin J. Lobaugh	LUST Cleanup Site	Open - Site Assessment	3/31/2009	Stoddard Solvent / Mineral Spirits / Distillates	Other Groundwater (uses other than drinking water)					
SL0608188850	SOUTHGATE CLEANERS	Cleanup Program Site	Open - Site Assessment	6/4/2008	Tetrachloroethylene (PCE)	Soil	Inside 2000ft Protection Zone				
SL0608189867	SATURN OF COLMA	Cleanup Program Site	Completed - Case Closed	12/2/2005	Diesel	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
SL1821A600	HASKINS JAMIE COURT	Cleanup Program Site	Open - Site Assessment	1/14/2000	Lead, Asphalt	Other Groundwater (uses other than drinking water), Sediments, Soil					
SL18251672	SFIA - SAN FRANCISCO INTERNATIONAL AIRPORT	Cleanup Program Site	Open - Remediation	7/1/1995	1,1,1-Trichloroethane (TCA), Aviation, Diesel, Gasoline	Other Groundwater (uses other than drinking water), Soil	Inside 2000ft Protection Zone				
SL18341761	OBRIEN CORP	Cleanup Program Site	Open - Verification Monitoring	7/6/2009	Other Chlorinated Hydrocarbons, Arsenic, Lead	Other Groundwater (uses other than drinking water), Sediments, Soil, Surface					
SL20251869	W C PROPERTIES	Cleanup Program Site	Open - Inactive	3/20/1995							
SL20261879	US STEEL FACILITY (FORMER)	Cleanup Program Site	Completed - Case Closed	9/17/2009	Polychlorinated biphenyls (PCBs), Lead, Diesel, Waste Oil / Motor / Hydraulic / Lubricating, Polynuclear aromatic	Other Groundwater (uses other than drinking water), Sediments, Soil	Inside 2000ft Protection Zone				
SL20292909	COIT CLEANERS	Cleanup Program Site	Open - Verification Monitoring	9/1/2009				MW 1	ACT	3/17/1998	0.32
SL373231180	Shell (Equilon) South San Francisco Terminal	Cleanup Program Site	Open - Remediation	7/1/2002	Benzene, Toluene, Xylene, Aviation, Diesel, Fuel Oxygenates, Gasoline	Other Groundwater (uses other than drinking water), Soil, Surface water		MW-13	ACT	9/26/2005	10.3
SL373261183	CHEVRON USA SFO	Cleanup Program Site	Open - Site Assessment	7/1/2002							

SL373291186	SFO TAXIWAY C PROJECT	Cleanup Program Site	Open - Assessment & Interim Remedial Action	12/29/2009	* Petroleum - Automotive gasolines, * Petroleum - Diesel fuels, * Petroleum - Jet Fuel / Aviation, * Volatile Organic Compounds						
SL374231190	SHELL OIL BARGE PLANT SFO (Plot 22)	Cleanup Program Site	Open - Assessment & Interim Remedial Action	12/29/2009				S-3	ACT	9/8/2006	7.65
SLT2O04349	DESERT PETROLEUM	Cleanup Program Site	Open - Inactive	6/2/2009							
SLT2O319210	PRICE COMPANY	Cleanup Program Site	Completed - Case Closed	1/1/1970							
SLT2O321212	HILLSIDE BOULEVARD E NURSERY	Cleanup Program Site	Completed - Case Closed	1/1/1970			Inside 2000ft Protection Zone				
SLT2O322213	EXIDE CORP	Cleanup Program Site	Completed - Case Closed	1/1/1970							
SLT2O324940	INTERNATIONAL PAINT COURTALD COATINGS	Cleanup Program Site	Completed - Case Closed	11/22/2002							
SLT2O326216	HOMART DEV CORP EDWARDS WIRE & ROPE	Cleanup Program Site	Open - Inactive	5/12/2010			Inside 2000ft Protection Zone				
SLT2O327217	BACON PROPERTY	Cleanup Program Site	Completed - Case Closed	1/1/1970			Inside 2000ft Protection Zone				
SLT2O330220	POETSCH PETERSON TANNERS	Cleanup Program Site	Completed - Case Closed	1/1/1970			Inside 2000ft Protection Zone				
T0608100003	AAMCO TRANSMISSION	LUST Cleanup Site	Open - Site Assessment	1/5/1988	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100005	OLYMPIAN SSF TERMINAL	LUST Cleanup Site	Open - Site Assessment	11/8/2006	Gasoline	Other Groundwater (uses other than drinking water)		MW-9	ACT	6/18/2002	8.9
T0608100010	ALAMO RENT-A-CAR	LUST Cleanup Site	Completed - Case Closed	10/10/1991	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)					
T0608100011	ALAMO RENT-A-CAR	LUST Cleanup Site	Completed - Case Closed	9/4/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100012	ALLAN BAKER COMPANY	LUST Cleanup Site	Completed - Case Closed	10/25/2000	Gasoline	Soil					
T0608100015	ALQUEST PROPERTY	LUST Cleanup Site	Completed - Case Closed	5/23/1994	Diesel	Other Groundwater (uses other than drinking water)					
T0608100017	AMERICAN AIRLINES SUPERBAY HANGER	LUST Cleanup Site	Completed - Case Closed	7/22/2009	Kerosene	Other Groundwater (uses other than drinking water)		B-3	ACT	9/9/2005	5.56
T0608100024	ARC ELECTRIC	LUST Cleanup Site	Completed - Case Closed	11/25/1998	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100027	ARCO #0465	LUST Cleanup Site	Open - Site Assessment	9/9/2003	Benzene, Toluene, Xylene, Fuel Oxygenates,	Aquifer used for drinking water supply	Inside 2000ft Protection Zone	MW-4	ACT	6/27/2002	56
T0608100029	ARCO #0743	LUST Cleanup Site	Open - Site Assessment	6/13/1984	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-5	ACT	6/25/2002	35.84
T0608100033	ARCO #2090	LUST Cleanup Site	Completed - Case Closed	5/27/2011	Gasoline	Aquifer used for drinking water supply, Soil, Soil Vapor	Inside 2000ft Protection Zone	MW-1	ACT	6/27/2002	48.85
T0608100046	AUTO TEKNIK	LUST Cleanup Site	Completed - Case Closed	4/23/2002	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)					
T0608100047	AUTOHAUS	LUST Cleanup Site	Completed - Case Closed	4/24/1997	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100050	AVIS RENT A CAR	LUST Cleanup Site	Completed - Case Closed	9/16/1998	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100051	AVIS RENT-A-CAR	LUST Cleanup Site	Completed - Case Closed	3/6/2002	Diesel	Other Groundwater (uses other than drinking water)					
T0608100053	B & B TRANSMISSION	LUST Cleanup Site	Completed - Case Closed	2/27/1992	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100056	BART	LUST Cleanup Site	Completed - Case Closed	1/27/1992	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100057	SFIA - San Francisco International Airport TWA CARGO FACILITY	LUST Cleanup Site	Completed - Case Closed	6/21/1999	Kerosene	Other Groundwater (uses other than drinking water)					
T0608100061	BAYSTAR MEDICAL SERVICES	LUST Cleanup Site	Completed - Case Closed	3/18/1997	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100071	BISCAY AUTO REPAIR	LUST Cleanup Site	Completed - Case Closed	8/11/2000	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100073	DEITER BLUHM	LUST Cleanup Site	Completed - Case Closed	9/30/1991		Soil					
T0608100077	BP #11202 (FORMER)	LUST Cleanup Site	Open - Site Assessment	4/20/1987	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	6/11/2003	29.34
T0608100080	BP #11200	LUST Cleanup Site	Open - Site Assessment	4/14/2009	Gasoline	Other Groundwater (uses other than drinking water)		MW-2	ACT	6/7/2002	3.14
T0608100081	BRESSIE & CO.	LUST Cleanup Site	Completed - Case Closed	6/11/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100084	BROADMOOR LUMBER & PLYWOOD CO	LUST Cleanup Site	Completed - Case Closed	7/3/1995	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100087	BUDGET RENT-A-CAR	LUST Cleanup Site	Completed - Case Closed	9/13/2002	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100089	BURLINGAME FIRE STA. #3	LUST Cleanup Site	Completed - Case Closed	10/19/2000	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100091	BURLINGAME POST OFFICE	LUST Cleanup Site	Completed - Case Closed	11/28/1995	Gasoline	Soil					
T0608100093	BURLINGTON AIR EXPRESS	LUST Cleanup Site	Completed - Case Closed	1/31/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100094	BROADWAY LOCKSMITH	LUST Cleanup Site	Completed - Case Closed	3/30/2000	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100105	CARLIN CO	LUST Cleanup Site	Completed - Case Closed	6/27/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100107	CARUFF CALIFORNIA CORP	LUST Cleanup Site	Completed - Case Closed	10/10/1993	Gasoline	Other Groundwater (uses other than drinking water)					

T0608100108	CAULKING WATERPROOFING INC.	LUST Cleanup Site	Completed - Case Closed	2/9/1993	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100110	CHEVRON 9-4000	LUST Cleanup Site	Completed - Case Closed	7/22/2009	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100113	CHEVRON 9-1909	LUST Cleanup Site	Completed - Case Closed	7/6/2005	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	3/1/2002	5.12
T0608100114	CHEVRON 9-1626	LUST Cleanup Site	Completed - Case Closed	10/25/2005	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-10	ACT	5/31/2002	28.08
T0608100115	CHEVRON 9-7640	LUST Cleanup Site	Completed - Case Closed	12/5/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100116	CHEVRON 9-5131	LUST Cleanup Site	Completed - Case Closed	6/27/2002	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100118	CHEVRON 9-0723	LUST Cleanup Site	Completed - Case Closed	1/18/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100122	CHEVRON 9-8165	LUST Cleanup Site	Open - Site Assessment	7/22/1985	Gasoline	Other Groundwater (uses other than drinking water)		C-3R	ACT	2/16/2002	12.24
T0608100125	CHEVRON 9-7455	LUST Cleanup Site	Completed - Case Closed	5/28/1999	Waste Oil / Motor / Hydraulic / Lubricating	Soil	Inside 2000ft Protection Zone				
T0608100126	CHEVRON 9-0781	LUST Cleanup Site	Completed - Case Closed	10/6/2010	Gasoline	Aquifer used for drinking water supply					
T0608100128	CHEVRON 9-0571	LUST Cleanup Site	Open - Verification Monitoring	4/27/2009	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	3/14/2002	6.86
T0608100132	CHEVRON 9-0206	LUST Cleanup Site	Completed - Case Closed	7/22/2004	Gasoline	Other Groundwater (uses other than drinking water)		EA-1	ACT	2/16/2002	3.16
T0608100137	CHEVRON 9-0645	LUST Cleanup Site	Completed - Case Closed	1/18/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100144	CHEVRON 9-0248	LUST Cleanup Site	Completed - Case Closed	12/19/2001	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100145	CHEVRON 9-5669	LUST Cleanup Site	Completed - Case Closed	4/9/2007	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-5	ACT	2/16/2002	38.88
T0608100147	CHEVRON 9-2759 ECR SB COMINGLED	LUST Cleanup Site	Open - Assessment & Interim	5/21/2010	Benzene, Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone	C-1	ACT	3/25/2002	12.72
T0608100148	CHEVRON 9-6982	LUST Cleanup Site	Completed - Case Closed	12/27/2011	Gasoline	Aquifer used for drinking water supply		MW-2	DRY	5/14/2004	
T0608100149	CHEVRON 9-0858	LUST Cleanup Site	Completed - Case Closed	12/4/2000	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100152	CITY OF DALY CITY	LUST Cleanup Site	Completed - Case Closed	5/28/1991	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100153	FEDERAL EXPRESS FLYNG TIGERS	LUST Cleanup Site	Completed - Case Closed	7/22/2009	Diesel	Other Groundwater (uses other than drinking water)					
T0608100157	CITY OF MILLBRAE CORP YARD	LUST Cleanup Site	Completed - Case Closed	4/28/1997	Diesel	Other Groundwater (uses other than					
T0608100165	CODON (GRAND/ROEBLING INV)	LUST Cleanup Site	Completed - Case Closed	11/13/1991	Gasoline	Soil					
T0608100167	COLUMBUS SALAME INC.	LUST Cleanup Site	Completed - Case Closed	6/13/1991	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100170	Mobil 99-ELM (Former)	LUST Cleanup Site	Open - Site Assessment	6/13/1990	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	GW-1	ACT	10/22/2002	8.44
T0608100171	COYNE CYLINDER CO	LUST Cleanup Site	Completed - Case Closed	7/20/2011	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-4	ACT	7/25/2003	6.55
T0608100172	CORTANA CORPORATION	LUST Cleanup Site	Completed - Case Closed	2/17/1993	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100173	COULTERS CARPETS	LUST Cleanup Site	Completed - Case Closed	11/14/2002	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100178	CYPRESS LAWN CEMETERY	LUST Cleanup Site	Completed - Case Closed	8/27/2001	Diesel	Other Groundwater (uses other than	Inside 2000ft Protection Zone				
T0608100179	DALY CITY CORP YARD	LUST Cleanup Site	Completed - Case Closed	1/24/2003	Gasoline	Aquifer used for drinking water supply	Inside 2000ft Protection Zone				
T0608100180	DALY CITY SERVICE	LUST Cleanup Site	Completed - Case Closed	4/19/1996	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100181	DALY CITY WASTEWATER PLANT	LUST Cleanup Site	Open - Verification Monitoring	2/1/1990	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100188	KEN FUNK PROPERTY	LUST Cleanup Site	Completed - Case Closed	12/3/1998	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100191	SAN BRUNO CORP. YARD	LUST Cleanup Site	Completed - Case Closed	11/7/2001	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100193	EARLY AMERICAN PAINT	LUST Cleanup Site	Completed - Case Closed	5/11/2000	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100194	OLYMPIC EAST GRAND CARDTOL	LUST Cleanup Site	Completed - Case Closed	4/23/2009	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	12/12/2002	5.25
T0608100195	EMERY AIR FREIGHT	LUST Cleanup Site	Completed - Case Closed	8/22/1996	Diesel	Other Groundwater (uses other than drinking water)					
T0608100196	ENCORE THEATER	LUST Cleanup Site	Completed - Case Closed	9/23/1997	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100199	ESCHELBACH PROPERTIES	LUST Cleanup Site	Completed - Case Closed	6/12/2001	Gasoline	Other Groundwater (uses other than drinking water)					

T0608100202	EUROPEAN CAR SERVICE	LUST Cleanup Site	Completed - Case Closed	10/17/2002	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100204	EXXON 7-0207, FORMER	LUST Cleanup Site	Open - Site Assessment	4/23/2009	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW1	ACT	9/12/2001	32.69
T0608100207	EXXON 7-0107 (Former)	LUST Cleanup Site	Open - Remediation	11/22/2006	Gasoline	Other Groundwater (uses other than drinking water)		MW7A	ACT	11/25/2002	8.04
T0608100214	FEDERAL SUPPLY WAREHOUSE	LUST Cleanup Site	Completed - Case Closed	4/28/1997	Gasoline	Other Groundwater (uses other than					
T0608100215	FINLEY CONSTRUCTION CO	LUST Cleanup Site	Completed - Case Closed	7/9/1992	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100220	FLAT RATE RENT-A-CAR	LUST Cleanup Site	Completed - Case Closed	8/11/1999	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100223	SFIA - AMERICAN AIRLINES PLOT 9	LUST Cleanup Site	Completed - Case Closed	1/1/2004	Aviation	Other Groundwater (uses other than drinking water)					
T0608100226	FOUR STAR AUTOMOTIVE, INC.	LUST Cleanup Site	Completed - Case Closed	6/28/1996	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)					
T0608100228	GALLO SALES CO.	LUST Cleanup Site	Open - Verification Monitoring	1/1/2011	Gasoline	Other Groundwater (uses other than drinking water)		MW-G1	ACT	3/26/2002	12.26
T0608100229	UNITED TRANSMISSION INC	LUST Cleanup Site	Completed - Case Closed	11/20/1996	Stoddard Solvent / Mineral Spirits / Distillates	Other Groundwater (uses other than drinking water)					
T0608100230	GASCO SERVICE STATION	LUST Cleanup Site	Completed - Case Closed	1/23/2002	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100231	GELCO TRUCK LEASING	LUST Cleanup Site	Completed - Case Closed	8/4/1992	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100233	GEORGIA PACIFIC	LUST Cleanup Site	Completed - Case Closed	11/10/1998	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100238	PENSKE TRUCK LEASING II	LUST Cleanup Site	Completed - Case Closed	1/17/2003	Gasoline	Other Groundwater (uses other than					
T0608100239	GRACE HONDA	LUST Cleanup Site	Completed - Case Closed	6/30/1994	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100240	GRANITE ROCK CO	LUST Cleanup Site	Completed - Case Closed	4/1/2008	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than		MW-1	ACT	3/28/2002	5.32
T0608100241	GREEN HILLS COUNTRY CLUB	LUST Cleanup Site	Completed - Case Closed	9/2/1993	Gasoline	Soil					
T0608100243	CITY OF DALY CITY	LUST Cleanup Site	Completed - Case Closed	5/28/1991		Soil	Inside 2000ft Protection Zone				
T0608100244	GREYHOUND EXPOSITION SERVICES	LUST Cleanup Site	Completed - Case Closed	7/28/2000	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100248	H.S. CROCKER CO.	LUST Cleanup Site	Completed - Case Closed	10/14/1998	Gasoline	Other Groundwater (uses other than					
T0608100250	HAMMETT & EDISON REAL ESTATE	LUST Cleanup Site	Completed - Case Closed	2/8/1994	Diesel	Soil					
T0608100252	HARMON SHRAGGE CO	LUST Cleanup Site	Completed - Case Closed	8/22/1996	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100253	HARRIS PROPERTY	LUST Cleanup Site	Open - Remediation	8/1/1989	Gasoline	Other Groundwater (uses other than drinking water)		PSB-5	ACT	4/28/2003	12.88
T0608100255	HUMBER REALTY	LUST Cleanup Site	Completed - Case Closed	12/29/1993	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100256	HERTZ	LUST Cleanup Site	Completed - Case Closed	7/19/2001	Gasoline	Other Groundwater (uses other than					
T0608100257	HERTZ RENTAL CAR	LUST Cleanup Site	Completed - Case Closed	9/16/1998	Gasoline	Under Investigation					
T0608100259	HIRAM WALKER	LUST Cleanup Site	Completed - Case Closed	1/27/1998	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100261	HOFFMAN BROTHERS	LUST Cleanup Site	Completed - Case Closed	4/18/2000	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100266	HOME SAVINGS OF AMERICA	LUST Cleanup Site	Completed - Case Closed	3/26/2002	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100269	HOUSING CONSTRUCTION	LUST Cleanup Site	Completed - Case Closed	7/27/2000	Diesel	Other Groundwater (uses other than drinking water)					
T0608100274	GEORGIA GERRITSEN	LUST Cleanup Site	Completed - Case Closed	11/10/2005	Gasoline	Other Groundwater (uses other than		MW-1	INACT	12/31/2003	
T0608100276	SFIA - SIGNITURE FLIGHT	LUST Cleanup Site	Completed - Case Closed	7/22/2009	Kerosene	Under Investigation					
T0608100283	J.R. FLYNN CO.	LUST Cleanup Site	Completed - Case Closed	7/6/1998	Gasoline	Other Groundwater (uses other than					
T0608100288	SHOPPING STRIP MALL	LUST Cleanup Site	Completed - Case Closed	10/8/1998	Gasoline	Soil					
T0608100291	DELANO NURSERY	LUST Cleanup Site	Completed - Case Closed	9/14/1993	Gasoline	Soil					
T0608100296	KPR PROPERTIES	LUST Cleanup Site	Completed - Case Closed	3/19/1998	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100300	LA MARK TRANSPORTATION	LUST Cleanup Site	Completed - Case Closed	1/2/2003	Gasoline	Other Groundwater (uses other than					
T0608100307	OYSTER POINT	LUST Cleanup Site	Completed - Case Closed	5/21/2009	Waste Oil / Motor / Hydraulic / Lubricating	Soil					
T0608100310	LONATI PROPERTIES	LUST Cleanup Site	Completed - Case Closed	12/1/2004	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	9/16/2002	8.62
T0608100312	LUBRIVAN TRUCK SERVICES	LUST Cleanup Site	Completed - Case Closed	3/7/2003	Gasoline	Other Groundwater (uses other than drinking water)					

T0608100313	LUCCA PACKING CORP.	LUST Cleanup Site	Completed - Case Closed	8/16/2001	Diesel	Other Groundwater (uses other than drinking water)					
T0608100318	MIZRA/SETO PROPERTY	LUST Cleanup Site	Completed - Case Closed	7/24/2000	Gasoline	Other Groundwater (uses other than					
T0608100322	MCCLENNAN PROPERTY	LUST Cleanup Site	Completed - Case Closed	4/20/1990	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100332	MIKE HARVEY CHRYSLER	LUST Cleanup Site	Completed - Case Closed	7/21/1997	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100341	MOBIL 04-FT7	LUST Cleanup Site	Completed - Case Closed	1/26/1999	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100350	BP #11204	LUST Cleanup Site	Open - Verification Monitoring	9/30/1988	Benzene, Toluene, Xylene, Diesel, Fuel Oxygenates, Gasoline, Waste Oil / Motor /	Other Groundwater (uses other than drinking water)		MW-1	ACT	6/19/2003	4.27
T0608100351	MONROE SCHNEIDER ASSOC.	LUST Cleanup Site	Completed - Case Closed	5/6/1992	Xylene	Other Groundwater (uses other than drinking water)					
T0608100353	MR DETAIL	LUST Cleanup Site	Completed - Case Closed	2/19/1999	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100355	MYERS AIR CONDITIONING	LUST Cleanup Site	Completed - Case Closed	6/7/1996	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100356	NATIONAL CAR RENTAL SYSTEM INC	LUST Cleanup Site	Completed - Case Closed	2/23/1998	Gasoline	Other Groundwater (uses other than					
T0608100362	OLIVET MEMORIAL PARK	LUST Cleanup Site	Completed - Case Closed	10/12/1994	Gasoline	Soil					
T0608100363	OLYMPIAN	LUST Cleanup Site	Completed - Case Closed	2/23/1996	Gasoline	Other Groundwater (uses other than					
T0608100366	OLYMPIAN OIL	LUST Cleanup Site	Completed - Case Closed	5/12/2003	Gasoline	Aquifer used for drinking water supply					
T0608100369	OLYMPIC AUTO SERVICE	LUST Cleanup Site	Open - Remediation	3/31/2003	Gasoline	Other Groundwater (uses other than drinking water)		MW1	ACT	2/4/2002	12.49
T0608100370	CHEVRON 209437, FORMER	LUST Cleanup Site	Completed - Case Closed	12/3/2002	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100376	PACIFIC BELL	LUST Cleanup Site	Completed - Case Closed	8/12/2010	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	12/12/2002	26.13
T0608100377	PACIFIC BELL	LUST Cleanup Site	Completed - Case Closed	7/9/1992	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100380	PACIFIC CONSTRUCTION	LUST Cleanup Site	Completed - Case Closed	11/13/1997	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100385	SFIA - San Francisco International Airport UAL OGDEN FORMER PAN	LUST Cleanup Site	Completed - Case Closed	7/22/2009	Diesel	Other Groundwater (uses other than					
T0608100389	PENINSULA PROPERTIES	LUST Cleanup Site	Completed - Case Closed	12/1/1993	Gasoline	Soil					
T0608100391	PENINSULA TOW SERVICE	LUST Cleanup Site	Completed - Case Closed	6/13/2002	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100393	PERIN COMPANY	LUST Cleanup Site	Completed - Case Closed	6/26/1997	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)					
T0608100401	GENERAL RENT-A-CAR	LUST Cleanup Site	Completed - Case Closed	3/19/1998	Gasoline	Other Groundwater (uses other than					
T0608100402	PONY EXPRESS	LUST Cleanup Site	Completed - Case Closed	3/16/2000	Gasoline	Soil					
T0608100406	PRESSURE GROUT COMPANY	LUST Cleanup Site	Completed - Case Closed	8/9/1993	Gasoline	Other Groundwater (uses other than					
T0608100407	PRICE COMPANY	LUST Cleanup Site	Completed - Case Closed	7/29/1992	Gasoline	Under Investigation					
T0608100411	COLOR CRAFT	LUST Cleanup Site	Completed - Case Closed	1/2/2001	Gasoline	Other Groundwater (uses other than					
T0608100415	RAGNI CONSTRUCTION	LUST Cleanup Site	Completed - Case Closed	3/20/1991	Gasoline	Soil					
T0608100418	RECTOR CADILLAC	LUST Cleanup Site	Completed - Case Closed	6/9/1992	Waste Oil / Motor / Hydraulic / Lubricating	Soil					
T0608100429	RON PRICE MOTORS	LUST Cleanup Site	Completed - Case Closed	1/8/1996	Waste Oil / Motor / Hydraulic / Lubricating	Soil	Inside 2000ft Protection Zone				
T0608100431	RPM RENT-A-CAR	LUST Cleanup Site	Completed - Case Closed	10/25/1995	Diesel	Other Groundwater (uses other than drinking water)					
T0608100434	SAGE TRANSPORTATION	LUST Cleanup Site	Completed - Case Closed	6/27/2001	Diesel	Other Groundwater (uses other than drinking water)					
T0608100436	SAM TRANS (VACANT)	LUST Cleanup Site	Completed - Case Closed	4/10/2000	Gasoline	Other Groundwater (uses other than					
T0608100438	SAN BRUNO CABLE TV	LUST Cleanup Site	Completed - Case Closed	12/11/1997	Waste Oil / Motor / Hydraulic / Lubricating	Soil	Inside 2000ft Protection Zone				
T0608100439	SAN BRUNO FORD	LUST Cleanup Site	Completed - Case Closed	12/20/2001	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100440	SAN BRUNO GLASS CENTER	LUST Cleanup Site	Completed - Case Closed	10/11/2002	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100441	SAN BRUNO LUMBER	LUST Cleanup Site	Completed - Case Closed	1/3/2002	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100443	SAN FRANCISCO NEWSPAPER AGENCY	LUST Cleanup Site	Completed - Case Closed	11/27/2002	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)					
T0608100444	MOSQUITO ABATEMENT OFFICE	LUST Cleanup Site	Completed - Case Closed	10/9/1997	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100452	SEARS AUTOMOTIVE CENTER	LUST Cleanup Site	Open - Site Assessment	4/10/1985	Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone	MW-4	ACT	4/30/2003	12.43
T0608100455	SERRAMONTE FORD	LUST Cleanup Site	Completed - Case Closed	9/17/1992	Gasoline	Soil	Inside 2000ft Protection Zone				

T0608100456	SF GARDEN MART	LUST Cleanup Site	Completed - Case Closed	8/7/1991	Gasoline	Soil					
T0608100458	SHAFFER'S TIRE CENTER	LUST Cleanup Site	Completed - Case Closed	1/14/1992	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)					
T0608100461	SHELL OIL	LUST Cleanup Site	Open - Remediation	2/6/2001	Gasoline	Other Groundwater (uses other than drinking water)		MW-2	ACT	12/17/2001	2.11
T0608100463	HICKEY FAMILY PARTNERSHIP	LUST Cleanup Site	Completed - Case Closed	5/20/1997	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100464	SHELL	LUST Cleanup Site	Open - Site Assessment	7/1/2009	Gasoline	Other Groundwater (uses other than drinking water)		S-4	ACT	1/9/2002	4.02
T0608100465	SHELL OIL	LUST Cleanup Site	Completed - Case Closed	6/24/2005	Diesel	Other Groundwater (uses other than drinking water)		MW-6	ACT	1/10/2002	6.65
T0608100468	SHELL	LUST Cleanup Site	Completed - Case Closed	8/21/2001	Gasoline	Other Groundwater (uses other than					
T0608100487	SHELL	LUST Cleanup Site	Completed - Case Closed	10/10/1991	Gasoline	Soil					
T0608100490	SHELL	LUST Cleanup Site	Completed - Case Closed	6/24/2005	Waste Oil / Motor / Hydraulic / Lubricating	Soil	Inside 2000ft Protection Zone	MW-1	ACT	2/14/2002	40.14
T0608100491	SHELL ECR SB COMINGLED	LUST Cleanup Site	Open - Verification Monitoring	3/8/2010	Gasoline	Other Groundwater (uses other than drinking water), Soil Vapor	Inside 2000ft Protection Zone	MW-1	ACT	10/16/2001	16.2
T0608100492	SHELL	LUST Cleanup Site	Open - Site Assessment	1/12/2009	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	1/15/2002	8.68
T0608100494	SHELL	LUST Cleanup Site	Completed - Case Closed	4/7/1992	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than					
T0608100498	SIMEON PROPERTIES	LUST Cleanup Site	Completed - Case Closed	2/24/2000	Diesel	Soil					
T0608100504	SOUTH CITY DODGE	LUST Cleanup Site	Completed - Case Closed	10/27/1992	Diesel	Soil	Inside 2000ft Protection Zone				
T0608100505	SOUTH CITY FORD	LUST Cleanup Site	Completed - Case Closed	8/9/2001	Gasoline	Other Groundwater (uses other than					
T0608100506	SOUTH CITY LUMBER	LUST Cleanup Site	Completed - Case Closed	12/14/1992	Gasoline	Soil					
T0608100507	TEXACO, SOUTH CITY (INDEP)	LUST Cleanup Site	Completed - Case Closed	11/17/2003	Gasoline	Other Groundwater (uses other than		MW-1	ACT	8/15/2002	1.33
T0608100508	S.S.F. HIGH SCHOOL	LUST Cleanup Site	Completed - Case Closed	8/4/1993	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100510	GARY HIRSCH	LUST Cleanup Site	Completed - Case Closed	10/18/1994	Gasoline	Soil					
T0608100512	SPRUCE CAR WASH	LUST Cleanup Site	Open - Remediation	5/12/2006	Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone	MW-9	ACT	2/20/2002	8.52
T0608100516	STEWART CHEVROLET	LUST Cleanup Site	Completed - Case Closed	10/10/1991	Waste Oil / Motor / Hydraulic / Lubricating	Soil	Inside 2000ft Protection Zone				
T0608100517	THE PROPERTY	LUST Cleanup Site	Completed - Case Closed	11/21/2000	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100526	SUPER CROWN CATERING	LUST Cleanup Site	Completed - Case Closed	6/12/2009	Gasoline	Other Groundwater (uses other than drinking water)		MW-1R	ACT	1/9/2003	5.81
T0608100530	STUMP PROPERTY	LUST Cleanup Site	Open - Remediation	9/12/2000	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	9/28/2001	19.59
T0608100537	EXXON 7-0259 (FORMER) ECR SB COMINGLED	LUST Cleanup Site	Open - Verification Monitoring	3/8/2010	Benzene, Other Chlorinated Hydrocarbons, Gasoline	Other Groundwater (uses other than drinking water), Soil Vapor	Inside 2000ft Protection Zone	MW16B	ACT	3/25/2002	12.06
T0608100541	THOMPSON AIR CRAFT TIRE CORP	LUST Cleanup Site	Completed - Case Closed	3/7/2003	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100543	HANSEN PROPERTY	LUST Cleanup Site	Completed - Case Closed	9/24/1992	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100545	TONY'S SERVICES	LUST Cleanup Site	Open - Remediation	12/18/2006	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-8	ACT	2/3/2003	45.56
T0608100548	TRADITIONAL WOOD WORKS	LUST Cleanup Site	Completed - Case Closed	6/27/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100549	TRAFFIC INTERNATIONAL CORP.	LUST Cleanup Site	Completed - Case Closed	10/4/2002	Gasoline	Other Groundwater (uses other than					
T0608100550	TREASURE ISLAND TRAILER COURT	LUST Cleanup Site	Completed - Case Closed	9/15/1993	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100551	TRUX AIRLINE CARGO SERVICE	LUST Cleanup Site	Completed - Case Closed	12/28/1992	Gasoline	Other Groundwater (uses other than					
T0608100552	TORNBERG ENTERPRISES	LUST Cleanup Site	Completed - Case Closed	6/12/1992	Gasoline	Soil					
T0608100554	U-FREIGHT AMERICA INC	LUST Cleanup Site	Completed - Case Closed	6/26/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100558	UNION CARBIDE CORP.	LUST Cleanup Site	Open - Remediation	12/21/2005	Acetone, Other Chlorinated Hydrocarbons, Vinyl chloride, Diesel, Gasoline	Other Groundwater (uses other than drinking water)		MW-4	ACT	5/1/2002	8.25
T0608100559	SFIA - UNITED AIRLINES SERVICE CENTER	LUST Cleanup Site	Completed - Case Closed	7/6/2009	Diesel	Other Groundwater (uses other than drinking water)					
T0608100566	UNOCAL STATION #3885	LUST Cleanup Site	Open - Site Assessment	6/26/1997	Gasoline	Other Groundwater (uses other than drinking water)		U-1	ACT	3/18/2002	4.78
T0608100567	UNOCAL #4527, FORMER	LUST Cleanup Site	Open - Site Assessment	12/30/1985	Gasoline	Other Groundwater (uses other than drinking water)		U-6	ACT	3/20/2002	78.81
T0608100570	UNOCAL STATION #0670	LUST Cleanup Site	Open - Site Assessment	11/1/1987	Gasoline	Other Groundwater (uses other than drinking water)		MW-4	ACT	4/7/2002	7.58
T0608100573	UNOCAL #3857	LUST Cleanup Site	Completed - Case Closed	4/4/2002	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				

T0608100575	UNOCAL STATION #3798	LUST Cleanup Site	Open - Site Assessment	6/1/1989	Gasoline	Other Groundwater (uses other than drinking water)		MW-3	ACT	3/28/2002	10.58
T0608100577	UNOCAL #6980 (FORMER)	LUST Cleanup Site	Open - Site Assessment	3/2/1993	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	10/13/2003	41.5
T0608100579	UNOCAL STATION #1020	LUST Cleanup Site	Open - Site Assessment	9/1/1991	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	9/14/2002	4.67
T0608100584	UNOCAL STATION #3676	LUST Cleanup Site	Open - Site Assessment	11/10/2000	Gasoline	Other Groundwater (uses other than		MW-2	ACT	5/1/2002	21.11
T0608100585	UNOCAL	LUST Cleanup Site	Completed - Case Closed	12/11/1995	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100586	TOSCO #4113 (FORMER UNOCAL)	LUST Cleanup Site	Completed - Case Closed	9/3/2008	Gasoline	Under Investigation	Inside 2000ft Protection Zone				
T0608100593	UNOCAL STATION #4524 (FORMER)	LUST Cleanup Site	Completed - Case Closed	7/7/2011	Gasoline	Other Groundwater (uses other than		MW-7	ACT	8/1/2006	6.71
T0608100597	USCG	LUST Cleanup Site	Completed - Case Closed	7/22/2009	Diesel	Under Investigation					
T0608100598	CITY OF SSF CORP YARD	LUST Cleanup Site	Open - Site Assessment	12/19/2011	Fuel Oxygenates, Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone	MW-1	ACT	11/4/2002	15.67
T0608100602	VALLEY SHEET METAL	LUST Cleanup Site	Completed - Case Closed	11/12/1991	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100613	WALL STREET PROPERTIES	LUST Cleanup Site	Completed - Case Closed	3/19/2001		Other Groundwater (uses other than drinking water)					
T0608100614	WAREHOUSE I	LUST Cleanup Site	Completed - Case Closed	8/26/1999	Gasoline	Other Groundwater (uses other than					
T0608100616	WESCO MANAGEMENT	LUST Cleanup Site	Completed - Case Closed	12/15/2000	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100619	WILL-STA, INC.	LUST Cleanup Site	Completed - Case Closed	1/17/1996	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100626	W. J. BRITTON COMPANY	LUST Cleanup Site	Completed - Case Closed	6/30/1998	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100628	YELLOW FREIGHT SYSTEM	LUST Cleanup Site	Completed - Case Closed	4/26/2002	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)					
T0608100631	ZELLERBACH PAPER CO	LUST Cleanup Site	Completed - Case Closed	10/16/2001	Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone				
T0608100635	PACIFIC BELL	LUST Cleanup Site	Completed - Case Closed	9/18/2002	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100640	HILLSIDE SERVICE STATION	LUST Cleanup Site	Completed - Case Closed	2/20/1996	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100642	BURLINGAME FIRE DEPT.	LUST Cleanup Site	Completed - Case Closed	8/9/2002	Gasoline	Other Groundwater (uses other than					
T0608100645	PACIFIC BELL	LUST Cleanup Site	Completed - Case Closed	11/13/2000	Gasoline	Soil					
T0608100646	R.E.H. PROPERTIES	LUST Cleanup Site	Open - Remediation	1/12/2005	Gasoline	Other Groundwater (uses other than		MW-1	ACT	5/13/2003	
T0608100649	PLATH NURSERY, FORMER	LUST Cleanup Site	Completed - Case Closed	10/4/2000	Gasoline	Soil					
T0608100650	BAY BRIDGE HARDWARE SUPPLY	LUST Cleanup Site	Completed - Case Closed	6/6/1995	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100651	SEE's CANDIES	LUST Cleanup Site	Completed - Case Closed	1/18/2001	Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone				
T0608100652	ABBEY HOMESTEAD NURSERY	LUST Cleanup Site	Completed - Case Closed	12/13/1999	Gasoline	Soil					
T0608100653	CALIFORNIA GOLF CLUB	LUST Cleanup Site	Completed - Case Closed	10/4/2000	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100658	DUPONT	LUST Cleanup Site	Completed - Case Closed	10/6/2011	Arsenic, Stoddard Solvent / Mineral Spirits / Distillates	Other Groundwater (uses other than drinking water)		MW-1	ACT	6/5/2002	7.16
T0608100659	BLANKENHORN PROPERTY	LUST Cleanup Site	Completed - Case Closed	6/12/2000	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100660	BP #11206	LUST Cleanup Site	Open - Site Assessment	2/2/1993	Gasoline	Other Groundwater (uses other than		MW-1	ACT	5/15/2003	22.75
T0608100664	VW AUTO REPAIR	LUST Cleanup Site	Completed - Case Closed	7/21/2000	Waste Oil / Motor / Hydraulic / Lubricating	Soil	Inside 2000ft Protection Zone				
T0608100668	WESTLAKE PONTIAC	LUST Cleanup Site	Completed - Case Closed	9/27/1991	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100674	ALQUEST PROPERTY CORP	LUST Cleanup Site	Completed - Case Closed	10/12/1994	Gasoline	Soil					
T0608100675	CALIF. FEDERAL SAVINGS BANK	LUST Cleanup Site	Completed - Case Closed	11/12/1995	Gasoline	Other Groundwater (uses other than					
T0608100693	CATERAIR INTERNATIONAL	LUST Cleanup Site	Completed - Case Closed	1/15/1995	Gasoline	Soil					
T0608100695	EL CAMINO LINES	LUST Cleanup Site	Completed - Case Closed	12/30/1996	Gasoline	Other Groundwater (uses other than					
T0608100696	STAN THE ROOF MAN	LUST Cleanup Site	Completed - Case Closed	8/10/2000	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100697	DALY CITY SCAVENGER	LUST Cleanup Site	Completed - Case Closed	12/2/1994	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100701	GUY F. ATKINSON CO.	LUST Cleanup Site	Completed - Case Closed	5/27/1997	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100704	TOWN OF HILLSBOROUGH	LUST Cleanup Site	Completed - Case Closed	3/5/1999	Gasoline	Other Groundwater (uses other than					
T0608100705	LEROY GREENWOOD PROPERTY	LUST Cleanup Site	Completed - Case Closed	12/29/1993	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100712	BUBBLE MACHINE	LUST Cleanup Site	Completed - Case Closed	12/7/1998	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100713	SWINERTON & WALBERG	LUST Cleanup Site	Completed - Case Closed	4/3/1996	Gasoline	Other Groundwater (uses other than drinking water)					

T0608100720	VOLONTE AUTOMOTIVE	LUST Cleanup Site	Completed - Case Closed	9/27/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100721	SOUTH CITY SCAVENGER	LUST Cleanup Site	Completed - Case Closed	4/19/2011	Gasoline	Other Groundwater (uses other than drinking water)		MW-2	ACT	6/16/2003	4.95
T0608100723	SAMTRANS NORTH BASE	LUST Cleanup Site	Completed - Case Closed	7/26/2002	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100725	HORN INVESTMENT & REALTY	LUST Cleanup Site	Completed - Case Closed	11/30/1995	Diesel	Other Groundwater (uses other than drinking water)					
T0608100727	CYCLE SHACK,INC	LUST Cleanup Site	Completed - Case Closed	11/13/2000	Gasoline	Other Groundwater (uses other than					
T0608100728	GARRATT CALLAHAN COMPANY	LUST Cleanup Site	Completed - Case Closed	1/26/1995	Gasoline	Soil					
T0608100736	WAREHOUSE II	LUST Cleanup Site	Completed - Case Closed	9/27/1996	Gasoline	Other Groundwater (uses other than					
T0608100738	INTERSTATE GRADING	LUST Cleanup Site	Completed - Case Closed	8/13/1999	Gasoline	Soil					
T0608100740	TOWN OF COLMA	LUST Cleanup Site	Completed - Case Closed	4/11/1994	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100742	MCKINLEY SCHOOL	LUST Cleanup Site	Completed - Case Closed	12/5/1994	Gasoline	Soil					
T0608100743	REPO DEPOT	LUST Cleanup Site	Completed - Case Closed	5/4/1994	Gasoline	Soil					
T0608100748	KLIX CORP.	LUST Cleanup Site	Completed - Case Closed	6/12/2003	Gasoline	Soil					
T0608100752	MERCY PENINSULA AMBULANCE	LUST Cleanup Site	Completed - Case Closed	12/26/2001	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100753	BOB LEECH'S AUTO RENTAL	LUST Cleanup Site	Completed - Case Closed	3/15/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100760	EFL TRANSPORTATION	LUST Cleanup Site	Completed - Case Closed	12/3/1996	Diesel	Other Groundwater (uses other than					
T0608100761	COLMA FIRE PROTECTION DIST.	LUST Cleanup Site	Completed - Case Closed	5/31/2002	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100765	SERBIAN CEMETERY	LUST Cleanup Site	Completed - Case Closed	2/17/2003	Gasoline	Soil					
T0608100766	SAN BRUNO FORD II	LUST Cleanup Site	Completed - Case Closed	8/21/1995	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100768	BCBM	LUST Cleanup Site	Completed - Case Closed	3/18/1996	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100772	SEWAGE PUMP STATION #4	LUST Cleanup Site	Completed - Case Closed	8/21/2003	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	5/31/2002	9.28
T0608100774	MONFREDINI PROPERTY	LUST Cleanup Site	Open - Site Assessment	3/9/2005	Diesel	Other Groundwater (uses other than		MW-1	ACT	12/17/2002	9.88
T0608100777	BLUES ROOFING	LUST Cleanup Site	Completed - Case Closed	6/28/1994	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100779	S F ENGINE RE-MANUFACTURING	LUST Cleanup Site	Completed - Case Closed	2/28/2001		Other Groundwater (uses other than					
T0608100782	MATTISON & SHIDLER	LUST Cleanup Site	Completed - Case Closed	11/29/1995	Gasoline	Soil					
T0608100783	OLYMPIAN WESTLAKE	LUST Cleanup Site	Open - Assessment & Interim	10/16/2008	Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone	MW-1	ACT	5/5/2009	12.78
T0608100785	PACIFIC CAR RENTAL	LUST Cleanup Site	Completed - Case Closed	9/28/1994	Gasoline	Soil					
T0608100791	AIRPORT BOULEVARD SERVICE STATION	LUST Cleanup Site	Completed - Case Closed	8/12/1997	Gasoline	Other Groundwater (uses other than					
T0608100794	FOUR STAR AUTOMOTIVE II	LUST Cleanup Site	Completed - Case Closed	6/12/1995	Gasoline	Soil					
T0608100795	COIT CLEANERS	Cleanup Program Site	Open - Inactive	1/1/2011	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)					
T0608100799	THRIFTY RENT-A-CAR	LUST Cleanup Site	Completed - Case Closed	6/19/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100801	PRIVATE RESIDENCE	LUST Cleanup Site	Completed - Case Closed	3/27/1995	Heating Oil / Fuel Oil	Other Groundwater (uses other than					
T0608100802	NERLI CONSTRUCTION	LUST Cleanup Site	Completed - Case Closed	11/9/2000	Gasoline	Soil					
T0608100806	EMERGENCY GENER DIESEL TANKS	LUST Cleanup Site	Completed - Case Closed	7/22/2009	Diesel	Other Groundwater (uses other than drinking water)					
T0608100807	GOOTNICK PROPERTY	LUST Cleanup Site	Completed - Case Closed	10/27/2011	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	3/20/2003	9.37
T0608100808	UNITED AIRLINES MAINTENANCE OPS CENTER	LUST Cleanup Site	Completed - Case Closed	7/22/2009	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)					
T0608100813	KING YEE PROPERTY	LUST Cleanup Site	Open - Remediation	3/3/1994	Gasoline	Other Groundwater (uses other than drinking water)		EW-15	ACT	4/24/2002	14.55
T0608100821	LIBERTY MARKET	LUST Cleanup Site	Completed - Case Closed	6/11/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100822	MOBIL, FORMER	LUST Cleanup Site	Completed - Case Closed	9/22/1997	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100824	TRICOR	LUST Cleanup Site	Completed - Case Closed	9/22/1997	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100828	DIADOTI CONSTRUCTION	LUST Cleanup Site	Completed - Case Closed	11/10/1998	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100829	NICOLET PROPERTY	LUST Cleanup Site	Completed - Case Closed	9/20/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100831	THE SERVICE ZONE	LUST Cleanup Site	Completed - Case Closed	4/24/2006	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				

T0608100835	FOLGER COFFEE CO	LUST Cleanup Site	Completed - Case Closed	10/12/1994	Diesel	Other Groundwater (uses other than drinking water)					
T0608100836	MIDAS MUFFLER	LUST Cleanup Site	Completed - Case Closed	5/13/1998		Other Groundwater (uses other than drinking water)					
T0608100837	PEKING HANDICRAFT	LUST Cleanup Site	Completed - Case Closed	8/18/1998	Gasoline	Other Groundwater (uses other than					
T0608100841	AGUNDIS TIRE SHOP	LUST Cleanup Site	Completed - Case Closed	11/28/2000	Waste Oil / Motor / Hydraulic / Lubricating	Soil					
T0608100842	JERAIR SHELL (FORMER)	LUST Cleanup Site	Open - Site Assessment	10/1/1995	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	3/31/2003	6.75
T0608100845	HOBART CORP	LUST Cleanup Site	Completed - Case Closed	12/6/1996		Other Groundwater (uses other than					
T0608100855	PENINSULA TRANSMISSION	LUST Cleanup Site	Completed - Case Closed	10/15/1997	Diesel	Aquifer used for drinking water supply	Inside 2000ft Protection Zone				
T0608100856	FEDERAL EXPRESS	LUST Cleanup Site	Completed - Case Closed	12/1/2004	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100863	BELL ELECTRICAL SUPPLY	LUST Cleanup Site	Completed - Case Closed	7/31/1995	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100864	CHEVRON 9-7875	LUST Cleanup Site	Completed - Case Closed	12/11/2002	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	7/10/2002	1.18
T0608100865	SO. SAN FRANCISCO TIRE SERVICE	LUST Cleanup Site	Completed - Case Closed	8/21/2003	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100868	UNOCAL #6329	LUST Cleanup Site	Completed - Case Closed	2/22/1996	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100872	ROBINSONS CARPET	LUST Cleanup Site	Completed - Case Closed	8/1/2005	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-2	ACT	12/10/2004	9.92
T0608100873	AVIS RENT A CAR SYSTEM	LUST Cleanup Site	Completed - Case Closed	8/5/2003	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)					
T0608100884	PELLEGRINI BROS WINES INC	LUST Cleanup Site	Open - Remediation	2/10/2004	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	9/13/2002	10.27
T0608100889	UNOCAL STATION #0109	LUST Cleanup Site	Open - Site Assessment	2/21/2000	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	3/5/2002	10.43
T0608100890	MELODY TOYOTA	LUST Cleanup Site	Open - Site Assessment	2/2/2005	Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone	MW-3	ACT	6/12/2003	11.7
T0608100893	SILVER TERRACE NURSERY II	LUST Cleanup Site	Completed - Case Closed	4/29/1996	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100904	DEVINCENZI METAL PRODUCTS	LUST Cleanup Site	Completed - Case Closed	5/23/2006	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	3/20/2003	4.22
T0608100905	CALEGARI PROPERTY	LUST Cleanup Site	Completed - Case Closed	6/29/2000	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100908	S. F. DEPT. OF PUBLIC WORKS	LUST Cleanup Site	Completed - Case Closed	8/12/2009	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100911	OROWEAT	LUST Cleanup Site	Completed - Case Closed	1/25/2005	Diesel	Other Groundwater (uses other than	Inside 2000ft Protection Zone				
T0608100912	UNOCAL STATION #3816	LUST Cleanup Site	Open - Remediation	7/13/2010	Gasoline	Soil, Soil Vapor	Inside 2000ft Protection Zone				
T0608100916	PRIVATE RESIDENCE	LUST Cleanup Site	Completed - Case Closed	9/17/1996	Heating Oil / Fuel Oil	Soil					
T0608100917	BUDGET RENT A CAR	LUST Cleanup Site	Completed - Case Closed	9/13/2002							
T0608100936	MARTINELLI PROPERTY	LUST Cleanup Site	Completed - Case Closed	5/17/2000	Gasoline	Other Groundwater (uses other than					
T0608100938	PRIVATE RESIDENCE	LUST Cleanup Site	Completed - Case Closed	4/1/1997		Soil					
T0608100945	DONS AUTO WRECKERS	LUST Cleanup Site	Completed - Case Closed	1/22/1997	Gasoline	Under Investigation					
T0608100946	KING COLE HOMES	LUST Cleanup Site	Completed - Case Closed	4/1/1997	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100949	HAMDI PROPERTY	LUST Cleanup Site	Completed - Case Closed	1/7/2005	Gasoline	Other Groundwater (uses other than drinking water)					
T0608100953	KIRKBRIDE PROPERTY	LUST Cleanup Site	Completed - Case Closed	12/9/1997	Diesel	Other Groundwater (uses other than drinking water)					
T0608100954	AUTOPRIDE CAR WASH	LUST Cleanup Site	Completed - Case Closed	6/30/2011	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	3/18/2002	4.9
T0608100963	CHEVRON 9-1035	LUST Cleanup Site	Completed - Case Closed	5/17/2011	Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone	MW-1	ACT	9/10/2002	8.86
T0608100965	PRICE DEALERSHIP	LUST Cleanup Site	Completed - Case Closed	6/11/2001	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100966	BEST WESTERN EL RANCHO INN	LUST Cleanup Site	Completed - Case Closed	2/29/2000	Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone				
T0608100969	PIMENTEL PROPERTY	LUST Cleanup Site	Open - Verification Monitoring	11/6/2009	Benzene, Toluene, Xylene, Fuel Oxygenates,	Soil	Inside 2000ft Protection Zone				
T0608100970	HOLY CROSS CEMETERY	LUST Cleanup Site	Completed - Case Closed	1/8/1998	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608100990	VINCE'S SHELLFISH	LUST Cleanup Site	Completed - Case Closed	1/1/2002	Diesel	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608100992	GOLDEN GATE DRYWALL	LUST Cleanup Site	Completed - Case Closed	10/4/2002	Gasoline	Other Groundwater (uses other than					
T0608100994	CAPUCHINO HIGH SCHOOL	LUST Cleanup Site	Completed - Case Closed	7/13/2000	Diesel	Soil					
T0608101008	FIRE STATION #1	LUST Cleanup Site	Completed - Case Closed	6/27/2001	Diesel	Other Groundwater (uses other than drinking water)					

T0608101013	GROSVENOR AIRPORT INN	LUST Cleanup Site	Completed - Case Closed	6/26/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608101015	PRIVATE RESIDENCE	LUST Cleanup Site	Completed - Case Closed	9/1/2000	Diesel	Other Groundwater (uses other than					
T0608101018	F ST LIFT STATION	LUST Cleanup Site	Completed - Case Closed	1/6/2000	Diesel	Soil	Inside 2000ft Protection Zone				
T0608101023	CTC FOOD INTERNATIONAL	LUST Cleanup Site	Completed - Case Closed	8/10/2000	Gasoline	Other Groundwater (uses other than drinking water)					
T0608101028	MILLBRAE SCHOOL WAREHOUSE	LUST Cleanup Site	Completed - Case Closed	6/1/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608101044	ARATA PROPERTY	LUST Cleanup Site	Completed - Case Closed	12/27/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608101045	PACIFIC BELL	LUST Cleanup Site	Completed - Case Closed	1/9/1991		Other Groundwater (uses other than					
T0608101051	CRESTMOOR HIGH SCHOOL	LUST Cleanup Site	Completed - Case Closed	1/9/1998	Diesel	Soil					
T0608101056	A-1 TRANSFER CO	LUST Cleanup Site	Completed - Case Closed	5/1/1991		Soil	Inside 2000ft Protection Zone				
T0608101058	PRIVATE RESIDENCE	LUST Cleanup Site	Completed - Case Closed	10/10/1991		Soil					
T0608101063	MOOSEHEAD INC	LUST Cleanup Site	Completed - Case Closed	10/30/1998	Gasoline	Soil					
T0608101069	LEXUS OF SERRAMONTE	LUST Cleanup Site	Completed - Case Closed	10/12/1994	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608101074	GOLDEN GATE NATIONAL CEMETERY	LUST Cleanup Site	Completed - Case Closed	4/12/2005	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608101083	AMERICAN AIRLINES FACILITY	LUST Cleanup Site	Completed - Case Closed	7/22/2009	Diesel	Other Groundwater (uses other than drinking water)					
T0608101086	CHEVRON (CORPORATE HANGAR)	LUST Cleanup Site	Completed - Case Closed	7/22/2009	Gasoline	Other Groundwater (uses other than drinking water)					
T0608101088	SHELL OIL	LUST Cleanup Site	Completed - Case Closed	9/19/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608101089	MILLBRAE CORP YARD	LUST Cleanup Site	Completed - Case Closed	4/28/1997	Gasoline	Other Groundwater (uses other than drinking water)					
T0608101090	CIRCLE K #5638 (TOSCO)	LUST Cleanup Site	Open - Site Assessment	9/9/1999	Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone	MW-1S	ACT	3/20/2002	15.21
T0608101091	MILLS HIGH SCHOOL	LUST Cleanup Site	Completed - Case Closed	1/12/1998	Diesel	Soil					
T0608101096	SFIA - NORTH TERMINAL AREA	LUST Cleanup Site	Completed - Case Closed	7/6/2009	Aviation	Other Groundwater (uses other than					
T0608101102	UNITED AIRLINES MOC	LUST Cleanup Site	Completed - Case Closed	7/22/2009	Diesel	Under Investigation					
T0608101103	SFIA - FAA - Runway 28 Right San Francisco International Airport	LUST Cleanup Site	Completed - Case Closed	7/6/2009	Aviation	Other Groundwater (uses other than drinking water), Soil					
T0608101111	SPRINT	LUST Cleanup Site	Completed - Case Closed	10/4/2000	Gasoline	Other Groundwater (uses other than drinking water)					
T0608101120	AL'S OLYMPIC	LUST Cleanup Site	Open - Verification Monitoring	4/7/2011	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	7/5/2005	47.19
T0608101122	MERCEDES BENZ	LUST Cleanup Site	Completed - Case Closed	6/27/2000		Other Groundwater (uses other than drinking water)					
T0608102301	CALTRANS MAINTENANCE STATION	LUST Cleanup Site	Open - Site Assessment	7/9/2008	Diesel	Other Groundwater (uses other than					
T0608105263	PRESSURE GROUT COMPANY	LUST Cleanup Site	Completed - Case Closed	6/4/1996	Waste Oil / Motor / Hydraulic / Lubricating	Soil					
T0608105470	ALAMO RENT A CAR, FORMER	LUST Cleanup Site	Completed - Case Closed	5/19/2000		Other Groundwater (uses other than					
T0608105654	STEEG PROPERTY	Cleanup Program Site	Completed - Case Closed	10/5/2001		Soil	Inside 2000ft Protection Zone				
T0608106256	OLYMPIAN SSF TERMINAL	LUST Cleanup Site	Open - Assessment & Interim Remedial Action	8/15/2006	Gasoline	Other Groundwater (uses other than drinking water)		MW-5	ACT	11/3/2006	7.59
T0608106763	CONTRERAS PAINTING	Cleanup Program Site	Completed - Case Closed	6/23/2011	Stoddard Solvent / Mineral Spirits / Distillates	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-3	ACT	3/29/2007	11.06
T0608108772	REAL ESTATE NORTH INVESTMENT PARTNERSHIP LP	LUST Cleanup Site	Completed - Case Closed	1/12/2012	Gasoline	Other Groundwater (uses other than		MW-1	ACT	10/9/2009	8.12
T0608110422	LOPEZ PROPERTY	Cleanup Program Site	Completed - Case Closed	1/17/2003	Lead	Soil					
T0608110689	D&M TOWING	LUST Cleanup Site	Completed - Case Closed	11/30/2001		Other Groundwater (uses other than drinking water)					
T0608111410	WINSTON TIRE #100	LUST Cleanup Site	Completed - Case Closed	5/26/2010	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	11/14/2008	16.09
T0608116637	STELLING PROPERTY	Cleanup Program Site	Open - Remediation	6/10/2005	* Solvents	Other Groundwater (uses other than drinking water)		MW-1	ACT	10/24/2005	13.5
T0608117321	AMPHLETT PRINTING	Cleanup Program Site	Completed - Case Closed	3/9/2005		Other Groundwater (uses other than drinking water)					
T0608117395	SHELL	LUST Cleanup Site	Completed - Case Closed	1/26/1995	Gasoline	Other Groundwater (uses other than					
T0608118237	BAUTISTA PROPERTY	LUST Cleanup Site	Completed - Case Closed	8/31/2000		Soil					
T0608119056	AGBAYANI CONSTRUCTION CORP	LUST Cleanup Site	Completed - Case Closed	2/25/2011	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	6/3/2005	18.97
T0608121993	ROB BAKER'S OLYMPIC	LUST Cleanup Site	Open - Site Assessment	2/9/2000	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	12/2/2003	17.53

T0608122176	THE CROSSING	LUST Cleanup Site	Completed - Case Closed	2/25/2004	Heating Oil / Fuel Oil	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608125206	AVIS RENT A CAR SYSTEM	LUST Cleanup Site	Completed - Case Closed	7/8/2010	Gasoline	Other Groundwater (uses other than drinking water)		MW-1R	ACT	8/19/2003	6.04
T0608126439	OLYMPIAN PRODUCE MKT CARD LOCK	LUST Cleanup Site	Open - Remediation	10/16/2003	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	7/19/2002	2.55
T0608128052	KB SOUTH SAN FRANCISCO	LUST Cleanup Site	Completed - Case Closed	3/11/2010	Diesel	Other Groundwater (uses other than drinking water)		MW-1	ACT	10/22/2008	9.5
T0608131587	ROLLINGWOOD AUTO SERVICE	LUST Cleanup Site	Open - Site Assessment	2/27/2002	Gasoline	Other Groundwater (uses other than		MW-1SP	ACT	12/16/2004	26.78
T0608138236	COLMA BART STATION APARTMENTS	Cleanup Program Site	Completed - Case Closed	4/8/2003	Lead	Soil	Inside 2000ft Protection Zone				
T0608138359	SOFOS PROPERTY	LUST Cleanup Site	Completed - Case Closed	6/23/2010	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than drinking water)					
T0608139599	AVIS RENT A CAR (TEMP FAC)	LUST Cleanup Site	Completed - Case Closed	9/25/2000	Gasoline	Other Groundwater (uses other than drinking water)					
T0608140024	CALIFORNIA GOLF CLUB OF SAN FRANCISCO	LUST Cleanup Site	Completed - Case Closed	8/17/2006	Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone				
T0608141952	WELCH PROPERTY	LUST Cleanup Site	Completed - Case Closed	2/11/2003	Diesel	Soil	Inside 2000ft Protection Zone				
T0608144136	CITY OF BURLINGAME	LUST Cleanup Site	Completed - Case Closed	7/30/2004	Gasoline	Other Groundwater (uses other than drinking water)					
T0608145778	SCHULZE MANUFACTURING	Cleanup Program Site	Completed - Case Closed	12/5/2003	* Solvents	Other Groundwater (uses other than drinking water)					
T0608147901	JIFFY CLEANERS	Cleanup Program Site	Open - Site Assessment	4/1/2001	* Solvents	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-2	ACT	3/25/2005	7.43
T0608148945	BINKS MANUFACTURING CO	Cleanup Program Site	Completed - Case Closed	12/16/1997		Other Groundwater (uses other than drinking water)					
T0608149730	OLYMPIAN GATEWAY	LUST Cleanup Site	Completed - Case Closed	2/26/2004	Diesel	Other Groundwater (uses other than drinking water)					
T0608150511	COSTCO	LUST Cleanup Site	Completed - Case Closed	8/8/2001	Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone				
T0608150735	SSF BART PROPERTY (FORMER COSTCO)	Cleanup Program Site	Completed - Case Closed	12/29/2003	Gasoline	Soil	Inside 2000ft Protection Zone				
T0608151141	GEMIGNANI NURSERY	Cleanup Program Site	Completed - Case Closed	6/25/1996		Soil					
T0608151779	TROYER AUTOMATIC DOORS, INC	LUST Cleanup Site	Open - Site Assessment	4/10/2008	Stoddard Solvent / Mineral Spirits / Distillates	Other Groundwater (uses other than drinking water)		MW-1S	ACT	6/29/2009	4.27
T0608151808	ACUTEC AUTOS	LUST Cleanup Site	Completed - Case Closed	5/13/2003	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608152226	BRESSIE & CO.	LUST Cleanup Site	Open - Site Assessment	7/25/2007	Diesel	Other Groundwater (uses other than		MW-12	ACT	3/22/2011	6.39
T0608152524	DELANO NURSERY II	Cleanup Program Site	Completed - Case Closed	6/25/1996	Polychlorinated biphenyls (PCBs)	Soil					
T0608153743	SHELL SERVICE STATION	LUST Cleanup Site	Completed - Case Closed	8/29/2006	Gasoline	Other Groundwater (uses other than		MW-1	ACT	6/14/2005	4.58
T0608153758	STANDARD BRANDS	Cleanup Program Site	Completed - Case Closed	12/31/1996		Soil	Inside 2000ft Protection Zone				
T0608158624	SSF WATER TREATMENT	Cleanup Program Site	Completed - Case Closed	12/2/1999		Other Groundwater (uses other than	Inside 2000ft Protection Zone				
T0608161472	PIERCE TRUCKING	LUST Cleanup Site	Completed - Case Closed	1/14/2000	Gasoline	Soil					
T0608164207	Texaco Service Station 35-2469, Former	LUST Cleanup Site	Open - Site Assessment	5/1/2008	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	2/5/2010	7.89
T0608164698	ARCO #0508	LUST Cleanup Site	Open - Site Assessment	5/29/2001	Benzene, Toluene, Xylene, Fuel Oxygenates, Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	6/28/2002	4.68
T0608165213	AUTO SERVICE PROPERTY	LUST Cleanup Site	Completed - Case Closed	10/5/1998		Other Groundwater (uses other than drinking water)					
T0608165551	BARBER-GREENE CO.	LUST Cleanup Site	Completed - Case Closed	9/27/2001	Gasoline	Other Groundwater (uses other than					
T0608171378	SILVER TERRACE NURSERY	Cleanup Program Site	Completed - Case Closed	6/6/1996		Soil	Inside 2000ft Protection Zone				
T0608174310	BAYHILL OFFICE CENTER	LUST Cleanup Site	Completed - Case Closed	6/12/1997	Waste Oil / Motor / Hydraulic / Lubricating	Soil	Inside 2000ft Protection Zone				
T0608174722	BRIDGESTONE/FIRESTONE	LUST Cleanup Site	Completed - Case Closed	2/14/2002	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608175368	REST PARKING GARAGE	Cleanup Program Site	Completed - Case Closed	8/8/2011	* Solvents	Other Groundwater (uses other than drinking water)		8245-MW1	ACT	3/10/2005	7.6
T0608175400	SHELL SERVICE STATION	LUST Cleanup Site	Completed - Case Closed	11/10/2009	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone				
T0608175868	WRIGHT CLEANERS	Cleanup Program Site	Open - Site Assessment	3/4/2004	Tetrachloroethylene (PCE), *	Other Groundwater (uses other than		MW-1	ACT	3/6/2006	10.79
T0608178422	MCLELLAN NURSERY	LUST Cleanup Site	Completed - Case Closed	5/11/2000		Soil					
T0608179229	NATIONAL CAR RENTAL	LUST Cleanup Site	Completed - Case Closed	9/9/2002	Diesel	Other Groundwater (uses other than drinking water)					
T0608179893	THRIFTY RENT-A-CAR	LUST Cleanup Site	Completed - Case Closed	4/8/2009	Gasoline	Other Groundwater (uses other than					
T0608179897	CHEVRON 9-5584, FORMER	LUST Cleanup Site	Open - Remediation	2/1/2005	Gasoline	Aquifer used for drinking water supply	Inside 2000ft Protection Zone	MW-1	ACT	12/29/2003	33.71
T0608182194	SHELL STATION	LUST Cleanup Site	Open - Remediation	3/15/2010	Benzene, Fuel Oxygenates, Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone	MW-1	DRY	5/29/2003	

T0608182660	SAN MATEO HOUSING AUTHORITY	LUST Cleanup Site	Completed - Case Closed	4/5/2000		Soil	Inside 2000ft Protection Zone				
T0608184609	OLIVET MEMORIAL PARK	LUST Cleanup Site	Completed - Case Closed	5/27/2011	Gasoline	Aquifer used for drinking water supply, Soil		MW-3	ACT	1/5/2007	24.15
T0608185252	OTTOBONI PROPERTY	Cleanup Program Site	Completed - Case Closed	8/24/2004		Soil	Inside 2000ft Protection Zone				
T0608186803	BERENSTEIN ASSOC. PROPERTY	Cleanup Program Site	Open - Site Assessment	10/19/2005	Tetrachloroethylene (PCE)	Other Groundwater (uses other than drinking water), Soil		MW-5	ACT	4/6/2009	11.62
T0608189277	DOLLAR RENT-A-CAR	LUST Cleanup Site	Completed - Case Closed	12/20/2002	Gasoline	Other Groundwater (uses other than					
T0608189622	LES VOGEL	LUST Cleanup Site	Completed - Case Closed	4/28/2000	Waste Oil / Motor / Hydraulic / Lubricating	Soil					
T0608190888	ALFRED MOLAKDIS PROPERTIES	Cleanup Program Site	Completed - Case Closed	12/31/1993		Soil					
T0608191137	STELLING PROPERTY	LUST Cleanup Site	Open - Verification Monitoring	9/20/2011	Gasoline	Other Groundwater (uses other than drinking water)		MW-6	ACT	6/13/2002	13.13
T0608191183	WEST ORANGE LIBRARY	LUST Cleanup Site	Completed - Case Closed	8/9/2001	Diesel	Other Groundwater (uses other than	Inside 2000ft Protection Zone				
T0608191578	SUN CHEMICAL	Cleanup Program Site	Completed - Case Closed	1/1/1990	Waste Oil / Motor / Hydraulic / Lubricating	Soil					
T0608191581	TEEVAN EXTERIOR CONTRACTORS	Cleanup Program Site	Open - Inactive	6/4/2009		Other Groundwater (uses other than					
T0608191585	DELUXE PACKAGES	Cleanup Program Site	Open - Inactive	6/4/2009	Alcohols	Soil					
T0608191588	INTERNATIONAL PAINT COURTALD COATINGS	Cleanup Program Site	Open - Inactive	6/4/2009	* Solvents	Other Groundwater (uses other than drinking water)					
T0608191592	COYNE CYLINDER COMPANY	Cleanup Program Site	Open - Inactive	6/4/2009	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-2	ACT	7/25/2003	7.19
T0608191596	SFIA - SIGNATURE FLIGHT	Cleanup Program Site	Open - Inactive	5/13/2009	* Solvents	Other Groundwater (uses other than drinking water)					
T0608191597	UAL HYDRANT LEAK SHELL CHEVRON	Cleanup Program Site	Open - Inactive	5/13/2009	* Solvents	Other Groundwater (uses other than					
T0608191598	FUEL HYDRANT SYSTEM UNITED PARKING LOT	Cleanup Program Site	Open - Inactive	5/13/2009	Kerosene	Soil					
T0608191600	SFIA - GHILOTTI BROS SPILL	Cleanup Program Site	Completed - Case Closed	1/1/1999	Kerosene	Soil					
T0608191601	MILLBRAE AVE GATE	Cleanup Program Site	Open - Inactive	5/13/2009	Diesel	Soil					
T0608191820	SAN BRUNO FIRE	LUST Cleanup Site	Completed - Case Closed	9/28/2011	Gasoline	Other Groundwater (uses other than drinking water)		MW-1	ACT	9/27/2002	6.89
T0608191865	BAY CITIES BUILDING MATERIALS	LUST Cleanup Site	Completed - Case Closed	8/27/2001	Diesel	Other Groundwater (uses other than drinking water)					
T0608192381	ANZA PARK & FLY	LUST Cleanup Site	Completed - Case Closed	3/17/2000	Diesel	Other Groundwater (uses other than drinking water)					
T0608192685	SAN BRUNO CAR WASH	LUST Cleanup Site	Completed - Case Closed	7/1/2010	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	9/19/2005	7.18
T0608192695	BACON PROPERTY	LUST Cleanup Site	Completed - Case Closed	3/14/2007	Gasoline	Other Groundwater (uses other than drinking water)					
T0608192696	A-1 BODY SHOP	LUST Cleanup Site	Open - Site Assessment	8/14/2000	Gasoline	Other Groundwater (uses other than	Inside 2000ft Protection Zone	MW-1	ACT	9/13/2002	23.13
T0608192697	DALY CITY FIRE DEPT	LUST Cleanup Site	Completed - Case Closed	9/25/2000		Soil					
T0608192721	FRIMER REALTY/APTMNT COMPLEX	LUST Cleanup Site	Completed - Case Closed	8/11/2000	Diesel	Other Groundwater (uses other than drinking water)					
T0608192783	MILLS PENINSULA MEDICAL CENTER	LUST Cleanup Site	Completed - Case Closed	9/7/2000	Diesel	Other Groundwater (uses other than drinking water)					
T0608193859	TOSCO #3857	LUST Cleanup Site	Open - Site Assessment	8/1/2003	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-9	ACT	3/29/2007	7.25
T0608194008	BLANDINI TRUST	LUST Cleanup Site	Completed - Case Closed	9/28/2001	Gasoline	Other Groundwater (uses other than drinking water)					
T0608194016	L.BOCCI & SONS INC	LUST Cleanup Site	Open - Site Assessment	4/14/2004	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	2/14/2003	21.8
T0608194021	TIMPAC	LUST Cleanup Site	Open - Verification Monitoring	3/25/2006	Gasoline	Other Groundwater (uses other than		MW-3	ACT	6/20/2002	1.57
T0608194029	U-SAVE PLUMBING HARDWARE	LUST Cleanup Site	Completed - Case Closed	2/21/2003	Gasoline	Aquifer used for drinking water supply					
T0608194030	CHEVRON, FORMER/EAGLE GAS STA	LUST Cleanup Site	Completed - Case Closed	5/17/2006	Gasoline	Other Groundwater (uses other than		C-5	ACT	1/13/2002	11.24
T0608194884	PRIVATE RESIDENCE	LUST Cleanup Site	Completed - Case Closed	3/14/1994		Soil					
T0608195324	BRITANNIA DEVELOPMENTS	Cleanup Program Site	Open - Verification Monitoring	6/7/2004	Lead	Other Groundwater (uses other than drinking water)					
T0608196820	PATEL PROPERTY	LUST Cleanup Site	Completed - Case Closed	3/27/2002		Other Groundwater (uses other than drinking water)					
T0608198948	OLYMPIAN JUNIPERO SERRA	LUST Cleanup Site	Open - Site Assessment	7/27/2004	Gasoline	Other Groundwater (uses other than drinking water)	Inside 2000ft Protection Zone	MW-1	ACT	2/11/2004	12.83
T0608199177	PENSKE TRUCK LEASING II	LUST Cleanup Site	Completed - Case Closed	1/17/2003	Gasoline	Other Groundwater (uses other than drinking water)					
T0608199761	MARY RUANE PROPERTY	LUST Cleanup Site	Completed - Case Closed	6/21/2002	Gasoline	Other Groundwater (uses other than drinking water)					
T10000000282	BRESSIE & CO.	Cleanup Program Site	Completed - Case Closed	3/15/2011	* Solvents	Other Groundwater (uses other than		MW-12	ACT	7/6/2010	7.25

T10000000968	Chevron AST Facility (Former)	Cleanup Program Site	Completed - Case Closed	2/16/2010	Lead, Diesel	Soil					
T10000001104	ARE San Francisco No. 12	Cleanup Program Site	Open - Assessment & Interim	5/7/2009	Heating Oil / Fuel Oil	Other Groundwater (uses other than					
T10000001468	Mills Park Cleaners	Cleanup Program Site	Open - Site Assessment	8/4/2009	Tetrachloroethylene (PCE)						
T10000001754	SFIA - SAN FRANCISCO AIRPORT BOARDING AREA B (eastern portion, TWA site)	Cleanup Program Site	Completed - Case Closed	7/6/2011	Aviation	Indoor Air, Other Groundwater (uses other than drinking water), Soil					
T10000002006	B and B Transmission	LUST Cleanup Site	Open - Site Assessment	5/6/2010	Diesel, Gasoline	Other Groundwater (uses other than					
T10000002008	Colson Residence	LUST Cleanup Site	Open - Site Assessment	5/6/2010	Diesel, Heating Oil / Fuel Oil	Soil, Surface water					
T10000002366	Parcels Northwest of Orange Park	Cleanup Program Site	Open - Site Assessment	8/11/2010	Chlordane, Endrin, Other Insecticides / Pesticides / Fumigants / Herbicides	Soil	Inside 2000ft Protection Zone				
T10000002568	San Francisco Water Department	Cleanup Program Site	Open - Assessment & Interim Remedial Action	9/29/2010	Diesel	Soil, Under Investigation	Inside 2000ft Protection Zone				
T10000002674	Agbayani Construction	Cleanup Program Site	Open - Assessment & Interim Remedial Action	12/6/2010	Tetrachloroethylene (PCE), Trichloroethylene (TCE), Vinyl chloride	Aquifer used for drinking water supply, Indoor Air, Other Groundwater (uses other	Inside 2000ft Protection Zone	MW-1	ACT	8/31/2011	22
T10000002807	California Water Service Company, Reservoir #1	Cleanup Program Site	Open - Assessment & Interim Remedial Action	2/8/2011	Mercury (elemental)	Soil, Under Investigation					
T10000002827	SFIA - SAN FRANCISCO AIRPORT BOARDING AREA B (western portion)	Cleanup Program Site	Open - Remediation	6/21/1999	Aviation	Other Groundwater (uses other than drinking water), Soil					
T10000002842	Unocal #1020	LUST Cleanup Site	Open - Site Assessment	2/17/2011	Waste Oil / Motor / Hydraulic / Lubricating	Other Groundwater (uses other than		MW-1	ACT	1/17/2011	2.82
T10000002843	39-49 El Camino Real	Cleanup Program Site	Open - Site Assessment	2/4/2011	Tetrachloroethylene (PCE)	Under Investigation					
T10000002916	City of Millbrae Corporation Yard	Cleanup Program Site	Open - Assessment & Interim Remedial Action	3/17/2011	Diesel	Other Groundwater (uses other than drinking water), Soil					
T10000003031	Gas & Wash Partners	LUST Cleanup Site	Open - Site Assessment	5/20/2011	Benzene, Toluene, Xylene, Gasoline	Aquifer used for drinking water supply, Soil, Soil Vapor, Under Investigation	Inside 2000ft Protection Zone				
T10000003038	Real Estate North Investment Partnership LP	Cleanup Program Site	Open - Site Assessment	5/26/2011	Tetrachloroethylene (PCE), Trichloroethylene (TCE), Vinyl chloride	Other Groundwater (uses other than drinking water), Soil, Soil Vapor					
T10000003068	Bishop Property	LUST Cleanup Site	Open - Assessment & Interim Remedial Action	6/23/2011	Diesel, Gasoline	Other Groundwater (uses other than drinking water), Soil	Inside 2000ft Protection Zone				
T10000003112	Grand Avenue Gas	LUST Cleanup Site	Open - Assessment & Interim Remedial Action	7/5/2011	Gasoline	Soil, Under Investigation	Inside 2000ft Protection Zone				
T10000003211	Sterling Cleaners (Former)	LUST Cleanup Site	Open - Site Assessment	8/11/2011	Stoddard Solvent / Mineral Spirits / Distillates	Other Groundwater (uses other than					
T10000003461	One Hour Dry Cleaning	Cleanup Program Site	Open - Site Assessment	10/19/2011	Tetrachloroethylene (PCE), Trichloroethylene (TCE)		Inside 2000ft Protection Zone				
T10000003495	Golden Gate Petroleum	LUST Cleanup Site	Open - Assessment & Interim	1/19/2012	Diesel	Other Groundwater (uses other than					
T10000003522	SFIA - San Francisco Airport Taxiway F Spill Cleanup	Cleanup Program Site	Completed - Case Closed	8/9/2011	Aviation	Soil					

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TECHNICAL MEMORANDUM 10-7 (Rev., Final)

To: Mr. Greg Bartow
San Francisco Public Utilities Commission

From: Peter Leffler, C.Hg.

Subject: **SFPUC Regional Groundwater Storage and Recovery Project; South Westside Basin Third Party Well Survey and Well Interference Analysis**

INTRODUCTION

This Technical Memorandum (TM) was prepared to document work performed by Fugro as part of contract CS-879A with Kenned/Jenks Consultants (Kennedy/Jenks) for the San Francisco Public Utilities Commission (SFPUC) pursuant to the amended Task Order authorizations CUW30103-TO-1.12 of the Regional Groundwater Storage and Recover (GSR) Project. This project is funded by the SFPUC's Water System Improvement Program (WSIP).

The San Francisco Public Utilities Commission is conducting environmental review for the proposed Regional Groundwater Storage and Recovery (GSR) Project in the South Westside Groundwater Basin in northern San Mateo County. The proposed GSR Project involves a partnership between SFPUC and the City of Daly City, California Water Service Company (Cal Water), and the City of San Bruno. The study area encompasses a portion of San Mateo County located between Millbrae and Daly City. Each of the Partner Agencies (Daly City, Cal Water, and San Bruno) has historically obtained municipal water supplies from a combination of groundwater and SFPUC surface water. In the proposed project, the SFPUC would provide a greater allocation (supplemental supply) of surface water to Partner Agencies (PAs) during average and wet years in order to allow Partner Agencies to reduce groundwater pumping. The project would create in-lieu groundwater recharge, which would be tapped during drought cycles via new wells installed by the SFPUC between Millbrae and Daly City. For reference, put/take/hold periods are defined as follows (see Kennedy/Jenks, 2012, Section 2.1.1 for more details):

- A put period is when the PAs would receive supplemental surface water from the SFPUC "in-lieu" of groundwater pumping. The reduced pumping would effectively increase the volume of groundwater in storage that would be available during dry years or an extended drought.
- A take period is when water shortages are triggered and water is recovered from the SFPUC Storage Account. During take periods, both the proposed GSR Project

wells and the PA wells would extract groundwater. The SFPUC would recover "stored" groundwater by pumping the proposed 16 GSR project wells. In addition, the PAs would return to their typical groundwater pumping.

- A hold period is when there are no water shortages, but the SFPUC Storage Account is "full" and supplemental water deliveries do not occur. During hold periods, the PAs would return to their typical groundwater pumping, and the GSR Project wells would pump only small amounts to exercise the wells.

Purpose of Study

The proposed project would only extract groundwater up to the amount in the SFPUC Storage Account. However, due to the possibility for localized effects, this study is being conducted as part of the effort to evaluate the localized cones of depression around proposed GSR wells that may potentially affect individual existing third-party wells. The other purpose of this Technical Memorandum is to provide the SFPUC with a well inventory (e.g., identification of existing wells, well location) of private third party irrigation wells in the South Westside Groundwater Basin. The well data in this memo were used as input to a third-party well interference (drawdown) analysis conducted by MWH related to proposed new GSR Project wells (labeled as CUP-X) to be installed by the SFPUC for extraction of in-lieu groundwater recharge stored under the GSR Project in the South Westside Groundwater Basin. The MWH well interference results were then superimposed on future regional groundwater levels to estimate how proposed GSR pumping would affect future static water levels of third party wells. MWH previously completed a well interference analysis for municipal wells (MWH, 2008) and was retained by the SFPUC to complete a similar analysis for third party wells as part of this study.

Background

The third-party (i.e., irrigation) groundwater pumpers in the South Westside Groundwater Basin that are the subject of this TM include the Colma cemeteries, California Golf Club, and Lake Merced Golf Club (Figures 1 and 2). In addition, this study provides GSR-related well interference calculations for the Olympic Golf Club and San Francisco Golf Club located near or within San Francisco City/County limits. A separate well interference study was conducted previously for Partner Agency municipal wells and included in the Conceptual Engineering Report (MWH, 2008).

The SFPUC invited cemetery and golf course owners/representatives to a Workshop that was held on June 25, 2009 at the Colma Town Hall Council Chamber. A presentation was given by SFPUC regarding plans for the proposed GSR Project. Attendees were informed that the SFPUC was conducting a survey of third party well owners as part of a series of studies in the groundwater basin to evaluate potential effects of the proposed project. A data request list pertaining to the well survey was made available to all attendees. As a follow-up, individual meetings were held with all known large irrigation well owners.

It is our understanding that some private homeowner irrigation wells exist in Hillsborough (HydroFocus 2007, 2011), however the GSR Project is not expected to affect these wells due to their distance from proposed GSR wells (about two miles south of CUP-M-1). The Green Hills Golf Club operates irrigation wells in Millbrae that are located about 0.75 miles from the nearest proposed GSR well (CUP-M-1) and greater than two miles from the next closest GSR well. In general, MWH determined that well interference effects on wells greater than 1.5 miles from a proposed GSR well would be negligible (Appendix B). Review of well logs for Green Hills Golf Club indicate that aquifer (sand) layers are within the depth interval from 120 to 260 feet below ground surface. The depth to water from 140 to 170 feet at these wells indicates unconfined aquifer conditions. Well CUP-M-1 has sand layers from 190 to 410 feet below ground surface with a depth to water of 160 feet. Theis calculations using an unconfined storage coefficient (0.05) and transmissivity value of 8,000 gpd/ft (derived from CUP-M-1 pumping test) show mutual interference drawdown of less than 5 feet after 7.5 years of continuous pumping. Given the distances from GSR wells and the small proposed pumping capacity of CUP-M-1 (about 150 gpm), the offsetting benefits of the GSR Put cycles, and differences in screen intervals and geologic conditions, mutual interference drawdown effects from GSR wells on Green Hills Golf Club wells are expected to be negligible.

Mr. Don Curry of CSW/Stuber-Strough was retained to facilitate contacting third party cemetery well owners due to his history of working with the cemeteries on their wells and water distribution facilities. Site visits were conducted with the California Golf Club and all Colma cemeteries that use groundwater for irrigation. The site visits included requests for well information, and measurement of water levels if an access port was available. Cypress Lawn did not provide a field visit to their irrigation wells nor provide any information regarding their wells. The SFPUC conducted site visits with the Olympic and San Francisco golf clubs. Multiple meetings were conducted with Lake Merced Golf Club, but they did not provide a field visit to their wells. Pump Repair Service (which services pumps in many of the third party wells) was also contacted to request data for various third party wells they service for owners that gave their approval for release of the information.

Previous Studies

Department of Water Resources (DWR) driller's logs and existing hydrogeologic reports and additional information obtained from the SFPUC were reviewed for purposes of undertaking the analysis in this Technical Memorandum. The Recycled Water Feasibility Study (Carollo, 2008) includes information that was used to help identify existing owners of wells that pump groundwater for irrigation purposes.

DATA COLLECTION

Site Visits

Owners of third party wells were contacted and site visits arranged as follows:

Holy Cross Cemetery - A site visit was conducted on September 11, 2009 and included a meeting with Mr. Roger Appleby (General Manager). Locations were obtained for four existing wells, and groundwater levels were measured in three of the four wells. A new (replacement) well was drilled in 2008, which would serve as the primary well in the future (Holy Cross 4). The current existing primary well (Holy Cross 1) is expected to become a secondary well. Available data from the 1999 to 2001 time period indicated the pumping rate for Holy Cross 1 was approximately 725 to 760 gpm. The existing emergency well (Holy Cross 2) would be maintained as a backup well, and the existing secondary well (Holy Cross 3) is planned for abandonment. The well interference analysis was conducted using Holy Cross 4 as the primary well and Holy Cross 1 as the secondary well.

A brief follow-up site visit was conducted on March 8, 2010 to obtain a groundwater level in the primary well that could not be obtained during the September 2009 site visit, and also to obtain groundwater levels in the other Holy Cross Cemetery wells.

Italian Cemetery - A site visit was conducted on January 22, 2010 and included a meeting with Giuseppe Timpano (Facility Manager). The location and a groundwater level were obtained for one existing primary well (IC-5). This is the only well utilized by the Italian Cemetery and they have no secondary or backup well. Available data from the 1999 to 2001 time period indicated the pumping rate was approximately 260 gpm. Future plans are to continue using this one primary well, and this primary well was used in the well interference analysis.

Woodlawn Cemetery - A site visit was conducted on January 22, 2010 and included a meeting with Margaret Hambrick. Locations were obtained for two existing wells (primary and backup), and a groundwater level was obtained in the primary well. Future plans are to continue using the same two wells. Available information from 2008 indicated that the primary well pumped at approximately 500 gpm. The well interference analysis was conducted using the primary well and backup well.

Eternal Home Cemetery - A site visit was conducted on February 4, 2010 and included a meeting with Lisa Matson (Office Manager). The location and a groundwater level were obtained for one existing primary well (ET-2). This is the only well utilized by the Eternal Home Cemetery and they have no secondary or backup well. Future plans are to continue using this one primary well. The well pumps water to an approximately 10,000 gallon storage tank located uphill from the well. At the time of our site visit, the well was reported to pump at an instantaneous rate of approximately 100 gpm. Available data from the 1999 to 2001 time period indicated the pumping rate ranged from 150 to 200 gpm. The well interference analysis used this one primary well.

Hills of Eternity/Home of Peace/Salem Cemeteries - A site visit was conducted on February 8, 2010 and included a meeting with James Carlson (Executive Director). Locations were obtained for two existing wells (HE-2 at Hills of Eternity and HP-3 at Home of Peace) and one proposed replacement well at Home of Peace Cemetery. Groundwater levels could not be obtained from the two existing wells. Historic operations have utilized the two existing wells to serve the three cemeteries, with the Home of Peace well being the primary well and Hills of Eternity well being the secondary well. Recently the primary (Home of Peace) well went out of service , and the Hills of Eternity well is currently the only well in operation. Available data from the 1999 to 2001 time period for the Hills of Eternity well indicated the pumping rate ranged from 170 to 180 gpm.

The proposed replacement well was drilled in 2010, and additional information on that well was obtained from Don Curry in 2011. Future plans are to use the new replacement well located at Home of Peace as the primary well to serve all three cemeteries (Hills of Eternity/Home of Peace/Salem). The future backup well would be the existing Hills of Eternity well (HE-2). The well interference analysis was based on the new replacement well at Home of Peace as the primary well and the existing Hills of Eternity well as the back-up well.

Cypress Lawn Cemetery - A site visit was conducted on February 4, 2010 and included a meeting with Ken Varner (President and CEO). We were not given a site visit to the wells and were not provided with a map of well locations. Ken said that they operate a primary well that is approximately six years old that pumps into the lake, and have a back-up well known as the South Well. The primary well is used to irrigate approximately 140 acres. They have an additional 32 acres of land on Hillside irrigated with water obtained from Cal-Water. Apparently two wells were damaged and/or lost during the BART construction process, including a well known as the North Well. Due to the lack of well data obtained for this study, well interference calculations for Cypress Lawn were conducted for historic wells known as Cypress 3 and 4. General well locations and construction data necessary to conduct the analysis were obtained from a review of DWR well logs and previous studies. Although specific current well locations could not be obtained, the selected well locations should provide representative well interference drawdowns for potential well locations on Cypress Lawn property.

California Golf Club - A site visit was conducted November 17, 2009 and included a meeting with Rick Kavakoff and Dennis Mahoney (General Manager). Locations were obtained for four existing wells, and groundwater levels were obtained in three of the four wells. Well 8 is considered the primary well (90% of pumping), Well 7 is a secondary well (10% of pumping), and Wells 5 and 6 are backup wells. Well 7 was tested at a rate of 200 gpm at the time of installation (1994), and Well 8 was originally tested at 800 gpm (2001). Future plans are to continue use of the wells as described above. The well interference analysis used Well 8 as the primary well and Well 7 as the secondary well.

Olivet Cemetery - A site visit was conducted on March 8, 2010 and included a meeting with Mario Falla, who is in charge of maintenance at the cemetery. A location was obtained for the one existing primary well. The port was not able to be accessed at the well head to obtain a groundwater level in the well. The well was tested at 480 gpm at the time of installation (1999). The well interference analysis used the one existing well which serves as the sole source of irrigation water supply for the cemetery.

Lake Merced Golf Club (LMGC) – Meetings were conducted March 5, 2010, March 11, 2011, and June 21, 2011 with Donna Lowe (General Manager) and other golf club representatives. LMGC did not provide a site visit to their wells and did not have any information on their wells, although they did provide a map with golf course well locations and indicated that essentially Well 3 is the only active well. Attempts were made to arrange for access to Pump Repair Service files for LMGC wells; however, multiple attempts at doing so were not successful. It is not clear whether or not Pump Repair Service is the most recent provider of pump contracting services, as LMGC indicated in our meetings that multiple pump service providers have been used over the years. The well interference analysis used Well 3 as the primary and only well. The majority of water utilized by LMGC has been recycled water since 2005.

Olympic Golf Club - A site visit and data collection effort for Olympic Golf Club were conducted by SFPUC. Data obtained by SFPUC were compiled and provided in this TM for use in MWH well interference calculations. Olympic Golf Club Well No.1 and Well No. 2 were used in the well interference analysis.

San Francisco Golf Club - A site visit and data collection effort for San Francisco Golf Club were conducted by SFPUC. Data obtained by SFPUC were compiled and provided in this TM for use in MWH well interference calculations. San Francisco Golf Club Well No. 2 was used in the well interference analysis.

Other Data Sources

CSW/Stuber-Strough assisted in making contacts with the cemetery owners and providing historic well data from their files related to their work for certain cemeteries. Some of the historic well data provided by CSW was related to well testing completed as follow-up work to the Colma area BART EIR. In addition, CSW/Stuber-Strough provided recent data regarding two new cemetery well installation projects with which they have been involved - one at Holy Cross and one at Home of Peace.

Pump Repair Service has historically been and continues to be the primary contractor providing pump services for several third party well owners in northern San Mateo County. Permission was obtained from each cemetery and golf course owner (with the exception of Cypress Lawn and Lake Merced Golf Club) to contact Pump Repair Service to ask for available well and pump data. At least some data were obtained from Pump Repair Service for the following cemeteries: Holy Cross, Hills of Eternity, Olivet, Eternal Home, Italian, Woodlawn, and California Golf Club.

Fugro submitted a request to California DWR for copies of well completion reports in the Colma area. The package of well completion reports obtained from DWR includes several reports for wells associated with the cemeteries and golf courses that are the subject of this survey. These reports were reviewed for purposes of undertaking this study for the SFPUC.

Well Inventory

A well inventory spreadsheet was compiled from the data obtained for this study (Table 1). The spreadsheet generally includes information on the following: well name and use, top of well screen, and specific capacity calculations. Well head elevation data were uniformly not available for any of the wells in this survey; thus, reference point elevations were estimated from Google Earth. Despite certain limitations in data availability mentioned above, it is our opinion that the available data are sufficient to allow for an adequate assessment of effects on third party wells from the proposed GSR Project.

General locations for each well identified in the field are plotted in Figures 1 and 2. The Colma cemeteries that pump groundwater extend from Woodlawn Cemetery in the north to Holy

Cross Cemetery in the south (Figure 2). The proposed GSR wells nearest to the Colma cemetery wells include CUP-11A at the northern end, CUP-18, CUP-19, CUP-22A, and CUP-23 at the southern end of the Colma cemeteries. Lake Merced Golf Club is located about 7,000 feet northwest of Woodlawn Cemetery, and the nearest proposed GSR wells are CUP-3A, 5, 6, and 7. Olympic and San Francisco golf clubs are located about 12,000 feet northwest of Woodlawn Cemetery, and about 4,000 to 5,000 feet from the nearest GSR wells (CUP-3A, 5, 6, and 7). California Golf Club wells are located about 6,000 feet southeast of Holy Cross Cemetery, and the nearest proposed GSR wells are CUP-31 and CUP-36-1.

Well screen information was obtained for most wells. CSW/Stuber-Strough provided the well screen information for the newly constructed Home of Peace well. The recently installed wells have top of screen intervals at 420 feet below ground surface (bgs) for the Holy Cross Replacement Well (Primary Well 4), and 400 feet bgs for the Home of Peace (Hills of Eternity and Salem) Replacement Well. These two new wells appear to be screened both above and below the W clay. In terms of the numerical model, these two wells are assumed to have screens in both Model Layer 4 and Model Layer 5. Other active wells such as Hills of Eternity, Olivet, Eternal Home, and Italian cemeteries have top of screens at depths ranging from as shallow as 224 feet bgs to as deep as 308 feet bgs, and all appear to be screened above the W clay in Model Layers 2, 3, and 4. The Holy Cross Secondary Well 1 is screened in from 368 feet bgs, likely contains screens both above and below the W clay, and is assumed to have screens in Model Layers 3, 4, and 5.

The Woodlawn primary well is screened from 275 feet bgs, which appears to encompass and extend slightly below the W clay. The Woodlawn primary well screen intervals are assumed to correspond primarily to Model Layers 2, 3, and 4. Lake Merced Golf Club Well 3 is screened from 294 feet bgs, and may extend into but not below the W clay. The Lake Merced Golf Club Well 3 screen intervals are assumed to correspond primarily to Model Layers 2, 3, and 4. California Golf Club Well 8 is screened from 320 feet bgs in an area of the basin where the W clay is not present. CGC8 well screen intervals correspond to Model Layers 3, 4, and 5.

It was assumed that Cypress Lawn Wells 3 and 4 are sufficient to represent the existing active wells for the cemetery. Cypress Lawn Well 3 is located at a higher surface elevation and screened at various depth intervals from 191 feet bgs (assumed to correspond to Model Layers 2, 3, and 4). Cypress Lawn Well 4 is located at a lower surface elevation and screened from 330 feet bgs (assumed to correspond to Model Layers 3, 4, and 5).

Based upon the well data collected for this study (and making certain assumptions about Cypress Lawn Cemetery and Lake Merced Golf Club wells), the wells tend to fall into two groups: one with relatively shallow elevations for the top of screen and one with deep elevations for the top of screen. Five cemeteries that have wells with tops of screens ranging from -100 feet (NGVD 29) to -166 feet (NGVD 29) include Eternal Home, Italian, Hills of Eternity, Woodlawn, and Olivet. Cypress Lawn Well 3 is assumed to have a top of screen elevation of about -40 feet (NGVD 29). Lake Merced Well 3 is assumed to have a top of screen elevation of -140 feet (NGVD 29). Two cemeteries that installed wells within the last two years having deeper top of screens at -274 and -279 feet (NGVD 29) include Holy Cross and Home of Peace (which also would serve Hills of Eternity and Salem). The assumed representative primary

Cypress Lawn well (No. 4) being used for this study has a somewhat intermediate depth top of screen at about -240 feet (NGVD 29), and California Golf Club Well 8 has top of screen at -259 feet (NGVD 29).

In terms of groundwater level measurements, some historic data are available from the time each well was installed. Other historic groundwater level data for several wells encompass the 1999-2001 time period. In addition, groundwater level measurements were obtained from the wells with accessible sounding ports during the site visits for this study. In general, groundwater levels increased 35 to 36 feet on average between spring 2001 and spring 2010 (Table 2). As discussed further below, this increase in water levels is generally attributed to the In-Lieu Recharge Demonstration Study, which started in 2002 (L&S, 2005).

Specific capacity calculations for this study are summarized in Table 1. Well specific capacities generally range from about 5 to 15 gallons per minute per foot of drawdown. The third party wells are generally operated at pumping rates ranging from about 150 to 800 gpm, with typical drawdowns in the range of 20 to 100 feet.

Data were obtained for several wells with respect to the type of pumps installed, capacity/head ratings, and pump curves. These data are summarized in Table 3. Pump models, pump curves, and capacity/head ratings were obtained for the following wells: Holy Cross 1, Holy Cross 4, Woodlawn, Italian, Eternal Home of Peace, Hills of Eternity, Olivet, and California Golf Club. Similar pump data were also available for Olympic Club and San Francisco Golf Club Wells (LSCE, 2012). As discussed further below, pump data were used to estimate changes in pumping rates under the maximum depth to water conditions during future Take cycles.

GROUNDWATER FLOW MODEL SCENARIO RESULTS

A numerical groundwater flow model for the Westside Groundwater Basin was developed over a period of time from 2000 to 2011 by HydroFocus and Gus Yates, who were retained by Daly City (HydroFocus 2007, 2009, 2011). It has been a collaborative effort sponsored by Daly City with review by the SFPUC, Cal Water, San Bruno and their respective consultants. Groundwater studies being conducted by the SFPUC for the San Francisco Groundwater project and the GSR Project have utilized the calibrated Westside Basin Groundwater Flow Model as one of the tools for evaluating potential project effects. Kennedy/Jenks Consultants have been the lead in applying the existing model to future project scenarios for the groundwater studies with review and input by Luhdorff & Scalmanini and Fugro.

Other studies currently being conducted by SFPUC include application of the groundwater flow model to a future scenario developed for the GSR Project. These model scenarios and results are described in detail in a Technical Memo prepared by Kennedy/Jenks (2012). Although the analyses conducted for this TM primarily are based upon analytical techniques, some applicable groundwater model scenario results are provided herein for comparison. In particular, model scenario 2 for the GSR Project is shown for comparison purposes in some of the graphical plots of analytical results for specific wells.

ANALYTICAL DATA ANALYSIS RESULTS

Colma Cemetery Wells

The analytical data analysis for the Colma area wells included in this study involved the following steps:

1. Based upon review of water level data from 2001 to 2010 for cemetery wells (cemetery well water level data was only available for early 2010 and was assumed to be similar to 2009 levels), it was concluded that an appropriate groundwater level recovery rate for the Colma area is 8.6 feet per 4,300 acre-feet of in-lieu recharge (this represents the amount of in-lieu recharge in the Daly City and Cal Water areas during a future Put Year). The rationale for this conclusion is that the SFPUC storage account calculations provided by SFPUC indicate that it had accumulated 17,987 acre-feet (af) of in-lieu recharge (as of the end of 2009) in Daly City and Cal Water areas since 2002 (Appendix A). It is assumed that the approximately 18,000 af of increased storage correlates with the 36-foot rise in groundwater levels at the cemetery wells between 2001 and 2010. Thus, dividing 18,000 af of Put by a total water level rise of 36 feet equals 500 af of Put per foot of groundwater level rise.
2. Under the proposed project, a year of Put is equal to about 6,180 af for the three Partner Agencies. However, factoring out Put for the San Bruno wells (due to the significant distance from Colma) results in a total in-lieu recharge of about 4,300 acre- feet per year (AFY) during a proposed project Put year in the Daly City and Cal Water areas. Using the above logic, a year of Put at 4,300 af divided by 500 af per foot of water level rise results in a Put year groundwater level rise of 8.6 feet.
3. The proposed GSR well locations were reviewed for proximity to Colma to determine the amount of Take from GSR wells in the Colma region. The only wells excluded from the Take calculation were CUP-41-4, CUP-44-1, CUP-44-2, and CUP-M-1 due their considerable distance from the Colma area (greater than two miles). Assuming a total Take year extraction of 7.23 MGD (8,100 AFY), and subtracting the Take amounts from the four wells listed above results in about 6,460 af of extraction from GSR wells in the Daly City, Colma, and Cal Water areas. Assuming that Take year extraction works in reverse of the recovery of water levels during Put years yields a one foot water level drop per every 500 af removed during a Take year. Dividing 6,460 af by 500 af per 1 foot of groundwater level decline yields 12.9 feet of groundwater level decline during a proposed Take year due to GSR pumping.
4. The background groundwater level decline due to regional groundwater (i.e., Partner Agency and third party wells) pumping was evaluated using both available cemetery well groundwater level data prior to 2002 (and the onset of the In-Lieu Recharge Demonstration Study) and groundwater flow model simulation results. Tabulation of pre-2002 cemetery well groundwater level data is provided in Appendix A. Data available from wells at three cemeteries (Eternal Home, Hills of Eternity, and Holy Cross) indicate groundwater level decline rates ranging from 1 to 2 feet per year between 1960 and 2001. The HydroFocus (May 2011) Historical Simulation (1958-2009) showed an average water level decline of about 1 foot/year, and the

HydroFocus 2008 No Project Scenario showed decline rates of 0.6 to 0.8 feet/year. The Existing Conditions Scenario (Scenario 1) by KJ (2012) showed a background groundwater level decline rate of about 0.75 feet/year in the Colma cemetery area. Based on available field data and model simulations, a background groundwater level decline rate of 0.75 feet/year is considered to be representative of future Hold year Partner Agency and cemetery well pumping effects on Colma area groundwater levels.

5. Combining the values above, we have a Put Year recovery rate of 8.6 feet/year, a Take Year decline rate of 12.9 feet/year, and a Hold Year decline rate of 0.75 feet/year. The Take Year decline rate of 12.9 feet/year is assumed to already include the background (Hold Year) decline rate related to basin pumping because many of the years in the 2001 to 2010 time frame used in the analysis did not have in-lieu recharge.

Using an example cemetery well (Eternal Home), a starting depth to water of 225 feet below ground surface was measured in early February 2010 (assumed representative of 2009 conditions). Based on the amount of in-lieu SFPUC storage account being approximately 20,000 af, another 40,500 af is required to achieve a full SFPUC Storage Account. Thus, it would require 6.5 years of Put at a rate of 6,180 AFY (4,300 AFY in Daly City and Cal Water areas) to achieve 60,500 af of in-lieu storage when starting with 20,000 af of storage. 6.5 years of Put at the proposed rate would increase groundwater levels another 56 feet at the Eternal Home well, resulting in the regional static water level associated with a Full SFPUC Storage Account being 169 feet bgs (the high point on Figure 3 in future scenario year 7).

The proposed Put/Hold/Take year sequence for the GSR scenario (Table 4) was used to develop a plot of future groundwater levels (depth to water and groundwater elevation) for the Eternal Home well (Figures 3 and 4). Both the Existing Conditions (Scenario 1) and the GSR scenario (Scenario 2) include the Design Drought. Using the annual changes in groundwater levels associated with Put, Hold, and Take years described above, Figures 3 and 4 show how regional groundwater levels are estimated to fluctuate at the Eternal Home well over the course of 47 future years based on the assumptions and calculations used in this analysis.

The next step was to add in the local GSR drawdown as calculated by MWH (Appendix B) to regional groundwater level fluctuations shown in Figures 3 and 4. Local well interference drawdowns ranged from 41 feet after one year of Take to 76 feet after 7.5 years of Take. The resulting new (end of water year) static water level for the Eternal Home Cemetery Well ranged from approximately 169 feet bgs (-41 feet NGVD 29) to 361 feet bgs (-233 feet NGVD 29). The background water level decline (i.e., existing conditions from 2009/2010 water level or 20,000 AF SFPUC storage account starting condition) would result in a static water level decline from 225 feet bgs (-97 feet NGVD 29) to 258 feet bgs (-130 feet NGVD 29) at the end of the Design Drought (Year 44). The background water level decline for existing conditions was calculated by applying an annual groundwater level decline of 0.75 feet per year (i.e., equal to Hold Year groundwater level decline). The annual background water level decline in this analysis is assumed to be linear for purposes of this analysis; however, in reality, depletion of aquifer storage and the related rate of decline in groundwater levels will generally decrease over time if groundwater extraction remains constant and there is available recharge. Therefore, the assumption of a consistent rate of decline is conservative.

The groundwater model results for Scenario 2 are plotted on Figure 4 for comparison with analytical results. There is general agreement between analytical and groundwater model results in terms of both short-term and longer term groundwater level fluctuations. The analytical results generally show equal or lower static water levels during Take cycles than Layer 4 groundwater model results and can be considered more conservative (i.e., more of a worst case) in evaluating potential effects of the GSR Project on the Eternal Home well.

Figures 3 and 4 show that Take-Year static water levels fall below existing conditions between the first and second year of drought. Scenario 2 static water levels (SWLs) for the Eternal Home Cemetery Well with implementation of the GSR Project are estimated to reach a maximum depth of 105 feet below the existing conditions (i.e., without the GSR Project) SWLs. The maximum decline in groundwater levels for the Eternal Home Cemetery well occurs at the end of the Design Drought in future scenario year 44 (middle of the eighth consecutive year of Take). The static water level in the well declined to 285 feet bgs (before factoring in local GSR well interference drawdown). Addition of the local well interference effects results in a SWL declining to a low of 363 feet bgs (compared to an existing conditions level of 258 feet bgs).

It should be noted that the absolute lowest static water level occurs in the middle of scenario year 44 (when the Design Drought ends and SFPUC Storage Account is empty) and not at the end of the year (361 feet bgs) as shown in the figures. The lowest level occurs when Take ends within future scenario year 44 at a SWL of 363 feet bgs (groundwater elevation of -235 feet NGVD 29).

Similar analytical analyses as described above were conducted for other Colma cemetery wells and the tables and figures with results for these wells are provided in Appendix C. In general and as described above, after the first year of Take static water levels begin to decline to below the level expected without the project (20,000 acre-feet SFPUC storage account starting condition). However, it should be noted that static water levels are generally positive (i.e., higher than would be expected under existing conditions) under all other conditions except the three years of recovery needed after the Design Drought to return to Existing Conditions water levels. Overall, GSR Project static water levels in cemetery wells are higher than existing conditions for 75% of years.

Analysis of Installed Pump Capacities for Colma Cemetery Wells

Limited data were obtained concerning the specific pumps installed in the various cemetery and golf course irrigation wells. Although complete data sets were unable to be obtained for any of the wells, the available data combined with certain assumptions were used to obtain estimates of how GSR-related effects on static water levels might alter pumping capacities for wells that had sufficient pump data. Wells with sufficient data available for analysis were Italian Cemetery Well, Olivet Cemetery Well, Home of Peace Well, Hills of Eternity Well, Holy Cross Cemetery Wells 1 and 4, Eternal Home Well, Woodlawn Primary Well, and California Golf Club wells and the results are summarized in Table 5.

The pump in the Italian Cemetery well has a capacity/head rating of 260 gpm at 420 feet. It was assumed that the pump had a total dynamic head of 420 feet and was pumping at 260 gpm at the time of the spring 2001 groundwater level measurement (294 feet bgs). Based upon a specific capacity of 4.8 gpm/ft and a pumping rate of 260 gpm, the pumping drawdown in the well was estimated to be 54 feet - resulting in a pumping water level of 348 feet bgs (294 + 54 feet) as of spring 2001. Thus, the discharge head needed to achieve 420 feet of total dynamic head (TDH) was estimated to be 72 feet (420 - 348 feet).

Utilizing the data and assumptions outlined above, a calculation was first made for the existing conditions. Under this future condition, the new static water level was calculated to be 290 feet, a decline of 33 feet from the initial SWL. Analysis of this condition using the pump curve for the well suggests a pumping capacity of 265 gpm with a pumping water level of 345 feet. The new pumping water level of 345 feet plus the 72 feet of discharge head yields a total dynamic head of 417 feet.

A similar analysis/calculation as described above was applied to the estimated maximum depth to water for the GSR Scenario. In this case, the SWL declines to 400 feet bgs. Analysis of this condition using the pump curve suggests that the Italian well pump capacity would decline to 145 gpm with a pumping water level of about 430 feet. Addition of the discharge head of 72 feet yields a TDH of 502 feet.

A similar logic/analysis as described above for the Italian Cemetery well was applied to the Olivet Cemetery Well, Home of Peace Well, Hills of Eternity Well, Holy Cross Cemetery Well 1 and 4, Eternal Home Well, and Woodlawn Primary Well, and results are provided in Table 5. The overall results indicate that the lowest point during a Design Drought would result in pump capacity declines ranging from about 10 to 50 percent from existing conditions for all wells except Woodlawn (87% decline). The encroachment of pumping water levels into the well screen intervals under the two different water level conditions described above (Existing Conditions and GSR Project) varies depending on well construction details. In the case of the Italian Cemetery, Eternal Home, and possibly Olivet Cemetery wells, it appears that they have historically had pumping water levels within the upper portion of the screen interval. However, existing conditions and GSR Project conditions would result in much greater decline of pumping water levels into the screen intervals, which might be expected to result in decreasing specific capacity (i.e., estimated future pumping capacities could be somewhat lower than described above). The Holy Cross Well 1 maintains pumping water levels above the top of screen under historic conditions and the existing conditions scenario; and then pumping water level declines approximately 25 feet into the screen interval by the end of the GSR Project scenario. These differences with respect to decline of pumping water levels into screen intervals reflect the generally shallow top of screen settings for the Italian and Olivet wells compared to the somewhat deeper (intermediate) top of screen setting for the Holy Cross Well 1. Schematic examples of what could be typical water levels in third party well under both Existing Conditions and GSR Project Conditions are provided in Appendix D.

The Holy Cross Well 4 has a significantly lower specific capacity (6 gpm/ft) than the Holy Cross Well 1 (11 gpm/ft). Therefore, although the top of screen in Holy Cross Well 4 is deeper than in Well 1, the end of Design Drought pumping well level declines all the way through the upper screen interval in Well 4. This condition of pumping water levels remaining above the top of screen without the GSR project versus declining through the upper well screen with the GSR project could result in a lower specific capacity during the latter half of the Design Drought with GSR wells pumping. The Home of Peace Replacement well has a specific capacity of 11 to 12 gpm/ft and the analysis presented herein shows that the pumping water level only encroaches into the uppermost portion of the well screen by about 5 feet at the end of the Design Drought.

The pump curve for the Woodlawn Primary Well indicates that the installed pump is apparently designed to operate within a relatively narrow range of water levels compared to other pumps in cemetery wells. The dramatic decline in pumping capacity estimated for future end of Design Drought GSR conditions for the Woodlawn Well (87%) compared to other cemetery wells (10 to 50%) is largely due to the particular pump installed in the well as opposed to differences in water level declines (e.g., about 15 feet more at Woodlawn than other cemetery wells) .

California Golf Club Wells

The data analysis for the California Golf Club wells is similar to the Colma cemetery wells and involved the following steps:

1. Based upon review of water level data from 2001 to 2010 for the CGC wells and the Colma area well data analysis (recovery rate of 8.6 feet/year), it was concluded that an appropriate recovery rate of CGC wells is approximately 8.5 feet/year.
2. Based upon review of the Colma area well data GSR Take Year analysis (decline rate of 12.9 feet/year) along with the estimated Take-Year groundwater level decline rate of up to 24 feet/year estimated by L&S for the Cal Water Well Field area (personal communication, Will Halligan), it was concluded that an appropriate decline rate for CGC wells is approximately 18.5 feet/year (average of Colma area 12.9 feet/year and 24 feet/year).
3. The groundwater level decline due to Partner Agency/third party pumping was estimated based upon the Colma area analysis (0.75 feet/year) and the groundwater model result for Model Layer 4 at the California Golf Club well (about 0.7 feet/year). Thus, it is concluded that the Hold year decline rate at the California Golf Club is 0.75 feet/year.
4. Summarizing the values above, the Put Year recovery rate is 8.5 feet/year, the Take Year decline rate is 18.5 feet/year, and the Hold Year decline rate is 0.75 feet/year.

A depth to water of 235 feet below ground surface (-174 feet NGVD 29) was measured in 2001 (pre In-Lieu Recharge Demonstration Study). Based upon a Fall 2009 measured depth to water of 214 feet and other data collected for this study, it is estimated that a representative Spring 2010 depth to water in CGC Well 8 is 200 feet. The proposed Put/Hold/Take year sequence for the GSR Project scenario (Table 6) was used to develop a plot of future (depth to water) groundwater levels for California Golf Club Well 8 (Figure 5). Using the annual changes in groundwater levels associated with Put, Hold, and Take years described above, Figure 5 shows how regional groundwater levels are estimated to fluctuate at the California Golf Club

Well 8 over the course of 47 future years based on the assumptions and calculations used in this analysis. A similar analysis was completed for California Golf Club Well 7 (Figure C-19 in Appendix C).

The next step was to add in the local GSR drawdown as calculated by MWH (Appendix B). This value ranged from 43 feet after one year of Take to 74 feet after 7.5 years of Take. The resulting new static water level for California Golf Club Well 8 ranged from approximately 145 feet bgs (-84 feet NGVD 29) to 400 feet bgs (-339 feet NGVD 29) (Figure 6). The background water level decline (i.e., existing conditions) would result in a static water level decline from 200 feet bgs (-139 feet NGVD 29) to 233 feet bgs (-172 feet NGVD 29) at future scenario year 44 without the GSR project. A similar analysis was completed for California Golf Club Well 7 (Figure C-20 in Appendix C).

Review of Figures 5 and 6 shows that Take-Year static water levels fall below the static water level without the project during the first year of drought. Subsequent years of drought continue to reduce static water levels further below where static water levels would be without the project. The static water levels reach a maximum depth of 169 feet below the existing conditions SWL.

As described above, during the first year of Take static water levels for the GSR Project scenario begin to decline to below the level expected without the project. However, it should be noted that static water levels are generally positive (i.e., higher than would be expected under existing conditions) during non-Take years leading up to the Design Drought. Overall, GSR Project static water levels at California Golf Club wells are higher than existing conditions for 68 percent of years.

Analysis of changes in pumping capacity using the California Golf Club Well 8 pump curve indicate that the lowest well pumping capacity under the GSR Project would be about 475 gpm compared to the existing conditions capacity of 800 gpm. The decline in pumping capacity at Well 8 amounts a maximum of 41 percent for the GSR Project as compared to existing conditions without the GSR project. The pumping capacity analysis for California Golf Club Well 7 shows a greater decline of 78 percent from 200 to 45 gpm. The difference in pumping capacity decline at the two California Golf Club wells is mostly a function of the characteristics of the pump curve for the specific pumps installed in each well.

Lake Merced Golf Club Wells

The data analysis for the Lake Merced Golf Club wells included in this study is similar to the Colma cemetery wells and involved the following steps:

1. Based upon the Colma area well data analysis (recovery rate of 8.6 feet/year) along with the estimated groundwater level recovery rate (11 to 15 feet/year) in Park Plaza and other Daly City wells during the in-lieu recharge demonstration study, it was concluded that an appropriate recovery rate of LMGC wells is approximately 10.5 feet/year.

2. Based upon review of the Colma area well data GSR Take year analysis (decline rate of 12.9 feet/year) along with an estimated groundwater level decline rate during Take Years for Daly City wells of 16 to 21 feet (personal communication, Will Halligan), it was concluded that an appropriate decline rate for LMGC wells is approximately 15 feet/year.
3. The groundwater level decline due to Partner/third party pumping was estimated based upon the Colma area analysis (0.75 feet/year) and the groundwater model result for Model Layer 4 at CUP-6 (about 1.0 feet/year). Thus, it is concluded that the Hold year decline rate at the Lake Merced Golf Club is 0.75 feet/year.
4. Summarizing the values above, the Put Year recovery rate is 10.5 feet/year, the Take Year decline rate is 15 feet/year, and the Hold Year decline rate is 0.75 feet/year.

Based upon review of water level data from 2001 to 2010 for the two wells near LMGC (CUP-6-420 and DC-8), the Winter/Spring 2010 groundwater elevation was estimated to be 238 feet bgs (-84 feet NGVD 29). The initial 6.5 Put Years result in an initial full SFPUC Storage Account regional groundwater elevation of -16 feet (NGVD 29) (DTW of 170 feet bgs) as indicated in Figure 8.

The proposed Put/Hold/Take year sequence for the GSR scenario (Table 7) was used to develop plots of future (depth to water) groundwater levels for Lake Merced Golf Club Well 3 (Figures 7 and 8). Using the annual changes in groundwater levels associated with Put, Hold, and Take years described above, Figures 7 and 8 show how regional groundwater levels are estimated to fluctuate at the Lake Merced Golf Club Well 3 over the course of 47 future years based on the assumptions and calculations used in this analysis.

The next step was to add in the local GSR drawdown as calculated by MWH (Appendix B). This value ranged from 29 feet after 1 year of Take to 56 feet after 7.5 years of Take. The resulting new static water level for the Lake Merced Golf Club well ranged from approximately 170 feet bgs (-16 feet NGVD 29) to 356 feet bgs (-202 feet NGVD 29) (Figure 8). The background water level decline (i.e., existing conditions) would result in a static water level decline from 238 feet bgs (-84 NGVD 29) to 271 feet bgs (-117 feet NGVD 29).

Review of Figures 7 and 8 shows that Take-Year static water levels initially stay above the static water level without the project at least through the end of the second year of drought. The third year of Design Drought brings the static water level below the existing conditions. Static water levels reach a maximum depth of 87 feet below the existing conditions SWLs. As described above, it takes at least until after the third year of Take for static water levels to decline to below the level expected without the project. However, it should be noted that static water levels are generally positive (i.e., higher than would be expected under existing conditions) under all other conditions except for initial recovery after the Design Drought. Overall, GSR Project static water levels at Lake Merced Golf Club are higher than existing conditions in 83 percent of years.

No pump information could be obtained for Lake Merced Well 3. However, given the magnitude of water level declines (87 feet) at Lake Merced Well 3 compared to the range of water level declines at cemetery wells (95 to 116 feet), it is anticipated that the range of pump capacity reduction is likely in the lower end (i.e., 10 to 30%) of the 10% to 50% range in pump capacity reduction at most cemetery wells.

Olympic Club Wells

The analytical data analysis for the Olympic Club area wells included in this study is similar to the Colma cemetery wells and involved the following steps:

1. Based upon review of water level data from January 2002 to January 2005 for Lake Merced area wells LMMW-3D and LMMW-6D, it was concluded that an appropriate groundwater level recovery rate for the Olympic Club area is 3.6 feet per 3,070 acre-feet of in-lieu recharge (this represents the amount of in-lieu recharge in the Daly City area during a future Put Year). The rationale for this conclusion is that the SFPUC storage account calculations provided by SFPUC indicate that it had accumulated 5,665 af of in-lieu recharge (as of the end of January 2005) in the Daly City area since 2002 (Appendix A). The study period for this analysis stopped as of January 2005 to avoid any groundwater level bias associated with the initiation of Daly City recycled water deliveries to the Olympic Club, Lake Merced Golf Club, and San Francisco Golf Club. It was also necessary to account for Lake Merced water additions during the January 2002 to January 2005 period, and this was accomplished by treating the total additions of 1,160 af to Lake Merced the same as in-lieu recharge in the Daly City area. Thus, the total amount of in-lieu recharge used in this calculation is 6,825 af (5,665 af + 1,160 af). It is assumed that the 6,825 af of increased storage correlates with the approximate 8-foot rise in groundwater levels at the Lake Merced wells near Olympic Club between January 2002 and January 2005. Thus, dividing 6,825 af of in-lieu recharge (Put) by a total water level rise of 8 feet equals 850 af of Put per foot of groundwater level rise.
2. Under the proposed project, a year of Put is equal to about 6,180 af for the three Partner Agencies. However, factoring out Put for the Cal Water and San Bruno wells (due to the significant distance from Olympic Club) results in a total in-lieu recharge of about 3,070 AFY during a proposed project Put year in the Daly City area. Using the above logic, a year of Put at 3,070 af divided by 850 af per foot of water level rise results in a Put year groundwater level rise of 3.6 feet.
3. The proposed GSR well locations were reviewed for proximity to Olympic Club to determine the amount of Take from GSR wells in the region. The wells included in the Take calculation were CUP-3A, CUP-5, CUP-6, CUP-7, CUP-10A, and CUP-11A. Assuming Take year of 7.23 MGD (8,100 AFY), and subtracting the Take amounts from the 11 wells not listed above results in about 3,360 af of extraction from GSR wells in the Daly City area. Assuming that Take year extraction works in reverse of the recovery of water levels during Put years yields a one foot water level drop per every 850 af removed during a Take year. Dividing 3,360 af by 850 af per 1

foot of groundwater level decline yields 4.0 feet of groundwater level decline during a proposed Take year due to GSR pumping.

4. The background groundwater level decline due to regional groundwater pumping was evaluated using both available groundwater level data prior to 2002 (and the onset of the In-Lieu Recharge Demonstration Study) and groundwater flow model simulation results. Available measured pre-2002 groundwater level data in this area for Olympic Club were collected primarily during the 1987 to 1992 drought. Available data indicate groundwater level decline rates of about one foot per year during the drought. The HydroFocus (May 2011) Historical Simulation (1959-2009) showed a water level decline of 0 to 0.2 in the Olympic Club area, and the HydroFocus 2008 No Project Scenario showed essentially no change in groundwater levels. The Existing Conditions Scenario (Scenario 1) by KJ (2012) showed a background groundwater level decline rate of about 0.5 feet/year in the Olympic Club area. Based on available field data and model simulations, a background groundwater level decline rate of 0.5 feet/year is considered to be representative of Hold year groundwater level declines in this area.

5. Combining the values above, we have a Put Year recovery rate of 3.6 feet/year and a Take Year decline rate of 4.0 feet/year, and a Hold Year decline rate of 0.5 feet/year.

A depth to water of 120 feet below ground surface (-45 feet NGVD 29) was measured in July 2001 (pre In-Lieu Recharge Demonstration Study) in Olympic Club Well 1 (#9). Because the water level was measured in mid-summer, it was assumed a representative Spring water level would be somewhat higher at 115 feet (-40 feet NGVD 29). The measured rise in water levels in this area from 2002 to 2009 is about 15 feet in LMMW-3D/6D; thus, a representative Spring 2010 depth to water is assumed to be 100 feet (-25 feet NGVD 29) in Olympic Club Well 1. The proposed Put/Hold/Take year sequences for the GSR scenario (Table 8) was used to develop a plot of future (depth to water) groundwater levels for Olympic Golf Club Well 9/No. 1 (Figure 9). Using the annual changes in groundwater levels associated with Put, Hold, and Take years described above, Figure 9 shows how regional groundwater levels are estimated to fluctuate at the Olympic Golf Club Well 1 (#9) over the course of 47 future years based on the assumptions and calculations used in this analysis.

The next step was to add in the local GSR drawdown as calculated by MWH (Appendix B). This value ranged from 7 feet after one year of Take to 23 feet after 7.5 years of Take. The resulting new static water level for the Olympic Golf Club well ranged from 77 feet bgs (-2 feet NGVD 29) to 136 feet bgs (-61 feet NGVD 29) (Figure 10). The background water level decline (i.e., existing conditions) would result in a static water level decline from 100 feet bgs (-25 feet NGVD 29) to 122 feet bgs (-47 feet NGVD 29) at future scenario year 44 without the GSR project.

Review of Figures 9 and 10 shows that Take-Year static water levels fall below the static water level without the project during the fifth year of drought. Subsequent years of Design Drought continue to reduce static water levels further below where static water levels would be without the project. The static water levels reach a maximum depth of 14 below the existing conditions SWLs.

As described above, after the fourth year of Take static water levels for the GSR Project begin to decline to below the level expected without the project. However, it should be noted that static water levels are positive (i.e., higher than would be expected under existing conditions) under all other conditions.

Analysis of changes in pumping capacity for using the Olympic Club Well No. 1 (#9) pump curve indicate that the well pumping capacity under the GSR Project at the end of the Design Drought would be about 660 gpm compared to the existing conditions capacity of 685 gpm. The decline in pumping capacity at Well 1 amounts to 4 percent for the end of the Design Drought with the GSR project as compared to existing conditions without the GSR project.

A similar analysis of changes in pumping capacity for using the Olympic Club Well No. 2 (#8) pump curve indicate that the well pumping capacity under the GSR Project at the end of the Design Drought would be about 935 gpm compared to the existing conditions capacity of 970 gpm. The decline in pumping capacity at Well 1 amounts to 4 percent for the end of the Design Drought with the GSR project as compared to existing conditions without the GSR project.

Alternative GSR Well Site Analysis

Three of the proposed 16 GSR well sites (CUP-3A, 7, and 44-1) were replaced by the three alternative well sites (CUP-20A, 22, and 36-2) and mutual interference drawdowns were calculated by MWH (Appendix B). Given the locations of wells removed (two at the northern end and one at the southern end of the GSR Project area) versus alternative well locations added (generally in the middle of the GSR Project area), the alternative well configuration analyzed in this study results in more drawdown in the Colma/South San Francisco area and less in the Daly City and San Bruno areas. The alternative well configuration could probably be viewed as a worst case for the Colma and South San Francisco areas, whereas the original 16 well configuration could likely be viewed as the worst case for the Daly City and San Bruno areas.

The amount of mutual interference drawdown in the alternative well site configuration scenario increased by 9 to 33 feet at Colma Cemetery wells, and 10 to 14 feet at the California Golf Club wells after 7.5 years of GSR Project pumping as compared to the original well site configuration. Drawdown at Lake Merced Golf Club wells for the alternative well site configuration (compared to the original well site configuration) decreased by 21 to 22 feet, and drawdowns at the Olympic and San Francisco Golf Clubs decreased by 11 to 13 feet after 7.5 years of GSR Project pumping. Detailed calculations on a well by well basis for both the original and alternative well site configurations are provided in the MWH memo in Appendix B.

Transfers among GSR Partner Agencies

Operation of the GSR project allows transfer of up to 10% of each partner's allowable pumping between partner agencies under certain conditions. However, transfers among partner agencies are not expected to occur during the later years of the design drought and therefore would not exacerbate the adverse effects reported from the GSR Project without the transfer. Transfers during the later years of the design drought are unlikely because:

- In Daly City, the designated quantity is 3.43 million gallons per day (mgd). Based on the analyses conducted previously, the City of Daly City's aggregate discharge capacity from their entire well field is estimated to be 3.3 mgd at the end of the Design Drought. This would suggest that any transfer of designated quantity from San Bruno and/or Cal Water to Daly City would not be able to be conducted near the later stages of the Design Drought, since Daly City would not have excess well capacity to handle such an increase in production (4 mgd). Therefore, additional well interference from a transfer during a Design Drought would not be able to be conducted to a degree that would exacerbate anticipated well interference effects that have been evaluated for the GSR Project.
- In the South San Francisco area, Cal Water has a designated quantity of 1.37 mgd. This designated quantity is slightly less than the maximum capacity of Cal Water's treatment plant (1.4 mgd). At the end of the Design Drought, Cal Water's design well capacities are estimated to be 0.8 mgd and 1.2 mgd if replacement pumps are installed. Similar in nature to Daly City, Cal Water would not have any excess design well capacity to accept a transfer from Daly City and/or San Bruno, nor would Cal Water have excess treatment plant capacity. Therefore, it is highly unlikely that transfers to Cal Water could occur with the existing well and treatment plant constraints. Therefore well interference effects would not exceed those already evaluated for the GSR Project
- In the San Bruno area, it is estimated that there would be a limited amount of excess design capacity at the end of the Design Drought. This excess is about 0.2 mgd (140 gpm) above the 2.1 mgd designated quantity. It is highly unlikely that Daly City and/or Cal Water would transfer 10 percent of their designated quantity near the end of the Design Drought, because they would likely want to use as much of their designated quantity as possible since any transfer would likely be met with opposition from ratepayers who will likely be subject to water rationing. However, in the remote chance such a transfer was to be conducted, the additional capacity pumped by San Bruno would not result in additional interference on third-party wells, since there are not any identified third-party wells in the main portion of the basin in San Bruno within 1.5 miles of San Bruno municipal supply wells.

CUMULATIVE WELL INTERFERENCE ANALYSIS

Introduction

In addition to the proposed SFPUC GSR project, the proposed San Francisco Groundwater (SFGW) Supply Project involves groundwater extraction of 3 million gallons per day (MGD) from four new wells installed in the vicinity of Lake Merced, the Sunset District, and Golden Gate Park (Scenario 3a) and possibly an additional 1 MGD from conversion of two existing irrigation wells in Golden Gate Park to municipal use for a combined total of 4 MGD (Scenario 3b). The study area for the SFGW Supply Project encompasses the western portion of San Francisco between the San Francisco/San Mateo county line and Golden Gate Park. The capacity of the proposed SFGW project, 3 or 4 MGD, would depend upon whether or not recycled water would become the source of irrigation water in Golden Gate Park. If the recycled water project is implemented, two existing irrigation wells at the west end of Golden Gate Park would be converted to municipal supply wells, and four additional municipal supply wells would be brought online to pump a total of 4 MGD from six wells on an average annual basis. If the recycled water project is not implemented, the two Golden Gate Park irrigation wells would continue irrigation pumping and only the four new municipal supply wells would be used to pump 3 MGD on an average annual basis for the SFGW project. This cumulative well interference analysis does not account for future additions of water to Lake Merced.

Background

In addition to GSR Project impacts to third-party wells described in this TM, Luhdorff and Scalmanini Consulting Engineers (LSCE) estimated well interference effects on third-party wells in San Francisco and the northern part of Daly City from the SFGW Supply Project (LSCE, 2012). The cumulative analysis includes assessment of well interference on third-party wells located in the SFGW Supply Project study area that may result from pumping of GSR wells. These calculations are added to well interference estimates from the SFGW Supply Project to obtain the total estimated well interference drawdown at the third-party wells, which incorporates pumping influences from both GSR and SFGW Supply Project wells.

The third-party wells in the South Westside Groundwater Basin that are the subject of this cumulative analysis include Lake Merced Golf Club Well 3 and two wells at Olympic Golf Club. The third-party wells in the North Westside Groundwater Basin that are considered in the cumulative analysis include one well at the San Francisco Golf Club. Other third party wells in the North Westside Groundwater Basin (e.g., Zoo well, Edgewood Development Center well, Pine Lake well) are too far away to warrant consideration in the cumulative analysis.

Previous Studies

As stated above, the third-party wells included in the GSR Project well interference analysis that are considered close enough to the subbasin boundary (between North and South Westside Basins) to show possible influence from SFGW Supply Project wells are the well at Lake Merced Golf Club, two wells at Olympic Club, and the San Francisco Golf Club well. GSR-related gross well interference estimates were 56 feet for Lake Merced Golf Club wells, 23 feet for Olympic Club wells, and 22 feet for San Francisco Golf Club well (Appendix B) as summarized in Table 10. Gross well interference estimates are the values derived directly from Theis calculations. Net well interference estimates provided in Table 11 are defined as the difference between gross estimates and water level declines associated with future existing conditions. The cumulative analysis provides estimates of drawdown at the golf club wells from the proposed SFGW Supply Project wells and the combined effects from both proposed projects. The Colma cemetery wells are located 2.6 to 3.8 miles from the nearest SFGW Project well at the Lake Merced Pump Station (LMPS) and the California Golf Club wells are about 5 miles from the LMPS well. As discussed further below, these other third-party wells are not considered in this study because interference effects would be negligible at these distances.

The LSCE study on third-party well Interference employed both Theis analytical and MODFLOW groundwater model-based calculations of well interference drawdown from proposed SFGW Supply Project wells (LSCE, 2012). Third-party wells included in that analysis that are considered close enough to the subbasin boundary (between North and South Westside Basins) to show possible influence from GSR Project wells include the Lake Merced Golf Club, Olympic Club, and San Francisco Golf Club. SFGW Supply project well interference estimates ranged from 4 to 6 feet for these well locations, as summarized in Table 12.

The two project-specific well interference analyses both provided estimated well interference effects at the Lake Merced, San Francisco, and Olympic Golf Club wells. Those previous results are combined in the current study to estimate total well interference effects from both proposed projects.

CUMULATIVE WELL INTERFERENCE CALCULATIONS

GSR Project Wells

The GSR wells located closest to the SFGW Project are in Daly City (CUP-3A, 5, 6, and 7). A 1.5-mile radius from the furthest north GSR well (CUP-3A) is shown on Figure 11 and encompasses the Olympic Club and San Francisco Golf Club. A 1.5-mile radius from the furthest south SFGW Project well (Lake Merced Pump Station) is also shown on Figure 11 and encompasses the Lake Merced Golf Club. These two 1.5-mile radii define the cumulative analysis study area and incorporate wells at the three golf courses.

As described in more detail below, due to the distances between the Daly City GSR wells and most San Francisco third-party wells (i.e., greater than 1.5 miles), combined with the presence of Lake Merced and associated vertical leakiness and areal recharge in the SFGW project area, the interference effects on third-party wells located north of Lake Merced (e.g., Zoo, Edgewood, Pine Lake) from GSR pumping south of Lake Merced (from CUP-3A, 5, 6, and 7) are considered to be negligible.

Previous Theis calculations of well interference effects by MWH for the GSR project conceptual engineering report (MWH, 2008) considered pumping wells within a 1.5-mile radius. The limitation of 1.5 miles was selected to represent a reasonable extent for a cone of depression given consideration of vertical leakage from one aquifer to another, groundwater recharge (that occurs related to precipitation, irrigation, and leaky pipes), interception of groundwater flow that otherwise discharges from the aquifer (e.g., coastal outflow), and/or encountering a surface water body (e.g., Lake Merced). As described by Driscoll (1986), the vertical leakage from upper to lower aquifers (and from underlying aquifers vertically upward to the pumped aquifer), groundwater recharge, and possibly other factors listed above, are expected to cause the cone of depression to stop expanding and stabilize.

SFGW Supply Project Wells

The SFGW Supply Project well interference study utilized Theis calculations (with a lower storativity value than used in the GSR Project calculations) and a sub-regional MODFLOW groundwater model to estimate well interference effects on third-party wells in the

Westside Basin within 1.5 miles of the SFGW Supply Project wells (LSCE, 2012). As discussed below, the study concluded that results from the sub-regional MODFLOW groundwater model provided more realistic estimates of potential interference effects for hydrogeologic conditions in the SFGW Supply project area. For the cumulative analysis, SFGW drawdown estimates for the Olympic Club and San Francisco Golf Club wells were obtained from the LSCE groundwater model results, and these model results were also used to provide SFGW drawdown estimates for the Lake Merced Golf Club wells. LSCE's report documents the model inputs in terms of pumping rates, transmissivity, storativity, and pumping durations. The MODFLOW model also accounts for vertical leakage that occurs from the Shallow Aquifer to deeper aquifers, which allows for a more realistic simulation of drawdown effects over long pumping durations than does the Theis analysis (which does not account for vertical leakage). Modeling was used because leakage was considered particularly important in the SFGW project area due to the hydrogeologic setting, which includes potential interaction between shallow and deeper aquifer units. The results of the well interference drawdown estimates are summarized in Table 12, and drawdown contour maps from the LSCE report are provided in Appendix E. The Theis analytical solution was used in the LSCE study to support assumptions that the cone of depression that developed did not appreciably expand after a one-year pumping duration.

The numerical flow model was constructed specifically for the SFGW Project well interference study using MODFLOW, to assess potential pumping influences in a multiple aquifer system more complex in nature than can be incorporated in the Theis solution. This model is a sub-regional model developed specifically for the evaluation of pumping influences for the SFGW Project. This model is not the basin-wide numerical groundwater flow model developed by Daly City (HydroFocus, 2011). The numerical model developed for this evaluation consists of multiple (3) layers separated by aquitards with assigned values of leakiness, in which vertical movement of water occurs. Unlike the Theis solution, the numerical model incorporates variations in hydrogeologic conditions north and south of Lake Merced where confinement decreases (i.e., due to pinch-outs of the "-100 Foot" and "X" Clay units). The numerical model provides a means to simulate how the pumping cones of depression around Project wells would be affected by changes in confinement as they expand beyond the lake footprint.

Well Interference Calculation Methodologies

The GSR Project and SFGW Supply Project well interference calculations described above utilize somewhat different approaches in that the GSR Project is based strictly upon Theis analytical calculations, whereas the SFGW Supply Project utilizes both Theis analytical calculations and a MODFLOW groundwater model for well interference analysis. The approach used for the GSR Project is considered appropriate for hydrogeologic conditions in the South Westside Groundwater Basin (SWB), and the SFGW Supply Project approach is considered appropriate for the North Westside Basin (NWB) hydrogeologic conditions. Important hydrogeologic differences between the North and South Westside Basins include generally shallower groundwater levels in the NWB, the presence of Lake Merced in the NWB, and multiple aquifers in the NWB (especially beneath and adjacent to Lake Merced) that result in greater vertical leakage in the NWB. There are also more open (fewer no-flow) hydrogeologic boundary conditions, higher aquifer hydraulic conductivities, and more rainfall recharge in the

NWB. A sensitivity analysis was conducted by LSCE on the Theis analytical solution storativity input value used in the SFGW Project analysis of well interference. The storativity value was changed to be consistent with the value used in the GSR Project analysis and the results were similar in nature to the numerical model results. This exercise provided greater certainty that the primary methods for analyzing well interference results for the GSR and SFGW projects are similar in nature.

The differences in basin hydrogeologic characteristics are such that the Theis analytical approach is generally adequate (although possibly slightly conservative) in evaluating mutual interference effects in the SWB; however, the Theis approach alone does not adequately simulate the nature of recharge, vertical leakage, and boundary conditions in the NWB. A MODFLOW groundwater flow model is necessary in the NWB to adequately simulate the effect of vertical leakage influences on well interference. The wells of concern in the cumulative analysis in terms of having measureable effects from both projects are the three golf clubs – Lake Merced, Olympic, and San Francisco. All of the golf club wells are located near the border between the NWB and SWB. The application of the MODFLOW groundwater flow model to these wells as part of the cumulative analysis is considered appropriate because the pumping wells in the SFGW project are located two-thirds of a mile or further north of the golf club wells where NWB hydrogeologic conditions described above serve to limit the areal extent of the cones of depression around pumping wells (e.g., vertical leakiness, Lake Merced is between SFGW pumping wells and golf club wells). GSR Project wells are located two-thirds mile or further south of the Olympic and San Francisco golf club wells in a different hydrogeologic regime where conditions are less conducive to limiting the extent of the cones of depression and where Theis analytical calculations with a higher storativity value than used in the SFGW well interference analysis would be more applicable.

Given the locations of the respective project wells and the golf club wells at issue in the cumulative analysis, it is likely that inaccuracies in the cumulative mutual well interference calculations at a given golf club well would be weighted toward being overestimated. The reasoning for this conclusion is that the cones of depression predicted for GSR wells by Theis analytical calculations do not account for likely increases in vertical leakiness (that would result in less drawdown) expected to occur in the vicinity of the Olympic and San Francisco golf clubs.

Combined Well Interference Drawdown Effects

The results from the two project-specific studies and additional calculations made for the cumulative analysis are summarized in Tables 10 and 11 for the GSR Project and Table 12 for the SFGW Supply Project. These results were added to obtain the combined well interference drawdown effects by both projects as summarized in Tables 13 and 14. Tables 13 and 14 show results for the 3-MGD and 4-MGD pumping scenarios under the SFGW project, as described previously. As indicated in Table 13, the results show the gross combined well interference drawdown of 28 feet at San Francisco Golf Club, 29 feet at Olympic Club, and 60 feet at Lake Merced Golf Club. The well sites influenced by the GSR project show a net drawdown impact as follows: 20 feet at Olympic and San Francisco Golf Clubs, and 91 feet at Lake Merced Golf Club (Tables 14 and 15).

CUMULATIVE WELL CAPACITY ANALYSIS

The consequences of the estimated interference drawdown effects are determined by considering well construction features and pump head-capacity relationships. Construction features and pump information for third-party wells subject to cumulative analysis are provided in Appendix F. The well capacity analysis method applied in this cumulative analysis evaluates the change, or reduction, in pumping capacity because of predicted increased drawdown from proposed project wells. The increased drawdown would represent additional head, or lift, for the pump and translates to reduced capacity according to the pump head-capacity relationship. When the additional head requirement caused by mutual well interference is small in relation to the total pump head (the sum of lift below ground surface, system discharge head, and other friction losses), there may be little discernible effect on the third-party well capacity. When the effect amounts to a substantial fraction of the total pump head, or when the pump head-capacity relationship is relatively flat, the interference effect may result in a large percentage change in operating capacity for the well. The potential operational effects on existing well capacities for the combined GSR and SFGW project influences are discussed below and summarized in Table 16.

San Francisco Golf Club

The San Francisco Golf Club (SFGC) irrigation well was drilled in 1985. As presented in the 2012 LSCE memorandum on SFGW project influences, the well is equipped with a 700-gpm well pump set to 350 feet, which is 10 feet above the top of the well screen. While the SFGW influences were estimated to have a negligible effect on pumping capacity, 28 feet of gross drawdown interference is estimated for the combined projects. This would have the effect of reducing the pump capacity by approximately 45 gpm from the reported design capacity, or 6 percent. However, due to a predicted slight decline in background water levels over the next 44 years, the net drawdown impacts for the cumulative scenario at the end of the Design Drought are estimated to be 20 feet. The estimated net reduction in well capacity in this case is 20 gpm or 3 percent (when comparing future end of Design Drought conditions to existing conditions without the projects). The net reduction in well capacity would be 20 gpm (or 3 percent) compared to the current pumping rate of 675 gpm.

The predicted decreases in capacity caused by the estimated interference drawdown do not indicate a loss in supply, but only slightly longer pumping times to produce the same quantity of water.

Olympic Club Wells

The active Olympic Club irrigation wells (Wells No.2/8 and No.1/9) were drilled in 1994 and 2001, respectively. Well 8 is equipped with a pump with a reported design capacity of 1,000 gpm and a setting depth of 270 feet, which is below the top of the screen interval (the well is screened from 200 feet bgs). Well 9 is equipped with a nominal 700-gpm pump with a setting depth of 250 feet, which is 10 feet above the top of screen in the well.

As is the case for the San Francisco Golf Club well, SFGW influences were previously determined to have a negligible effect on well capacity based on mutual well interference drawdown of 6 feet. The estimated gross well interference drawdown for the combined GSR and SFGW projects at these well sites is 29 feet (Table 13). Examination of the pump curve for Well 8 indicates that cumulative mutual well interference would reduce its capacity by about 90 gpm, or 9 percent, from the design capacity of 1,000 gpm. The reduction in capacity for Well 9 is 60 gpm with a similar percentage change of 9 percent for the design capacity of 700 gpm.

However, due to a predicted slight decline in background water levels over the next 44 years, the net drawdown impacts at the end of the Design Drought (Table 14) are estimated to be 20 feet (when comparing future end of Design Drought conditions to existing conditions without the projects). The estimated net reduction in Well 9 capacity in this case is 45 gpm or 7 percent. The estimated net reduction in Well 8 capacity is 60 gpm or 6 percent.

Lake Merced Golf Club Well

Interference drawdown effects at the Lake Merced Golf Club (LMGC) Well 3 from the combined projects are estimated to be 60 feet (Table 13). The GSR Project alone is expected to account for over 90 percent of the well interference drawdown at Lake Merced Golf Club well. Therefore, the effect on well capacity for the combined projects is very similar to the effect on well capacity for just the GSR Project, which was addressed in the GSR Project well interference section of this TM. Pump information from LMGC Well 3 is not available; thus, the actual reduction in pumping capacity cannot be estimated at this time. However, the well capacity reduction was estimated to be in the range of 10 to 30% in the GSR section of this TM. The cumulative project well capacity reduction is estimated to also fall within the range of 10 to 30%.

SUMMARY AND CONCLUSIONS

The primary purpose of this study was to evaluate the pumping of GSR wells on individual existing third-party wells. The third-party (i.e., irrigation) groundwater pumpers in the South Westside Groundwater Basin that are the subject of this TM include the Colma cemeteries, California Golf Club, and Lake Merced Golf Club (Figures 1 and 2). In addition, as part of the Cumulative Project Analysis, this study provides GSR-related well interference calculations for the Olympic Golf Club and San Francisco Golf Club located near or within San Francisco City/County limits.

GSR Project Analysis

The GSR project would only extract groundwater up to the amount that has been stored in the SFPUC Storage Account. However, due to the possibility for localized effects, this study was conducted as part of the effort to evaluate the localized cones of depression around proposed GSR wells that may potentially affect individual existing third-party wells. The results presented herein represent “worst case” with respect to being calculated at the end of the Design Drought (7.5 years continuous pumping) for the GSR Project wells. The Design Drought is two years longer than the historic drought of record (1987 to 1992).

The results of the data analysis for the GSR Project are summarized in Table 9. The analytical calculations indicate that the proposed GSR Project would cause cemetery well static water levels to be from 95 to 116 feet lower than would occur without the project at the end of the Design Drought. The effects are greatest at the Woodlawn Cemetery well at the northern end of the group of Colma cemeteries, and least in the vicinity of Home of Peace, Hills of Eternity, and Cypress Lawn cemeteries. There is a gradual decline in GSR Project influence on cemetery wells from Woodlawn to Home of Peace. The project effects begin to increase again to the south of Cypress Lawn for the Holy Cross wells. Review of Figure 2 indicates that the pattern of project effects observed at the cemetery wells corresponds to the presence of three GSR wells at the north end near Woodlawn (CUP-10, CUP-11A, and CUP-18), one GSR well near the middle of the cemetery wells (CUP-19), and two GSR wells at the south end near Holy Cross (CUP-22A and CUP-23).

The maximum project effect at the Lake Merced Golf Club well amounts to about 87 feet compared to existing conditions. The Lake Merced Golf Club well is influenced primarily by GSR wells CUP-3A, CUP-5, CUP-6, and CUP-7. The maximum project effects at the California Golf Club wells amount to about 169 feet compared to existing conditions. The California Golf Club wells are influenced primarily by GSR wells CUP-31 and CUP-36-1 (and to a lesser extent by CUP-41-4 and CUP-44-2). While there are fewer GSR wells in vicinity of the California Golf Club, the area has greater overall drawdown due to an estimated Take year regional decline rate of 18.5 feet compared to 12.9 feet in the Colma area and 15 feet for Lake Merced Golf Club.

Pump curves and other pump information were obtained for most wells and certain assumptions were made to estimate how project-related changes in water levels may affect pumping rates (i.e., well capacity) and pumping water levels. The results indicated that pumping capacities would be reduced by 10 to 50 percent at the end of the Design Drought (with the GSR Project) at most wells. Greater decreases in pumping capacities were calculated for the Woodlawn Primary Well (87 percent) and California Golf Club Well 7 (78 percent) due to the specific characteristics of the pumps installed in these two wells.

It should be noted that the maximum effects described above occur for a short duration (i.e., a few months) in the middle of Future Scenario Year 44 (at the end of the Design Drought when the SFPUC Storage Account is empty). During the majority of the years (68 to 83%) while the project is in place there will be a net benefit (i.e., higher groundwater levels and higher pumping capacities) to third party wells from the proposed GSR Project. At other times during project take cycles, the project effects will be slightly to considerably less than those described above and analyzed in detail in this TM.

Cumulative Project Analysis

The well interference effects on third-party wells were estimated separately for each individual proposed project (Fugro, this TM; LSCE, 2012). The cumulative analysis section of this TM provides additional calculations using results of project-specific well interference studies to estimate combined effects on third-party wells from both proposed SFPUC projects. The results presented herein represent a “worst case” with respect to being calculated at the end of the Design Drought (7.5 years continuous pumping) for the GSR Project wells and incorporate interference estimated for the SFGW Project scenario consisting of 6 wells pumping at 4 MGD.

In summary, there are no well interference effects from pumping GSR Project wells (CUP-3A, 5, 6, and 7) on the Zoo, Edgewood, and Pine Lake wells located north of Lake Merced in San Francisco. The SFGW Supply Project has little effect (about 4 feet) on the Lake Merced Golf Club well located south of Lake Merced in northern San Mateo County. Greater effects from the combined projects occur for the San Francisco Golf Club and Olympic Club wells that are located along the San Francisco-San Mateo County line and between proposed wells for the two SFPUC projects.

Pumping capacity reductions from the combined projects were estimated to be 9 percent for the San Francisco Golf Club well and 9 percent for the Olympic Golf Club wells. The cumulative project pumping capacity for Lake Merced Golf Club Well 3 was estimated to decrease by 10 to 30%, primarily due to GSR pumping effects.

As discussed by LSCE (2012) for the SFGW Supply project, where groundwater use from third-party wells has been replaced by recycled water (e.g., golf clubs), mutual interference between high capacity irrigation supply wells no longer occurs (except possibly to a small degree when groundwater is used to supplement the recycled water source). As a result, it is likely that the estimated effects on capacities for some wells will be partially offset by less use of the golf club wells. Additionally, it should be noted that the reductions in well capacities have been evaluated based on the well construction features and the characteristics of the head-capacity relationships of the well pumps. As such, the influences may be eliminated when pumps eventually are replaced (due to normal wear and tear) and the increased drawdown is factored into pump sizing. Therefore, the reductions in well capacities are generally classified as an operational issue, one that is common where multiple pumpers co-exist in a groundwater basin setting.

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Table 1. Well Inventory

Well Name	Current Well Name and Use	Future Use of Well	Top of Screen (feet bgs)	Pump Test Duration (hours)	Pump Test Q/s (gpm/feet)
Holy Cross 1	Primary Well	Secondary Well	368	4	10.8
				0.5	19.7
				0.5	19.7
				0.5	17.9
				0.5	17.8
Holy Cross 4	Replacement Well	Primary Well	420	1.5	6.0
California Golf Club 7	Secondary Well	Secondary Well	255	24	2.9
California Golf Club 8	Primary Well	Primary Well	320	24	15.1
				?	20.5
Woodlawn	Primary Well	Primary Well	275	3.33	17.5
Woodlawn	Backup well	Backup well			
Cypress Lawn 3	Not Available	Assumed to be secondary well	191	121.5	7.5
Cypress Lawn 4	Not Available	Assumed to be primary well	330	9	5.5
				0.5	2.9
Italian Cemetery	Primary Well	Primary Well	300	4	4.8
				0.5	4.0
				0.5	6.8
				0.5	10.2
				0.5	6.1
Home of Peace	Was Primary Well	To be abandoned	224	27	19.2
				0.5	11.9
				0.5	32.7
				0.5	13.2
				0.5	6.3
Will serve Home of Peace, Hills of Eternity, and Salem	Replacement well	Primary Well	400		
Hills of Eternity	Was Secondary Well	Back-up Well	224	108	16.8
	Now Primary Well			0.5	4.0
				0.5	5.1
				0.5	17.6
				0.5	6.2
Eternal Home	Primary Well	Primary Well	280	48	7.1
				0.5	5.5
				0.5	15.8
				24	7.0
				0.5	9.3
				0.5	9.1
Olivet Memorial	Primary Well	Primary Well	308	24	9.1
Olympic Club	No. 1 (#9)	Active	260	24	17.1
Olympic Club	No. 2 (#8)	Active	200	4	15.4
SF Golf Club	No. 1 (East)	Inactive	200		
SF Golf Club	No. 2 (West)	Active	360	1	6.1
LMGC	No. 3	Active	294	8	10.5

Notes: bgs = below ground surface; gpm = gallons per minutes; Q = discharge/pumping rate;
Q/s = discharge/foot of drawdown; SF = San Francisco; LMGC = Lake Merced Golf Club

Table 2. Groundwater Level Measurements

Cemetery Well Number	Well Name	Date	Approximate G.E. R.P. (Feet NGVD 29)	DTW (Feet)	Est. GW Elev. (Feet NGVD 29)
Holy Cross 1	Primary Well	5/13/1986	94	202	-108
		5/15/1986	94	218	-124
		1/5/1989	94	203.08	-109
		2/8/1989	94	202.34	-108
		3/15/1989	94	201.61	-108
		4/25/1989	94	202.6	-109
		5/31/1989	94	212.78	-119
		7/7/1989	94	214.68	-121
		8/16/1989	94	217.2	-123
		9/19/1989	94	209.92	-116
		10/27/1989	94	207.68	-114
		11/21/1989	94	207.29	-113
		12/7/1989	94	205.48	-111
		2/7/1990	94	204.2	-110
		3/6/1990	94	204.91	-111
		4/5/1990	94	205.51	-112
		5/1/1990	94	213	-119
		6/5/1990	94	213.97	-120
		7/2/1990	94	214.94	-121
		8/1/1990	94	215.76	-122
		9/5/1990	94	216.62	-123
		10/10/1990	94	213.99	-120
		11/6/1990	94	214.04	-120
		12/4/1990	94	208.08	-114
		2/5/1991	94	204.63	-111
		11/24/1998	94	238	-144
		1/18/1999	94	224	-130
		5/18/1999	94	237.4	-143
		2/7/2000	94	237	-143
		6/26/2000	94	255.7	-162
		3/13/2001	94	236	-142
		3/8/2010	94	199.7	-106
Holy Cross 3	Secondary Well	9/16/1960	138	192	-54
		12/21/1998	138	262	-124
		5/18/1999	138	232	-94
		2/9/2000	138	233.7	-96
		6/26/2000	138	250.5	-113
		3/13/2001	138	264	-126
		8/7/2003	138	262.32	-124
		9/11/2009	138	244.81	-107
		3/8/2010	138	230.63	-93
Holy Cross 2	Emergency Well	11/24/1998	127	238	-111
		5/18/1999	127	238	-111
		2/7/2000	127	252	-125
		6/26/2000	127	264	-137
		3/13/2001	127	252.3	-125
		9/11/2009	127	216.26	-89
		3/8/2010	127	204.73	-78
Holy Cross 4	Replacement Well	11/7/2008	114	232	-118
		9/11/2009	114	243.4	-129
		3/8/2010	114	221.13	-107
Cypress Lawn	Unknown	11/24/1998		223	
		7/8/1999		223	
Cypress Lawn	Unknown	11/25/1998		272	
		7/8/1999		233	
		3/13/2001		272	

Cemetery Well Number	Well Name	Date	Approximate G.E. R.P. (Feet NGVD 29)	DTW (Feet)	Est. GW Elev. (Feet NGVD 29)
Cypress Lawn	Unknown	8/2/1989		228	
		12/3/1998		223	
		7/8/1999		234	
Italian	Primary	4/19/1994	159	300	-141
		4/16/1999	159	276	-117
		7/8/1999	159	276	-117
		12/8/1999	159	295	-136
		6/27/2000	159	300.5	-142
		3/13/2001	159	294	-135
		1/22/2010	159	256.60	-98
Home of Peace		6/16/1998	128	239	-111
		7/8/1999	128	227	-99
		2/9/2000	128	227.9	-100
		6/27/2000	128	229.6	-102
		3/13/2001	128	234	-106
Hills of Eternity		5/15/1985	124	226	-102
		10/15/1996	124	244	-120
		12/16/1996	124	238	-114
		2/11/1999	124	238	-114
		7/8/1999	124	238	-114
		2/9/2000	124	240.3	-116
		6/27/2000	124	253	-129
		3/13/2001	124	242	-118
		10/26/2006	124	224	-100
		10/29/2007	124	214	-90
Eternal Home	Primary	2/15/1978	128	223	-95
		4/8/1999	128	253	-125
		7/15/1999	128	253	-125
		2/9/2000	128	259.5	-132
		6/27/2000	128	265	-137
		3/13/2001	128	261.4	-133
		2/4/2010	128	225.00	-97
Olivet		6/16/1998	150	269	-119
		7/8/1999	150	269	-119
Woodlawn	Primary Well	5/26/1982	135	227.8	-93
		8/6/2008		234.13	-234
		1/22/2010	135	220.00	-85
CGC 5		11/19/1966	53	159	-106
		1/30/1989	53	193.2	-140
		2/23/1989	53	196.3	-143
		11/17/2009	53	186.57	-134
CGC 6		8/8/1984	52	211.5	-160
		1/25/1989		183.8	-184
		11/17/2009	52	173.22	-121
CGC 7		3/14/1994	78	231.68	-154
		11/17/2009	78	NM	
					0
CGC 8		4/24/2001	61	235	-174
		10/26/2006	61	212	-151
		11/17/2009	61	213.85	-153
Olympic Club No. 1		7/9/2001		120	
		11/21/2008		101.76	
Olympic Club No. 2		11/12/1994		99.46	

Cemetery Well Number	Well Name	Date	Approximate G.E. R.P. (Feet NGVD 29)	DTW (Feet)	Est. GW Elev. (Feet NGVD 29)
SF Golf Club No. 1		4/24/1951	143.02	60.02	83.00
		4/5/1990	143.02	176.92	-33.90
		5/2/1990	143.02	178.07	-35.05
		6/5/1990	143.02	177.00	-33.98
		7/2/1990	143.02	178.84	-35.82
		8/1/1990	143.02	178.27	-35.25
		12/4/1990	143.02	178.42	-35.40
		2/5/1991	143.02	177.87	-34.85
		5/1/1991	143.02	178.42	-35.40
		9/17/1991	143.02	179.29	-36.27
		2/4/1992	143.02	178.42	-35.40
SF Golf Club No. 2		8/8/1985	139.10	210	-70.90
		1/5/1989	139.10	192.00	-52.90
		2/8/1989	139.10	190.47	-51.37
		3/20/1989	139.10	192.76	-53.66
		4/25/1989	139.10	202.34	-63.24
		10/25/1989	139.10	200.20	-61.10
		2/7/1990	139.10	198.06	-58.96
		3/6/1990	139.10	198.82	-59.72
		5/2/1990	139.10	213.26	-74.16
		8/1/1990	139.10	210.72	-71.62
		9/5/1990	139.10	203.81	-64.71
		10/10/1990	139.10	203.13	-64.03
		11/6/1990	139.10	203.09	-63.99
		11/1/1993	139.10	211	-71.90

Notes: CGC = California Golf Club; DTW = depth to water; R.P. = Reference Point (ground surface)
G.E. = Google Earth

Table 3. Pump Data

Cemetery Well Number	Well Name	Pump Type	Brand and Model	Horsepower	Capacity/Head Rating	Pump Setting Depth	Top Screen (feet bgs)	1999-2001 Q Range (gpm)	1999-2001 SWL Range (feet bgs)	1999-2001 PWL Range (feet bgs)	1999-2001 Q/s Range (gpd/ft)	2010 SWL (feet bgs)	Other Spec. Cap. Data and Date
Holy Cross 1	Primary Well	Submersible	Bryon Jackson/ 11MQH/12 Stage	200	800 gpm/ 700 ft.	340	368	725-760	236-256	276-296	17.8-19.7	200	10.8 @ 800 gpm (1986)
Holy Cross 4	Replacement Well	Submersible	Byron Jackson / 12EML/ 12 Stage	200	800 gpm/720 ft.	395	420	NA	NA	NA	NA	221	6.0 @ 950 gpm (2008)
Italian	Primary (only) Well	Submersible	Byron Jackson/ 8MQL/ 14 Stage	40	260 gpm/420 ft.	450	300	258-263	276-301	326-340	4.0-10.2	257	4.8 @300 gpm (1994)
Home of Peace	Abandoned						223	166-175	227-234	233-262	6.3-32.7	NA	19.2 @ 615 gpm (1966)
Home of Peace/Hills of Eternity/Salem	Replacement Well		10EMM/ 11 Stage		600 gpm/470 ft.	Unknown	400	NA	NA	NA	NA	240	11.6 @ 800 gpm (2010)
Hills of Eternity	Secondary	Submersible	Goulds/ VIS-T/ 8 Stage	40	235 gpm/500 ft.	305	224	170-181	238-253	263-280	4.0-17.6	NA	16.8 @ 505 gpm (1965)
Eternal Home	Primary (only) Well	Submersible	Byron Jackson/ 7MQH/ 20 Stage	30	Unknown	Unknown	280	155-200	253-265	270-287	5.5-15.8	225	7.1 @ 640 gpm (1978)
Olivet	Primary (only) Well	Submersible	Byron Jackson/ 8MQH/ 19 Stage	75	300 gpm/640 ft.	415	308	NA	267 (3/13/02)	320 (3/13/02)	NA	NA	9.1 @ 480 gpm (2002)
Woodlawn	Primary Well	Submersible	Byron Jackson/ 10MQH/ 6 Stage	50	500 gpm/300 ft.	350	275	550 (1982)	250 (1982)	281 (1982)	NA	220	17.5 @ 550 gpm (1982)
Woodlawn	Backup Well	Submersible		40	375 gpm/275 ft.		NA	NA	NA	NA	NA	NA	NA
Cypress Lawn 4	Primary	NA	NA	NA	NA	NA	330	600 (1989)	228 (1989)	338 (1989)	NA	NA	5.5 @600 gpm (1989)
Cypress Lawn 3	Secondary	NA	NA	NA	NA	NA							
California Golf Club 8	Primary Well		11MQL/ 9 Stage		800 gpm/ 400 ft.		320	800 (2001)	235 (2001)	288 (2001)	15.1 (2001)	214 (2009)	
California Golf Club 7	Secondary Well	NA	7MQH/15 Stage	30	200 gpm/350 ft.	NA	255	200 (1994)	232 (1994)	301 (1994)	NA	NA	2.9 @ 200 gpm (1994)
Lake Merced Golf Club 3	Primary (only active) Well	NA	NA	NA	NA	NA	294	800 (1986)	217 (1986)	293 (1986)	NA	NA	10.5 @ 800 gpm (1986)
Olympic 1 (No. 9)	Primary Well	Vertical Line Shaft Turbine	Byron Jackson/ 10GH/ 6 Stage	NA	700 gpm/276 ft.	250	260	NA	NA	NA	17.1	NA	NA
Olympic 2 (No. 8)	Primary Well	Vertical Line Shaft Turbine	Byron Jackson/ 11MQH/ 4 Stage	NA	1000/ 216 ft.	270	200	NA	NA	NA	15.4	NA	NA
San Francisco Golf Club 2	Primary Well	Vertical Line Shaft Turbine	Byron Jackson/ 10MQH/ 11 Stage	NA	700 gpm/ 390 ft.	350	360	NA	NA	NA	NA	NA	6.1 @ 700 gpm (1985)

Notes: gpm = gallons per minute; ft = feet; NA = Not Available; Q = discharge/pumping rate; Spec. Cap. = Specific Capacity (Q/s)

Table 4. Eternal Home Cemetery Well Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	ET Well DTW (Feet)	ET Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	ET Well SWL (Feet bgs)	ET Well GWE (Feet NGVD 29)	ET Well Background DTW (Feet)	ET Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 2 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)
1	put	214.2	-86.2	27,742				225.8	-97.8	-81.2	-88.2
2	put	205.6	-77.6	33,925				226.5	-98.5	-73.9	-80.9
3	put	197.0	-69.0	40,108				227.3	-99.3	-68.6	-75.3
4	put	188.4	-60.4	46,291				228.0	-100.0	-66.8	-72.1
5	put	179.8	-51.8	52,475				228.8	-100.8	-61.6	-67.8
6	put	171.2	-43.2	58,658				229.5	-101.5	-58.6	-64.3
7	Put/Hold	169.1	-41.1	60,500				230.3	-102.3	-56.2	-62.2
8	Hold	169.9	-41.9	60,500				231.0	-103.0	-52.0	-63.2
9	Hold/Take	173.6	-45.6	58,475				231.8	-103.8	-61.9	-78.7
10	take	186.5	-58.5	50,375	41	227.5	-99.5	232.5	-104.5	-74.3	-101.3
11	Take/Put	194.1	-66.1	45,858	49	243.1	-115.1	233.3	-105.3	-80.2	-104.9
12	put	185.5	-57.5	52,042				234.0	-106.0	-77.0	-93.5
13	put	176.9	-48.9	58,225				234.8	-106.8	-75.0	-88.0
14	Put/Hold	174.2	-46.2	60,430				235.5	-107.5	-70.8	-82.8
15	Hold	175.0	-47.0	60,430				236.3	-108.3	-70.4	-83.0
16	Hold	175.7	-47.7	60,430				237.0	-109.0	-69.7	-82.5
17	Hold	176.5	-48.5	60,430				237.8	-109.8	-69.5	-83.0
18	Hold	177.2	-49.2	60,430				238.5	-110.5	-69.1	-83.1
19	Hold	178.0	-50.0	60,430				239.3	-111.3	-69.9	-84.0
20	Hold	178.7	-50.7	60,430				240.0	-112.0	-70.6	-85.0
21	Hold	179.5	-51.5	60,430				240.8	-112.8	-72.6	-87.4
22	Hold	180.2	-52.2	60,430				241.5	-113.5	-72.6	-87.8
23	Hold	181.0	-53.0	60,430				242.3	-114.3	-71.8	-87.1
24	Hold	181.7	-53.7	60,430				243.0	-115.0	-71.7	-87.4
25	Hold/Take	185.5	-57.5	58,405				243.8	-115.8	-78.9	-101.6
26	take	198.4	-70.4	50,305	41	239.4	-111.4	244.5	-116.5	-91.7	-123.8
27	take/put	205.9	-77.9	45,788	49	254.9	-126.9	245.3	-117.3	-97.5	-125.9
28	put	197.3	-69.3	51,972				246.0	-118.0	-95.0	-115.0
29	put	188.7	-60.7	58,155				246.8	-118.8	-89.7	-106.7
30	Put/Hold	186.1	-58.1	60,360				247.5	-119.5	-86.2	-101.6
31	Hold	186.8	-58.8	60,360				248.3	-120.3	-78.7	-96.4
32	Hold	187.6	-59.6	60,360				249.0	-121.0	-80.3	-95.2
33	Hold	188.3	-60.3	60,360				249.8	-121.8	-81.2	-96.1
34	Hold	189.1	-61.1	60,360				250.5	-122.5	-79.9	-95.7
35	Hold	189.8	-61.8	60,360				251.3	-123.3	-78.8	-95.2
36	hold/take	193.6	-65.6	58,335				252.0	-124.0	-86.4	-108.9
37	take	206.5	-78.5	50,235	41	247.5	-119.5	252.8	-124.8	-98.6	-130.3
38	take	219.4	-91.4	42,135	49	268.4	-140.4	253.5	-125.5	-105.3	-143.6
39	take	232.3	-104.3	34,035	57	289.3	-161.3	254.3	-126.3	-121.2	-158.9
40	take	245.2	-117.2	25,935	65	310.2	-182.2	255.0	-127.0	-131.3	-171.4
41	take	258.1	-130.1	17,835	68	326.1	-198.1	255.8	-127.8	-142.3	-183.9
42	take	271.0	-143.0	9,735	72	343.0	-215.0	256.5	-128.5	-158.1	-201.4
43	take	283.9	-155.9	1,635	75	358.9	-230.9	257.3	-129.3	-185.8	-224.8
44	take/hold/put	285.4	-157.4	1,168	76	361.4	-233.4	258.0	-130.0	-179.1	-209.7
45	put	276.8	-148.8	7,352				258.8	-130.8	-163.8	-188.4
46	put	268.2	-140.2	13,535				259.5	-131.5	-152.1	-171.4
47	put	259.6	-131.6	19,718				260.3	-132.3	-144.4	-160.1

Assumptions:
1) Put Rate of 5.52 MGD results in 8.6 feet/year increase in groundwater levels in Colma area
2) Take Rate of 7.23 MGD results in 12.9 feet/year decrease in groundwater levels in Colma area
3) Hold Year results in 0.75 feet/year decrease in groundwater levels in Colma area
4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.
Notes: DTW = depth to water; ET = Eternal Home; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table 5. Analysis of Well Pump Capacities for GSR Project and Cumulative Project

Well	Top of Screen (feet bgs)	Spring 2001 DTW (feet)	2010 DTW (feet)	Pump Setting Depth (feet bgs)	Capacity/Head Rating	Calculated PWL and Q for 2001 Conditions	Calculated Discharge Head (feet)	Existing Conditions DTW at Year 44 (feet)	PWL and Q for Existing Conditions at Year 44 (feet)	GSR Max DTW (feet)	PWL and Q for GSR Max DTW	Cumulative Design Drought Max DTW (feet)	PWL and Q for Cumulative DD Max DTW
Woodlawn Primary	275	256 (Est.)	220	350	500 gpm/300 ft. (1982 SWL=228 ft.)	450 gpm @ 315 ft.	33	253	450 gpm @ 312 ft.	369	60 gpm @ 405 ft.	NA	NA
Italian	300	294	257	450	260 gpm/420 feet	260 gpm @ 348 ft	72	290	265 gpm @345 ft.	400	145 gpm @ 430 ft.	NA	NA
Eternal Home	280	261	225	NA	200 gpm/460 feet (assumed)	200 gpm @283 ft.	177	258	200 gpm @280 ft.	363	100 gpm @ 374 ft.	NA	NA
Olivet	308	NA	NA	415	300 gpm/640 feet	300 gpm @ 300 ft.	340	264	300 gpm @ 297 ft.	363	180 gpm @ 381 ft.	NA	NA
Home of Peace	400	NA	240	NA	600 gpm/470 feet	600 gpm @ 328 ft.	142	273	600 gpm @ 325 ft.	370	440 gpm @ 406 ft.	NA	NA
Hills of Eternity	224	242	NA	310	235 gpm/500 feet	235 gpm @ 256 ft.	254	239	235 gpm @ 253 ft.	334	135 gpm @ 342 ft.	NA	NA
Holy Cross 1	368	236	200	340	800 gpm/700 feet	800 gpm @ 310 ft.	390	233	800 gpm @ 307 ft	337	625 gpm @ 393 ft.	NA	NA
Holy Cross 4	420	NA	221	395	800 gpm/720 feet	800 gpm @ 389 ft.	331	253	800 gpm @ 386 ft.	352	700 gpm @ 467 ft.	NA	NA
California Golf Club 7	255	235 (Est.)	200 (Est.)	NA	200 gpm/350 feet (1994 SWL=232 ft.)	200 gpm @ 301 ft.	49	233	200 gpm @ 302 ft.	401	45 gpm @ 417 ft.	NA	NA
California Golf Club 8	320	236	200 (Est.)	NA	800 gpm/400 feet	800 gpm @ 289 ft.	111	233	800 gpm @ 286 ft.	402	475 gpm @ 433 ft.	NA	NA
Olympic Club 1 (No. 9)	260	115 (Est.)	100	250	700 gpm/276 ft.	700 gpm @ 156 ft.	120	122	685 gpm@ 160 ft	136	660 gpm@ 164 ft	142	640 gpm@ 168 ft
Olympic Club 2 (No. 8)	200	115 (Est.)	100	270	1000 gpm/ 216 ft	1000 gpm @ 180 ft.	36	122	970 gpm@ 185 ft	136	935 gpm@ 195 ft	142	910 gpm@ 200 ft
San Francisco Golf Club 2	360	180 (Est.)	160 (Est.)	350	700 gpm/ 390 ft.	675 gpm @ 218 ft.	186	182	675 gpm@ 217 ft	196	660 gpm@ 228 ft	202	655 gpm@ 230 ft

Notes: DTW = depth to water; gpm = gallons per minute; PWL = pumping water level; Q = discharge/pumping rate; ft = feet

2001 DTW and 2010 DTW for Olympic Club and San Francisco Golf Clubs are estimated (i.e., not measured)

Table 6. California Golf Club Well 8 Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	CGC8 Well DTW (Feet)	CGC8 Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	CGC8 Well SWL (Feet bgs)	CGC8 Well GWE (Feet NGVD 29)	CGC8 Well Background DTW (Feet)	CGC8 Well Background GWE (Feet NGVD 29)	GW Model SC 2-Lay 3 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 5 GWE (Feet NGVD 29)
1	put	189.4	-128.4	27,742				200.8	-139.8	-87.9	-130.7	-133.9
2	put	180.9	-119.9	33,925				201.5	-140.5	-84.6	-125.6	-128.0
3	put	172.4	-111.4	40,108				202.3	-141.3	-81.0	-120.4	-122.5
4	put	163.9	-102.9	46,291				203.0	-142.0	-78.5	-116.8	-119.5
5	put	155.4	-94.4	52,475				203.8	-142.8	-75.1	-112.1	-114.4
6	put	146.9	-85.9	58,658				204.5	-143.5	-72.3	-108.3	-110.8
7	Put/Hold	144.8	-83.8	60,500				205.3	-144.3	-73.3	-117.7	-121.7
8	Hold	145.6	-84.6	60,500				206.0	-145.0	-74.5	-124.3	-125.7
9	Hold/Take	150.8	-89.8	58,475				206.8	-145.8	-81.1	-140.5	-144.9
10	take	169.3	-108.3	50,375	43	212.3	-151.3	207.5	-146.5	-94.6	-169.5	-174.1
11	Take/Put	181.0	-120.0	45,858	50	231.0	-170.0	208.3	-147.3	-107.1	-183.7	-186.6
12	put	172.5	-111.5	52,042				209.0	-148.0	-103.0	-166.9	-170.2
13	put	164.0	-103.0	58,225				209.8	-148.8	-96.3	-153.2	-156.1
14	Put/Hold	161.4	-100.4	60,430				210.5	-149.5	-92.7	-152.8	-156.7
15	Hold	162.2	-101.2	60,430				211.3	-150.3	-93.9	-157.5	-161.6
16	Hold	162.9	-101.9	60,430				212.0	-151.0	-95.3	-160.9	-165.3
17	Hold	163.7	-102.7	60,430				212.8	-151.8	-96.5	-163.9	-168.1
18	Hold	164.4	-103.4	60,430				213.5	-152.5	-97.5	-166.1	-170.2
19	Hold	165.2	-104.2	60,430				214.3	-153.3	-99.0	-169.0	-173.3
20	Hold	165.9	-104.9	60,430				215.0	-154.0	-100.3	-171.4	-175.6
21	Hold	166.7	-105.7	60,430				215.8	-154.8	-101.5	-173.7	-177.4
22	Hold	167.4	-106.4	60,430				216.5	-155.5	-103.1	-176.1	-180.2
23	Hold	168.2	-107.2	60,430				217.3	-156.3	-103.8	-177.3	-181.4
24	Hold	168.9	-107.9	60,430				218.0	-157.0	-104.4	-178.6	-182.7
25	Hold/Take	174.1	-113.1	58,405				218.8	-157.8	-106.5	-186.9	-191.3
26	take	192.6	-131.6	50,305	43	235.6	-174.6	219.5	-158.5	-118.1	-211.5	-216.1
27	take/put	204.3	-143.3	45,788	50	254.3	-193.3	220.3	-159.3	-129.0	-221.7	-224.9
28	put	195.8	-134.8	51,972				221.0	-160.0	-123.8	-202.5	-206.0
29	put	187.3	-126.3	58,155				221.8	-160.8	-115.0	-184.8	-187.6
30	Put/Hold	184.7	-123.7	60,360				222.5	-161.5	-110.4	-182.5	-186.1
31	Hold	185.5	-124.5	60,360				223.3	-162.3	-107.3	-180.4	-181.9
32	Hold	186.2	-125.2	60,360				224.0	-163.0	-108.9	-183.1	-186.9
33	Hold	187.0	-126.0	60,360				224.8	-163.8	-110.2	-185.8	-190.3
34	Hold	187.7	-126.7	60,360				225.5	-164.5	-110.1	-186.1	-190.1
35	Hold	188.5	-127.5	60,360				226.3	-165.3	-109.9	-186.2	-189.7
36	hold/take	193.7	-132.7	58,335				227.0	-166.0	-112.6	-194.9	-199.7
37	take	212.2	-151.2	50,235	43	255.2	-194.2	227.8	-166.8	-123.9	-219.1	-224.3
38	take	230.7	-169.7	42,135	50	280.7	-219.7	228.5	-167.5	-133.9	-237.7	-240.6
39	take	249.2	-188.2	34,035	57	306.2	-245.2	229.3	-168.3	-147.5	-258.6	-264.1
40	take	267.7	-206.7	25,935	64	331.7	-270.7	230.0	-169.0	-157.3	-273.7	-279.2
41	take	286.2	-225.2	17,835	67	353.2	-292.2	230.8	-169.8	-166.4	-287.3	-293.0
42	take	304.7	-243.7	9,735	70	374.7	-313.7	231.5	-170.5	-174.0	-298.7	-304.1
43	take	323.2	-262.2	1,635	73	396.2	-335.2	232.3	-171.3	-181.4	-309.0	-314.1
44	take/hold/put	326.0	-265.0	1,168	74	400.0	-339.0	233.0	-172.0	-182.7	-296.3	-300.0
45	put	317.5	-256.5	7,352				233.8	-172.8	-171.8	-269.2	-272.7
46	put	309.0	-248.0	13,535				234.5	-173.5	-159.4	-245.3	-248.0
47	put	300.5	-239.5	19,718				235.3	-174.3	-148.9	-226.2	-228.8

Assumptions:
1) Put Rate of 5.52 MGD results in 8.5 feet/year increase in groundwater levels in CGC area
2) Take Rate of 7.23 MGD results in 18.5 feet/year decrease in groundwater levels in CGC area
3) Hold Year results in 0.75 feet/year decrease in groundwater levels in CGC area
4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.
Notes: DTW = depth to water; CGC = California Golf Club; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table 7. Lake Merced Golf Club Well 3 Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	LMGC3 DTW (Feet)	LMGC3 GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	LMGC3 SWL (Feet bgs)	LMGC3 GWE (Feet NGVD 29)	LMGC3 Background DTW (Feet)	LMGC3 Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 2 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 3 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)
1	put	224.9	-70.9	27,742				238.8	-84.8	-45.9	-46.4	-48.9
2	put	214.4	-60.4	33,925				239.5	-85.5	-36.3	-37.1	-40.6
3	put	203.9	-49.9	40,108				240.3	-86.3	-30.8	-31.5	-34.6
4	put	193.4	-39.4	46,291				241.0	-87.0	-26.7	-27.5	-30.4
5	put	182.9	-28.9	52,475				241.8	-87.8	-23.8	-24.5	-27.4
6	put	172.4	-18.4	58,658				242.5	-88.5	-21.3	-22.0	-24.7
7	Put/Hold	169.7	-15.7	60,500				243.3	-89.3	-26.2	-28.5	-35.9
8	Hold	170.5	-16.5	60,500				244.0	-90.0	-31.9	-34.2	-42.5
9	Hold/Take	174.8	-20.8	58,475				244.8	-90.8	-41.7	-45.7	-58.2
10	take	189.8	-35.8	50,375	29	218.8	-64.8	245.5	-91.5	-56.0	-60.5	-75.6
11	Take/Put	198.4	-44.4	45,858	35	233.4	-79.4	246.3	-92.3	-60.5	-62.2	-69.7
12	put	187.9	-33.9	52,042				247.0	-93.0	-50.6	-51.0	-53.5
13	put	177.4	-23.4	58,225				247.8	-93.8	-44.5	-44.9	-47.3
14	Put/Hold	174.1	-20.1	60,430				248.5	-94.5	-45.1	-47.2	-54.5
15	Hold	174.8	-20.8	60,430				249.3	-95.3	-49.0	-51.3	-59.1
16	Hold	175.6	-21.6	60,430				250.0	-96.0	-50.4	-52.8	-60.9
17	Hold	176.3	-22.3	60,430				250.8	-96.8	-53.0	-55.1	-62.8
18	Hold	177.1	-23.1	60,430				251.5	-97.5	-53.4	-55.6	-63.5
19	Hold	177.8	-23.8	60,430				252.3	-98.3	-54.7	-56.7	-64.4
20	Hold	178.6	-24.6	60,430				253.0	-99.0	-55.9	-57.9	-65.4
21	Hold	179.3	-25.3	60,430				253.8	-99.8	-57.5	-59.4	-67.3
22	Hold	180.1	-26.1	60,430				254.5	-100.5	-56.5	-58.7	-66.9
23	Hold	180.8	-26.8	60,430				255.3	-101.3	-55.5	-57.7	-65.9
24	Hold	181.6	-27.6	60,430				256.0	-102.0	-56.6	-58.7	-66.6
25	Hold/Take	185.9	-31.9	58,405				256.8	-102.8	-62.9	-66.6	-79.0
26	take	200.9	-46.9	50,305	29	229.9	-75.9	257.5	-103.5	-74.5	-78.8	-94.2
27	take/put	209.5	-55.5	45,788	35	244.5	-90.5	258.3	-104.3	-77.0	-78.7	-86.3
28	put	199.0	-45.0	51,972				259.0	-105.0	-65.7	-65.9	-68.5
29	put	188.5	-34.5	58,155				259.8	-105.8	-56.3	-56.7	-59.7
30	Put/Hold	185.2	-31.2	60,360				260.5	-106.5	-56.1	-58.2	-65.8
31	Hold	185.9	-31.9	60,360				261.3	-107.3	-57.0	-59.4	-68.1
32	Hold	186.7	-32.7	60,360				262.0	-108.0	-56.3	-58.7	-67.4
33	Hold	187.4	-33.4	60,360				262.8	-108.8	-57.5	-59.7	-67.8
34	Hold	188.2	-34.2	60,360				263.5	-109.5	-58.3	-60.3	-68.8
35	Hold	188.9	-34.9	60,360				264.3	-110.3	-58.1	-60.2	-69.0
36	hold/take	193.2	-39.2	58,335				265.0	-111.0	-64.5	-68.3	-81.1
37	take	208.2	-54.2	50,235	29	237.2	-83.2	265.8	-111.8	-76.4	-80.9	-96.0
38	take	223.2	-69.2	42,135	35	258.2	-104.2	266.5	-112.5	-85.5	-89.8	-105.8
39	take	238.2	-84.2	34,035	41	279.2	-125.2	267.3	-113.3	-96.6	-100.9	-116.1
40	take	253.2	-99.2	25,935	47	300.2	-146.2	268.0	-114.0	-106.4	-110.7	-126.1
41	take	268.2	-114.2	17,835	49	317.2	-163.2	268.8	-114.8	-115.3	-119.9	-135.8
42	take	283.2	-129.2	9,735	52	335.2	-181.2	269.5	-115.5	-127.6	-132.3	-148.7
43	take	298.2	-144.2	1,635	54	352.2	-198.2	270.3	-116.3	-143.3	-148.8	-166.3
44	take/hold/put	299.7	-145.7	1,168	56	355.7	-201.7	271.0	-117.0	-140.4	-141.3	-148.4
45	put	289.2	-135.2	7,352				271.8	-117.8	-121.1	-120.7	-123.3
46	put	278.7	-124.7	13,535				272.5	-118.5	-105.1	-105.0	-108.2
47	put	268.2	-114.2	19,718				273.3	-119.3	-91.4	-91.8	-95.7

Assumptions:

1) Put Rate of 5.52 MGD results in 10.5 feet/year increase in groundwater levels in LMGC area
2) Take Rate of 7.23 MGD results in 15.0 feet/year decrease in groundwater levels in LMGC area
3) Hold Year results in 0.75 feet/year decrease in groundwater levels in LMGC area
4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.

Notes: DTW = depth to water; LMGC = Lake Merced Golf Club; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table 8. Olympic Golf Club Well 1 (#9) Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	Oly1 Well DTW (Feet)	Oly1 Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	Oly1 Well SWL (Feet bgs)	Oly1 Well GWE (Feet NGVD 29)	Oly1 Well Background DTW (Feet)	Oly1 Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 3 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)
1	put	95.5	-20.5	27,742				100.5	-25.5	-8.8	-21.1
2	put	91.9	-16.9	33,925				101.0	-26.0	-4.1	-16.5
3	put	88.3	-13.3	40,108				101.5	-26.5	-0.8	-12.0
4	put	84.7	-9.7	46,291				102.0	-27.0	1.3	-9.0
5	put	81.1	-6.1	52,475				102.5	-27.5	2.6	-6.7
6	put	77.5	-2.5	58,658				103.0	-28.0	3.6	-5.2
7	Put/Hold	76.8	-1.8	60,500				103.5	-28.5	3.4	-5.9
8	Hold	77.3	-2.3	60,500				104.0	-29.0	0.9	-9.6
9	Hold/Take	78.6	-3.6	58,475				104.5	-29.5	-2.4	-13.1
10	take	82.6	-7.6	50,375	7	89.6	-14.6	105.0	-30.0	-8.8	-21.6
11	Take/Put	84.7	-9.7	45,858	12	96.7	-21.7	105.5	-30.5	-13.2	-28.0
12	put	81.1	-6.1	52,042				106.0	-31.0	-10.9	-23.6
13	put	77.5	-2.5	58,225				106.5	-31.5	-9.1	-20.3
14	Put/Hold	76.5	-1.5	60,430				107.0	-32.0	-8.1	-19.2
15	Hold	77.0	-2.0	60,430				107.5	-32.5	-9.2	-21.5
16	Hold	77.5	-2.5	60,430				108.0	-33.0	-9.4	-22.7
17	Hold	78.0	-3.0	60,430				108.5	-33.5	-10.0	-23.5
18	Hold	78.5	-3.5	60,430				109.0	-34.0	-9.9	-24.1
19	Hold	79.0	-4.0	60,430				109.5	-34.5	-9.9	-24.1
20	Hold	79.5	-4.5	60,430				110.0	-35.0	-10.3	-24.5
21	Hold	80.0	-5.0	60,430				110.5	-35.5	-11.4	-25.3
22	Hold	80.5	-5.5	60,430				111.0	-36.0	-10.6	-25.6
23	Hold	81.0	-6.0	60,430				111.5	-36.5	-9.7	-24.9
24	Hold	81.5	-6.5	60,430				112.0	-37.0	-10.0	-24.7
25	Hold/Take	82.9	-7.9	58,405				112.5	-37.5	-11.9	-25.9
26	take	86.9	-11.9	50,305	7	93.9	-18.9	113.0	-38.0	-17.5	-32.8
27	take/put	89.0	-14.0	45,788	12	101.0	-26.0	113.5	-38.5	-20.7	-38.1
28	put	85.4	-10.4	51,972				114.0	-39.0	-17.4	-32.5
29	put	81.8	-6.8	58,155				114.5	-39.5	-14.0	-27.8
30	Put/Hold	80.8	-5.8	60,360				115.0	-40.0	-12.6	-25.7
31	Hold	81.3	-6.3	60,360				115.5	-40.5	-12.1	-26.6
32	Hold	81.8	-6.8	60,360				116.0	-41.0	-10.7	-26.3
33	Hold	82.3	-7.3	60,360				116.5	-41.5	-10.1	-25.6
34	Hold	82.8	-7.8	60,360				117.0	-42.0	-10.6	-25.6
35	Hold	83.3	-8.3	60,360				117.5	-42.5	-10.5	-25.9
36	hold/take	84.7	-9.7	58,335				118.0	-43.0	-11.9	-26.8
37	take	88.7	-13.7	50,235	7	95.7	-20.7	118.5	-43.5	-17.2	-33.4
38	take	92.7	-17.7	42,135	12	104.7	-29.7	119.0	-44.0	-21.9	-39.3
39	take	96.7	-21.7	34,035	15	111.7	-36.7	119.5	-44.5	-27.0	-45.2
40	take	100.7	-25.7	25,935	17	117.7	-42.7	120.0	-45.0	-31.9	-50.9
41	take	104.7	-29.7	17,835	19	123.7	-48.7	120.5	-45.5	-36.6	-56.9
42	take	108.7	-33.7	9,735	21	129.7	-54.7	121.0	-46.0	-42.0	-63.0
43	take	112.7	-37.7	1,635	22	134.7	-59.7	121.5	-46.5	-48.5	-70.6
44	take/hold/put	113.0	-38.0	1,168	23	136.0	-61.0	122.0	-47.0	-50.8	-74.6
45	put	109.4	-34.4	7,352				122.5	-47.5	-45.9	-67.1
46	put	105.8	-30.8	13,535				123.0	-48.0	-40.0	-59.3
47	put	102.2	-27.2	19,718				123.5	-48.5	-34.1	-52.0

Assumptions:
1) Put Rate of 5.52 MGD results in 3.6 feet/year increase in groundwater levels in Olympic Club area
2) Take Rate of 7.23 MGD results in 4.0 feet/year decrease in groundwater levels in the Olympic Club area
3) Hold Year results in 0.5 feet/year decrease in groundwater levels in the Olympic Club area
4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.
Notes: DTW = depth to water; Oly = Olympic Club; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table 9. Summary of Analytical Data Analysis for GSR Project

Well	Top of Screen (Feet bgs)	2001/2010 DTW (Feet)	Existing Conditions Max DTW at Year 44 (Feet)	GSR Design Drought End of Water Year Max DTW at Year 44 (Feet)	GSR Design Drought Max DTW Mid-Year 44 (Feet)	Max Depth Below Existing Conditions (Feet)
Woodlawn Primary	275	NA/220	253	367	369	116
Italian	300	294/257	290	398	400	110
Eternal Home	280	261/225	258	361	363	105
Olivet	308	NA/NA	264	361	363	99
Home of Peace	400	NA/240	273	368	370	97
Hills of Eternity	224	242/NA	239	332	334	95
Cypress 3	191	NA/NA	289	382	384	95
Cypress 4	330	272(?)/NA	232	328	330	98
Holy Cross 4	420	NA/221	253	350	352	99
Holy Cross 1	368	236/200	233	335	337	104
Olympic Club No. 1 (#9)	260	NA/NA	122	135	136	14
Olympic Club No. 2 (#8)	200	NA/NA	122	135	136	14
San Francisco Golf Club No. 2	360	NA/NA	182	194	196	14
Lake Merced Golf Club No. 3	294	NA/NA	271	356	358	87
California Golf Club No. 7	255	NA/NA	233	400	401	168
California Golf Club No. 8	320	235/NA	233	400	402	169

Notes: LMGC = Lake Merced Golf Club; CGC = California Golf Club; NA = Not Available;
bgs = below ground surface; DTW = depth to water

Table 10. Summary of Gross GSR Project Well Interference Drawdown Estimates for Third-Party Wells (feet)[3]

Well I.D.	San Francisco Golf Club Well 2	Olympic Golf Club Wells	Lake Merced Golf Club Well 3
Well CUP-3A (pumping at 400 gpm 7.5 years)	8.2	7.2	10.8
Well CUP-5 (pumping at 300 gpm for 7.5 years)	4.6	5.2	10.4
Well CUP-6 (pumping at 300 gpm for 7.5 years)	4.9	5.4	12.4
Well CUP-7 (pumping at 300 gpm for 7.5 years)	4.4	4.9	10.1
Other GSR Wells[1,2]	NA	NA	12.1
Totals	22	23	56

1. "Other GSR Wells" refers to GSR wells located south of CUP-5, 6, 7.
2. NA means not applicable because other GSR wells are too far away.
3. Gross Drawdown is equal to the difference between "Regional SWL with GSR Project" and "SWL with Local GSR Drawdown" as labeled on Figures 3 through 10.

Table 11. Summary of Net GSR Project Well Interference Drawdown Estimates for Third-Party Wells Compared to Existing Conditions (feet)[1]

Baseline Case	San Francisco Golf Club Well 2	Olympic Golf Club Wells	Lake Merced Golf Club Well 3
Existing Conditions – 20,000 AF beginning SFPUC storage account	14	14	87

1. Net Drawdown is equal to the difference between "SWL Under Existing Conditions without Project" and "SWL with Local GSR Drawdown" as labeled on Figures 3 through 10

Table 12. Summary of SFGW Supply Project Well Interference Drawdown Estimates for Third-Party Wells (feet)

Well I.D.	SF Golf Club[1]	Olympic Golf Club[1]	Lake Merced Golf Club[2]
SFGW Project with 4 Wells (3 MGD)	6	6	4
SFGW Project with 6 Wells (4 MGD)	6	6	4

1. Calculations from LSCE (2012).
2. Calculations made in this TM.

Table 13. Combined Gross GSR and SFGW Supply Project Well Interference Drawdown Estimates for Third-Party Wells (feet)

Well I.D.	SF Golf Club[1]	Olympic Golf Club[1]	Lake Merced Golf Club[1]
GSR and SFGW Project with 4 Wells (3-MGD)	28	29	60
GSR and SFGW Project with 6 Wells (4-MGD)	28	29	60

1. Drawdown estimates are sum of results from Tables 10 and 12.

Table 14. Combined Net GSR and SFGW Supply Project Well Interference Drawdown Estimates for Third-Party Wells (feet)

Well I.D.	SF Golf Club[1]	Olympic Golf Club[1]	Lake Merced Golf Club[1]
GSR and SFGW Project with 4 Wells (3-MGD)	20	20	91
GSR and SFGW Project with 6 Wells (4-MGD)	20	20	91

1. Drawdown estimates are sum of results from Tables 11 and 12.

Table 15. Summary of Analytical Data Analysis for Cumulative GSR and SFGW Projects

Well	Top of Screen (Feet bgs)	Estimated Spring 2001/2010 DTW (Feet)	Existing Conditions Future Scenario Year 44 Max DTW (Feet)	Cumulative Project Future Scenario Year 44 End of Water Year Max DTW (Feet)	Cumulative Project Future Scenario Year 44 Mid-Year Max DTW (Feet)	Cumulative Project Max Depth Below Existing Conditions (Feet)
Olympic Club No. 1 (#9)	260	115/100	122	141	142	20
Olympic Club No. 2 (#8)	200	115/100	122	141	142	20
San Francisco Golf Club No. 2	360	180/160	182	200	202	20
Lake Merced Golf Club No. 3	294	273/238	271	360	362	91

Notes: NA = Not Available; bgs = below ground surface; DTW = depth to water

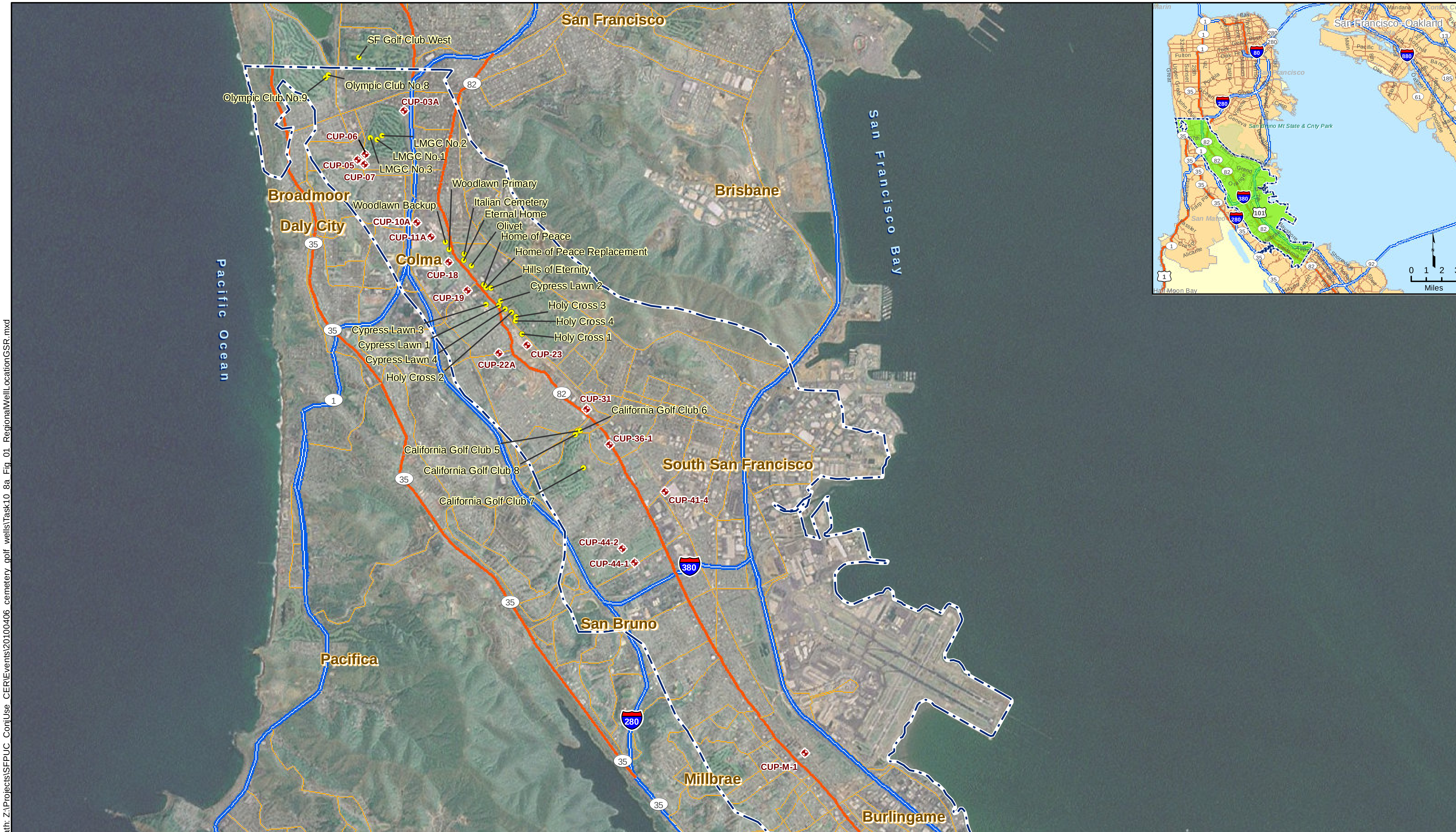
Estimated Spring 2001 DTW for Olympic Club Wells - based upon measured DTW in Olympic Club No. 1 in July 2001 (DTW= 120 feet) and then added 5 feet (115 feet) for presumed higher spring levels
Estimated Spring 2010 DTW for Olympic Club Wells - based upon measured rise in groundwater levels of about 15 feet from 2002 to 2009 observed in LMMW-3D and LMMW-6D (DTW=100 feet)
Estimated Spring 2001/2010 DTW for San Francisco Golf Club Well - personal communication, Jeff Gilman

Table 16. Combined GSR and SFGW Supply Project Well Interference Pumping Capacity Reductions for Third-Party Wells[1]

Well I.D.	SF Golf Club	Olympic Golf Club	Lake Merced Golf Club
Gross GSR and SFGW Project with 6 Wells (4-MGD)	6%	9%	10 –30%
Net GSR and SFGW Project with 6 Wells (4-MGD)	3%	7%	10 –30%

1. Reduction in pumping capacity discharge rates (gpm) are discussed in text where available information allows.

FIGURES



Path: Z:\Projects\SFPUC ConjUse CER\Events\20100406 cemetery golf wells\Task10 8a Fig 01 RegionalWellLocationGSR.mxd

Note:
Cypress Lawn Cemetery well locations are estimated and not based on gps coordinates.
Other well locations are based on site visits and gps coordinates.

Legend

GSR Project Proposed Well

Third Party Well

South Westside Groundwater Basin

0 2,500 5,000

Scale Feet

1 " = 5,000 '

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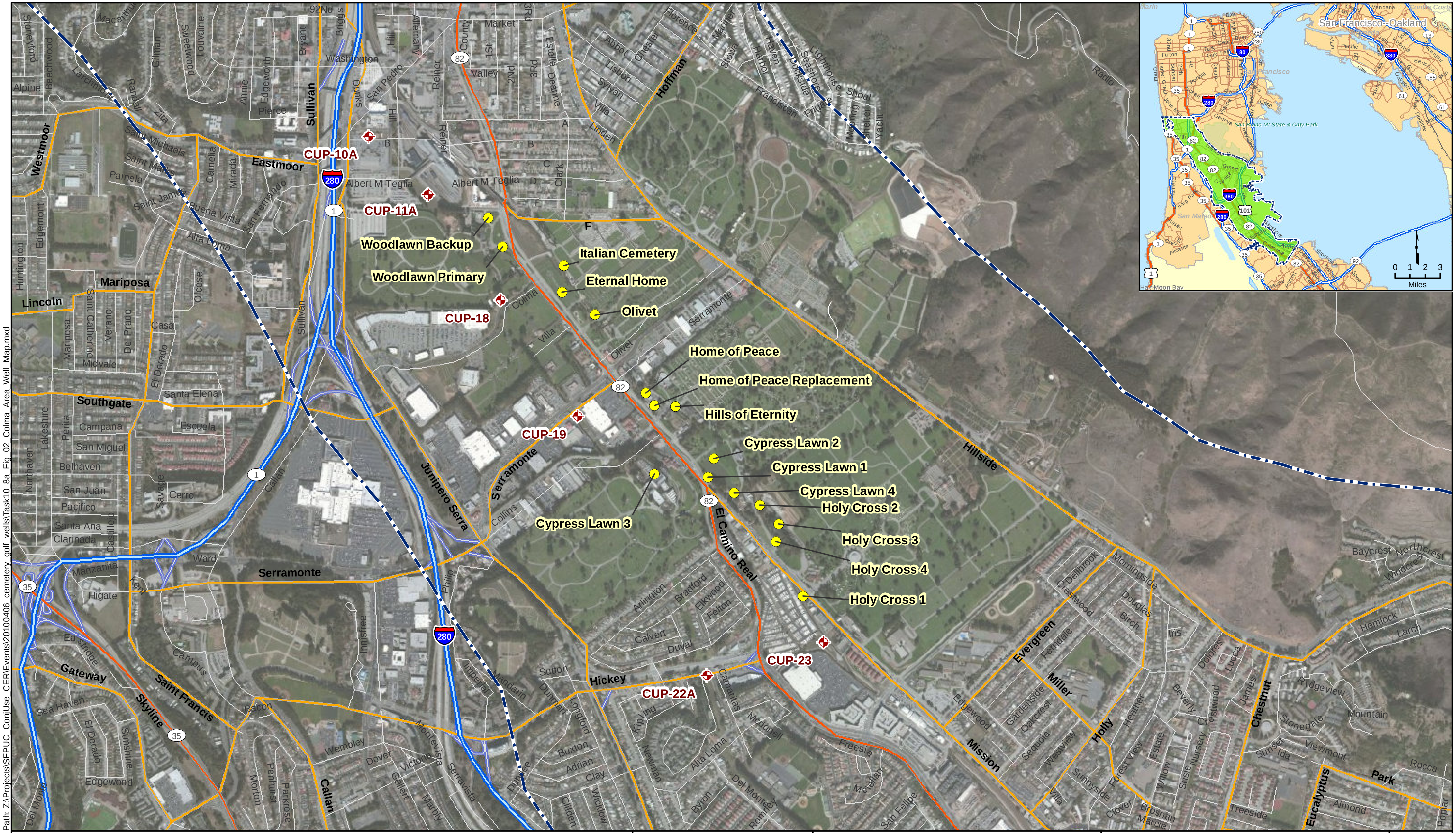
REGIONAL WELL LOCATION MAP FOR GSR PROJECT

FIGURE

1

DATE

April 2012



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Note:
Cypress Lawn Cemetery well locations are estimated and not based on gps coordinates.
Other well locations are based on site visits and gps coordinates.

Legend

- GSR Project Proposed Well
- Third Party Well
- South Westside Groundwater Basin

0 600 1,200
Scale Feet
1 " = 1,200 '

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FIGURE
2

COLMA AREA WELL LOCATION MAP

DATE
April 2012

Figure 3. Estimated Static Water Levels at Eternal Home Cemetery Well for GSR Project

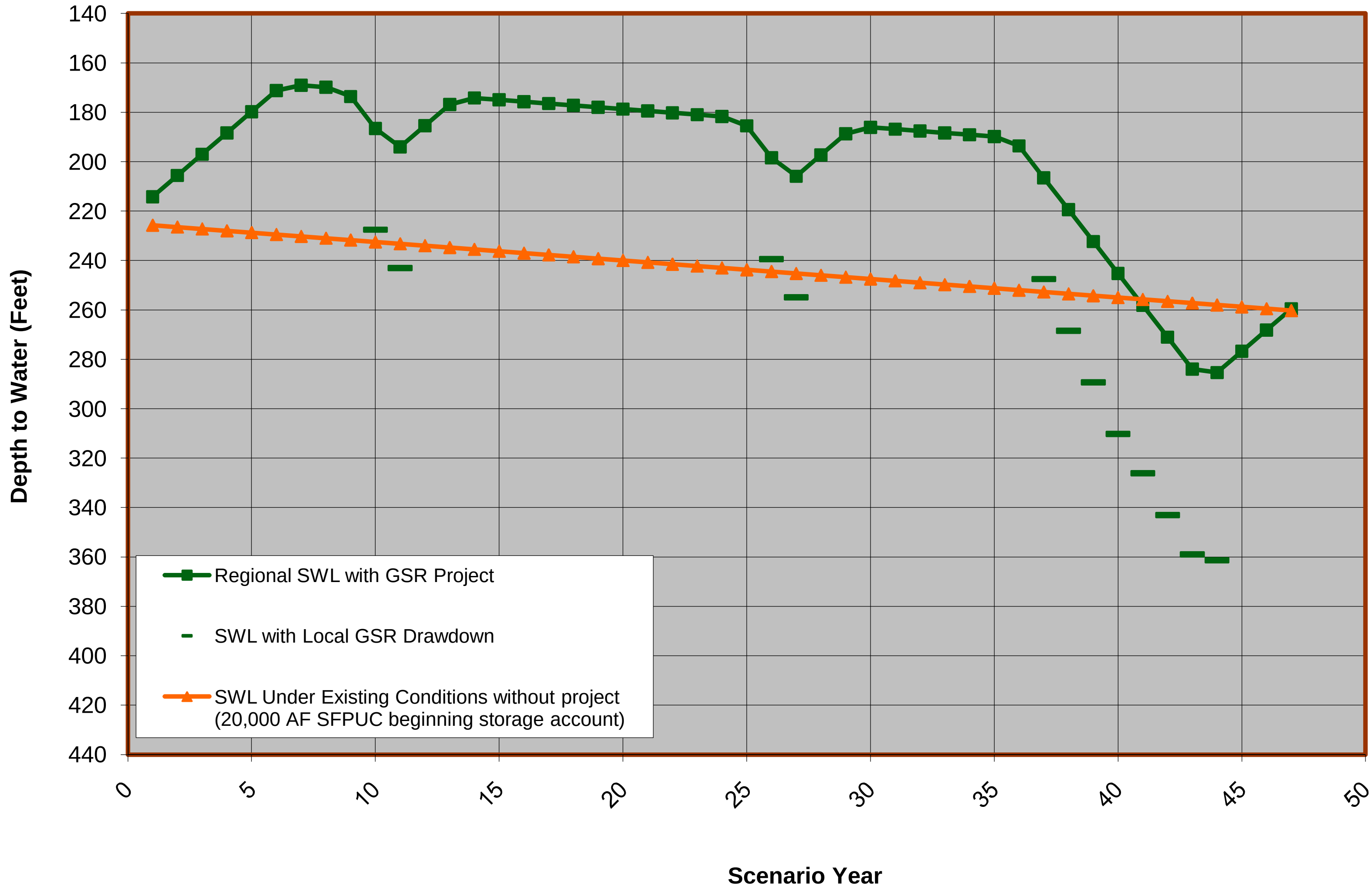


Figure 4. Estimated Groundwater Elevations at Eternal Home Cemetery Well for GSR Project (Scenario 2)

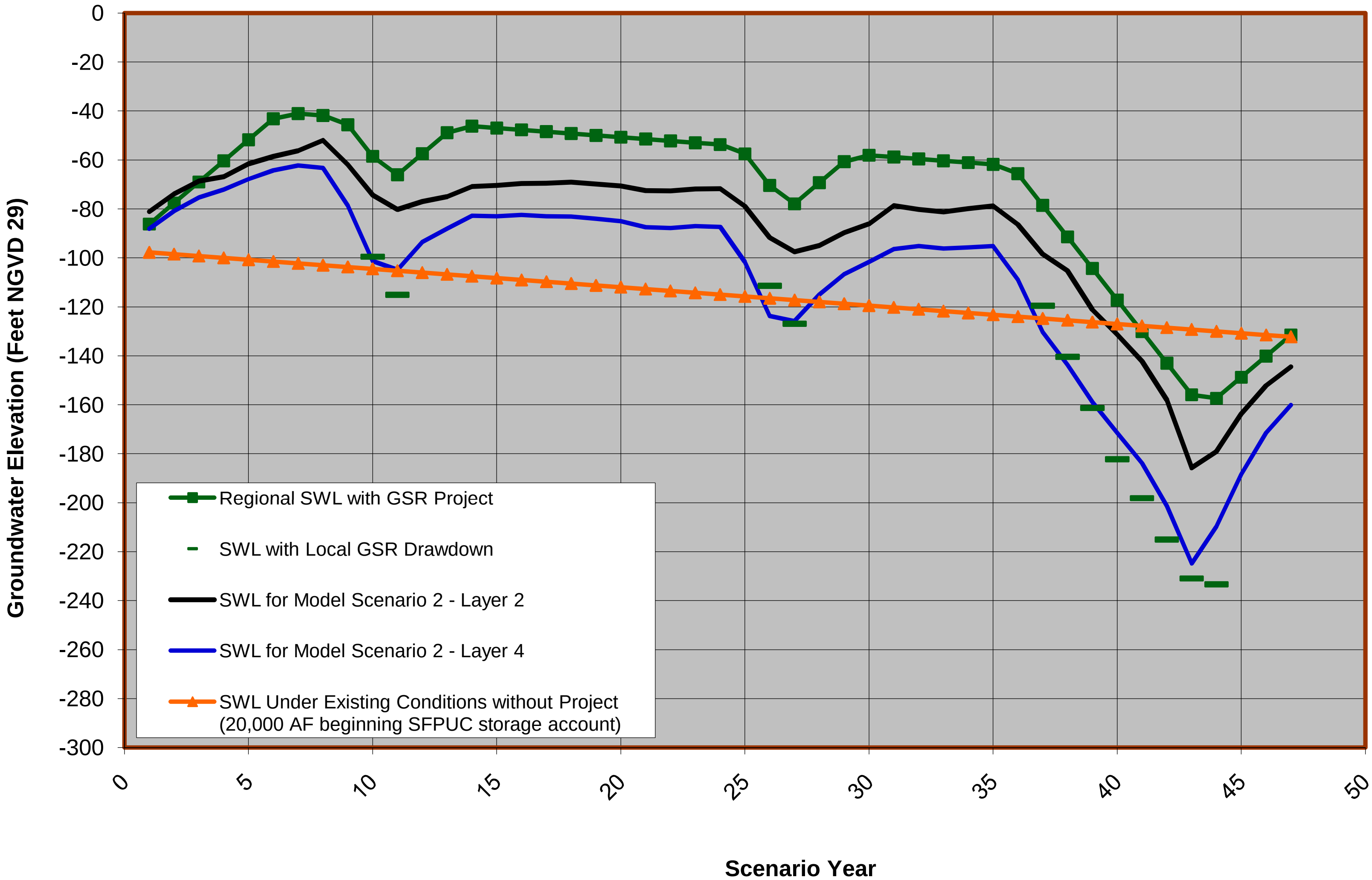


Figure 5. Estimated Static Water Levels at California Golf Club Well 8 for GSR Project

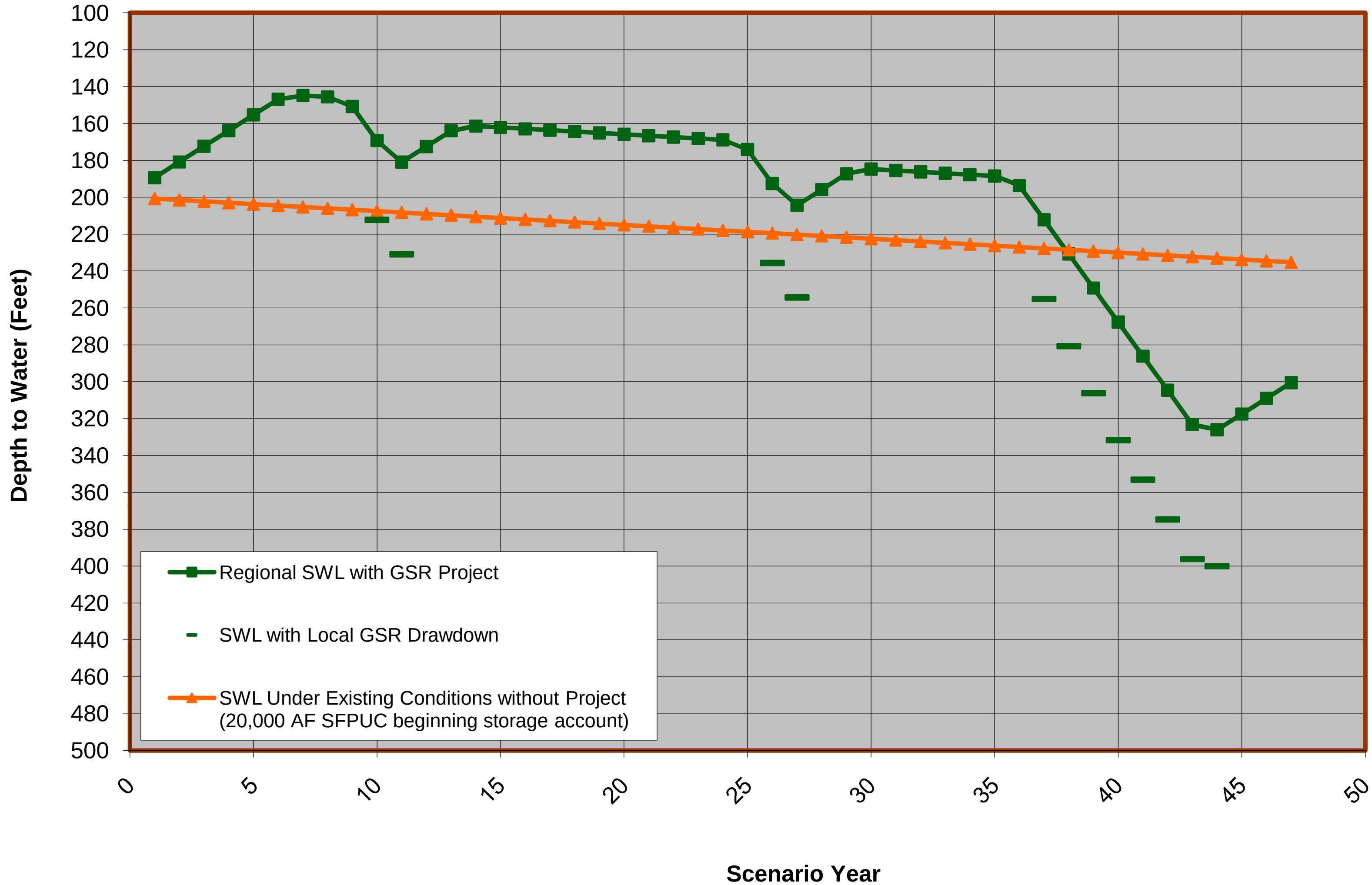


Figure 6. Estimated Groundwater Elevations at California Golf Club Well 8 for GSR Project (Scenario 2)

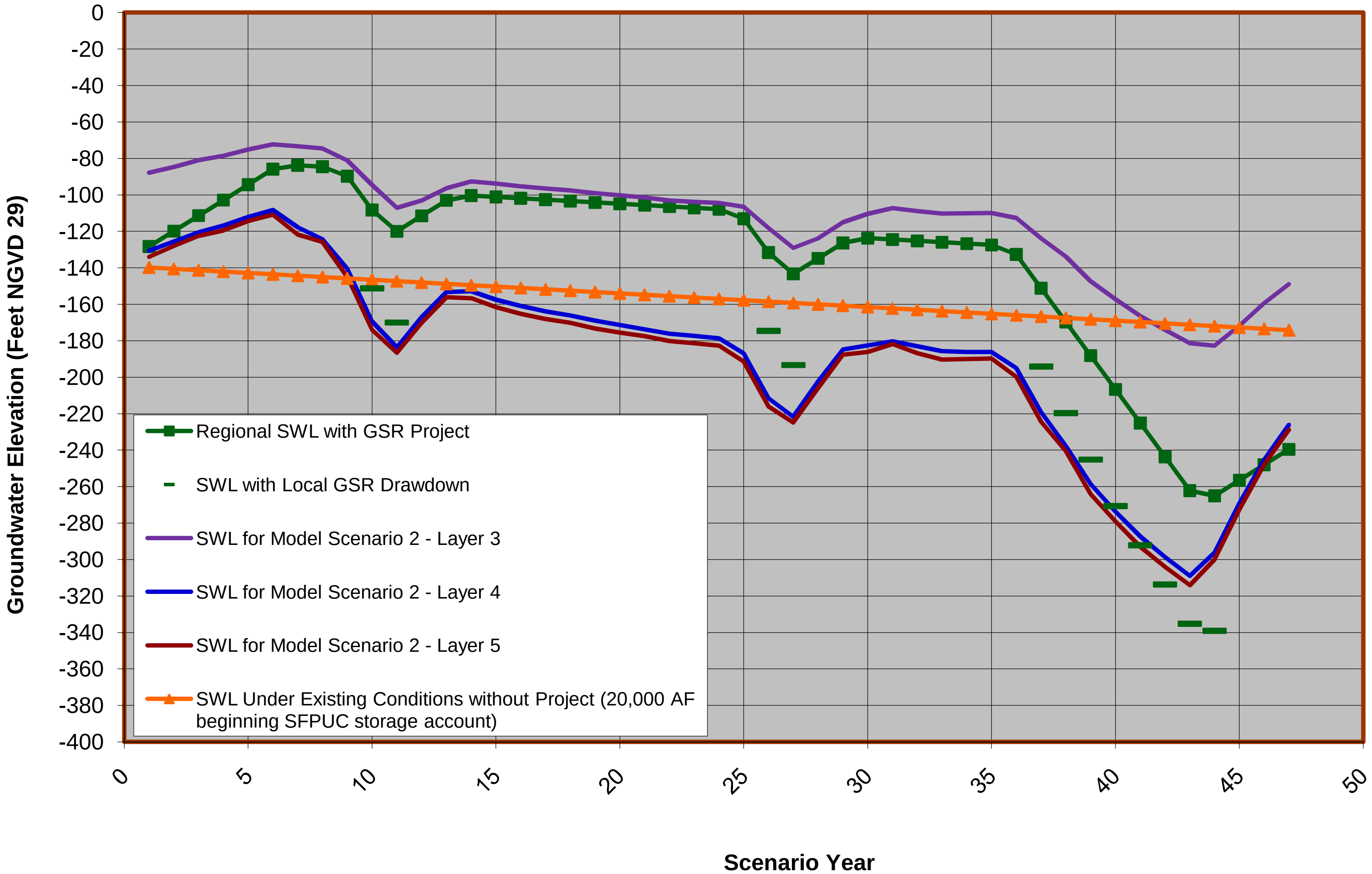


Figure 7. Estimated Static Water Levels at Lake Merced Golf Club Well 3 for GSR Project

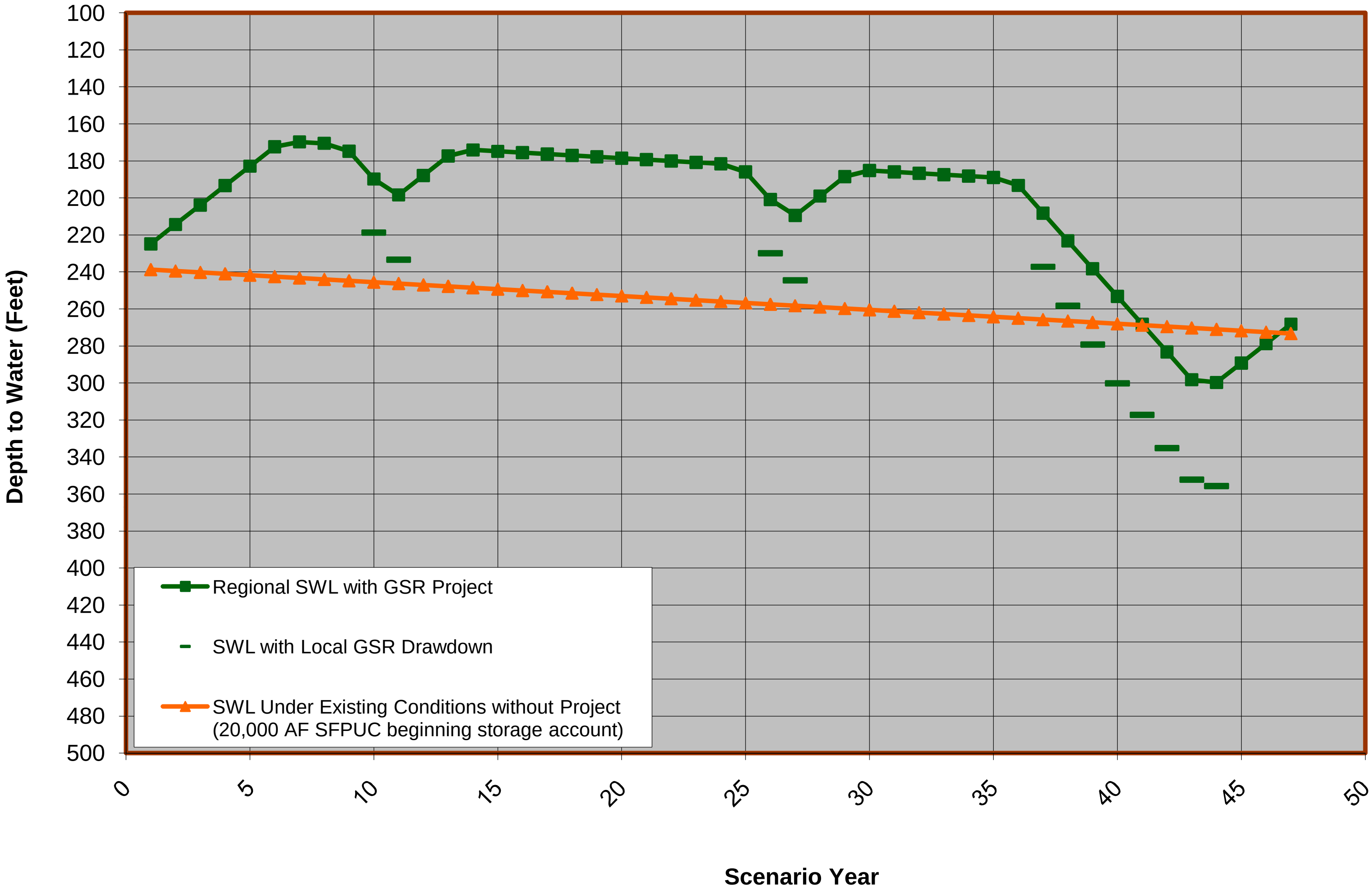


Figure 8. Estimated Groundwater Elevations at Lake Merced Golf Club Well 3 for GSR Project (Scenario 2)

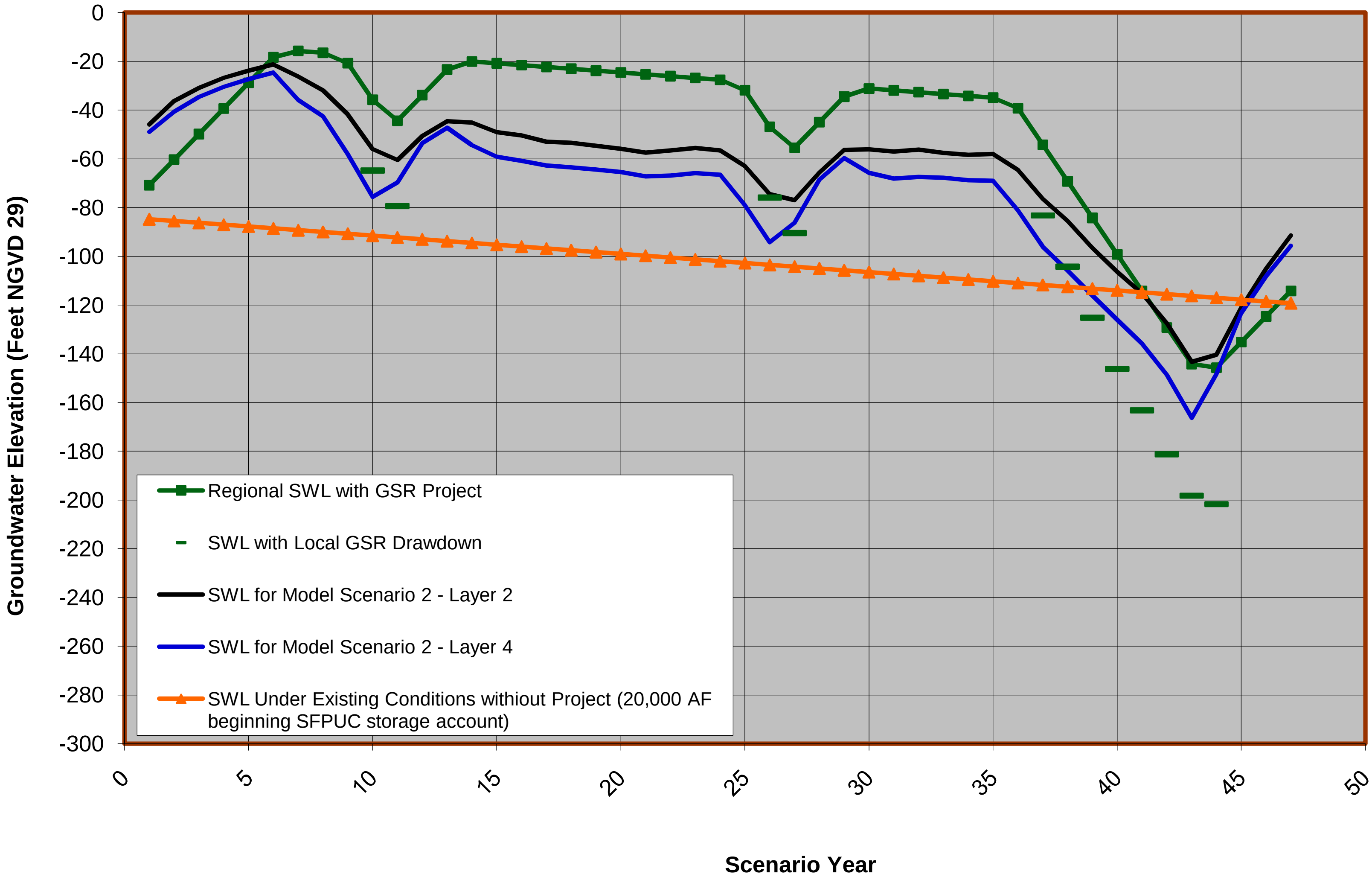


Figure 9. Estimated Static Water Levels at Olympic Golf Club Well 1 (#9) and Well 2 (#8) for GSR Project

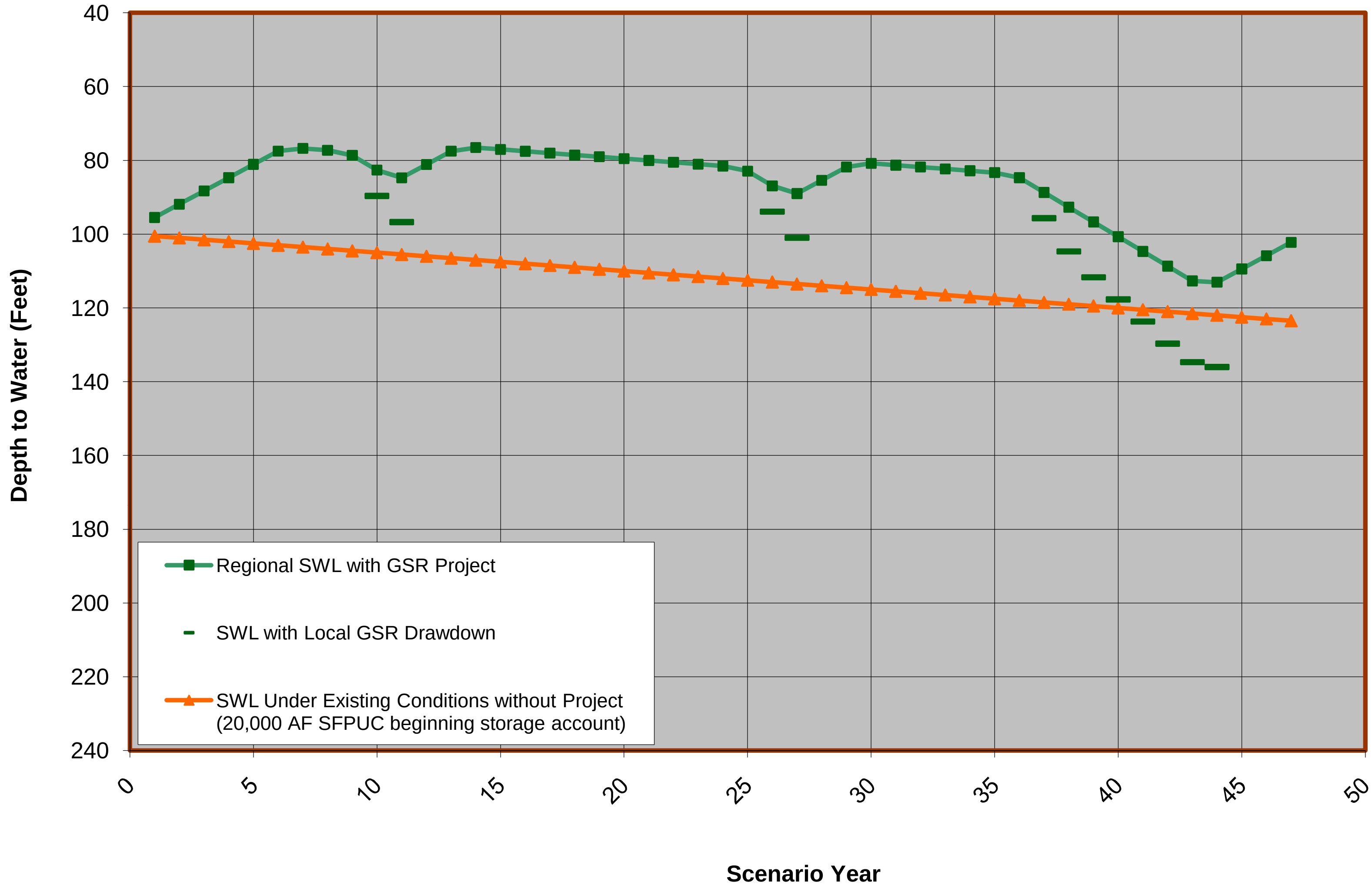
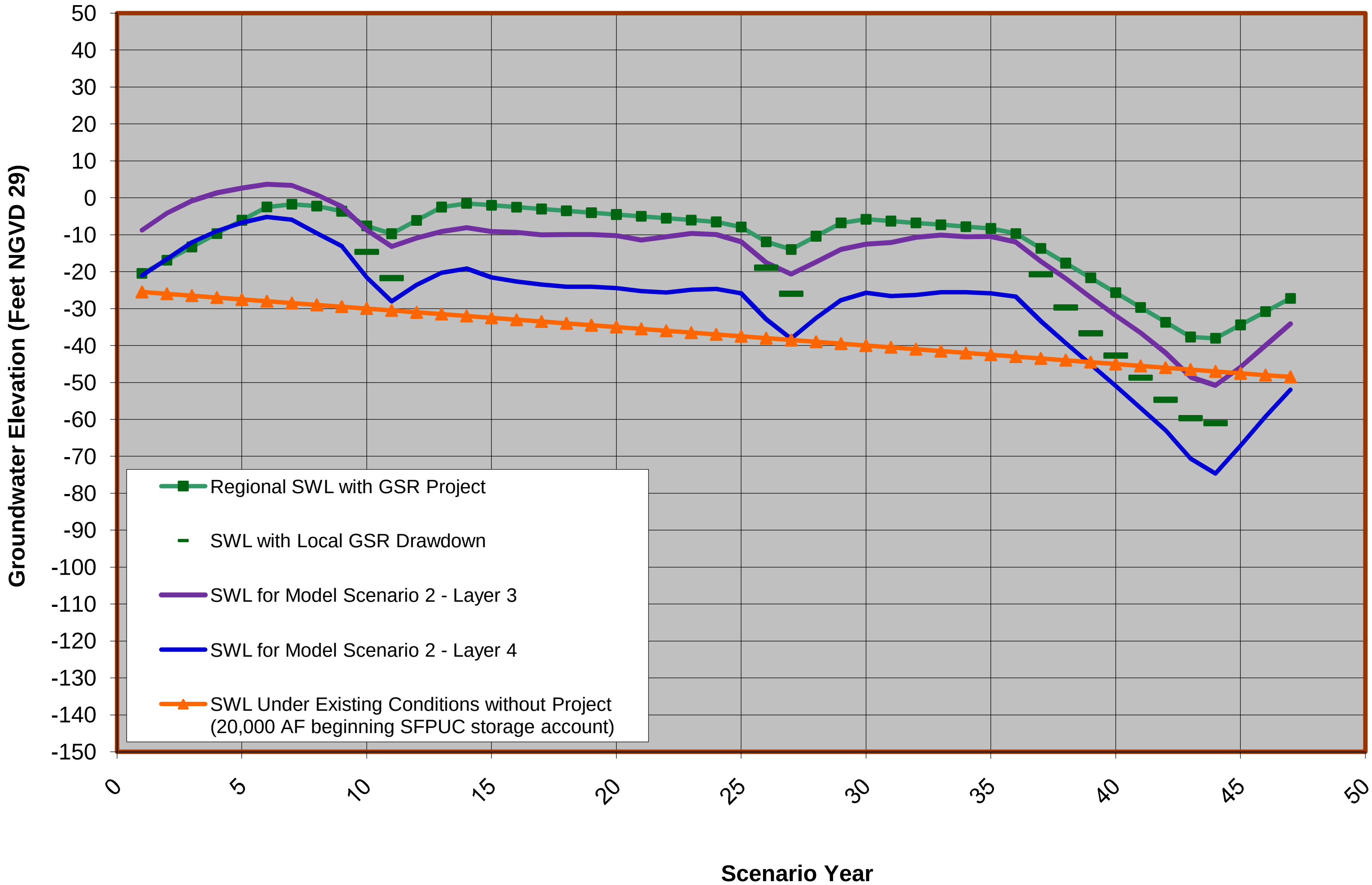


Figure 10. Estimated Groundwater Elevations at Olympic Club Well 1 (#9) for GSR Project (Scenario 2)



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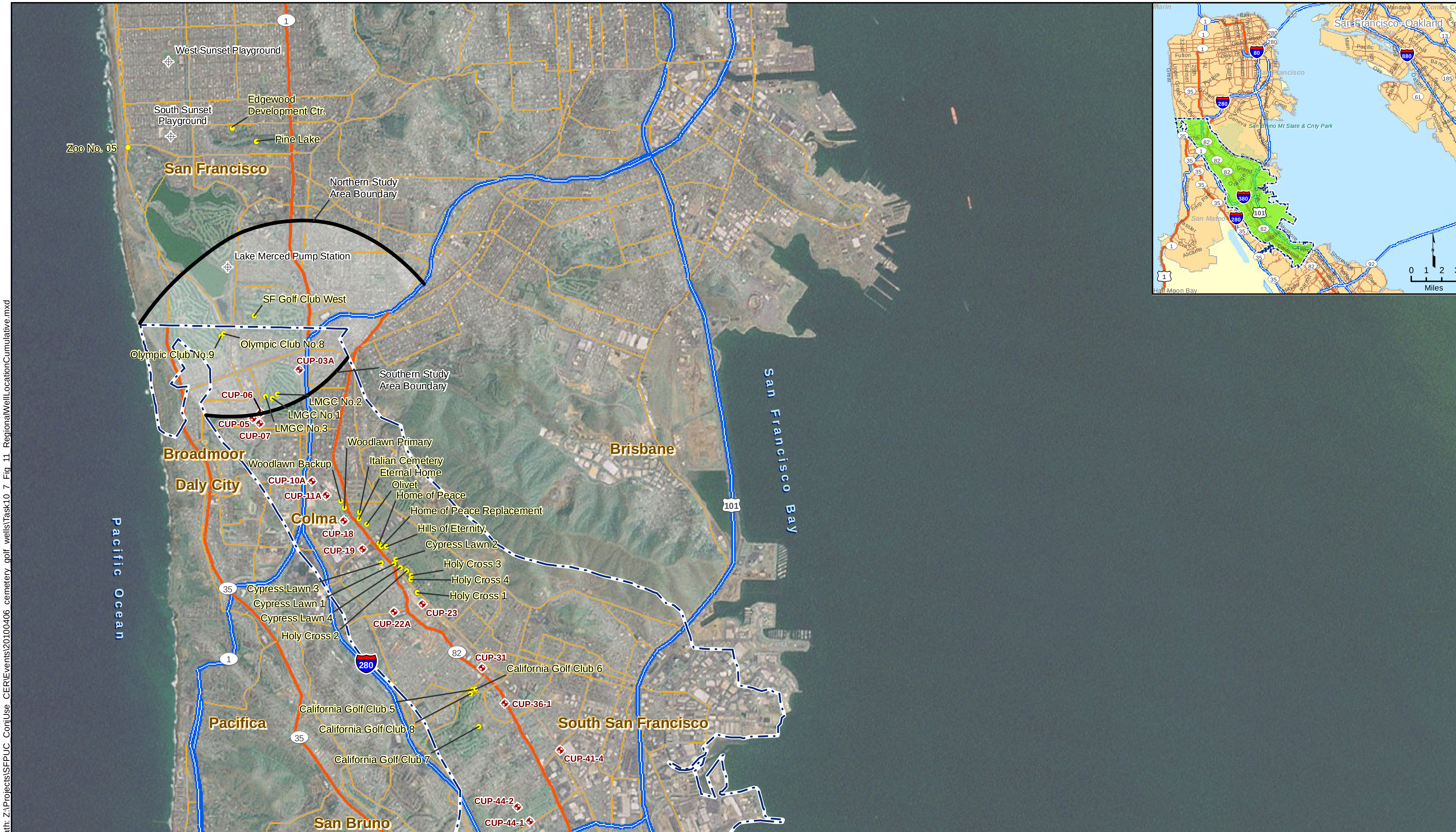

Legend

Study Area Boundary (based upon 1.5 mile radius)	GSR Project Proposed Well	South Westside Groundwater Basin
	Third Party Well	SFGW Project Proposed Well

0 2,500 5,000
Scale Feet
1 " = 5,000 '

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REGIONAL WELL LOCATION MAP FOR CUMULATIVE PROJECT

FIGURE
11

DATE
April 2012

APPENDICES

APPENDIX A

Table A-1. Colma Area Put Year Groundwater Level Rise Analysis

Well	Date	DTW (feet bgs)	Net Rise (feet)
Eternal Home	3/13/2001	261.4	
	2/4/2010	225	36
Hills of Eternity	6/27/2000	253	
	10/29/2007	214	39
Holy Cross 1	3/13/2001	236	
	3/8/2010	199.7	36
Holy Cross 2	3/13/2001	252.3	
	3/8/2010	204.73	48
Holy Cross 3	3/13/2001	264	
	3/8/2010	230.63	33
Italian	3/13/2001	294	
	1/22/2010	256.6	37

Logic/Data Analysis

In-lieu Recharge in Daly City/Cal Water areas from 2002 to 2009 = 18,147 AF

36 feet of rise/18,147 AF = 1 foot/500 AF

Amount of future Put in Daly City and Cal Water areas will be 4,300 AFY out of total Put of 6,180 AFY
(1,880 AFY will be in San Bruno)

4,300 AF per future Put Year/500 AF = **8.6 feet/year** (groundwater level rise per put year)

Assume 1 foot/500 AF relationship applies during take years as well

Amount of future CUP Take in Daly City and Cal Water areas will be 6,460 AF out of total Take of 8,100 AFY
(1,640 AFY of Take from wells CUP 41-4, CUP-44-1, CUP-44-2, and CUP-M-1 was discounted from Colma area)

6,460 AF per future Take Year/500 AF = **12.9 feet/year** (groundwater level decline per take year)

Table A-2. Colma Area Hold Year Groundwater Level Decline Analysis

Well	Date	DTW (feet bgs)	Net Decline (feet)	Years	Rate of Decline (feet/year)
Eternal Home	2/15/78	223			
	4/8/99	253	30	21	1.4
	3/13/01	261	38	23	1.7
Holy Cross 1	5/13/86	202			
	5/18/99	237	35	13	2.7
	3/13/01	236	34	15	2.3
Holy Cross 3	9/16/60	192			
	6/26/00	251	59	40	1.5
Hills of Eternity	5/15/85	226			
	7/8/99	238	12	14	0.9
	3/13/01	242	16	16	1.0

Logic/Data Analysis

Eternal Home Rate of Decline is about 1.5 feet/year
Two Holy Cross wells average Rate of Decline is about 2.0 feet/year
Hills of Eternity Rate of Decline is about 1.0 feet/year

Net average Rate of Decline for the three cemeteries from 1960 to 2001 is about 1.5 feet/year

Hydrofocus Historic Model Run Rate of Decline in Colma area is about 1 foot/year
Hydrofocus Future No-Project Model Run Rate of Decline in Colma area is 0.6 to 0.8 feet/year

KJ Model Scenario 1 (Future No Project) Rate of Decline n Colma area is about 0.75 feet/year

Future Hold Year Rate of Decline used in anlaysis = **0.75 feet/year**

Summary of Supplemental Water Deliveries
Program Inception to December 31, 2009
As of 2/3/10

		Cal Water Ccf	Daly City Ccf	San Bruno Ccf			
October-02	31		82,452.00				
November-02	30		105,213.90				
December-02	31		108,989.30				
January-03	31		112,624.33	31,426.47			
February-03	28	33,951.87	98,320.86	79,994.65			
March-03	31	37,589.57	108,346.26	88,565.51			
April-03	30	36,377.01	104,961.23	85,708.56			
May-03	31	37,589.57	108,180.48	88,565.51			
June-03	30	36,377.01	104,886.36	85,708.56			
July-03	31	37,589.57	108,140.37	88,565.51			
August-03	31	37,589.57	108,433.16	86,310.16			
September-03	30	36,377.01	104,414.44	85,708.56			
October-03	31	37,589.57	109,300.80	82,883.69			
November-03	30	18,188.50		10,533.42			
December-03	31						
January-04	31						
February-04	29						
March-04	31						
April-04	30	37,589.58	109,306.15	65,709.89			
May-04	31	36,377.01	112,934.49	88,565.51			
June-04	30	37,589.58	122,084.22	62,852.94			
July-04	31	36,377.01	126,266.04	88,565.51			
August-04	31	37,589.58	126,950.53	88,565.51			
September-04	30	37,589.58	123,144.39	85,708.56			
October-04	31	36,377.01	141,422.46	88,565.51			
November-04	30	37,589.58	116,322.19	85,708.56			
December-04	31	36,377.01	124,954.55	88,565.51			
January-05	31	37,589.58		88,565.51			
February-05	28	37,589.58	109,621.66	59,995.99			
March-05	31	33,951.88	124,495.99				
April-05	30	37,589.58	109,983.96				
May-05	31	36,377.01	124,504.01				
June-05	30	37,589.58	120,379.68				
July-05	31	36,377.01	124,852.94				
August-05	31	37,589.58	125,205.88				
September-05	30	37,589.58	121,474.60				
October-05	31	36,377.01	125,494.65				
November-05	30	37,589.58	122,058.82				
December-05	31	36,377.01	129,724.60				
January-06	31	37,589.58	124,906.42				
February-06	28	37,589.58	113,911.76				
March-06	31	33,951.88	125,987.97				
April-06	30	37,589.58	121,073.53				
May-06	31	36,377.01					
June-06	30	37,589.58					
July-06	31	36,377.01	138,706.50				
August-06	31	37,589.58	115,407.75				
September-06	30	37,589.58	112,946.52				
October-06	31	36,377.01	115,421.12				
November-06	30	37,589.58	120,008.02				
December-06	31	36,377.01	124,605.61				
January-07	31	37,589.58	124,139.04				
February-07			109,248.66				
March-07			109,724.60				
April-07			102,418.45				
No supplemental deliveries May 2007 - May 2009							
subtotal ccf		1,605,439	5,463,951	1,705,340	**Total**	**8,774,730**	**ccf**
subtotal AF		3,685	12,541	3,914	**Total**	**20,140**	**AF**
June-09			165,750.00				
July-09			121,665.78				
August-09			119,991.98				
September-09			109,283.42				
October-09			117,137.70				
November-09			100,427.81				
December-09			102,699.20				
subtotal ccf			836,956	**ccf**			
subtotal AF			1,921	**AF**			

Round to 20,000 AF

APPENDIX B

Regional Groundwater Storage and Recovery Project

To: Greg Bartow

From: Matt Holt, PE
Nick Johnson, PG

Date: 07/12/10

Subject: Estimated Drawdown at Third Party Wells

BACKGROUND AND OBJECTIVE

The Regional Groundwater Storage and Recovery Project in the South Westside Basin has been proposed to increase water supply reliability by balancing groundwater and surface water usage in wet and dry years. The proposed project includes installation of up to 16 Conjunctive Use wells to pump stored groundwater during dry years. The locations of primary and alternate Conjunctive Use wells are shown on Figure 1.

Groundwater extraction at Conjunctive Use wells will create localized cones of depression in water levels near each well. The purpose of this technical memorandum (TM) is to estimate potential groundwater level drawdown at representative Third Party wells resulting from operation of the Regional Groundwater Storage and Recovery Project.

METHODS AND ASSUMPTIONS

Water level drawdown at representative Third Party wells was estimated using a spreadsheet programmed to solve the Theis equation (Theis, 1935). The Theis equation estimates groundwater level drawdown at various distances from a pumping well based on an assumed rate and duration of pumping and estimated values of aquifer transmissivity and storage coefficient.

The Theis equation is a standard method for estimating time-varying drawdown. Its formulation assumes an idealized aquifer that is confined, homogenous, and isotropic, and has infinite areal extent. Although these conditions are rarely strictly met, the Theis equation generally provides informative results under a wide range of reasonably equivalent conditions. In the case of the South Westside Basin, the aquifer consists of multiple units that are unconfined at shallow depths and become increasingly confined with depth. Additionally, the basin is bounded by bedrock to the northeast and southwest. For each Conjunctive Use well evaluated, suitable aquifer parameter values were selected based on available aquifer tests generally representative of local conditions. Where unconfined or semi-confined conditions are present, the Theis equation may overestimate drawdown, and thus provide a conservative impact assessment. For these reasons, the Theis equation may be assumed to provide reasonable preliminary estimates of drawdown for the purpose of this analysis[1]. Furthermore, this approach is consistent with the drawdown estimates presented in the project's Conceptual Engineering Report (MWH, 2008). More accurate estimates may require site-specific aquifer testing and three-dimensional groundwater modeling.

The transmissivities and storage coefficients assumed for this evaluation are based on aquifer tests in Daly City and San Bruno performed and analyzed by Luhdorff and Scalmanini Consulting Engineers (LSCE) in 2003 (LSCE, 2004). The transmissivity, specific yield, and storativity estimated from the Daly City test were 16,400 gallons per day per foot (gpd/ft), 0.14, and $2.4x10^{-3}$, respectively. The transmissivity and storage coefficient estimated from the San Bruno test were 14,200 gpd/ft and $2.4x10^{-4}$, respectively.

For the analysis presented in this TM, the storage coefficient for Daly City was adjusted to $5.2x10^{-2}$ to reflect semi-confined conditions and the storage coefficient for San Bruno was adjusted to $5.2x10^{-3}$ to reflect leaky confined conditions. These adjusted storage coefficients were agreed upon during discussions between LSCE, Fugro, and MWH in February 2008. Daly City aquifer parameters were applied to wells in Daly City and Colma, while San Bruno aquifer parameters were applied to wells in South San Francisco, San Bruno, and Millbrae.

Based on Fugro's well inventory in the Task 8L Technical Memorandum, MWH estimated drawdown for nineteen "third party" wells at golf courses and cemeteries in the South Westside Basin that are known to use groundwater for irrigation. The representative Third Party wells are shown on Figure 1. Drawdown was estimated for all active wells at each golf course. Drawdown was estimated for a primary well at each cemetery, and a secondary backup well where applicable. The locations of the primary and secondary wells for Cypress Lawn Memorial Park were not provided to the project team. Consequently, primary and secondary well locations have been assumed for Cypress Lawn, based on the estimated locations of Cypress Lawn wells 4 and 3, respectively.

The drawdown at each Third Party well was estimated by considering the pumping rates of all Conjunctive Use wells within 1.5 miles. Primary and alternate configurations of the Regional Groundwater Storage and Recovery Project were evaluated because the project environmental impact report includes 16 primary Conjunctive Use wells and 3 alternate Conjunctive Use wells. The alternate configuration replaces primary wells CUP-3A, CUP-07, and CUP-44-1 with alternate wells CUP-20A, CUP-22, and CUP-36-2. Since the project is only expected to use up to 16 wells, the primary configuration and alternate configuration provide a collective analysis of all 19 wells. Drawdown was estimated for pumping durations of 1, 4, and 7.5 years. The 7.5-year duration represents the design drought assumed for this project.

[1] The accuracy of the drawdown estimates presented in this TM is limited by the assumed conditions and the available data and tools. The South Westside Basin is a complex system that cannot be fully modeled with the Theis spreadsheet tool. The Theis spreadsheet tool may not adequately reflect the three-dimensional and boundary effects of the groundwater system. If an accepted groundwater model of the South Westside Basin has been completed, its use should be considered for validating and improving the results of this analysis.

Existing and proposed wells that were considered as part of this analysis are listed in Table 1 along with their well screen intervals, the assumed Conjunctive Use well pumping rates, and the assumed aquifer parameters.

RESULTS

Table 2 lists the estimated drawdown for Third Party wells, after 1, 4, and 7.5 years of pumping from the primary configuration of Conjunctive Use wells. Table 3 lists the estimated drawdown for Third Party wells, after 1, 4, and 7.5 years of pumping from the alternate configuration of Conjunctive Use wells.

The Regional Groundwater Storage and Recovery Project will be operated with a "put before take" principle, meaning that the volume of extracted groundwater will not exceed the amount that was stored through in-lieu recharge. Regional groundwater levels will be higher at the start of any take cycle than they were prior to groundwater storage activities associated with this project. The drawdown estimates shown in Tables 2 and 3 will be relative to regional groundwater levels 1, 4, and 7.5 years after the take cycle begins.

Aquifer testing at the selected well sites is recommended to collect site-specific aquifer parameters. Anticipated drawdowns should be re-estimated after the exploratory drilling and aquifer testing activities are completed.

REFERENCES

LSCE, 2004. Update on the Conceptualization of the Lake-Aquifer System, Westside Ground Water Basin, San Francisco and San Mateo Counties. Prepared for San Francisco Public Utilities Commission.

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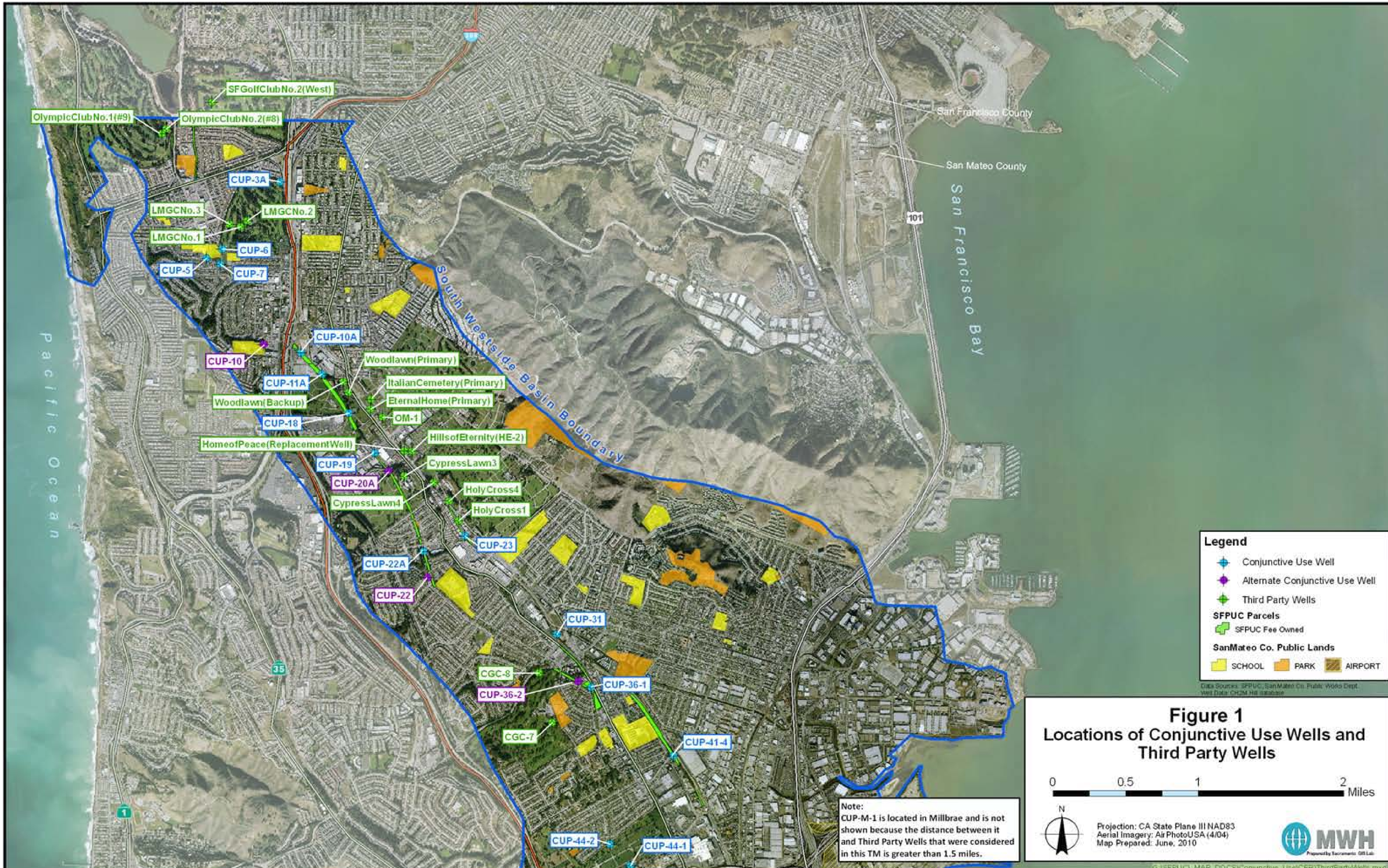


Figure 1
Locations of Conjunctive Use Wells and Third Party Wells

Table 1
Conjunctive Use Wells and Representative Third Party Wells

System or Owner	Well	Future Use of Well	Screen Interval (depth, ft)	Assumed Pump Rate (gpm)	Assumed Trans-missivity (gpd/ft)	Assumed Storage Coeff.
Conjunctive Use well	CUP-3A	Primary	410 to 625 (Proposed in CER)	400	16,400	5.0E-02
Conjunctive Use well	CUP-5	Primary	410 to 730 (Proposed in CER)	300	16,400	5.0E-02
Conjunctive Use well	CUP-6	Primary	420 to 730 (Proposed in CER)	300	16,400	5.0E-02
Conjunctive Use well	CUP-7	Primary	420 to 730 (Proposed in CER)	300	16,400	5.0E-02
Conjunctive Use well	CUP-10A	Primary	430 to 730 (Proposed in CER)	400	16,400	5.0E-02
Conjunctive Use well	CUP-11A	Primary	440 to 730 (Proposed in CER)	400	16,400	5.0E-02
Conjunctive Use well	CUP-18	Primary	430 to 640 (Proposed in CER)	400	16,400	5.0E-02
Conjunctive Use well	CUP-19	Primary	400 to 640 (Proposed in CER)	400	16,400	5.0E-02
Conjunctive Use well	CUP-22A	Primary	400 to 640 (Proposed in CER)	330	14,200	5.0E-03
Conjunctive Use well	CUP-23	Primary	400 to 640 (Proposed in CER)	330	14,200	5.0E-03
Conjunctive Use well	CUP-31	Primary	375 to 580 (Proposed in CER)	220	14,200	5.0E-03
Conjunctive Use well	CUP-36-1	Primary	395 to 580 (Proposed in CER)	220	14,200	5.0E-03
Conjunctive Use well	CUP-41	Primary	375 to 580 (Proposed)	220	14,200	5.0E-03
Conjunctive Use well	CUP-44-1	Primary	400 to 620 (Proposed in CER)	330	14,200	5.0E-03
Conjunctive Use well	CUP-44-2	Primary	410 to 620 (Proposed in CER)	330	14,200	5.0E-03
Conjunctive Use well	CUP-M-1	Primary	Not Identified in CER	160	14,200	5.0E-03
Conjunctive Use well	CUP-20A	Alternate	Not Identified in CER	400	16,400	5.0E-02
Conjunctive Use well	CUP-22	Alternate	Not Identified in CER	330	14,200	5.0E-03
Conjunctive Use well	CUP-36-2	Alternate	Not Identified in CER	220	14,200	5.0E-03

Table 1
Conjunctive Use Wells and Representative Third Party Wells

System or Owner	Well	Future Use of Well	Screen Interval (depth, ft)	Assumed Pump Rate (gpm)	Assumed Trans-missivity (gpd/ft)	Assumed Storage Coeff.
The Olympic Club	No. 1 (#9)	Active	Top of screen at 260	N/A	16,400	5.0E-02
The Olympic Club	No. 2 (#8)	Active	Top of screen at 200	N/A	16,400	5.0E-02
San Francisco Golf Club	No. 2 (West)	Active	Top of screen at 360	N/A	16,400	5.0E-02
Lake Merced Golf Club	LMGC No. 1	Active	Top of screen not reported	N/A	16,400	1.4E-01
Lake Merced Golf Club	LMGC No. 2	Active	Top of screen not reported	N/A	16,400	1.4E-01
Lake Merced Golf Club	LMGC No. 3	Active	Top of screen at 294	N/A	16,400	1.4E-01
Olivet Memorial Park	OM-1	Primary Well	Top of screen at 220	N/A	16,400	1.4E-01
Woodlawn Memorial Park	Primary Well	Primary Well	Top of screen at 275	N/A	16,400	1.4E-01
Woodlawn Memorial Park	Backup Well	Backup Well	Top of screen not reported	N/A	16,400	1.4E-01
Italian Cemetery	Primary Well	Primary Well	Top of screen at 300	N/A	16,400	1.4E-01
Eternal Home Cemetery	Primary Well	Primary Well	Top of screen at 280	N/A	16,400	1.4E-01
Salem Memorial Park, Home of Peace Cemetery, and Hills of Eternity Cemetery	Replacement Well	Primary Well	Not Constructed	N/A	16,400	5.0E-02
Salem Memorial Park, Home of Peace Cemetery, and Hills of Eternity Cemetery	HE-2	Secondary Well	Top of screen at 224	N/A	16,400	1.4E-01
Cypress Lawn Memorial Park	Cypress Lawn 3	Assumed Secondary Well	Top of screen at 191	N/A	16,400	1.4E-01
Cypress Lawn Memorial Park	Cypress Lawn 4	Assumed Primary Well	Top of screen at 330	N/A	16,400	5.0E-02
Holy Cross Cemetery	Holy Cross 1	Secondary Well	Top of screen at 368	N/A	16,400	5.0E-02
Holy Cross Cemetery	Holy Cross 4	Primary Well	Top of screen at 420	N/A	16,400	5.0E-02
California Golf Club of San Francisco	CGC-7	Secondary Well	Top of screen at 255	N/A	14,200	5.0E-03
California Golf Club of San Francisco	CGC-8	Primary Well	Top of screen at 320	N/A	14,200	5.0E-03

Table 2
Summary of Calculated Water Level Drawdowns in Third Party Wells, Primary Configuration of Conjunctive Use Wells

Owner	Well ID	Drawdown (ft) [1]			Number of Wells Used to Calculate Drawdown
		1 year	4 years	7.5 years	
The Olympic Club	No. 1 (#9)	7	17	23	4
The Olympic Club	No. 2 (#8)	7	17	23	4
San Francisco Golf Club	No. 2 (West)	7	17	22	4
Lake Merced Golf Club	LMGC No. 1	29	50	60	7
Lake Merced Golf Club	LMGC No. 2	27	47	58	7
Lake Merced Golf Club	LMGC No. 3	29	47	56	6
Olivet Memorial Park	OM-1	38	60	70	6
Woodlawn Memorial Park	Primary Well	45	73	87	9
Woodlawn Memorial Park	Backup Well	45	76	91	10
Italian Cemetery	Primary Well	40	68	81	9
Eternal Home Cemetery	Primary Well	41	65	76	7
Salem Memorial Park, Home of Peace Cemetery, and Hills of Eternity Cemetery	Replacement Well (Primary Well)	36	58	68	6
Salem Memorial Park, Home of Peace Cemetery, and Hills of Eternity Cemetery	HE-2 (Secondary Well)	34	56	66	6
Cypress Lawn Memorial Park	3 (Assumed Secondary)	35	56	66	6
Cypress Lawn Memorial Park	4 (Assumed Primary)	36	58	69	7
Holy Cross Cemetery	Holy Cross 1	43	64	75	7
Holy Cross Cemetery	Holy Cross 4	37	58	69	7
California Golf Club of San Francisco	CGC-7	41	63	73	7
California Golf Club of San Francisco	CGC-8	43	64	74	7

Table 3
Summary of Calculated Water Level Drawdowns in Third Party Wells, Alternate Configuration of Conjunctive Use Wells

Owner	Well ID	Drawdown (ft) [1]			Number of Wells Used to Calculate Drawdown
		1 year	4 years	7.5 years	
The Olympic Club	No. 1 (#9)	3	8	11	2
The Olympic Club	No. 2 (#8)	3	8	10	2
San Francisco Golf Club	No. 2 (West)	3	7	10	2
Lake Merced Golf Club	LMGC No. 1	17	31	39	5
Lake Merced Golf Club	LMGC No. 2	15	29	36	5
Lake Merced Golf Club	LMGC No. 3	17	29	35	4
Olivet Memorial Park	OM-1	50	80	93	8
Woodlawn Memorial Park	Primary Well	52	83	98	10
Woodlawn Memorial Park	Backup Well	51	85	100	10
Italian Cemetery	Primary Well	50	83	98	10
Eternal Home Cemetery	Primary Well	51	81	94	8
Salem Memorial Park, Home of Peace Cemetery, and Hills of Eternity Cemetery	Replacement Well (Primary Well)	54	82	96	8
Salem Memorial Park, Home of Peace Cemetery, and Hills of Eternity Cemetery	HE-2 (Secondary Well)	51	80	93	8
Cypress Lawn Memorial Park	3 (Assumed Secondary)	57	85	99	8
Cypress Lawn Memorial Park	4 (Assumed Primary)	52	82	96	9
Holy Cross Cemetery	Holy Cross 1	61	92	107	10
Holy Cross Cemetery	Holy Cross 4	52	81	95	9
California Golf Club of San Francisco	CGC-7	49	72	83	8
California Golf Club of San Francisco	CGC-8	53	77	88	8

APPENDIX C

Table C-1. Woodlawn Cemetery Primary Well Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	WL Well DTW (Feet)	WL Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	WL Well SWL (Feet bgs)	WL Well GWE (Feet NGVD 29)	WL Well Background DTW (Feet)	WL Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 2 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)
1	put	209.2	-74.2	27,742				220.8	-85.8	-77.5	-84.9
2	put	200.6	-65.6	33,925				221.5	-86.5	-70.8	-77.9
3	put	192.0	-57.0	40,108				222.3	-87.3	-65.7	-72.2
4	put	183.4	-48.4	46,291				223.0	-88.0	-61.8	-68.4
5	put	174.8	-39.8	52,475				223.8	-88.8	-58.0	-64.4
6	put	166.2	-31.2	58,658				224.5	-89.5	-54.5	-60.9
7	Put/Hold	164.1	-29.1	60,500				225.3	-90.3	-51.9	-59.1
8	Hold	164.9	-29.9	60,500				226.0	-91.0	-51.8	-60.7
9	Hold/Take	168.6	-33.6	58,475				226.8	-91.8	-63.1	-89.1
10	take	181.5	-46.5	50,375	45	226.5	-91.5	227.5	-92.5	-77.3	-111.3
11	Take/Put	189.1	-54.1	45,858	54	243.1	-108.1	228.3	-93.3	-80.1	-101.0
12	put	180.5	-45.5	52,042				229.0	-94.0	-75.3	-89.6
13	put	171.9	-36.9	58,225				229.8	-94.8	-72.7	-84.2
14	Put/Hold	169.2	-34.2	60,430				230.5	-95.5	-68.6	-79.6
15	Hold	170.0	-35.0	60,430				231.3	-96.3	-67.9	-79.7
16	Hold	170.7	-35.7	60,430				232.0	-97.0	-67.0	-79.3
17	Hold	171.5	-36.5	60,430				232.8	-97.8	-67.3	-79.9
18	Hold	172.2	-37.2	60,430				233.5	-98.5	-67.1	-80.1
19	Hold	173.0	-38.0	60,430				234.3	-99.3	-67.8	-80.9
20	Hold	173.7	-38.7	60,430				235.0	-100.0	-68.7	-81.9
21	Hold	174.5	-39.5	60,430				235.8	-100.8	-71.1	-84.3
22	Hold	175.2	-40.2	60,430				236.5	-101.5	-70.7	-84.6
23	Hold	176.0	-41.0	60,430				237.3	-102.3	-70.2	-84.0
24	Hold	176.7	-41.7	60,430				238.0	-103.0	-70.4	-84.4
25	Hold/Take	180.5	-45.5	58,405				238.8	-103.8	-81.6	-111.8
26	take	193.4	-58.4	50,305	45	238.4	-103.4	239.5	-104.5	-96.1	-133.5
27	take/put	200.9	-65.9	45,788	54	254.9	-119.9	240.3	-105.3	-98.2	-121.7
28	put	192.3	-57.3	51,972				241.0	-106.0	-93.9	-110.6
29	put	183.7	-48.7	58,155				241.8	-106.8	-88.5	-102.6
30	Put/Hold	181.1	-46.1	60,360				242.5	-107.5	-85.0	-98.0
31	Hold	181.8	-46.8	60,360				243.3	-108.3	-80.2	-93.7
32	Hold	182.6	-47.6	60,360				244.0	-109.0	-78.5	-91.9
33	Hold	183.3	-48.3	60,360				244.8	-109.8	-78.8	-92.5
34	Hold	184.1	-49.1	60,360				245.5	-110.5	-78.5	-92.4
35	Hold	184.8	-49.8	60,360				246.3	-111.3	-77.9	-92.0
36	hold/take	188.6	-53.6	58,335				247.0	-112.0	-88.5	-118.8
37	take	201.5	-66.5	50,235	45	246.5	-111.5	247.8	-112.8	-102.2	-139.8
38	take	214.4	-79.4	42,135	54	268.4	-133.4	248.5	-113.5	-113.2	-153.4
39	take	227.3	-92.3	34,035	64	291.3	-156.3	249.3	-114.3	-126.4	-167.8
40	take	240.2	-105.2	25,935	73	313.2	-178.2	250.0	-115.0	-137.7	-180.4
41	take	253.1	-118.1	17,835	77	330.1	-195.1	250.8	-115.8	-149.2	-192.9
42	take	266.0	-131.0	9,735	81	347.0	-212.0	251.5	-116.5	-171.9	-211.8
43	take	278.9	-143.9	1,635	85	363.9	-228.9	252.3	-117.3	-198.9	-235.6
44	take/hold/put	280.4	-145.4	1,168	87	367.4	-232.4	253.0	-118.0	-182.3	-205.8
45	put	271.8	-136.8	7,352				253.8	-118.8	-164.6	-183.7
46	put	263.2	-128.2	13,535				254.5	-119.5	-152.5	-167.2
47	put	254.6	-119.6	19,718				255.3	-120.3	-144.2	-156.2

Assumptions:

1) Put Rate of 5.52 MGD results in 8.6 feet/year increase in groundwater levels in Colma area
2) Take Rate of 7.23 MGD results in 12.9 feet/year decrease in groundwater levels in Colma area
3) Hold Year results in 0.75 feet/year decrease in groundwater levels in Colma area
4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.

Notes: DTW = depth to water; WL = Woodlawn; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table C-2. Italian Cemetery Well Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Date	Year Type	IT Well DTW (Feet)	IT Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	IT Well SWL (Feet bgs)	IT Well GWE (Feet NGVD 29)	IT Well Background DTW (Feet)	IT Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 2 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)
1	put	245.8	-86.8	27,742				257.4	-98.4	-81.2	-88.2
2	put	237.2	-78.2	33,925				258.1	-99.1	-73.9	-80.9
3	put	228.6	-69.6	40,108				258.9	-99.9	-68.6	-75.3
4	put	220.0	-61.0	46,291				259.6	-100.6	-66.8	-72.1
5	put	211.4	-52.4	52,475				260.4	-101.4	-61.6	-67.8
6	put	202.8	-43.8	58,658				261.1	-102.1	-58.6	-64.3
7	Put/Hold	200.7	-41.7	60,500				261.9	-102.9	-56.2	-62.2
8	Hold	201.5	-42.5	60,500				262.6	-103.6	-52.0	-63.2
9	Hold/Take	205.2	-46.2	58,475				263.4	-104.4	-61.9	-78.7
10	take	218.1	-59.1	50,375	40	258.1	-99.1	264.1	-105.1	-74.3	-101.3
11	Take/Put	225.7	-66.7	45,858	50	275.7	-116.7	264.9	-105.9	-80.2	-104.9
12	put	217.1	-58.1	52,042				265.6	-106.6	-77.0	-93.5
13	put	208.5	-49.5	58,225				266.4	-107.4	-75.0	-88.0
14	Put/Hold	205.8	-46.8	60,430				267.1	-108.1	-70.8	-82.8
15	Hold	206.6	-47.6	60,430				267.9	-108.9	-70.4	-83.0
16	Hold	207.3	-48.3	60,430				268.6	-109.6	-69.7	-82.5
17	Hold	208.1	-49.1	60,430				269.4	-110.4	-69.5	-83.0
18	Hold	208.8	-49.8	60,430				270.1	-111.1	-69.1	-83.1
19	Hold	209.6	-50.6	60,430				270.9	-111.9	-69.9	-84.0
20	Hold	210.3	-51.3	60,430				271.6	-112.6	-70.6	-85.0
21	Hold	211.1	-52.1	60,430				272.4	-113.4	-72.6	-87.4
22	Hold	211.8	-52.8	60,430				273.1	-114.1	-72.6	-87.8
23	Hold	212.6	-53.6	60,430				273.9	-114.9	-71.8	-87.1
24	Hold	213.3	-54.3	60,430				274.6	-115.6	-71.7	-87.4
25	Hold/Take	217.1	-58.1	58,405				275.4	-116.4	-78.9	-101.6
26	take	230.0	-71.0	50,305	40	270.0	-111.0	276.1	-117.1	-91.7	-123.8
27	take/put	237.5	-78.5	45,788	50	287.5	-128.5	276.9	-117.9	-97.5	-125.9
28	put	228.9	-69.9	51,972				277.6	-118.6	-95.0	-115.0
29	put	220.3	-61.3	58,155				278.4	-119.4	-89.7	-106.7
30	Put/Hold	217.7	-58.7	60,360				279.1	-120.1	-86.2	-101.6
31	Hold	218.4	-59.4	60,360				279.9	-120.9	-78.7	-96.4
32	Hold	219.2	-60.2	60,360				280.6	-121.6	-80.3	-95.2
33	Hold	219.9	-60.9	60,360				281.4	-122.4	-81.2	-96.1
34	Hold	220.7	-61.7	60,360				282.1	-123.1	-79.9	-95.7
35	Hold	221.4	-62.4	60,360				282.9	-123.9	-78.8	-95.2
36	hold/take	225.2	-66.2	58,335				283.6	-124.6	-86.4	-108.9
37	take	238.1	-79.1	50,235	40	278.1	-119.1	284.4	-125.4	-98.6	-130.3
38	take	251.0	-92.0	42,135	50	301.0	-142.0	285.1	-126.1	-105.3	-143.6
39	take	263.9	-104.9	34,035	59	322.9	-163.9	285.9	-126.9	-121.2	-158.9
40	take	276.8	-117.8	25,935	68	344.8	-185.8	286.6	-127.6	-131.3	-171.4
41	take	289.7	-130.7	17,835	72	361.7	-202.7	287.4	-128.4	-142.3	-183.9
42	take	302.6	-143.6	9,735	77	379.6	-220.6	288.1	-129.1	-158.1	-201.4
43	take	315.5	-156.5	1,635	80	395.5	-236.5	288.9	-129.9	-185.8	-224.8
44	take/hold/put	317.0	-158.0	1,168	81.5	398.5	-239.5	289.6	-130.6	-179.1	-209.7
45	put	308.4	-149.4	7,352				290.4	-131.4	-163.8	-188.4
46	put	299.8	-140.8	13,535				291.1	-132.1	-152.1	-171.4
47	put	291.2	-132.2	19,718				291.9	-132.9	-144.4	-160.1

Assumptions:

1) Put Rate of 5.52 MGD results in 8.6 feet/year increase in groundwater levels in Colma area
2) Take Rate of 7.23 MGD results in 12.9 feet/year decrease in groundwater levels in Colma area
3) Hold Year results in 0.75 feet/year decrease in groundwater levels in Colma area
4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.

Notes: DTW = depth to water; IT = Italian; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table C-3. Olivet Cemetery Well Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	OV Well DTW (Feet)	OV Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	OV Well SWL (Feet bgs)	OV Well GWE (Feet NGVD 29)	OV Well Background DTW (Feet)	OV Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 2 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)
1	put	220.2	-78.2	27,742				231.8	-89.8	-81.6	-91.8
2	put	211.6	-69.6	33,925				232.5	-90.5	-74.2	-84.8
3	put	203.0	-61.0	40,108				233.3	-91.3	-68.8	-79.3
4	put	194.4	-52.4	46,291				234.0	-92.0	-67.2	-76.0
5	put	185.8	-43.8	52,475				234.8	-92.8	-62.9	-72.1
6	put	177.2	-35.2	58,658				235.5	-93.5	-60.4	-68.5
7	Put/Hold	175.1	-33.1	60,500				236.3	-94.3	-58.3	-65.9
8	Hold	175.9	-33.9	60,500				237.0	-95.0	-49.7	-67.7
9	Hold/Take	179.6	-37.6	58,475				237.8	-95.8	-60.2	-80.7
10	take	192.5	-50.5	50,375	38	230.5	-88.5	238.5	-96.5	-69.5	-105.7
11	Take/Put	200.1	-58.1	45,858	46	246.1	-104.1	239.3	-97.3	-75.7	-112.9
12	put	191.5	-49.5	52,042				240.0	-98.0	-74.7	-100.2
13	put	182.9	-40.9	58,225				240.8	-98.8	-73.4	-94.0
14	Put/Hold	180.2	-38.2	60,430				241.5	-99.5	-69.5	-87.7
15	Hold	181.0	-39.0	60,430				242.3	-100.3	-69.2	-87.8
16	Hold	181.7	-39.7	60,430				243.0	-101.0	-68.7	-87.1
17	Hold	182.5	-40.5	60,430				243.8	-101.8	-68.1	-87.7
18	Hold	183.2	-41.2	60,430				244.5	-102.5	-67.3	-88.0
19	Hold	184.0	-42.0	60,430				245.3	-103.3	-68.1	-88.9
20	Hold	184.7	-42.7	60,430				246.0	-104.0	-68.5	-89.9
21	Hold	185.5	-43.5	60,430				246.8	-104.8	-69.7	-92.5
22	Hold	186.2	-44.2	60,430				247.5	-105.5	-70.3	-93.0
23	Hold	187.0	-45.0	60,430				248.3	-106.3	-69.4	-92.2
24	Hold	187.7	-45.7	60,430				249.0	-107.0	-69.0	-92.6
25	Hold/Take	191.5	-49.5	58,405				249.8	-107.8	-73.9	-105.0
26	take	204.4	-62.4	50,305	38	242.4	-100.4	250.5	-108.5	-83.9	-129.4
27	take/put	211.9	-69.9	45,788	46	257.9	-115.9	251.3	-109.3	-90.9	-134.8
28	put	203.3	-61.3	51,972				252.0	-110.0	-90.6	-122.7
29	put	194.7	-52.7	58,155				252.8	-110.8	-85.9	-113.6
30	Put/Hold	192.1	-50.1	60,360				253.5	-111.5	-82.7	-107.7
31	Hold	192.8	-50.8	60,360				254.3	-112.3	-72.7	-102.4
32	Hold	193.6	-51.6	60,360				255.0	-113.0	-77.8	-100.6
33	Hold	194.3	-52.3	60,360				255.8	-113.8	-79.2	-101.7
34	Hold	195.1	-53.1	60,360				256.5	-114.5	-77.0	-101.3
35	Hold	195.8	-53.8	60,360				257.3	-115.3	-75.3	-100.8
36	hold/take	199.6	-57.6	58,335				258.0	-116.0	-81.8	-112.4
37	take	212.5	-70.5	50,235	38	250.5	-108.5	258.8	-116.8	-91.4	-136.2
38	take	225.4	-83.4	42,135	46	271.4	-129.4	259.5	-117.5	-92.9	-151.2
39	take	238.3	-96.3	34,035	53	291.3	-149.3	260.3	-118.3	-110.8	-166.5
40	take	251.2	-109.2	25,935	60	311.2	-169.2	261.0	-119.0	-118.9	-179.4
41	take	264.1	-122.1	17,835	63	327.1	-185.1	261.8	-119.8	-128.5	-192.0
42	take	277.0	-135.0	9,735	66	343.0	-201.0	262.5	-120.5	-139.5	-208.2
43	take	289.9	-147.9	1,635	69	358.9	-216.9	263.3	-121.3	-157.9	-229.8
44	take/hold/put	291.4	-149.4	1,168	70	361.4	-219.4	264.0	-122.0	-158.9	-217.2
45	put	282.8	-140.8	7,352				264.8	-122.8	-150.6	-196.8
46	put	274.2	-132.2	13,535				265.5	-123.5	-141.7	-178.6
47	put	265.6	-123.6	19,718				266.3	-124.3	-136.2	-166.3

Assumptions:

1) Put Rate of 5.52 MGD results in 8.6 feet/year increase in groundwater levels in Colma area
2) Take Rate of 7.23 MGD results in 12.9 feet/year decrease in groundwater levels in Colma area
3) Hold Year results in 0.75 feet/year decrease in groundwater levels in Colma area
4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.

Notes: DTW = depth to water; OV = Olivet; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table C-4. Home of Peace Cemetery Well Groundwater Levels for GSR Project (Scenario 2)

Date	Year Type	HP Well DTW (Feet)	HP Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	HP Well SWL (Feet bgs)	HP Well GWE (Feet NGVD 29)	HP Well Background DTW (Feet)	HP Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 3 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 5 GWE (Feet NGVD 29)
1	put	229.2	-108.2	27,742				240.8	-119.8	-85.7	-98.5	-118.7
2	put	220.6	-99.6	33,925				241.5	-120.5	-79.3	-91.4	-111.2
3	put	212.0	-91.0	40,108				242.3	-121.3	-74.3	-85.9	-106.0
4	put	203.4	-82.4	46,291				243.0	-122.0	-71.7	-83.0	-103.2
5	put	194.8	-73.8	52,475				243.8	-122.8	-68.1	-79.2	-99.6
6	put	186.2	-65.2	58,658				244.5	-123.5	-64.9	-75.7	-96.5
7	Put/Hold	184.1	-63.1	60,500				245.3	-124.3	-62.0	-72.6	-107.0
8	Hold	184.9	-63.9	60,500				246.0	-125.0	-61.0	-74.7	-124.7
9	Hold/Take	188.6	-67.6	58,475				246.8	-125.8	-68.8	-85.3	-148.3
10	take	201.5	-80.5	50,375	36	237.5	-116.5	247.5	-126.5	-86.0	-113.1	-196.7
11	Take/Put	209.1	-88.1	45,858	43	252.1	-131.1	248.3	-127.3	-94.3	-125.3	-214.0
12	put	200.5	-79.5	52,042				249.0	-128.0	-87.3	-111.2	-170.1
13	put	191.9	-70.9	58,225				249.8	-128.8	-83.6	-103.8	-145.8
14	Put/Hold	189.2	-68.2	60,430				250.5	-129.5	-78.3	-96.2	-141.3
15	Hold	190.0	-69.0	60,430				251.3	-130.3	-78.0	-96.2	-154.1
16	Hold	190.7	-69.7	60,430				252.0	-131.0	-77.0	-95.5	-159.7
17	Hold	191.5	-70.5	60,430				252.8	-131.8	-77.2	-96.3	-163.4
18	Hold	192.2	-71.2	60,430				253.5	-132.5	-77.0	-96.6	-165.3
19	Hold	193.0	-72.0	60,430				254.3	-133.3	-77.6	-97.7	-167.6
20	Hold	193.7	-72.7	60,430				255.0	-134.0	-78.4	-98.7	-169.4
21	Hold	194.5	-73.5	60,430				255.8	-134.8	-80.6	-101.4	-171.9
22	Hold	195.2	-74.2	60,430				256.5	-135.5	-81.0	-102.1	-173.3
23	Hold	196.0	-75.0	60,430				257.3	-136.3	-80.1	-101.2	-173.6
24	Hold	196.7	-75.7	60,430				258.0	-137.0	-80.1	-101.6	-174.6
25	Hold/Take	200.5	-79.5	58,405				258.8	-137.8	-87.2	-111.5	-189.0
26	take	213.4	-92.4	50,305	36	249.4	-128.4	259.5	-138.5	-104.8	-138.6	-232.5
27	take/put	220.9	-99.9	45,788	43	263.9	-142.9	260.3	-139.3	-112.2	-148.5	-245.3
28	put	212.3	-91.3	51,972				261.0	-140.0	-106.1	-135.3	-200.1
29	put	203.7	-82.7	58,155				261.8	-140.8	-99.8	-124.8	-172.2
30	Put/Hold	201.1	-80.1	60,360				262.5	-141.5	-95.1	-117.7	-167.0
31	Hold	201.8	-80.8	60,360				263.3	-142.3	-89.1	-111.5	-173.3
32	Hold	202.6	-81.6	60,360				264.0	-143.0	-88.8	-109.9	-177.7
33	Hold	203.3	-82.3	60,360				264.8	-143.8	-89.6	-111.5	-181.7
34	Hold	204.1	-83.1	60,360				265.5	-144.5	-88.7	-110.9	-182.3
35	Hold	204.8	-83.8	60,360				266.3	-145.3	-87.9	-110.2	-182.1
36	hold/take	208.6	-87.6	58,335				267.0	-146.0	-94.9	-119.3	-196.3
37	take	221.5	-100.5	50,235	36	257.5	-136.5	267.8	-146.8	-111.5	-145.7	-239.3
38	take	234.4	-113.4	42,135	43	277.4	-156.4	268.5	-147.5	-121.9	-162.2	-265.6
39	take	247.3	-126.3	34,035	50	297.3	-176.3	269.3	-148.3	-136.2	-178.6	-287.4
40	take	260.2	-139.2	25,935	58	318.2	-197.2	270.0	-149.0	-146.7	-192.0	-303.1
41	take	273.1	-152.1	17,835	61	334.1	-213.1	270.8	-149.8	-157.4	-204.9	-316.5
42	take	286.0	-165.0	9,735	64	350.0	-229.0	271.5	-150.5	-170.0	-219.6	-328.0
43	take	298.9	-177.9	1,635	67	365.9	-244.9	272.3	-151.3	-189.2	-238.9	-338.0
44	ake/hold/pu	300.4	-179.4	1,168	68	368.4	-247.4	273.0	-152.0	-186.2	-229.6	-309.0
45	put	291.8	-170.8	7,352				273.8	-152.8	-172.6	-210.1	-260.8
46	put	283.2	-162.2	13,535				274.5	-153.5	-158.8	-190.0	-227.3
47	put	274.6	-153.6	19,718				275.3	-154.3	-149.8	-176.4	-205.2

Assumptions:

1) Put Rate of 5.52 MGD results in 8.6 feet/year increase in groundwater levels in Colma area

2) Take Rate of 7.23 MGD results in 12.9 feet/year decrease in groundwater levels in Colma area

3) Hold Year results in 0.75 feet/year decrease in groundwater levels in Colma area

4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.

Notes: DTW = depth to water; HP = Home of Peace; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table C-5. Hills of Eternity Cemetery Well Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	HE Well DTW (Feet)	HE Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	HE Well SWL (Feet bgs)	HE Well GWE (Feet NGVD)	HE Well Background DTW (Feet)	HE Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 1 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 2 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)
1	put	195.2	-71.2	27,742				206.8	-82.8	-60.7	-69.2	-100.7
2	put	186.6	-62.6	33,925				207.5	-83.5	-56.2	-64.0	-93.5
3	put	178.0	-54.0	40,108				208.3	-84.3	-52.8	-59.8	-87.9
4	put	169.4	-45.4	46,291				209.0	-85.0	-50.0	-57.8	-85.2
5	put	160.8	-36.8	52,475				209.8	-85.8	-47.5	-54.6	-81.2
6	put	152.2	-28.2	58,658				210.5	-86.5	-44.7	-52.1	-77.8
7	Put/Hold	150.1	-26.1	60,500				211.3	-87.3	-41.6	-49.6	-74.8
8	Hold	150.9	-26.9	60,500				212.0	-88.0	-40.2	-45.4	-76.0
9	Hold/Take	154.6	-30.6	58,475				212.8	-88.8	-39.5	-49.4	-89.8
10	take	167.5	-43.5	50,375	34	201.5	-77.5	213.5	-89.5	-42.5	-55.8	-118.5
11	Take/Put	175.1	-51.1	45,858	41	216.1	-92.1	214.3	-90.3	-45.9	-60.7	-128.8
12	put	166.5	-42.5	52,042				215.0	-91.0	-47.1	-60.1	-114.5
13	put	157.9	-33.9	58,225				215.8	-91.8	-49.2	-59.9	-106.7
14	Put/Hold	155.2	-31.2	60,430				216.5	-92.5	-47.5	-57.3	-98.7
15	Hold	156.0	-32.0	60,430				217.3	-93.3	-46.2	-56.7	-98.7
16	Hold	156.7	-32.7	60,430				218.0	-94.0	-44.4	-55.7	-98.2
17	Hold	157.5	-33.5	60,430				218.8	-94.8	-43.4	-55.0	-98.9
18	Hold	158.2	-34.2	60,430				219.5	-95.5	-42.9	-54.4	-99.2
19	Hold	159.0	-35.0	60,430				220.3	-96.3	-42.6	-54.4	-100.4
20	Hold	159.7	-35.7	60,430				221.0	-97.0	-43.1	-54.9	-101.4
21	Hold	160.5	-36.5	60,430				221.8	-97.8	-46.1	-56.7	-103.9
22	Hold	161.2	-37.2	60,430				222.5	-98.5	-45.0	-56.7	-104.8
23	Hold	162.0	-38.0	60,430				223.3	-99.3	-43.8	-55.7	-103.9
24	Hold	162.7	-38.7	60,430				224.0	-100.0	-43.3	-55.3	-104.3
25	Hold/Take	166.5	-42.5	58,405				224.8	-100.8	-46.9	-58.8	-116.5
26	take	179.4	-55.4	50,305	34	213.4	-89.4	225.5	-101.5	-52.0	-66.5	-144.3
27	take/put	186.9	-62.9	45,788	41	227.9	-103.9	226.3	-102.3	-55.7	-71.8	-152.6
28	put	178.3	-54.3	51,972				227.0	-103.0	-58.0	-72.2	-139.0
29	put	169.7	-45.7	58,155				227.8	-103.8	-57.7	-69.9	-128.0
30	Put/Hold	167.1	-43.1	60,360				228.5	-104.5	-58.0	-68.2	-120.4
31	Hold	167.8	-43.8	60,360				229.3	-105.3	-55.1	-62.9	-113.5
32	Hold	168.6	-44.6	60,360				230.0	-106.0	-53.1	-64.1	-112.7
33	Hold	169.3	-45.3	60,360				230.8	-106.8	-52.3	-64.2	-114.4
34	Hold	170.1	-46.1	60,360				231.5	-107.5	-51.4	-63.0	-113.7
35	Hold	170.8	-46.8	60,360				232.3	-108.3	-51.3	-62.2	-112.8
36	hold/take	174.6	-50.6	58,335				233.0	-109.0	-53.5	-65.8	-124.6
37	take	187.5	-63.5	50,235	34	221.5	-97.5	233.8	-109.8	-57.6	-72.5	-151.8
38	take	200.4	-76.4	42,135	41	241.4	-117.4	234.5	-110.5	-63.2	-76.3	-167.9
39	take	213.3	-89.3	34,035	48	261.3	-137.3	235.3	-111.3	-71.2	-87.6	-185.4
40	take	226.2	-102.2	25,935	56	282.2	-158.2	236.0	-112.0	-77.5	-94.1	-198.9
41	take	239.1	-115.1	17,835	59	298.1	-174.1	236.8	-112.8	-84.0	-101.3	-211.9
42	take	252.0	-128.0	9,735	62	314.0	-190.0	237.5	-113.5	-92.8	-109.6	-226.3
43	take	264.9	-140.9	1,635	65	329.9	-205.9	238.3	-114.3	-102.3	-121.2	-244.8
44	take/hold/put	266.4	-142.4	1,168	66	332.4	-208.4	239.0	-115.0	-108.0	-124.7	-233.2
45	put	257.8	-133.8	7,352				239.8	-115.8	-110.0	-121.9	-213.8
46	put	249.2	-125.2	13,535				240.5	-116.5	-108.1	-117.5	-193.2
47	put	240.6	-116.6	19,718				241.3	-117.3	-106.0	-114.3	-179.3

Assumptions:

1) Put Rate of 5.52 MGD results in 8.6 feet/year increase in groundwater levels in Colma area

2) Take Rate of 7.23 MGD results in 12.9 feet/year decrease in groundwater levels in Colma area

3) Hold Year results in 0.75 feet/year decrease in groundwater levels in Colma area

4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.

Notes: DTW = depth to water; HE = Hills of Eternity: GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table C-6. Cypress Lawn Cemetery Well 3 Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	CL3 Well DTW (Feet)	CL3 Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	CL3 Well SWL (Feet bgs)	CL3 Well GWE (Feet NGVD 29)	CL3 Well Background DTW (Feet)	CL3 Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 2 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)
1	put	245.2	-95.2	27,742				256.8	-106.8	-59.2	-109.6
2	put	236.6	-86.6	33,925				257.5	-107.5	-55.4	-102.4
3	put	228.0	-78.0	40,108				258.3	-108.3	-51.9	-96.8
4	put	219.4	-69.4	46,291				259.0	-109.0	-50.2	-94.6
5	put	210.8	-60.8	52,475				259.8	-109.8	-47.7	-90.5
6	put	202.2	-52.2	58,658				260.5	-110.5	-45.4	-87.3
7	Put/Hold	200.1	-50.1	60,500				261.3	-111.3	-43.0	-84.3
8	Hold	200.9	-50.9	60,500				262.0	-112.0	-40.4	-84.8
9	Hold/Take	204.6	-54.6	58,475				262.8	-112.8	-41.6	-97.4
10	take	217.5	-67.5	50,375	35	252.5	-102.5	263.5	-113.5	-45.5	-128.6
11	Take/Put	225.1	-75.1	45,858	46	271.1	-121.1	264.3	-114.3	-49.0	-144.1
12	put	216.5	-66.5	52,042				265.0	-115.0	-48.5	-128.9
13	put	207.9	-57.9	58,225				265.8	-115.8	-48.9	-119.6
14	Put/Hold	205.2	-55.2	60,430				266.5	-116.5	-47.2	-110.2
15	Hold	206.0	-56.0	60,430				267.3	-117.3	-46.6	-110.5
16	Hold	206.7	-56.7	60,430				268.0	-118.0	-45.5	-110.2
17	Hold	207.5	-57.5	60,430				268.8	-118.8	-44.7	-111.2
18	Hold	208.2	-58.2	60,430				269.5	-119.5	-44.1	-111.5
19	Hold	209.0	-59.0	60,430				270.3	-120.3	-43.8	-112.9
20	Hold	209.7	-59.7	60,430				271.0	-121.0	-44.1	-114.1
21	Hold	210.5	-60.5	60,430				271.8	-121.8	-46.0	-116.5
22	Hold	211.2	-61.2	60,430				272.5	-122.5	-45.8	-117.6
23	Hold	212.0	-62.0	60,430				273.3	-123.3	-44.7	-116.8
24	Hold	212.7	-62.7	60,430				274.0	-124.0	-44.3	-117.3
25	Hold/Take	216.5	-66.5	58,405				274.8	-124.8	-46.9	-126.7
26	take	229.4	-79.4	50,305	35	264.4	-114.4	275.5	-125.5	-52.7	-156.8
27	take/put	236.9	-86.9	45,788	46	282.9	-132.9	276.3	-126.3	-56.8	-170.0
28	put	228.3	-78.3	51,972				277.0	-127.0	-57.4	-155.4
29	put	219.7	-69.7	58,155				277.8	-127.8	-56.3	-142.5
30	Put/Hold	217.1	-67.1	60,360				278.5	-128.5	-55.6	-133.6
31	Hold	217.8	-67.8	60,360				279.3	-129.3	-52.6	-125.2
32	Hold	218.6	-68.6	60,360				280.0	-130.0	-52.4	-125.8
33	Hold	219.3	-69.3	60,360				280.8	-130.8	-52.0	-128.2
34	Hold	220.1	-70.1	60,360				281.5	-131.5	-51.3	-127.1
35	Hold	220.8	-70.8	60,360				282.3	-132.3	-51.0	-125.9
36	hold/take	224.6	-74.6	58,335				283.0	-133.0	-53.2	-135.5
37	take	237.5	-87.5	50,235	35	272.5	-122.5	283.8	-133.8	-57.9	-164.9
38	take	250.4	-100.4	42,135	46	296.4	-146.4	284.5	-134.5	-61.7	-181.5
39	take	263.3	-113.3	34,035	52	315.3	-165.3	285.3	-135.3	-69.8	-201.4
40	take	276.2	-126.2	25,935	56	332.2	-182.2	286.0	-136.0	-75.0	-215.3
41	take	289.1	-139.1	17,835	60	349.1	-199.1	286.8	-136.8	-80.6	-228.9
42	take	302.0	-152.0	9,735	63	365.0	-215.0	287.5	-137.5	-87.2	-241.9
43	take	314.9	-164.9	1,635	65	379.9	-229.9	288.3	-138.3	-95.4	-257.8
44	take/hold/put	316.4	-166.4	1,168	66	382.4	-232.4	289.0	-139.0	-99.5	-249.3
45	put	307.8	-157.8	7,352				289.8	-139.8	-99.2	-230.3
46	put	299.2	-149.2	13,535				290.5	-140.5	-97.2	-207.7
47	put	290.6	-140.6	19,718				291.3	-141.3	-95.6	-192.2

Assumptions:

1) Put Rate of 5.52 MGD results in 8.6 feet/year increase in groundwater levels in Colma area
2) Take Rate of 7.23 MGD results in 12.9 feet/year decrease in groundwater levels in Colma area
3) Hold Year results in 0.75 feet/year decrease in groundwater levels in Colma area
4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.

Notes: DTW = depth to water; CL = Cypress Lawn; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table C-7. Cypress Lawn Cemetery Well 4 Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	CL4 Well DTW (Feet)	CL4 Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	CL4 Well SWL (Feet bgs)	CL4 Well GWE (Feet NGVD 29)	CL4 Well Background DTW (Feet)	CL4 Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 3 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 5 GWE (Feet NGVD 29)
1	put	188.2	-96.2	27,742				199.8	-107.8	-87.2	-109.6	-123.3
2	put	179.6	-87.6	33,925				200.5	-108.5	-81.4	-102.4	-115.7
3	put	171.0	-79.0	40,108				201.3	-109.3	-76.7	-96.8	-110.3
4	put	162.4	-70.4	46,291				202.0	-110.0	-74.6	-94.6	-107.9
5	put	153.8	-61.8	52,475				202.8	-110.8	-71.1	-90.5	-103.9
6	put	145.2	-53.2	58,658				203.5	-111.5	-68.2	-87.3	-100.9
7	Put/Hold	143.1	-51.1	60,500				204.3	-112.3	-65.2	-84.3	-109.4
8	Hold	143.9	-51.9	60,500				205.0	-113.0	-64.0	-84.8	-123.1
9	Hold/Take	147.6	-55.6	58,475				205.8	-113.8	-71.9	-97.4	-145.2
10	take	160.5	-68.5	50,375	36	196.5	-104.5	206.5	-114.5	-90.3	-128.6	-189.7
11	Take/Put	168.1	-76.1	45,858	47	215.1	-123.1	207.3	-115.3	-99.6	-144.1	-209.8
12	put	159.5	-67.5	52,042				208.0	-116.0	-92.0	-128.9	-172.4
13	put	150.9	-58.9	58,225				208.8	-116.8	-87.4	-119.6	-149.8
14	Put/Hold	148.2	-56.2	60,430				209.5	-117.5	-81.6	-110.2	-143.6
15	Hold	149.0	-57.0	60,430				210.3	-118.3	-81.3	-110.5	-155.1
16	Hold	149.7	-57.7	60,430				211.0	-119.0	-80.5	-110.2	-160.3
17	Hold	150.5	-58.5	60,430				211.8	-119.8	-80.6	-111.2	-163.7
18	Hold	151.2	-59.2	60,430				212.5	-120.5	-80.5	-111.5	-165.5
19	Hold	152.0	-60.0	60,430				213.3	-121.3	-81.1	-112.9	-168.0
20	Hold	152.7	-60.7	60,430				214.0	-122.0	-81.9	-114.1	-169.9
21	Hold	153.5	-61.5	60,430				214.8	-122.8	-83.8	-116.5	-172.0
22	Hold	154.2	-62.2	60,430				215.5	-123.5	-84.5	-117.6	-173.8
23	Hold	155.0	-63.0	60,430				216.3	-124.3	-83.7	-116.8	-174.1
24	Hold	155.7	-63.7	60,430				217.0	-125.0	-83.8	-117.3	-175.1
25	Hold/Take	159.5	-67.5	58,405				217.8	-125.8	-90.5	-126.7	-186.5
26	take	172.4	-80.4	50,305	36	208.4	-116.4	218.5	-126.5	-109.1	-156.8	-226.2
27	take/put	179.9	-87.9	45,788	47	226.9	-134.9	219.3	-127.3	-117.6	-170.0	-242.3
28	put	171.3	-79.3	51,972				220.0	-128.0	-110.9	-155.4	-203.6
29	put	162.7	-70.7	58,155				220.8	-128.8	-103.8	-142.5	-176.8
30	Put/Hold	160.1	-68.1	60,360				221.5	-129.5	-98.5	-133.6	-169.9
31	Hold	160.8	-68.8	60,360				222.3	-130.3	-92.2	-125.2	-172.8
32	Hold	161.6	-69.6	60,360				223.0	-131.0	-92.3	-125.8	-178.7
33	Hold	162.3	-70.3	60,360				223.8	-131.8	-93.4	-128.2	-182.9
34	Hold	163.1	-71.1	60,360				224.5	-132.5	-92.4	-127.1	-183.0
35	Hold	163.8	-71.8	60,360				225.3	-133.3	-91.5	-125.9	-182.4
36	hold/take	167.6	-75.6	58,335				226.0	-134.0	-98.2	-135.5	-194.4
37	take	180.5	-88.5	50,235	36	216.5	-124.5	226.8	-134.8	-116.0	-164.9	-233.7
38	take	193.4	-101.4	42,135	47	240.4	-148.4	227.5	-135.5	-126.7	-181.5	-257.2
39	take	206.3	-114.3	34,035	53	259.3	-167.3	228.3	-136.3	-141.2	-201.4	-281.0
40	take	219.2	-127.2	25,935	58	277.2	-185.2	229.0	-137.0	-151.6	-215.3	-296.6
41	take	232.1	-140.1	17,835	62	294.1	-202.1	229.8	-137.8	-162.0	-228.9	-310.3
42	take	245.0	-153.0	9,735	65	310.0	-218.0	230.5	-138.5	-172.7	-241.9	-321.5
43	take	257.9	-165.9	1,635	68	325.9	-233.9	231.3	-139.3	-187.2	-257.8	-331.5
44	take/hold/put	259.4	-167.4	1,168	69	328.4	-236.4	232.0	-140.0	-184.8	-249.3	-309.6
45	put	250.8	-158.8	7,352				232.8	-140.8	-173.7	-230.3	-265.9
46	put	242.2	-150.2	13,535				233.5	-141.5	-159.9	-207.7	-233.2
47	put	233.6	-141.6	19,718				234.3	-142.3	-150.5	-192.2	-211.5

Assumptions:

1) Put Rate of 5.52 MGD results in 8.6 feet/year increase in groundwater levels in Colma area
2) Take Rate of 7.23 MGD results in 12.9 feet/year decrease in groundwater levels in Colma area
3) Hold Year results in 0.75 feet/year decrease in groundwater levels in Colma area
4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.

Notes: DTW = depth to water; CL = Cypress Lawn; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table C-8. Holy Cross Cemetery Well 1 Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	HC1 Well DTW (Feet)	HC1 Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	HC1 Well SWL (Feet bgs)	HC1 Well GWE (Feet NGVD 29)	HC1 Well Background DTW (Feet)	HC1 Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 3 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 5 GWE (Feet NGVD 29)
1	put	189.2	-95.2	27,742				200.8	-106.8	-83.4	-113.1	-125.1
2	put	180.6	-86.6	33,925				201.5	-107.5	-79.0	-106.9	-118.1
3	put	172.0	-78.0	40,108				202.3	-108.3	-75.0	-101.6	-112.8
4	put	163.4	-69.4	46,291				203.0	-109.0	-72.6	-99.1	-110.3
5	put	154.8	-60.8	52,475				203.8	-109.8	-69.4	-95.2	-106.1
6	put	146.2	-52.2	58,658				204.5	-110.5	-66.5	-91.8	-102.9
7	Put/Hold	144.1	-50.1	60,500				205.3	-111.3	-63.8	-89.7	-109.9
8	Hold	144.9	-50.9	60,500				206.0	-112.0	-64.7	-92.6	-121.3
9	Hold/Take	148.6	-54.6	58,475				206.8	-112.8	-75.3	-111.6	-139.1
10	take	161.5	-67.5	50,375	43	204.5	-110.5	207.5	-113.5	-93.8	-144.3	-178.5
11	Take/Put	169.1	-75.1	45,858	50	219.1	-125.1	208.3	-114.3	-100.2	-155.6	-200.7
12	put	160.5	-66.5	52,042				209.0	-115.0	-92.4	-139.4	-170.8
13	put	151.9	-57.9	58,225				209.8	-115.8	-86.8	-128.3	-150.8
14	Put/Hold	149.2	-55.2	60,430				210.5	-116.5	-81.2	-118.8	-144.4
15	Hold	150.0	-56.0	60,430				211.3	-117.3	-80.7	-119.5	-153.6
16	Hold	150.7	-56.7	60,430				212.0	-118.0	-80.2	-119.9	-158.1
17	Hold	151.5	-57.5	60,430				212.8	-118.8	-80.4	-121.1	-161.3
18	Hold	152.2	-58.2	60,430				213.5	-119.5	-80.6	-121.8	-163.1
19	Hold	153.0	-59.0	60,430				214.3	-120.3	-81.3	-123.5	-165.6
20	Hold	153.7	-59.7	60,430				215.0	-121.0	-82.1	-124.9	-167.6
21	Hold	154.5	-60.5	60,430				215.8	-121.8	-83.9	-127.4	-169.8
22	Hold	155.2	-61.2	60,430				216.5	-122.5	-84.8	-128.8	-171.7
23	Hold	156.0	-62.0	60,430				217.3	-123.3	-84.4	-128.4	-172.1
24	Hold	156.7	-62.7	60,430				218.0	-124.0	-84.7	-129.1	-173.2
25	Hold/Take	160.5	-66.5	58,405				218.8	-124.8	-94.8	-144.8	-181.3
26	take	173.4	-79.4	50,305	43	216.4	-122.4	219.5	-125.5	-113.2	-175.7	-216.2
27	take/put	180.9	-86.9	45,788	50	230.9	-136.9	220.3	-126.3	-118.3	-184.0	-234.3
28	put	172.3	-78.3	51,972				221.0	-127.0	-110.9	-167.9	-203.0
29	put	163.7	-69.7	58,155				221.8	-127.8	-103.6	-153.4	-178.9
30	Put/Hold	161.1	-67.1	60,360				222.5	-128.5	-98.1	-143.9	-171.6
31	Hold	161.8	-67.8	60,360				223.3	-129.3	-93.7	-137.0	-172.4
32	Hold	162.6	-68.6	60,360				224.0	-130.0	-92.3	-136.9	-177.4
33	Hold	163.3	-69.3	60,360				224.8	-130.8	-93.1	-139.3	-181.2
34	Hold	164.1	-70.1	60,360				225.5	-131.5	-92.6	-138.7	-181.3
35	Hold	164.8	-70.8	60,360				226.3	-132.3	-92.2	-137.9	-180.8
36	hold/take	168.6	-74.6	58,335				227.0	-133.0	-101.8	-153.3	-189.4
37	take	181.5	-87.5	50,235	43	224.5	-130.5	227.8	-133.8	-119.6	-183.7	-223.9
38	take	194.4	-100.4	42,135	50	244.4	-150.4	228.5	-134.5	-132.2	-202.9	-246.1
39	take	207.3	-113.3	34,035	57	264.3	-170.3	229.3	-135.3	-144.9	-222.7	-269.5
40	take	220.2	-126.2	25,935	64	284.2	-190.2	230.0	-136.0	-155.5	-237.5	-285.0
41	take	233.1	-139.1	17,835	68	301.1	-207.1	230.8	-136.8	-165.2	-251.1	-298.9
42	take	246.0	-152.0	9,735	70	316.0	-222.0	231.5	-137.5	-175.0	-263.8	-310.2
43	take	258.9	-164.9	1,635	73	331.9	-237.9	232.3	-138.3	-186.2	-277.3	-320.4
44	take/hold/put	260.4	-166.4	1,168	75	335.4	-241.4	233.0	-139.0	-179.0	-261.3	-305.4
45	put	251.8	-157.8	7,352				233.8	-139.8	-169.3	-241.5	-267.4
46	put	243.2	-149.2	13,535				234.5	-140.5	-156.5	-218.1	-236.9
47	put	234.6	-140.6	19,718				235.3	-141.3	-146.5	-200.9	-215.9

Assumptions:
1) Put Rate of 5.52 MGD results in 8.6 feet/year increase in groundwater levels in Colma area
2) Take Rate of 7.23 MGD results in 12.9 feet/year decrease in groundwater levels in Colma area
3) Hold Year results in 0.75 feet/year decrease in groundwater levels in Colma area
4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.
Notes: DTW = depth to water; HC = Holy Cross; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table C-9. Holy Cross Cemetery Well 4 Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	HC4 Well DTW (Feet)	HC4 Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	HC4 Well SWL (Feet bgs)	HC4 Well GWE (Feet NGVD 29)	HC4 Well Background DTW (Feet)	HC4 Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 5 GWE (Feet NGVD 29)
1	put	210.2	-96.2	27,742				220.3	-106.3	-115.0	-126.9
2	put	201.6	-87.6	33,925				221.0	-107.0	-108.0	-119.3
3	put	193.0	-79.0	40,108				221.8	-107.8	-102.5	-113.9
4	put	184.4	-70.4	46,291				222.5	-108.5	-100.4	-111.7
5	put	175.8	-61.8	52,475				223.3	-109.3	-96.2	-107.4
6	put	167.2	-53.2	58,658				224.0	-110.0	-93.1	-104.4
7	Put/Hold	165.1	-51.1	60,500				224.8	-110.8	-90.8	-111.7
8	Hold	165.9	-51.9	60,500				225.5	-111.5	-91.3	-121.7
9	Hold/Take	169.6	-55.6	58,475				226.3	-112.3	-108.7	-141.8
10	take	182.5	-68.5	50,375	37	219.5	-105.5	227.0	-113.0	-141.1	-182.1
11	Take/Put	190.1	-76.1	45,858	44	234.1	-120.1	227.8	-113.8	-155.1	-204.2
12	put	181.5	-67.5	52,042				228.5	-114.5	-139.4	-173.2
13	put	172.9	-58.9	58,225				229.3	-115.3	-128.7	-152.5
14	Put/Hold	170.2	-56.2	60,430				230.0	-116.0	-118.9	-145.9
15	Hold	171.0	-57.0	60,430				230.8	-116.8	-119.5	-155.7
16	Hold	171.7	-57.7	60,430				231.5	-117.5	-119.9	-160.5
17	Hold	172.5	-58.5	60,430				232.3	-118.3	-121.0	-163.6
18	Hold	173.2	-59.2	60,430				233.0	-119.0	-121.4	-165.3
19	Hold	174.0	-60.0	60,430				233.8	-119.8	-123.2	-168.0
20	Hold	174.7	-60.7	60,430				234.5	-120.5	-124.5	-169.8
21	Hold	175.5	-61.5	60,430				235.3	-121.3	-126.7	-171.8
22	Hold	176.2	-62.2	60,430				236.0	-122.0	-128.1	-173.8
23	Hold	177.0	-63.0	60,430				236.8	-122.8	-127.7	-174.2
24	Hold	177.7	-63.7	60,430				237.5	-123.5	-128.2	-175.2
25	Hold/Take	181.5	-67.5	58,405				238.3	-124.3	-140.8	-183.8
26	take	194.4	-80.4	50,305	37	231.4	-117.4	239.0	-125.0	-171.6	-219.4
27	take/put	201.9	-87.9	45,788	44	245.9	-131.9	239.8	-125.8	-183.1	-237.8
28	put	193.3	-79.3	51,972				240.5	-126.5	-167.7	-205.3
29	put	184.7	-70.7	58,155				241.3	-127.3	-153.1	-180.3
30	Put/Hold	182.1	-68.1	60,360				242.0	-128.0	-143.4	-172.7
31	Hold	182.8	-68.8	60,360				242.8	-128.8	-134.7	-172.6
32	Hold	183.6	-69.6	60,360				243.5	-129.5	-136.3	-179.3
33	Hold	184.3	-70.3	60,360				244.3	-130.3	-139.1	-183.6
34	Hold	185.1	-71.1	60,360				245.0	-131.0	-138.0	-183.3
35	Hold	185.8	-71.8	60,360				245.8	-131.8	-136.7	-182.5
36	hold/take	189.6	-75.6	58,335				246.5	-132.5	-149.7	-192.1
37	take	202.5	-88.5	50,235	37	239.5	-125.5	247.3	-133.3	-180.0	-227.5
38	take	215.4	-101.4	42,135	44	259.4	-145.4	248.0	-134.0	-197.1	-248.4
39	take	228.3	-114.3	34,035	51	279.3	-165.3	248.8	-134.8	-218.6	-273.5
40	take	241.2	-127.2	25,935	58	299.2	-185.2	249.5	-135.5	-233.2	-288.9
41	take	254.1	-140.1	17,835	61	315.1	-201.1	250.3	-136.3	-246.9	-303.0
42	take	267.0	-153.0	9,735	65	332.0	-218.0	251.0	-137.0	-259.3	-314.0
43	take	279.9	-165.9	1,635	68	347.9	-233.9	251.8	-137.8	-273.2	-323.9
44	take/hold/put	281.4	-167.4	1,168	69	350.4	-236.4	252.5	-138.5	-261.0	-308.4
45	put	272.8	-158.8	7,352				253.3	-139.3	-241.6	-269.2
46	put	264.2	-150.2	13,535				254.0	-140.0	-217.9	-237.9
47	put	255.6	-141.6	19,718				254.8	-140.8	-201.1	-216.7

Assumptions:

1) Put Rate of 5.52 MGD results in 8.6 feet/year increase in groundwater levels in Colma area

2) Take Rate of 7.23 MGD results in 12.9 feet/year decrease in groundwater levels in Colma area

3) Hold Year results in 0.75 feet/year decrease in groundwater levels in Colma area

4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.

Notes: DTW = depth to water; HC = Holy Cross; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table C-10. California Golf Club Well 7 Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	CGC Well DTW (Feet)	CGC Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	CGC Well SWL (Feet bgs)	CGC Well GWE (Feet NGVD 29)	CGC Well Background DTW (Feet)	CGC Well Background GWE (Feet NGVD 29)	GW Model SC 2-Lay 2 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 3 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)
1	put	189.4	-111.4	27,742				200.8	-122.8	-45.1	-87.9	-130.7
2	put	180.9	-102.9	33,925				201.5	-123.5	-43.3	-84.6	-125.6
3	put	172.4	-94.4	40,108				202.3	-124.3	-41.3	-81.0	-120.4
4	put	163.9	-85.9	46,291				203.0	-125.0	-39.7	-78.5	-116.8
5	put	155.4	-77.4	52,475				203.8	-125.8	-37.7	-75.1	-112.1
6	put	146.9	-68.9	58,658				204.5	-126.5	-35.8	-72.3	-108.3
7	Put/Hold	144.8	-66.8	60,500				205.3	-127.3	-34.9	-73.3	-117.7
8	Hold	145.6	-67.6	60,500				206.0	-128.0	-34.0	-74.5	-124.3
9	Hold/Take	150.8	-72.8	58,475				206.8	-128.8	-35.1	-81.1	-140.5
10	take	169.3	-91.3	50,375	41	210.3	-132.3	207.5	-129.5	-37.9	-94.6	-169.5
11	Take/Put	181.0	-103.0	45,858	52	233.0	-155.0	208.3	-130.3	-41.7	-107.1	-183.7
12	put	172.5	-94.5	52,042				209.0	-131.0	-41.5	-103.0	-166.9
13	put	164.0	-86.0	58,225				209.8	-131.8	-39.6	-96.3	-153.2
14	Put/Hold	161.4	-83.4	60,430				210.5	-132.5	-38.2	-92.7	-152.8
15	Hold	162.2	-84.2	60,430				211.3	-133.3	-38.1	-93.9	-157.5
16	Hold	162.9	-84.9	60,430				212.0	-134.0	-38.1	-95.3	-160.9
17	Hold	163.7	-85.7	60,430				212.8	-134.8	-38.0	-96.5	-163.9
18	Hold	164.4	-86.4	60,430				213.5	-135.5	-38.0	-97.5	-166.1
19	Hold	165.2	-87.2	60,430				214.3	-136.3	-38.1	-99.0	-169.0
20	Hold	165.9	-87.9	60,430				215.0	-137.0	-38.3	-100.3	-171.4
21	Hold	166.7	-88.7	60,430				215.8	-137.8	-38.6	-101.5	-173.7
22	Hold	167.4	-89.4	60,430				216.5	-138.5	-39.2	-103.1	-176.1
23	Hold	168.2	-90.2	60,430				217.3	-139.3	-39.2	-103.8	-177.3
24	Hold	168.9	-90.9	60,430				218.0	-140.0	-39.3	-104.4	-178.6
25	Hold/Take	174.1	-96.1	58,405				218.8	-140.8	-39.7	-106.5	-186.9
26	take	192.6	-114.6	50,305	41	233.6	-155.6	219.5	-141.5	-42.9	-118.1	-211.5
27	take/put	204.3	-126.3	45,788	52	256.3	-178.3	220.3	-142.3	-47.0	-129.0	-221.7
28	put	195.8	-117.8	51,972				221.0	-143.0	-47.0	-123.8	-202.5
29	put	187.3	-109.3	58,155				221.8	-143.8	-45.1	-115.0	-184.8
30	Put/Hold	184.7	-106.7	60,360				222.5	-144.5	-43.7	-110.4	-182.5
31	Hold	185.5	-107.5	60,360				223.3	-145.3	-42.6	-107.3	-180.4
32	Hold	186.2	-108.2	60,360				224.0	-146.0	-43.0	-108.9	-183.1
33	Hold	187.0	-109.0	60,360				224.8	-146.8	-43.1	-110.2	-185.8
34	Hold	187.7	-109.7	60,360				225.5	-147.5	-42.9	-110.1	-186.1
35	Hold	188.5	-110.5	60,360				226.3	-148.3	-42.9	-109.9	-186.2
36	hold/take	193.7	-115.7	58,335				227.0	-149.0	-43.5	-112.6	-194.9
37	take	212.2	-134.2	50,235	41	253.2	-175.2	227.8	-149.8	-46.4	-123.9	-219.1
38	take	230.7	-152.7	42,135	52	282.7	-204.7	228.5	-150.5	-49.9	-133.9	-237.7
39	take	249.2	-171.2	34,035	58	307.2	-229.2	229.3	-151.3	-55.3	-147.5	-258.6
40	take	267.7	-189.7	25,935	62	329.7	-251.7	230.0	-152.0	-59.6	-157.3	-273.7
41	take	286.2	-208.2	17,835	66	352.2	-274.2	230.8	-152.8	-63.8	-166.4	-287.3
42	take	304.7	-226.7	9,735	69	373.7	-295.7	231.5	-153.5	-67.7	-174.0	-298.7
43	take	323.2	-245.2	1,635	71	394.2	-316.2	232.3	-154.3	-71.8	-181.4	-309.0
44	take/hold/put	326.0	-248.0	1,168	73	399.0	-321.0	233.0	-155.0	-74.8	-182.7	-296.3
45	put	317.5	-239.5	7,352				233.8	-155.8	-73.8	-171.8	-269.2
46	put	309.0	-231.0	13,535				234.5	-156.5	-71.6	-159.4	-245.3
47	put	300.5	-222.5	19,718				235.3	-157.3	-69.5	-148.9	-226.2

Assumptions:

1) Put Rate of 5.52 MGD results in 8.5 feet/year increase in groundwater levels in CGC area

2) Take Rate of 7.23 MGD results in 18.5 feet/year decrease in groundwater levels in CGC area

3) Hold Year results in 0.75 feet/year decrease in groundwater levels in CGC area

4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.

Notes: DTW = depth to water; CGC = California Golf Club; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table C-11 . Olympic Golf Club Well 2 (#8) Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	Oly2 Well DTW (Feet)	Oly2 Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	Oly2 Well SWL (Feet bgs)	Oly2 Well GWE (Feet NGVD 29)	Oly2 Well Background DTW (Feet)	Oly2 Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 2 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 5 GWE (Feet NGVD 29)
1	put	95.5	-20.5	27,742				100.5	-25.5	5.3	-21.1	-57.4
2	put	91.9	-16.9	33,925				101.0	-26.0	10.8	-16.5	-52.2
3	put	88.3	-13.3	40,108				101.5	-26.5	11.5	-12.0	-48.5
4	put	84.7	-9.7	46,291				102.0	-27.0	12.5	-9.0	-46.1
5	put	81.1	-6.1	52,475				102.5	-27.5	12.5	-6.7	-44.4
6	put	77.5	-2.5	58,658				103.0	-28.0	13.1	-5.2	-43.0
7	Put/Hold	76.8	-1.8	60,500				103.5	-28.5	13.5	-5.9	-62.8
8	Hold	77.3	-2.3	60,500				104.0	-29.0	12.1	-9.6	-81.3
9	Hold/Take	78.6	-3.6	58,475				104.5	-29.5	9.9	-13.1	-98.5
10	take	82.6	-7.6	50,375	7	89.6	-14.6	105.0	-30.0	6.3	-21.6	-137.6
11	Take/Put	84.7	-9.7	45,858	12	96.7	-21.7	105.5	-30.5	4.0	-28.0	-143.6
12	put	81.1	-6.1	52,042				106.0	-31.0	3.8	-23.6	-96.1
13	put	77.5	-2.5	58,225				106.5	-31.5	3.7	-20.3	-74.1
14	Put/Hold	76.5	-1.5	60,430				107.0	-32.0	4.8	-19.2	-81.6
15	Hold	77.0	-2.0	60,430				107.5	-32.5	4.8	-21.5	-95.9
16	Hold	77.5	-2.5	60,430				108.0	-33.0	6.4	-22.7	-102.2
17	Hold	78.0	-3.0	60,430				108.5	-33.5	5.1	-23.5	-105.0
18	Hold	78.5	-3.5	60,430				109.0	-34.0	6.4	-24.1	-106.5
19	Hold	79.0	-4.0	60,430				109.5	-34.5	6.1	-24.1	-107.3
20	Hold	79.5	-4.5	60,430				110.0	-35.0	5.7	-24.5	-108.1
21	Hold	80.0	-5.0	60,430				110.5	-35.5	3.9	-25.3	-109.1
22	Hold	80.5	-5.5	60,430				111.0	-36.0	7.1	-25.6	-109.8
23	Hold	81.0	-6.0	60,430				111.5	-36.5	7.8	-24.9	-110.0
24	Hold	81.5	-6.5	60,430				112.0	-37.0	6.6	-24.7	-110.2
25	Hold/Take	82.9	-7.9	58,405				112.5	-37.5	4.1	-25.9	-119.0
26	take	86.9	-11.9	50,305	7	93.9	-18.9	113.0	-38.0	0.4	-32.8	-154.2
27	take/put	89.0	-14.0	45,788	12	101.0	-26.0	113.5	-38.5	0.3	-38.1	-157.6
28	put	85.4	-10.4	51,972				114.0	-39.0	0.4	-32.5	-108.7
29	put	81.8	-6.8	58,155				114.5	-39.5	2.0	-27.8	-85.4
30	Put/Hold	80.8	-5.8	60,360				115.0	-40.0	2.3	-25.7	-92.0
31	Hold	81.3	-6.3	60,360				115.5	-40.5	4.9	-26.6	-104.8
32	Hold	81.8	-6.8	60,360				116.0	-41.0	8.0	-26.3	-109.4
33	Hold	82.3	-7.3	60,360				116.5	-41.5	7.1	-25.6	-111.6
34	Hold	82.8	-7.8	60,360				117.0	-42.0	5.9	-25.6	-112.6
35	Hold	83.3	-8.3	60,360				117.5	-42.5	7.2	-25.9	-113.0
36	hold/take	84.7	-9.7	58,335				118.0	-43.0	5.2	-26.8	-121.7
37	take	88.7	-13.7	50,235	7	95.7	-20.7	118.5	-43.5	1.9	-33.4	-156.5
38	take	92.7	-17.7	42,135	12	104.7	-29.7	119.0	-44.0	-1.0	-39.3	-175.8
39	take	96.7	-21.7	34,035	15	111.7	-36.7	119.5	-44.5	-5.4	-45.2	-187.8
40	take	100.7	-25.7	25,935	17	117.7	-42.7	120.0	-45.0	-8.7	-50.9	-196.5
41	take	104.7	-29.7	17,835	19	123.7	-48.7	120.5	-45.5	-11.3	-56.9	-203.3
42	take	108.7	-33.7	9,735	21	129.7	-54.7	121.0	-46.0	-16.1	-63.0	-209.4
43	take	112.7	-37.7	1,635	22	134.7	-59.7	121.5	-46.5	-21.0	-70.6	-214.8
44	take/hold/put	113.0	-38.0	1,168	23	136.0	-61.0	122.0	-47.0	-21.4	-74.6	-183.9
45	put	109.4	-34.4	7,352				122.5	-47.5	-20.1	-67.1	-136.2
46	put	105.8	-30.8	13,535				123.0	-48.0	-17.0	-59.3	-111.7
47	put	102.2	-27.2	19,718				123.5	-48.5	-12.8	-52.0	-97.2

Assumptions:

1) Put Rate of 5.52 MGD results in 3.6 feet/year increase in groundwater levels in Olympic Club area
2) Take Rate of 7.23 MGD results in 4.0 feet/year decrease in groundwater levels in the Olympic Club area
3) Hold Year results in 0.5 feet/year decrease in groundwater levels in the Olympic Club area
4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.

Notes: DTW = depth to water; Oly = Olympic Club; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table C-12. San Francisco Golf Club Well 2 Groundwater Levels for GSR Project (Scenario 2)

Future Scenario Year	Year Type	SFGC2 Well DTW (Feet)	SFCG2 Well GWE (Feet NGVD 29)	SFPUC Storage Account	GSR Local Drawdown (Feet)	SFGC2 Well SWL (Feet bgs)	SFGC2 Well GWE (Feet NGVD 29)	SFGC2 Well Background DTW (Feet)	SFGC2 Well Background GWE (Feet NGVD 29)	GW Model Sc 2-Lay 3 GWE (Feet NGVD 29)	GW Model Sc 2-Lay 4 GWE (Feet NGVD 29)
1	put	155.5	-16.5	27,742				160.5	-21.5	-9.1	-23.6
2	put	151.9	-12.9	33,925				161.0	-22.0	-4.2	-18.6
3	put	148.3	-9.3	40,108				161.5	-22.5	-0.7	-14.0
4	put	144.7	-5.7	46,291				162.0	-23.0	1.3	-11.0
5	put	141.1	-2.1	52,475				162.5	-23.5	3.3	-7.4
6	put	137.5	1.5	58,658				163.0	-24.0	3.4	-7.3
7	Put/Hold	136.8	2.2	60,500				163.5	-24.5	3.0	-8.5
8	Hold	137.3	1.7	60,500				164.0	-25.0	1.4	-10.6
9	Hold/Take	138.6	0.4	58,475				164.5	-25.5	-3.2	-15.9
10	take	142.6	-3.6	50,375	7	149.6	-10.6	165.0	-26.0	-9.9	-24.9
11	Take/Put	144.7	-5.7	45,858	11	155.7	-16.7	165.5	-26.5	-13.8	-31.0
12	put	141.1	-2.1	52,042				166.0	-27.0	-11.5	-26.2
13	put	137.5	1.5	58,225				166.5	-27.5	-9.7	-22.9
14	Put/Hold	136.5	2.5	60,430				167.0	-28.0	-9.1	-22.5
15	Hold	137.0	2.0	60,430				167.5	-28.5	-9.7	-24.3
16	Hold	137.5	1.5	60,430				168.0	-29.0	-9.9	-25.5
17	Hold	138.0	1.0	60,430				168.5	-29.5	-10.5	-26.3
18	Hold	138.5	0.5	60,430				169.0	-30.0	-10.2	-26.6
19	Hold	139.0	0.0	60,430				169.5	-30.5	-10.3	-26.9
20	Hold	139.5	-0.5	60,430				170.0	-31.0	-10.6	-27.2
21	Hold	140.0	-1.0	60,430				170.5	-31.5	-11.0	-26.6
22	Hold	140.5	-1.5	60,430				171.0	-32.0	-10.0	-26.8
23	Hold	141.0	-2.0	60,430				171.5	-32.5	-9.9	-27.5
24	Hold	141.5	-2.5	60,430				172.0	-33.0	-10.2	-27.3
25	Hold/Take	142.9	-3.9	58,405				172.5	-33.5	-12.7	-29.0
26	take	146.9	-7.9	50,305	7	153.9	-14.9	173.0	-34.0	-17.8	-35.0
27	take/put	149.0	-10.0	45,788	11	160.0	-21.0	173.5	-34.5	-21.4	-41.4
28	put	145.4	-6.4	51,972				174.0	-35.0	-18.0	-35.6
29	put	141.8	-2.8	58,155				174.5	-35.5	-13.4	-28.8
30	Put/Hold	140.8	-1.8	60,360				175.0	-36.0	-12.0	-26.8
31	Hold	141.3	-2.3	60,360				175.5	-36.5	-11.5	-27.7
32	Hold	141.8	-2.8	60,360				176.0	-37.0	-11.1	-29.3
33	Hold	142.3	-3.3	60,360				176.5	-37.5	-10.3	-28.4
34	Hold	142.8	-3.8	60,360				177.0	-38.0	-9.9	-26.8
35	Hold	143.3	-4.3	60,360				177.5	-38.5	-9.8	-27.1
36	hold/take	144.7	-5.7	58,335				178.0	-39.0	-12.8	-30.1
37	take	148.7	-9.7	50,235	7	155.7	-16.7	178.5	-39.5	-18.3	-37.1
38	take	152.7	-13.7	42,135	11	163.7	-24.7	179.0	-40.0	-22.2	-41.6
39	take	156.7	-17.7	34,035	15	171.7	-32.7	179.5	-40.5	-28.4	-49.3
40	take	160.7	-21.7	25,935	17	177.7	-38.7	180.0	-41.0	-33.3	-55.0
41	take	164.7	-25.7	17,835	19	183.7	-44.7	180.5	-41.5	-38.2	-61.4
42	take	168.7	-29.7	9,735	20	188.7	-49.7	181.0	-42.0	-43.7	-67.6
43	take	172.7	-33.7	1,635	22	194.7	-55.7	181.5	-42.5	-49.6	-74.1
44	take/hold/put	173.0	-34.0	1,168	22	195.0	-56.0	182.0	-43.0	-51.9	-78.8
45	put	169.4	-30.4	7,352				182.5	-43.5	-46.6	-70.5
46	put	165.8	-26.8	13,535				183.0	-44.0	-40.2	-62.0
47	put	162.2	-23.2	19,718				183.5	-44.5	-34.1	-54.5

Assumptions:

1) Put Rate of 5.52 MGD results in 3.6 feet/year increase in groundwater levels in San Francisco Golf Club area

2) Take Rate of 7.23 MGD results in 4.0 feet/year decrease in groundwater levels in the San Francisco Golf Club area

3) Hold Year results in 0.5 feet/year decrease in groundwater levels in the San Francisco Golf Club area

4) Exact Put amounts are derived from SFPUC (D. Cameron) spreadsheet for resequenced hydrology years.

Notes: DTW = depth to water; SFGC = San Francisco Golf Club; GWE = groundwater elevation; Sc = Model Scenario; Lay = Model Layer

Table C-13. SFPUC Storage Account and Colma Cemetery Water Level Changes for Third Party Well Interference Analysis.

Scenario Year	Put Months	Hold Months	Take Months	Put Storage Chanage	Take Storage Change	Net Storage Change	Put WL Change	Hold WL Change	Take WL Change	Net WL Change	Cum Storage Change
0	3	0	0	1,559	0	1,559	-2.17	0.00	0.00	-2.17	21,559
1	12	0	0	6,183	0	6,183	-8.60	0.00	0.00	-8.60	27,742
2	12	0	0	6,183	0	6,183	-8.60	0.00	0.00	-8.60	33,925
3	12	0	0	6,183	0	6,183	-8.60	0.00	0.00	-8.60	40,108
4	12	0	0	6,183	0	6,183	-8.60	0.00	0.00	-8.60	46,291
5	12	0	0	6,184	0	6,184	-8.60	0.00	0.00	-8.60	52,475
6	12	0	0	6,183	0	6,183	-8.60	0.00	0.00	-8.60	58,658
7	4	8	0	1,842	0	1,842	-2.56	0.50	0.00	-2.06	60,500
8	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,500
9	0	9	3	0	-2,025	-2,025	0.00	0.56	3.23	3.79	58,475
10	0	0	12	0	-8,100	-8,100	0.00	0.00	12.90	12.90	50,375
11	3	0	9	1,558	-6,075	-4,517	-2.17	0.00	9.68	7.51	45,858
12	12	0	0	6,184	0	6,184	-8.60	0.00	0.00	-8.60	52,042
13	12	0	0	6,183	0	6,183	-8.60	0.00	0.00	-8.60	58,225
14	5	7	0	2,205	0	2,205	-3.07	0.44	0.00	-2.63	60,430
15	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
16	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
17	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
18	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
19	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
20	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
21	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
22	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
23	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
24	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
25	0	9	3	0	-2,025	-2,025	0.00	0.56	3.23	3.79	58,405
26	0	0	12	0	-8,100	-8,100	0.00	0.00	12.90	12.90	50,305
27	3	0	9	1,558	-6,075	-4,517	-2.17	0.00	9.68	7.51	45,788
28	12	0	0	6,184	0	6,184	-8.60	0.00	0.00	-8.60	51,972
29	12	0	0	6,183	0	6,183	-8.60	0.00	0.00	-8.60	58,155
30	5	7	0	2,205	0	2,205	-3.07	0.44	0.00	-2.63	60,360
31	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
32	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
33	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
34	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
35	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
36	0	9	3	0	-2,025	-2,025	0.00	0.56	3.23	3.79	58,335
37	0	0	12	0	-8,100	-8,100	0.00	0.00	12.90	12.90	50,235
38	0	0	12	0	-8,100	-8,100	0.00	0.00	12.90	12.90	42,135
39	0	0	12	0	-8,100	-8,100	0.00	0.00	12.90	12.90	34,035
40	0	0	12	0	-8,100	-8,100	0.00	0.00	12.90	12.90	25,935
41	0	0	12	0	-8,100	-8,100	0.00	0.00	12.90	12.90	17,835
42	0	0	12	0	-8,100	-8,100	0.00	0.00	12.90	12.90	9,735
43	0	0	12	0	-8,100	-8,100	0.00	0.00	12.90	12.90	1,635
44	3	6	3	1,558	-2,025	-467	-2.17	0.38	3.23	1.43	1,168
45	12	0	0	6,184	0	6,184	-8.60	0.00	0.00	-8.60	7,352
46	12	0	0	6,183	0	6,183	-8.60	0.00	0.00	-8.60	13,535
47	12	0	0	6,183	0	6,183	-8.60	0.00	0.00	-8.60	19,718
Totals	182	247	138	92,868	-93,150	-282	-129.2	15.4	148.4	34.6	

Assumptions: Put Year Water Level Rise = 8.6 feet; Take Year Water Level Decline = 12.9 feet; Hold Year Water Level Decline = 0.75 feet. It is assumed that method of calculating Put/Take Year WL changes includes background decline component.

Table C-14. SFPUC Storage Account and California Golf Club Water Level Changes for Third Party Well Interference Analysis.

Scenario Year	Put Months	Hold Months	Take Months	Put Storage Chanage	Take Storage Change	Net Storage Change	Put WL Change	Hold WL Change	Take WL Change	Net WL Change	Cum Storage Change
0	3	0	0	1,559	0	1,559	-2.14	0.00	0.00	-2.14	21,559
1	12	0	0	6,183	0	6,183	-8.50	0.00	0.00	-8.50	27,742
2	12	0	0	6,183	0	6,183	-8.50	0.00	0.00	-8.50	33,925
3	12	0	0	6,183	0	6,183	-8.50	0.00	0.00	-8.50	40,108
4	12	0	0	6,183	0	6,183	-8.50	0.00	0.00	-8.50	46,291
5	12	0	0	6,184	0	6,184	-8.50	0.00	0.00	-8.50	52,475
6	12	0	0	6,183	0	6,183	-8.50	0.00	0.00	-8.50	58,658
7	4	8	0	1,842	0	1,842	-2.53	0.50	0.00	-2.03	60,500
8	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,500
9	0	9	3	0	-2,025	-2,025	0.00	0.56	4.63	5.19	58,475
10	0	0	12	0	-8,100	-8,100	0.00	0.00	18.50	18.50	50,375
11	3	0	9	1,558	-6,075	-4,517	-2.14	0.00	13.88	11.73	45,858
12	12	0	0	6,184	0	6,184	-8.50	0.00	0.00	-8.50	52,042
13	12	0	0	6,183	0	6,183	-8.50	0.00	0.00	-8.50	58,225
14	5	7	0	2,205	0	2,205	-3.03	0.44	0.00	-2.59	60,430
15	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
16	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
17	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
18	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
19	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
20	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
21	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
22	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
23	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
24	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
25	0	9	3	0	-2,025	-2,025	0.00	0.56	4.63	5.19	58,405
26	0	0	12	0	-8,100	-8,100	0.00	0.00	18.50	18.50	50,305
27	3	0	9	1,558	-6,075	-4,517	-2.14	0.00	13.88	11.73	45,788
28	12	0	0	6,184	0	6,184	-8.50	0.00	0.00	-8.50	51,972
29	12	0	0	6,183	0	6,183	-8.50	0.00	0.00	-8.50	58,155
30	5	7	0	2,205	0	2,205	-3.03	0.44	0.00	-2.59	60,360
31	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
32	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
33	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
34	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
35	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
36	0	9	3	0	-2,025	-2,025	0.00	0.56	4.63	5.19	58,335
37	0	0	12	0	-8,100	-8,100	0.00	0.00	18.50	18.50	50,235
38	0	0	12	0	-8,100	-8,100	0.00	0.00	18.50	18.50	42,135
39	0	0	12	0	-8,100	-8,100	0.00	0.00	18.50	18.50	34,035
40	0	0	12	0	-8,100	-8,100	0.00	0.00	18.50	18.50	25,935
41	0	0	12	0	-8,100	-8,100	0.00	0.00	18.50	18.50	17,835
42	0	0	12	0	-8,100	-8,100	0.00	0.00	18.50	18.50	9,735
43	0	0	12	0	-8,100	-8,100	0.00	0.00	18.50	18.50	1,635
44	3	6	3	1,558	-2,025	-467	-2.14	0.38	4.63	2.86	1,168
45	12	0	0	6,184	0	6,184	-8.50	0.00	0.00	-8.50	7,352
46	12	0	0	6,183	0	6,183	-8.50	0.00	0.00	-8.50	13,535
47	12	0	0	6,183	0	6,183	-8.50	0.00	0.00	-8.50	19,718
Totals	182	247	138	92,868	-93,150	-282	-127.7	15.4	212.8	100.5	

Assumptions: Put Year Water Level Rise = 8.5 feet; Take Year Water Level Decline = 18.5 feet; Hold Year Water Level Decline = 0.75 feet. It is assumed that method of calculating Put/Take Year WL changes includes background decline component.

Table C-15. SFPUC Storage Account and Lake Merced Golf Club Water Level Changes for Third Party Well Interference Analysis.

Scenario Year	Put Months	Hold Months	Take Months	Put Storage Chanage	Take Storage Change	Net Storage Change	Put WL Change	Hold WL Change	Take WL Change	Net WL Change	Cum Storage Change
0	3	0	0	1,559	0	1,559	-2.65	0.00	0.00	-2.65	21,559
1	12	0	0	6,183	0	6,183	-10.50	0.00	0.00	-10.50	27,742
2	12	0	0	6,183	0	6,183	-10.50	0.00	0.00	-10.50	33,925
3	12	0	0	6,183	0	6,183	-10.50	0.00	0.00	-10.50	40,108
4	12	0	0	6,183	0	6,183	-10.50	0.00	0.00	-10.50	46,291
5	12	0	0	6,184	0	6,184	-10.50	0.00	0.00	-10.50	52,475
6	12	0	0	6,183	0	6,183	-10.50	0.00	0.00	-10.50	58,658
7	4	8	0	1,842	0	1,842	-3.13	0.50	0.00	-2.63	60,500
8	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,500
9	0	9	3	0	-2,025	-2,025	0.00	0.56	3.75	4.31	58,475
10	0	0	12	0	-8,100	-8,100	0.00	0.00	15.00	15.00	50,375
11	3	0	9	1,558	-6,075	-4,517	-2.65	0.00	11.25	8.60	45,858
12	12	0	0	6,184	0	6,184	-10.50	0.00	0.00	-10.50	52,042
13	12	0	0	6,183	0	6,183	-10.50	0.00	0.00	-10.50	58,225
14	5	7	0	2,205	0	2,205	-3.74	0.44	0.00	-3.31	60,430
15	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
16	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
17	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
18	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
19	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
20	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
21	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
22	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
23	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
24	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,430
25	0	9	3	0	-2,025	-2,025	0.00	0.56	3.75	4.31	58,405
26	0	0	12	0	-8,100	-8,100	0.00	0.00	15.00	15.00	50,305
27	3	0	9	1,558	-6,075	-4,517	-2.65	0.00	11.25	8.60	45,788
28	12	0	0	6,184	0	6,184	-10.50	0.00	0.00	-10.50	51,972
29	12	0	0	6,183	0	6,183	-10.50	0.00	0.00	-10.50	58,155
30	5	7	0	2,205	0	2,205	-3.74	0.44	0.00	-3.31	60,360
31	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
32	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
33	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
34	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
35	0	12	0	0	0	0	0.00	0.75	0.00	0.75	60,360
36	0	9	3	0	-2,025	-2,025	0.00	0.56	3.75	4.31	58,335
37	0	0	12	0	-8,100	-8,100	0.00	0.00	15.00	15.00	50,235
38	0	0	12	0	-8,100	-8,100	0.00	0.00	15.00	15.00	42,135
39	0	0	12	0	-8,100	-8,100	0.00	0.00	15.00	15.00	34,035
40	0	0	12	0	-8,100	-8,100	0.00	0.00	15.00	15.00	25,935
41	0	0	12	0	-8,100	-8,100	0.00	0.00	15.00	15.00	17,835
42	0	0	12	0	-8,100	-8,100	0.00	0.00	15.00	15.00	9,735
43	0	0	12	0	-8,100	-8,100	0.00	0.00	15.00	15.00	1,635
44	3	6	3	1,558	-2,025	-467	-2.65	0.38	3.75	1.48	1,168
45	12	0	0	6,184	0	6,184	-10.50	0.00	0.00	-10.50	7,352
46	12	0	0	6,183	0	6,183	-10.50	0.00	0.00	-10.50	13,535
47	12	0	0	6,183	0	6,183	-10.50	0.00	0.00	-10.50	19,718
Totals	182	247	138	92,868	-93,150	-282	-157.7	15.4	172.5	30.2	

Assumptions: Put Year Water Level Rise = 10.5 feet; Take Year Water Level Decline = 15.0 feet; Hold Year Water Level Decline = 0.75 feet. It is assumed that method of calculating Put/Take Year WL changes includes background decline component.

Table C-16. SFPUC Storage Account and Olympic Club Well Water Level Changes for Third Party Well Interference Analysis (based upon 2002-2005 data only)

Scenario Year	Put Months	Hold Months	Take Months	Put Storage Chanage	Take Storage Change	Net Storage Change	Put WL Change	Hold WL Change	Take WL Change	Net WL Change	Cum Storage Change
0	3	0	0	1,559	0	1,559	-0.91	0.00	0.00	-0.91	21,559
1	12	0	0	6,183	0	6,183	-3.60	0.00	0.00	-3.60	27,742
2	12	0	0	6,183	0	6,183	-3.60	0.00	0.00	-3.60	33,925
3	12	0	0	6,183	0	6,183	-3.60	0.00	0.00	-3.60	40,108
4	12	0	0	6,183	0	6,183	-3.60	0.00	0.00	-3.60	46,291
5	12	0	0	6,184	0	6,184	-3.60	0.00	0.00	-3.60	52,475
6	12	0	0	6,183	0	6,183	-3.60	0.00	0.00	-3.60	58,658
7	4	8	0	1,842	0	1,842	-1.07	0.33	0.00	-0.74	60,500
8	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,500
9	0	9	3	0	-2,025	-2,025	0.00	0.38	1.00	1.38	58,475
10	0	0	12	0	-8,100	-8,100	0.00	0.00	4.00	4.00	50,375
11	3	0	9	1,558	-6,075	-4,517	-0.91	0.00	3.00	2.09	45,858
12	12	0	0	6,184	0	6,184	-3.60	0.00	0.00	-3.60	52,042
13	12	0	0	6,183	0	6,183	-3.60	0.00	0.00	-3.60	58,225
14	5	7	0	2,205	0	2,205	-1.28	0.29	0.00	-0.99	60,430
15	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,430
16	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,430
17	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,430
18	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,430
19	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,430
20	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,430
21	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,430
22	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,430
23	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,430
24	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,430
25	0	9	3	0	-2,025	-2,025	0.00	0.38	1.00	1.38	58,405
26	0	0	12	0	-8,100	-8,100	0.00	0.00	4.00	4.00	50,305
27	3	0	9	1,558	-6,075	-4,517	-0.91	0.00	3.00	2.09	45,788
28	12	0	0	6,184	0	6,184	-3.60	0.00	0.00	-3.60	51,972
29	12	0	0	6,183	0	6,183	-3.60	0.00	0.00	-3.60	58,155
30	5	7	0	2,205	0	2,205	-1.28	0.29	0.00	-0.99	60,360
31	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,360
32	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,360
33	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,360
34	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,360
35	0	12	0	0	0	0	0.00	0.50	0.00	0.50	60,360
36	0	9	3	0	-2,025	-2,025	0.00	0.38	1.00	1.38	58,335
37	0	0	12	0	-8,100	-8,100	0.00	0.00	4.00	4.00	50,235
38	0	0	12	0	-8,100	-8,100	0.00	0.00	4.00	4.00	42,135
39	0	0	12	0	-8,100	-8,100	0.00	0.00	4.00	4.00	34,035
40	0	0	12	0	-8,100	-8,100	0.00	0.00	4.00	4.00	25,935
41	0	0	12	0	-8,100	-8,100	0.00	0.00	4.00	4.00	17,835
42	0	0	12	0	-8,100	-8,100	0.00	0.00	4.00	4.00	9,735
43	0	0	12	0	-8,100	-8,100	0.00	0.00	4.00	4.00	1,635
44	3	6	3	1,558	-2,025	-467	-0.91	0.25	1.00	0.34	1,168
45	12	0	0	6,184	0	6,184	-3.60	0.00	0.00	-3.60	7,352
46	12	0	0	6,183	0	6,183	-3.60	0.00	0.00	-3.60	13,535
47	12	0	0	6,183	0	6,183	-3.60	0.00	0.00	-3.60	19,718
Totals	182	247	138	92,868	-93,150	-282	-54.1	10.3	46.0	2.2	

Assumptions: Put Year Water Level Rise = 3.6 feet; Take Year Water Level Decline = 4.0 feet; Hold Year Water Level Decline = 0.5 feet. It is assumed that method of calculating Put/Take Year WL changes includes background decline component.

Figure C-1. Estimated Static Water Levels at Woodlawn Cemetery Primary Well for GSR Project

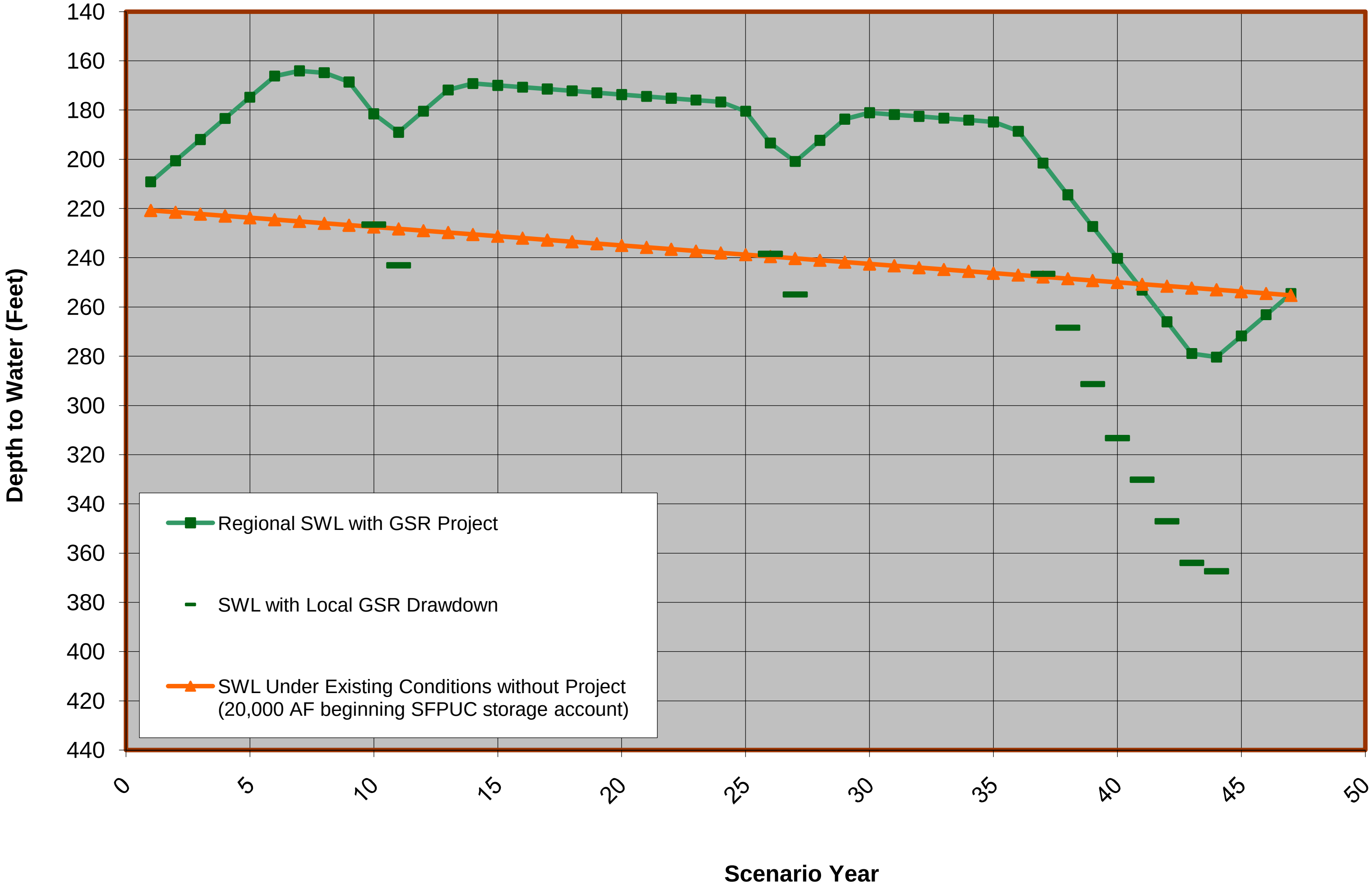


Figure C-2. Estimated Groundwater Elevations at Woodlawn Cemetery Primary Well for GSR Project (Scenario 2)

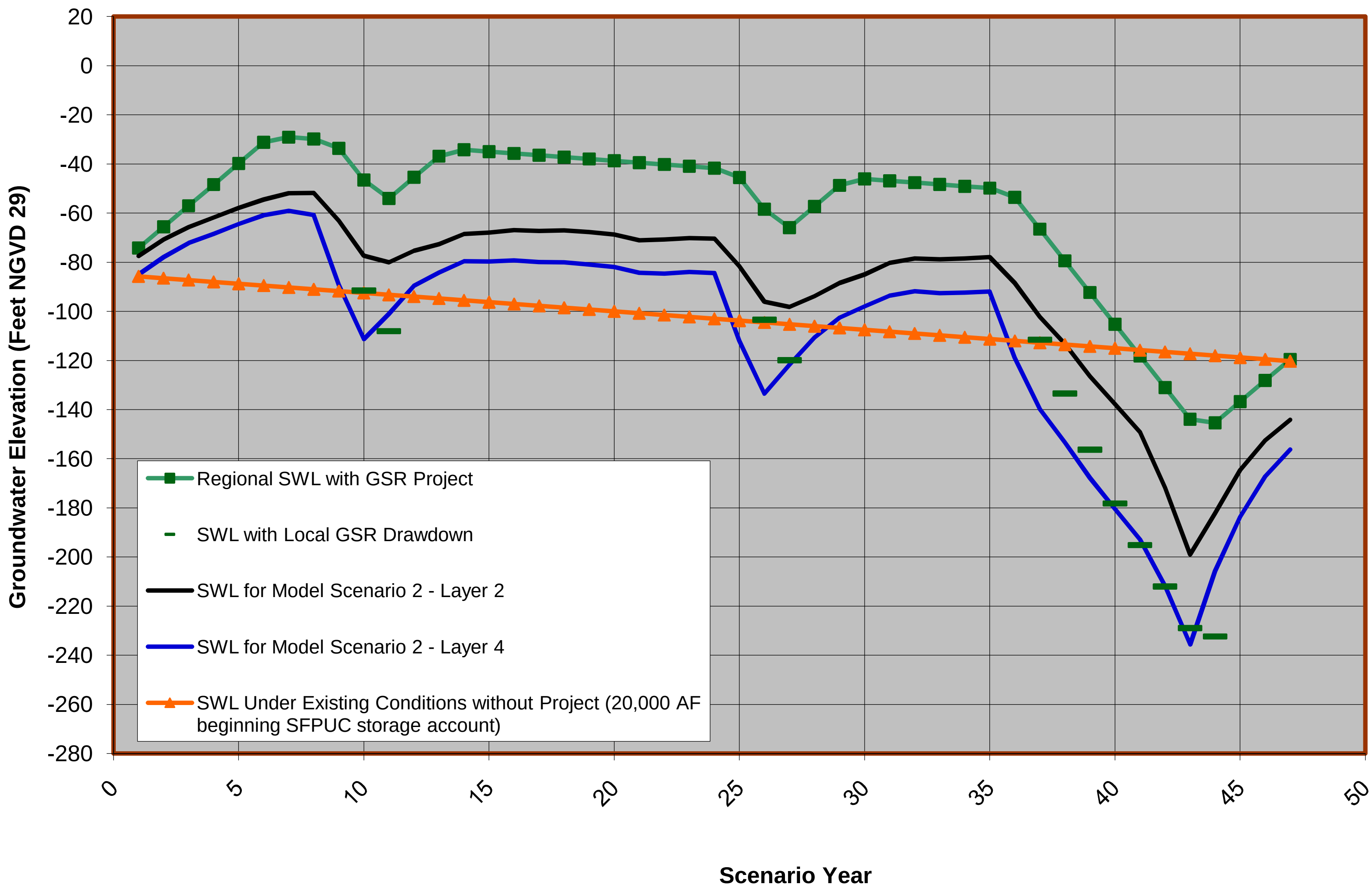


Figure C-3. Estimated Static Water Levels at Italian Cemetery Well for GSR Project

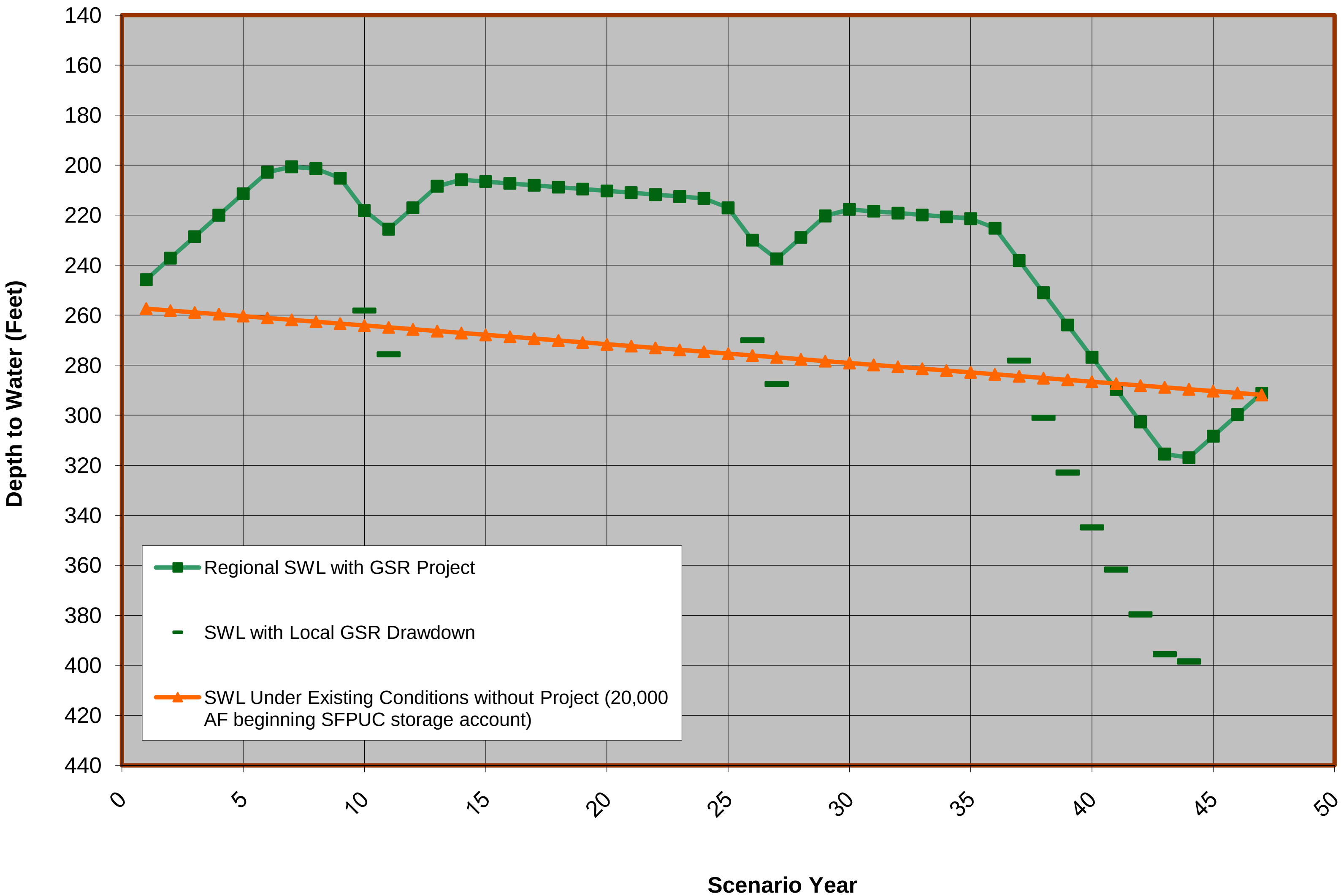


Figure C-4. Estimated Groundwater Elevations at Italian Cemetery Well for GSR Project (Scenario 2)

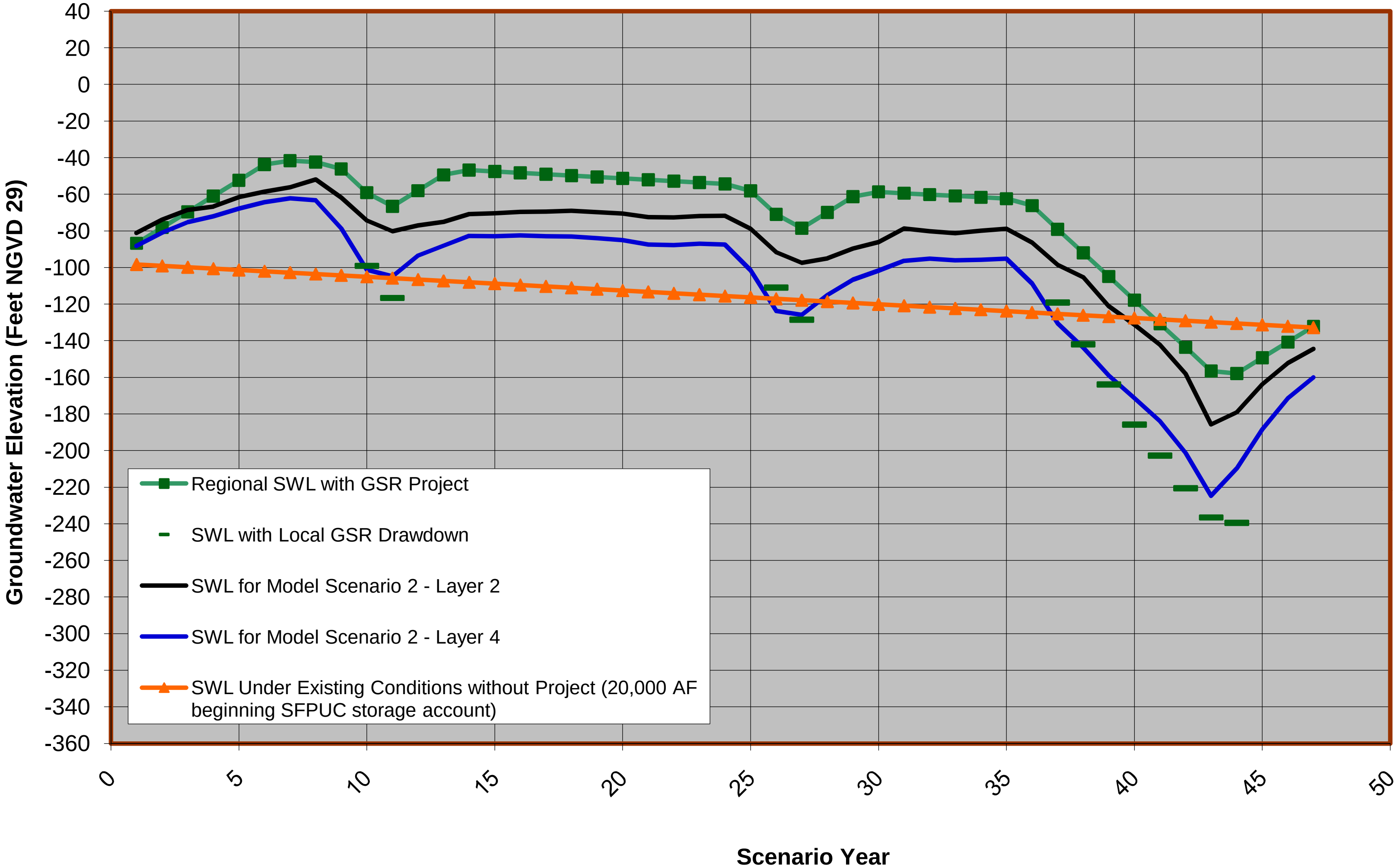


Figure C-5. Estimated Static Water Levels at Olivet Cemetery Well for GSR Project

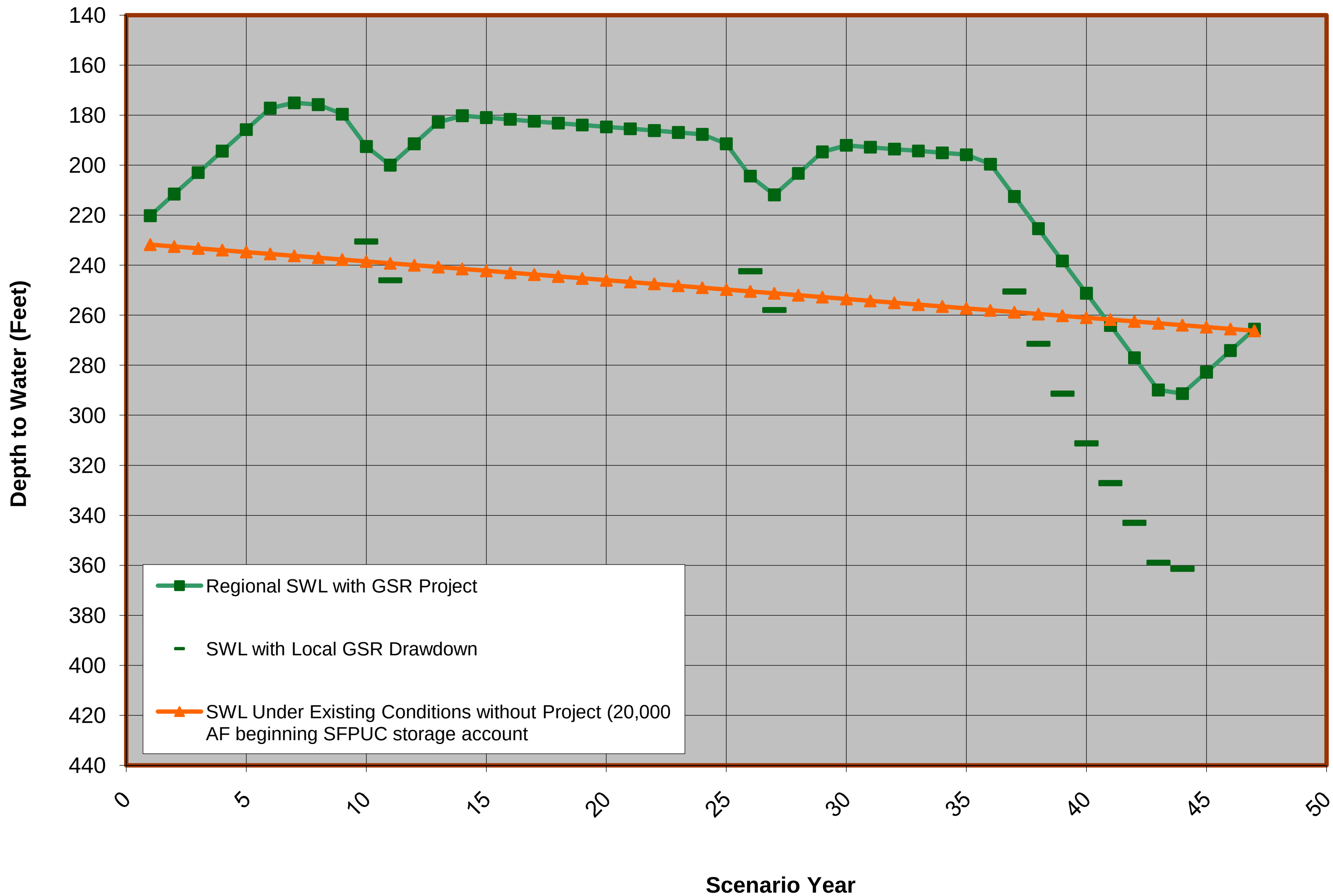


Figure C-6. Estimated Groundwater Elevations at Olivet Cemetery Well for GSR Project (Scenario 2)

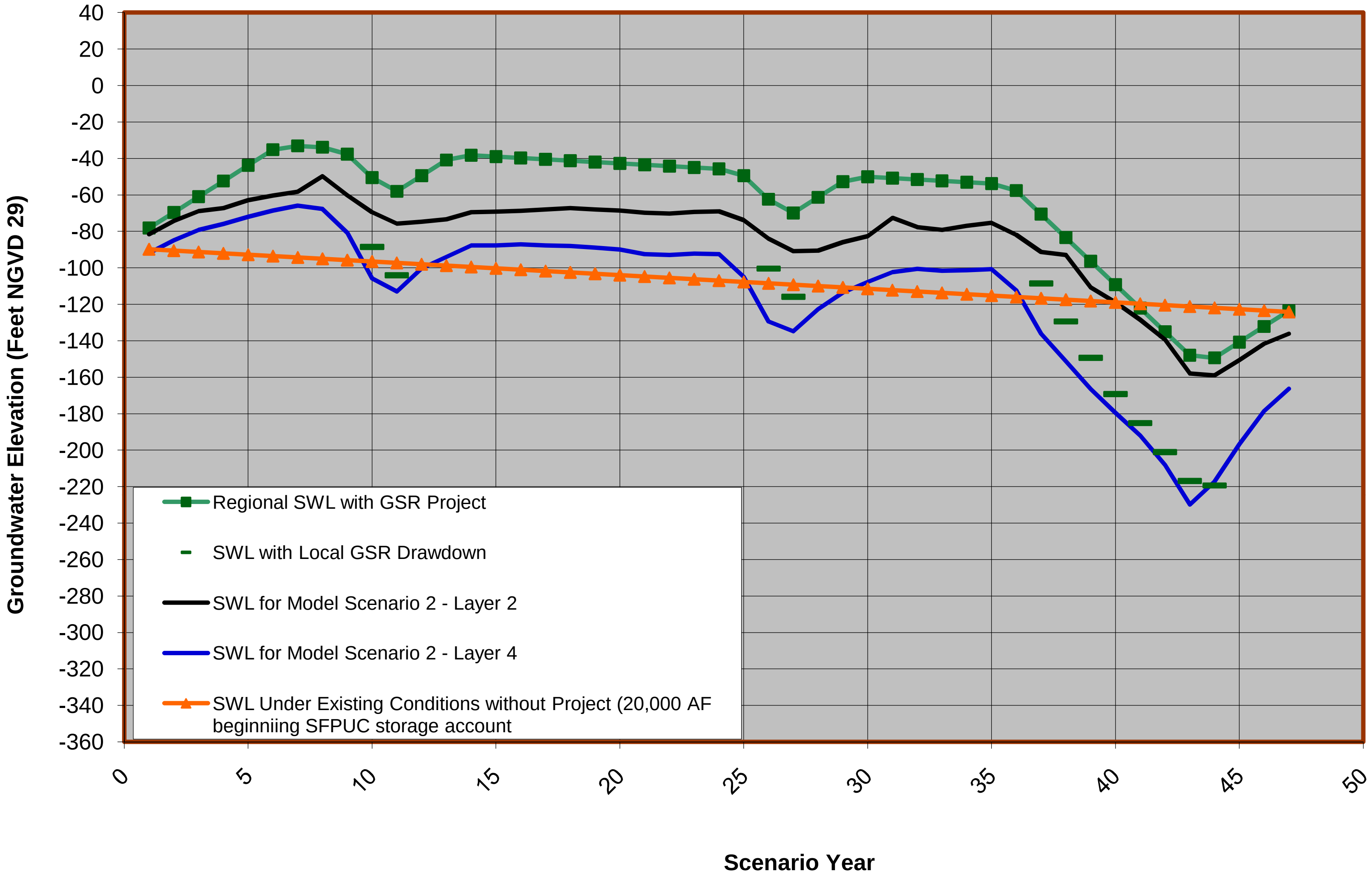


Figure C-7. Estimated Static Water Levels at Home of Peace Cemetery Well for GSR Project

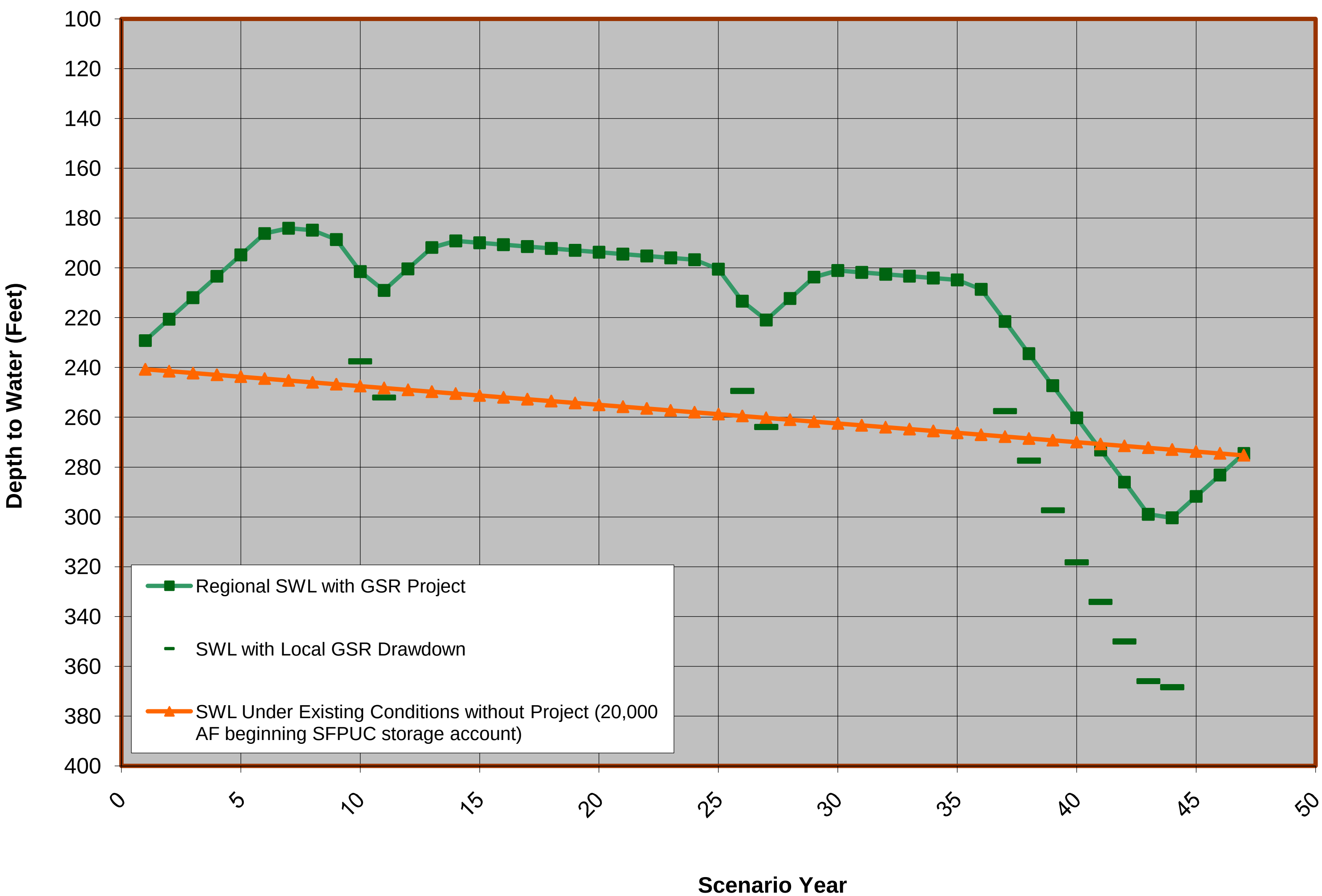


Figure C-8. Estimated Groundwater Elevations at Home of Peace Cemetery Well for GSR Project (Scenario 2)

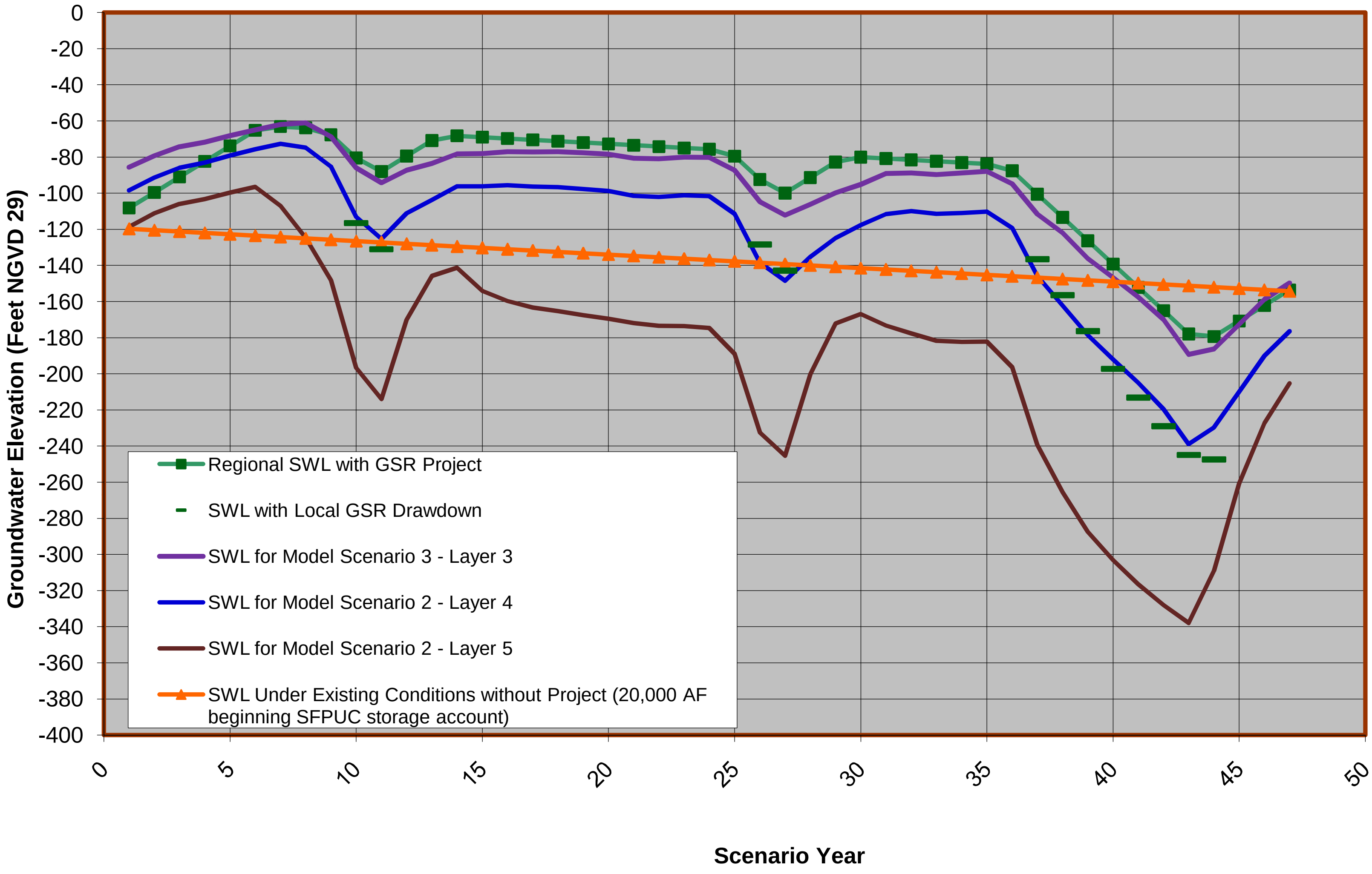


Figure C-9. Estimated Static Water Levels at Hills of Eternity Cemetery Well for GSR Project

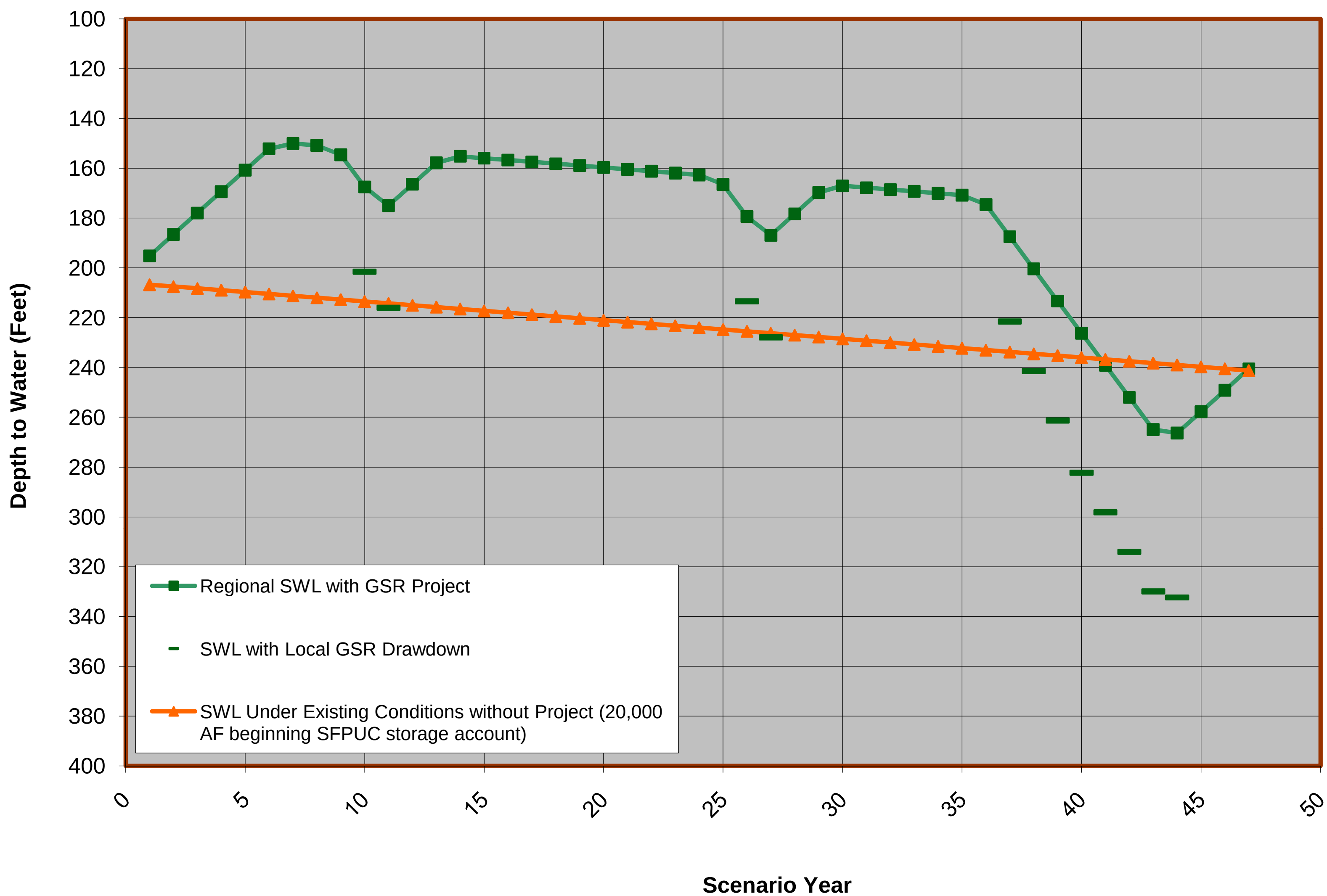


Figure C-10. Estimated Groundwater Elevations at Hills of Eternity Cemetery Well for GSR Project (Scenario 2)

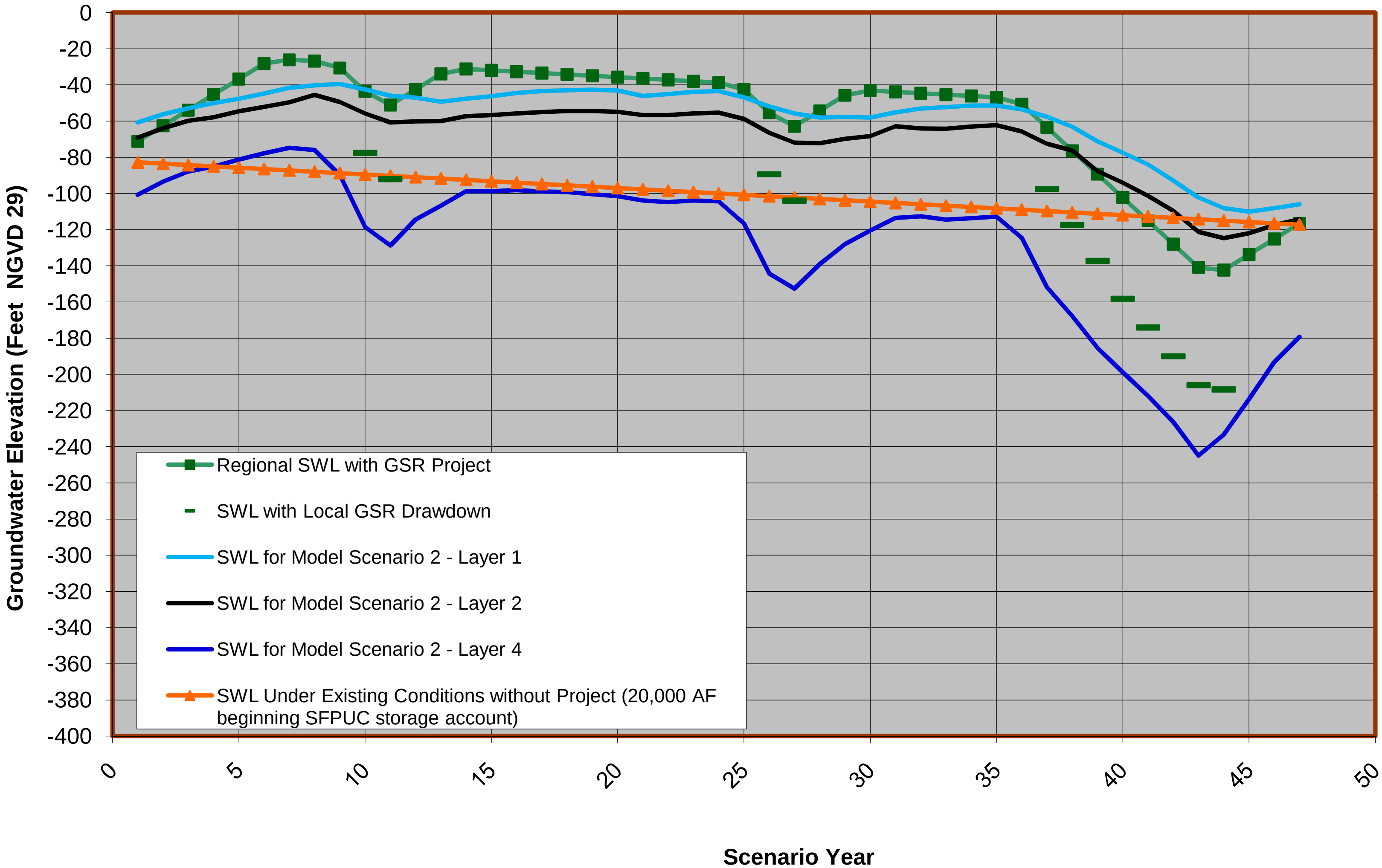


Figure C-11. Estimated Static Water Levels at Cypress Lawn Cemetery Well 3 for GSR Project

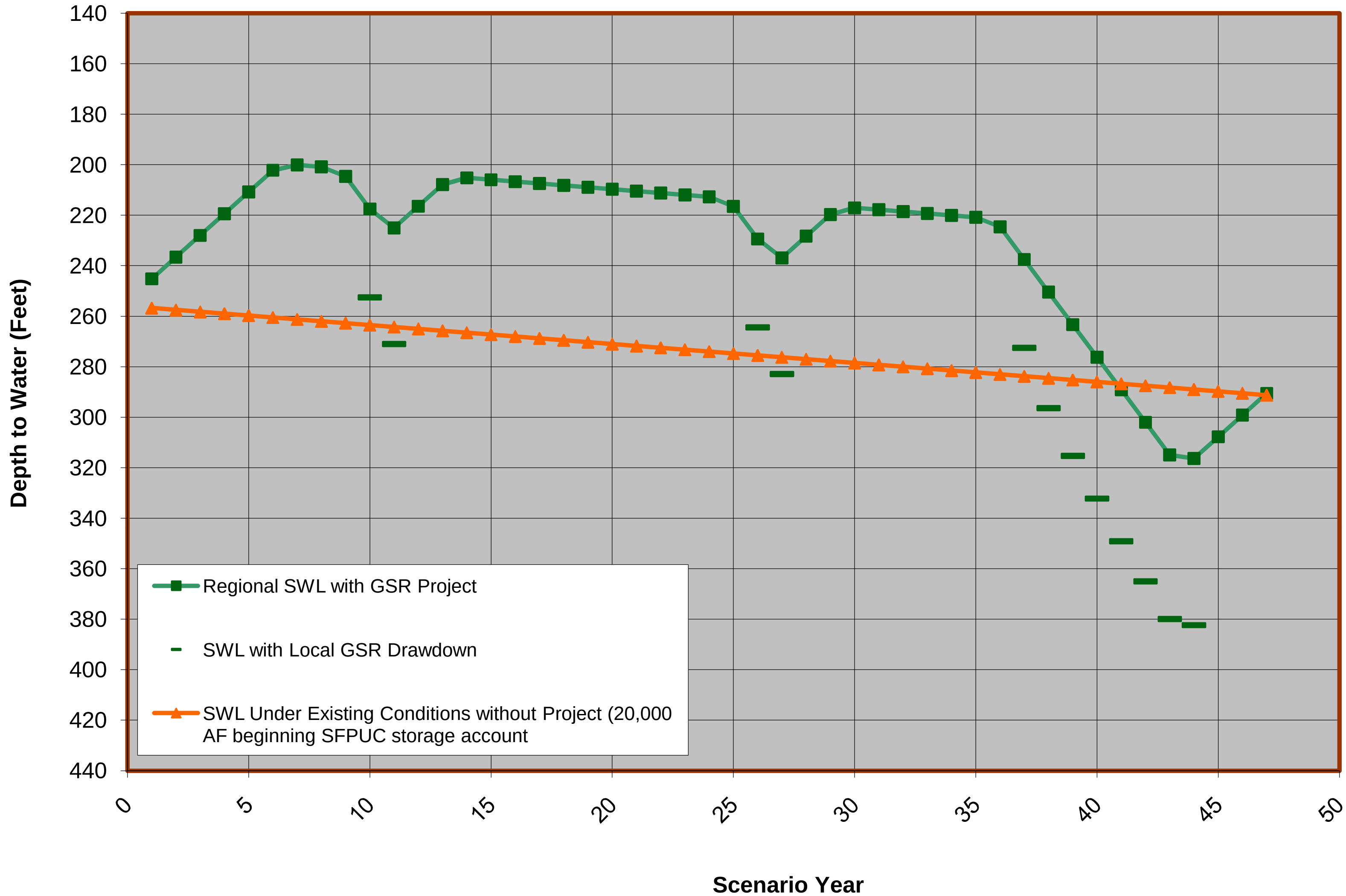


Figure C-12. Estimated Groundwater Elevations at Cypress Lawn Cemetery Well 3 for GSR Project (Scenario 2)

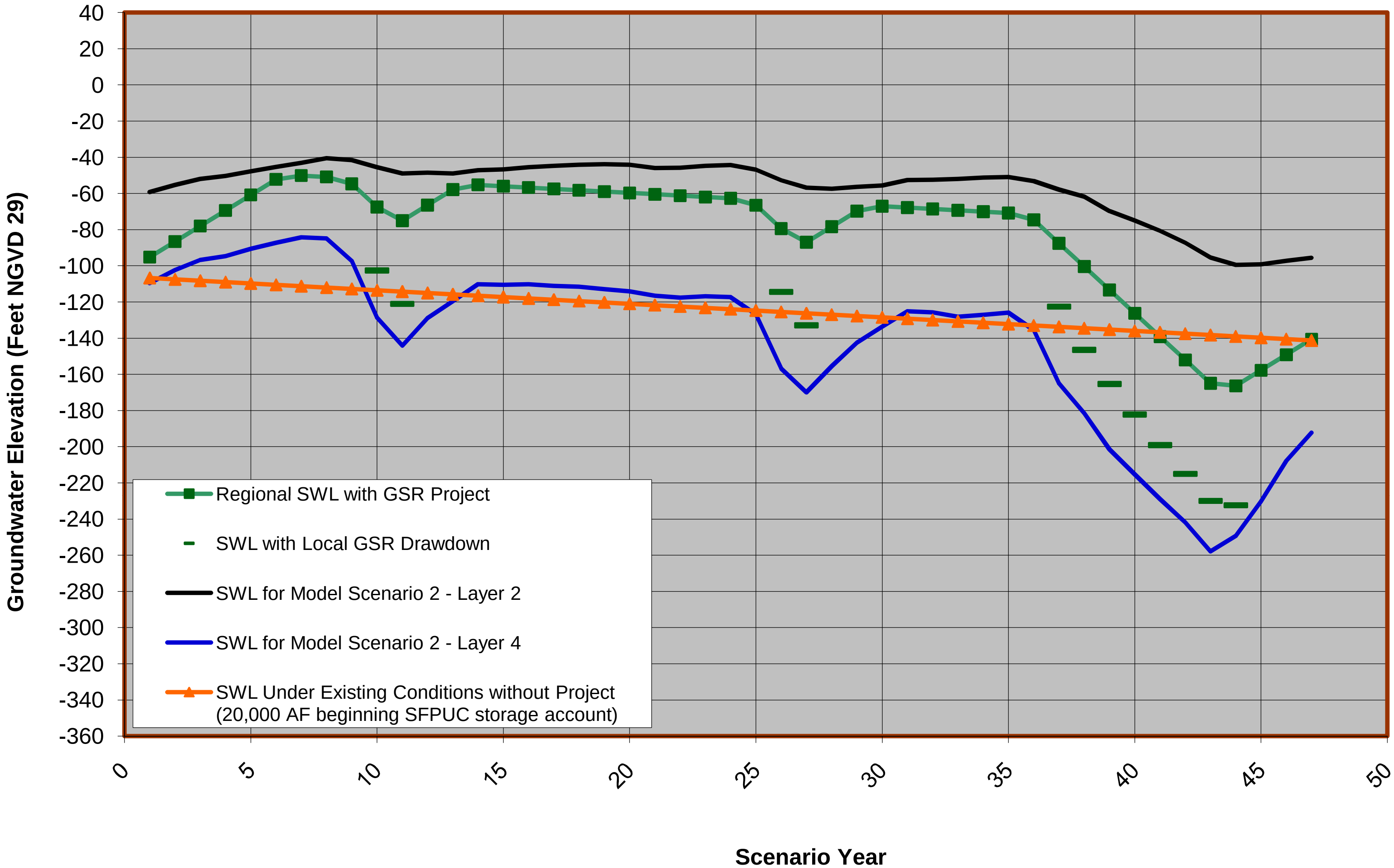


Figure C-13. Estimated Static Water Levels at Cypress Lawn Cemetery Well 4 for GSR Project

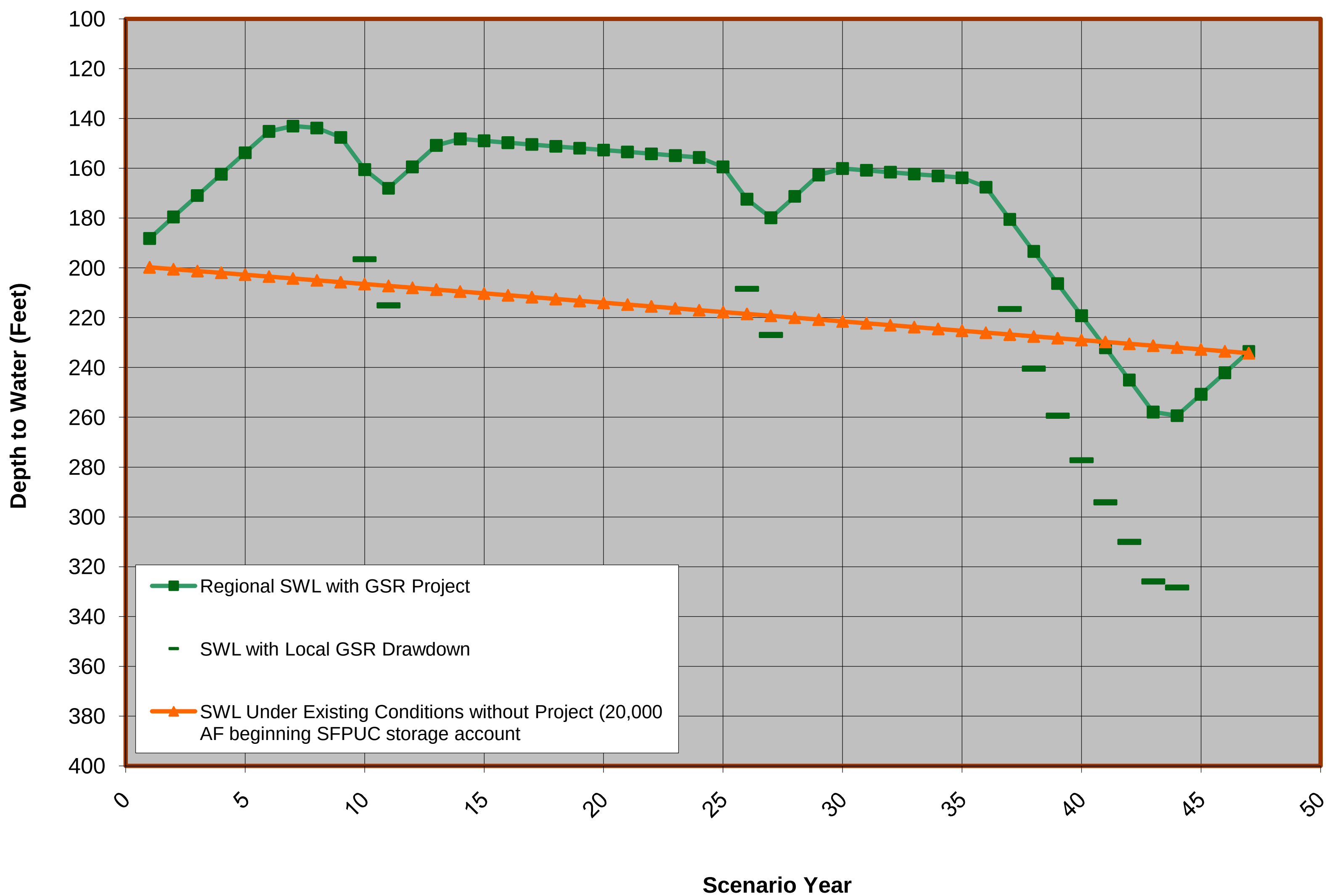


Figure C-14. Estimated Groundwater Elevations at Cypress Lawn Cemetery Well 4 for GSR Project (Scenario 2)

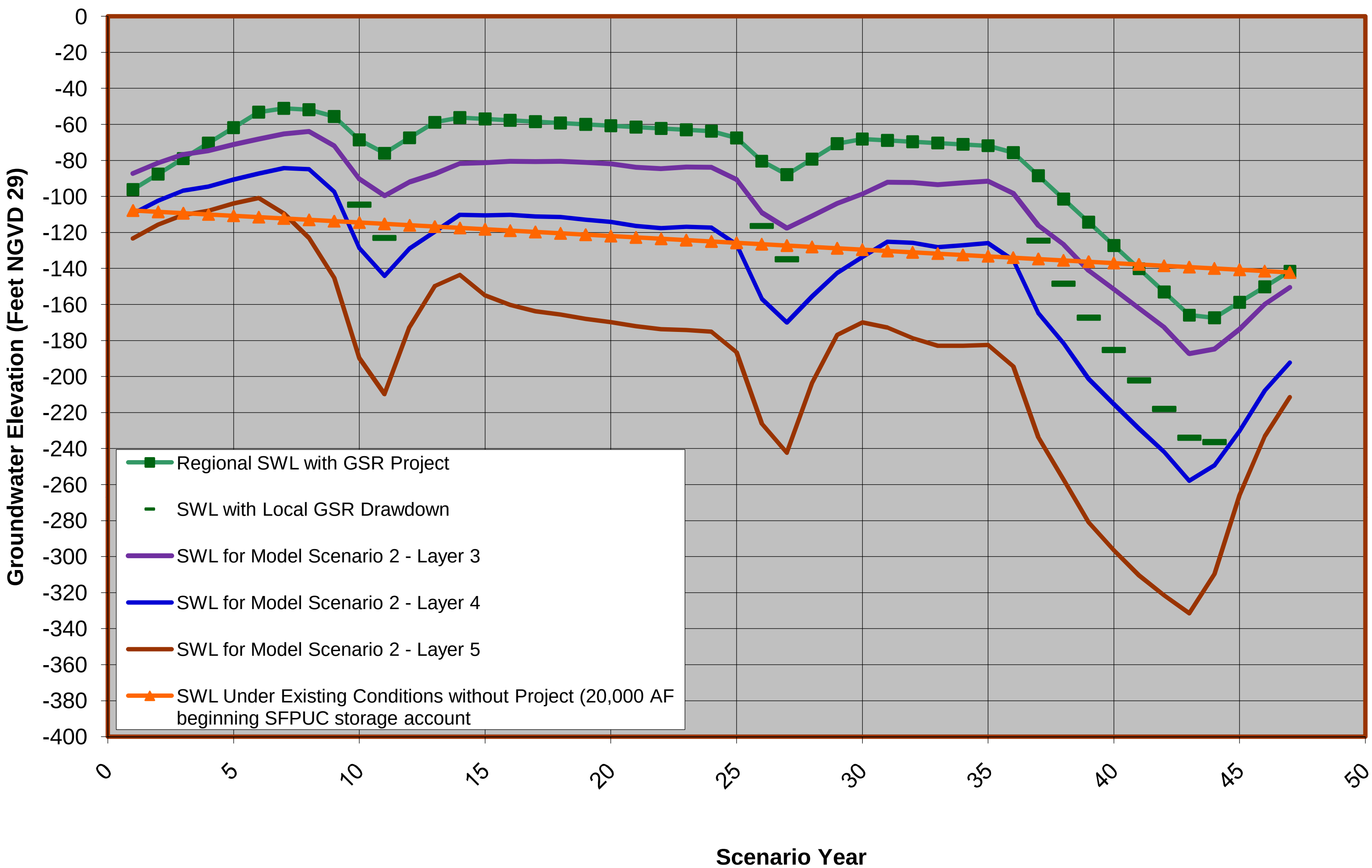


Figure C-15. Estimated Static Water Levels at Holy Cross Cemetery Well 1 for GSR Project

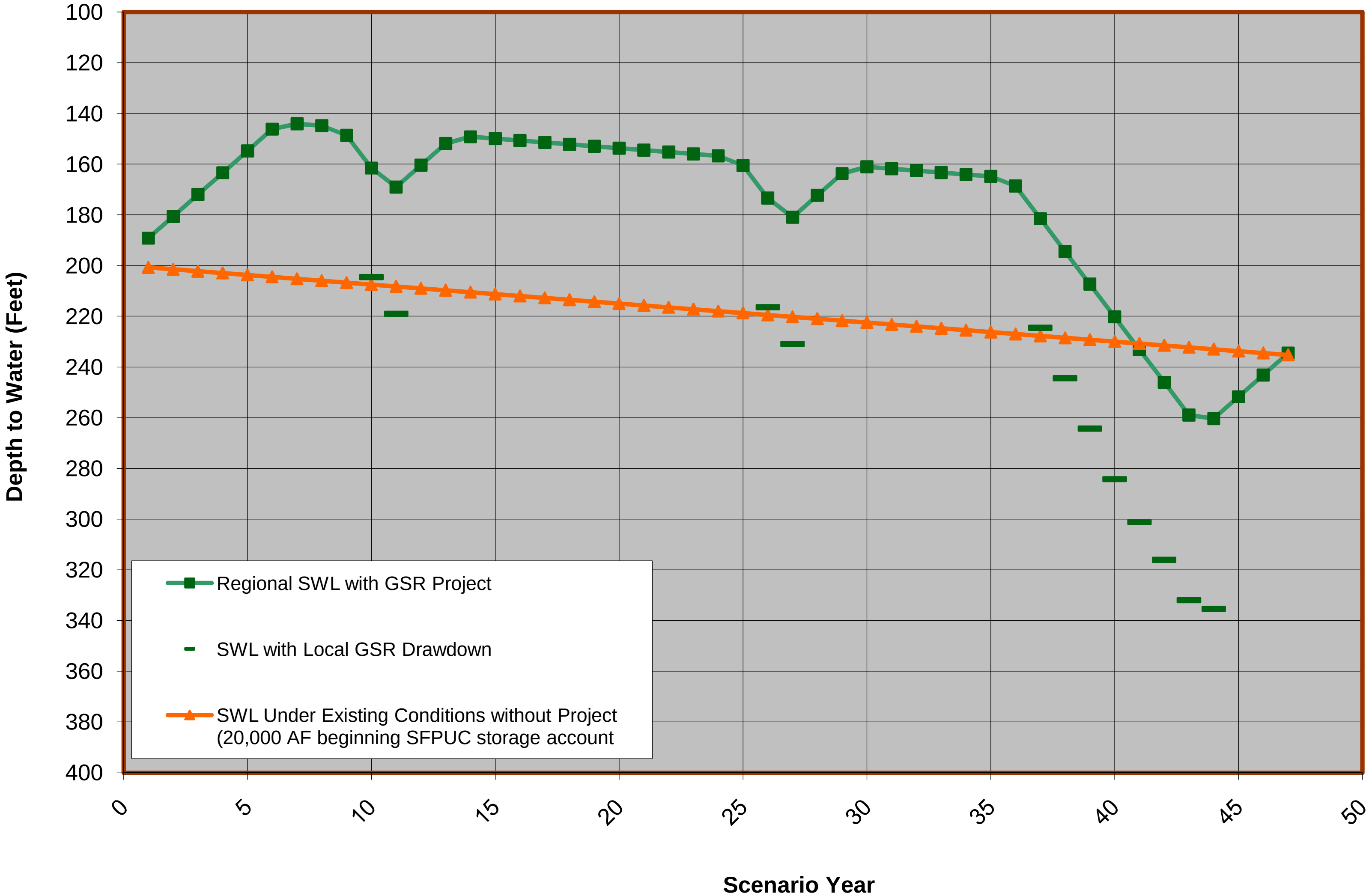


Figure C-16. Estimated Groundwater Elevations at Holy Cross Cemetery Well 1 for GSR Project (Scenario 2)

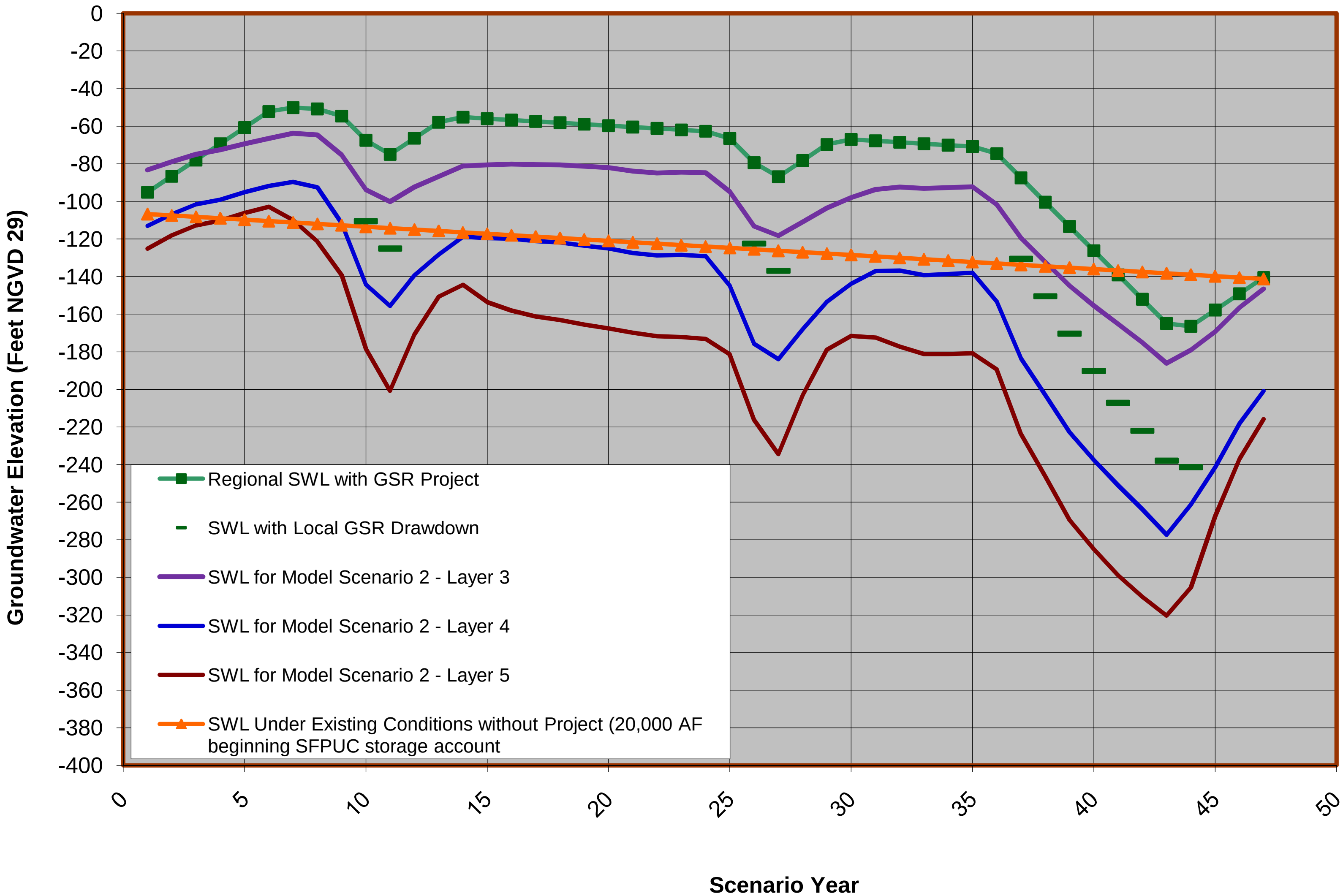


Figure C-17. Estimated Static Water Levels at Holy Cross Cemetery Well 4 for GSR Project

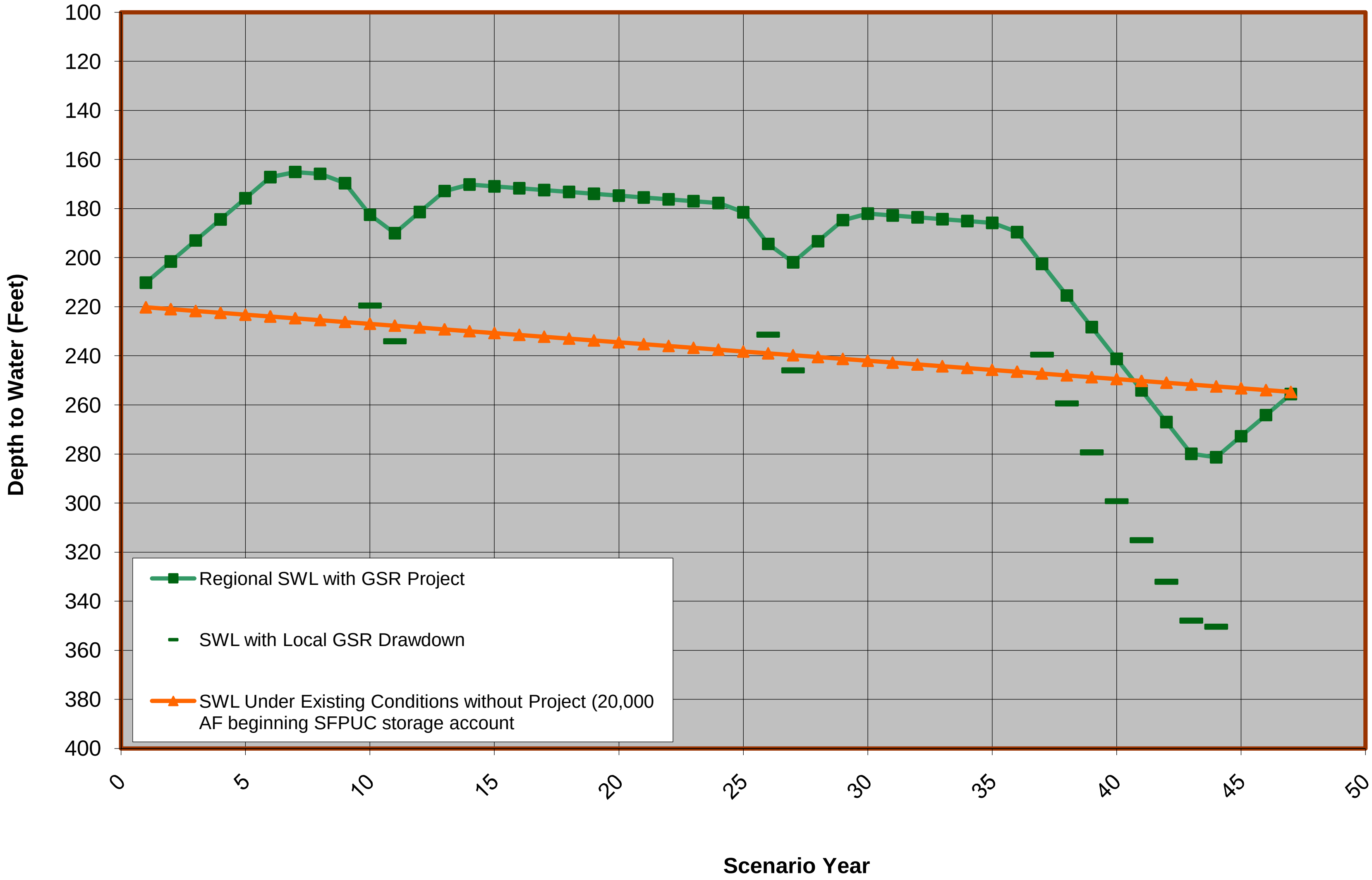


Figure C-18. Estimated Groundwater Elevations at Holy Cross Cemetery Well 4 for GSR Project (Scenario 2)

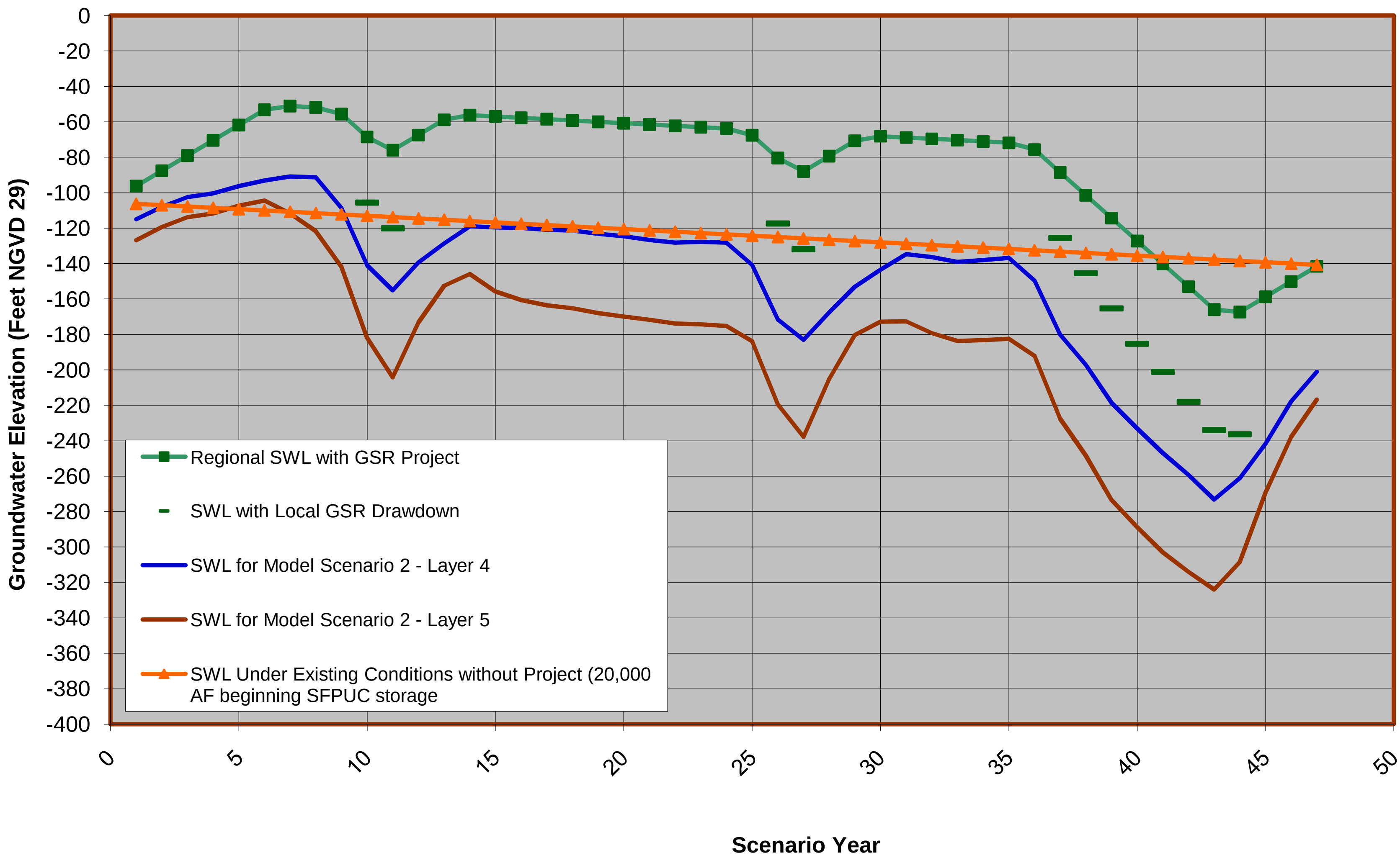


Figure C-19. Estimated Static Water Levels at California Golf Club Well 7 for GSR Project

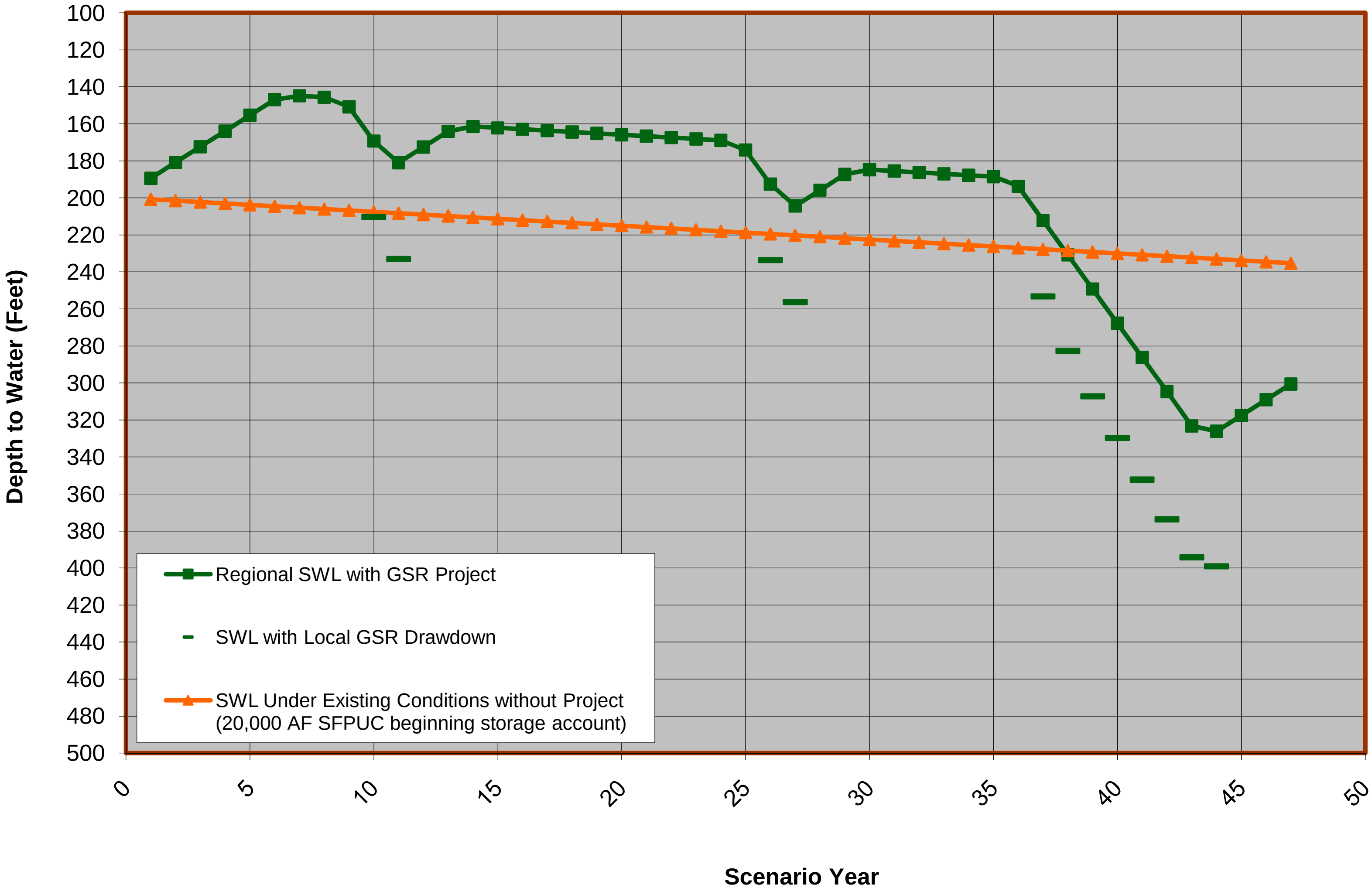


Figure C-20. Estimated Groundwater Elevations at California Golf Club Well 7 for GSR Project

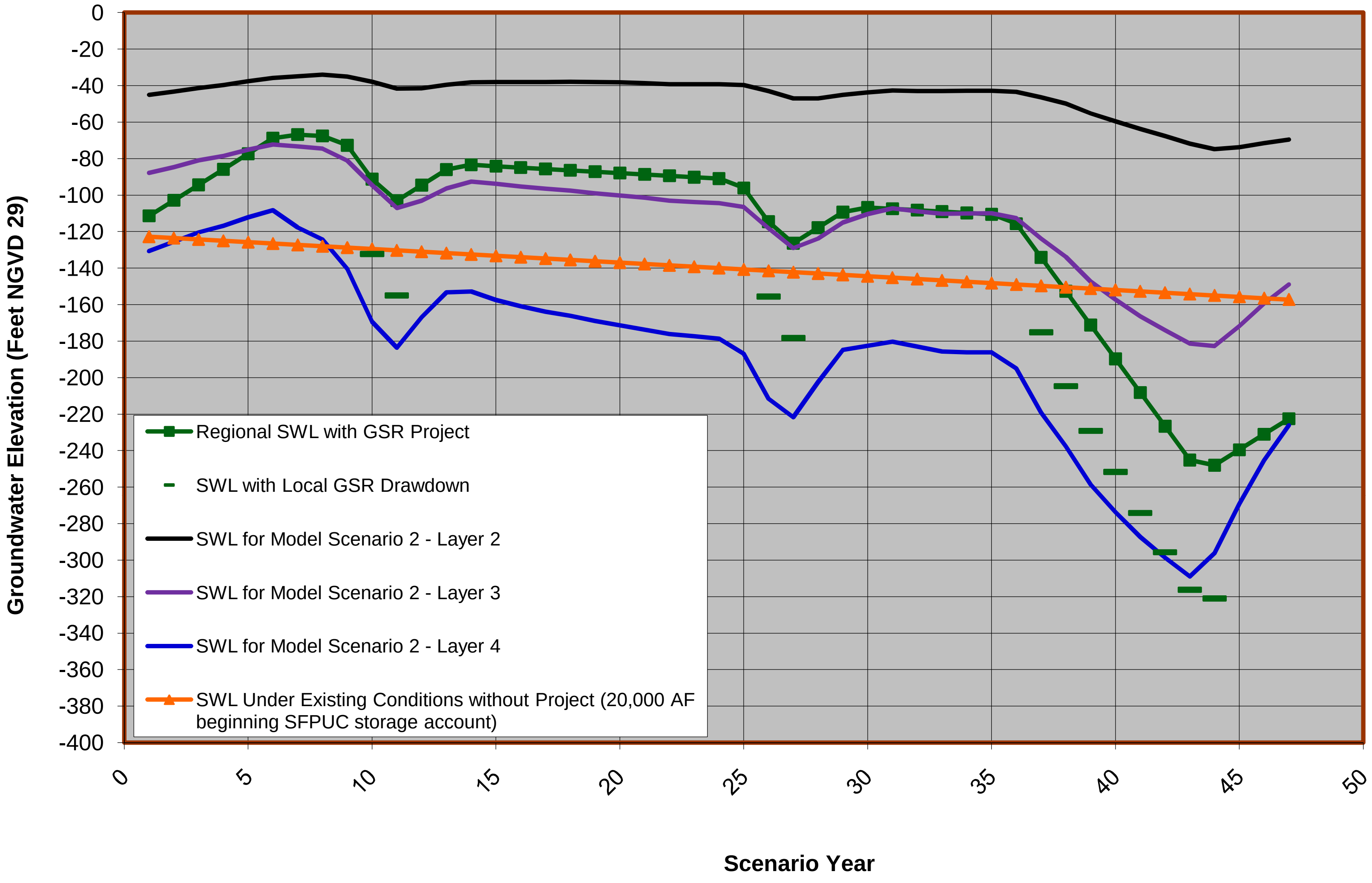


Figure C-21. Estimated Groundwater Elevations at Olympic Club Well No. 2 (#8) for GSR Project (Scenario 2)

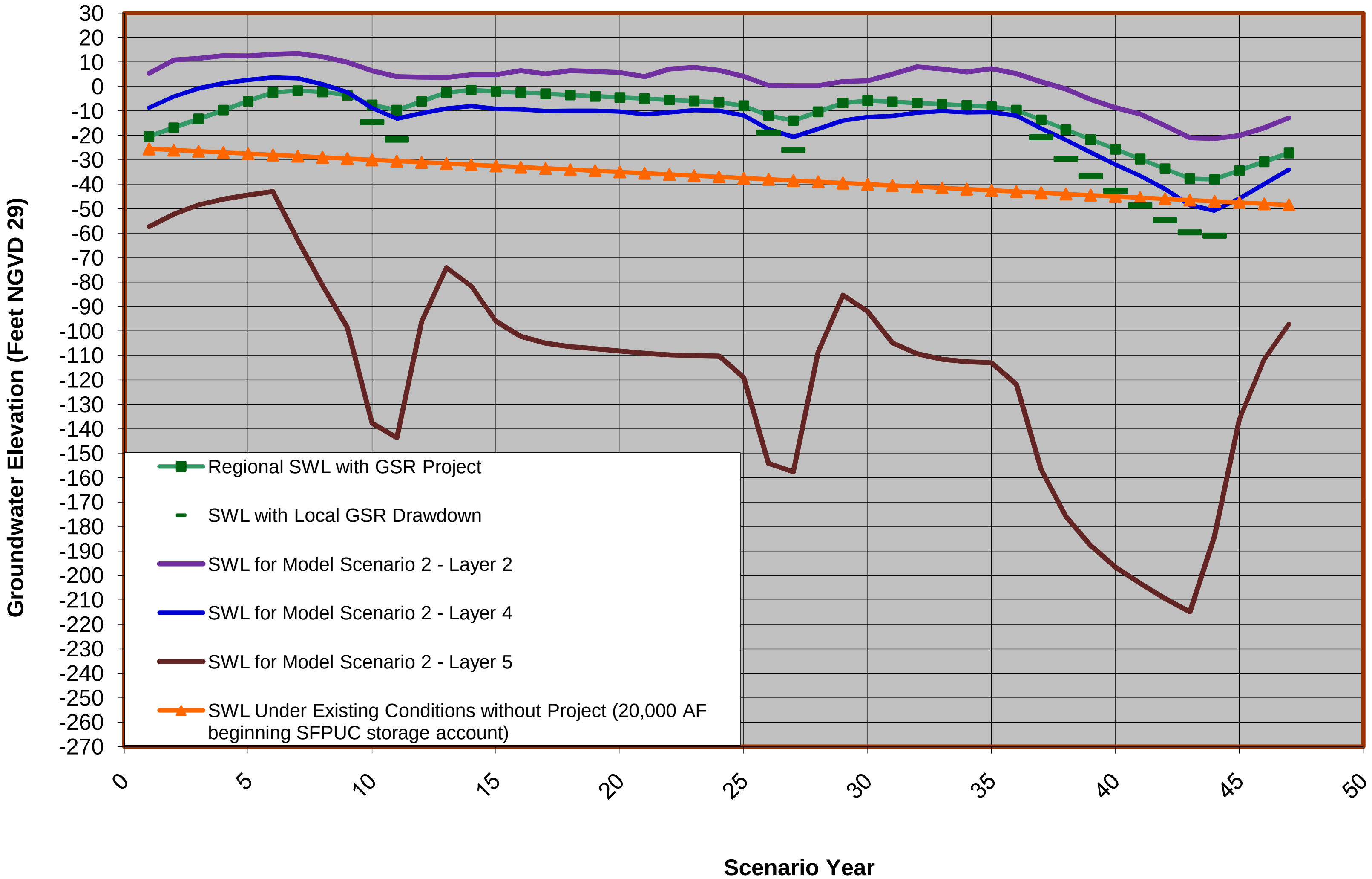


Figure C-22. Estimated Static Water Levels at San Francisco Golf Club Well 2 for GSR Project

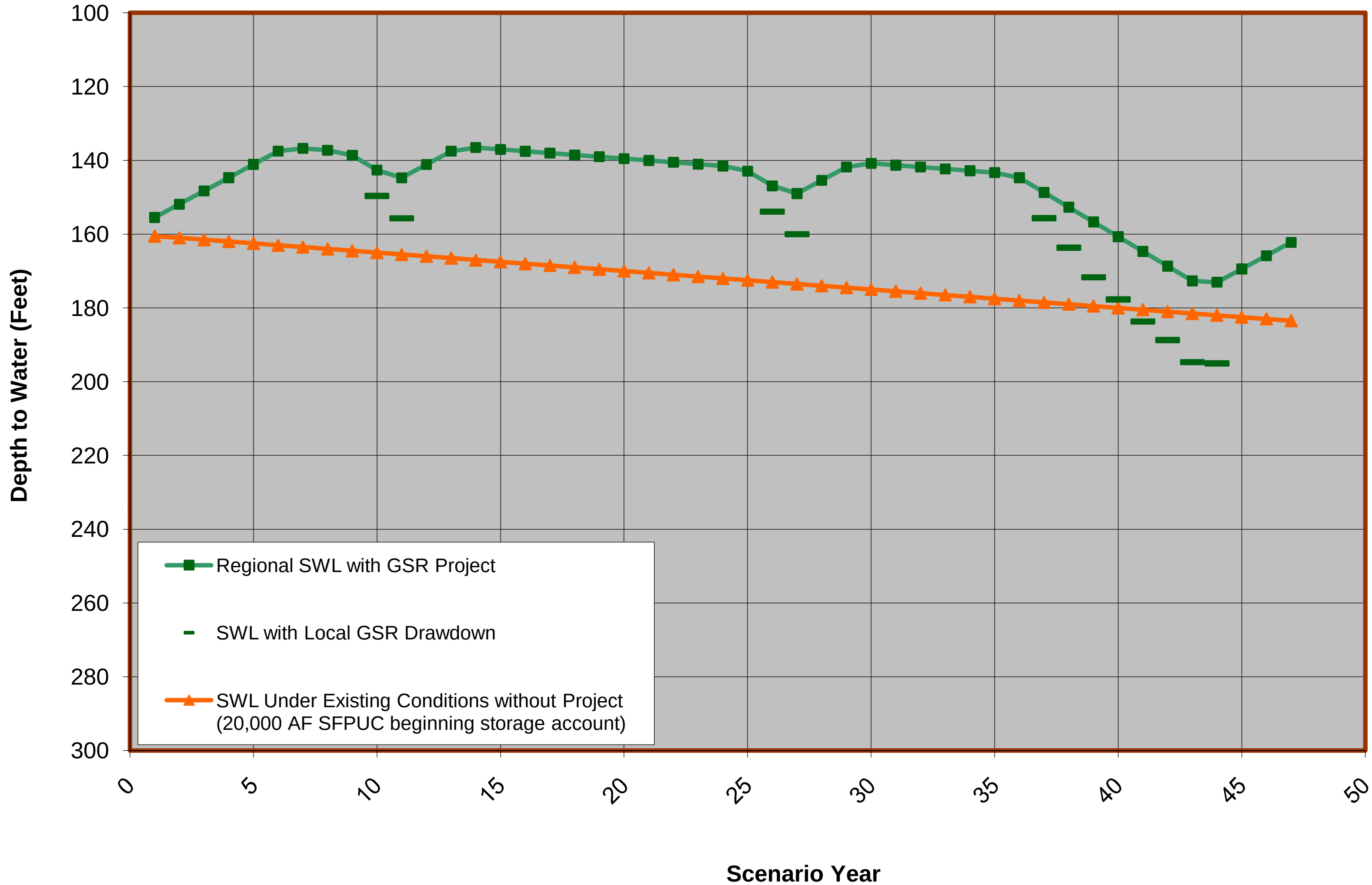
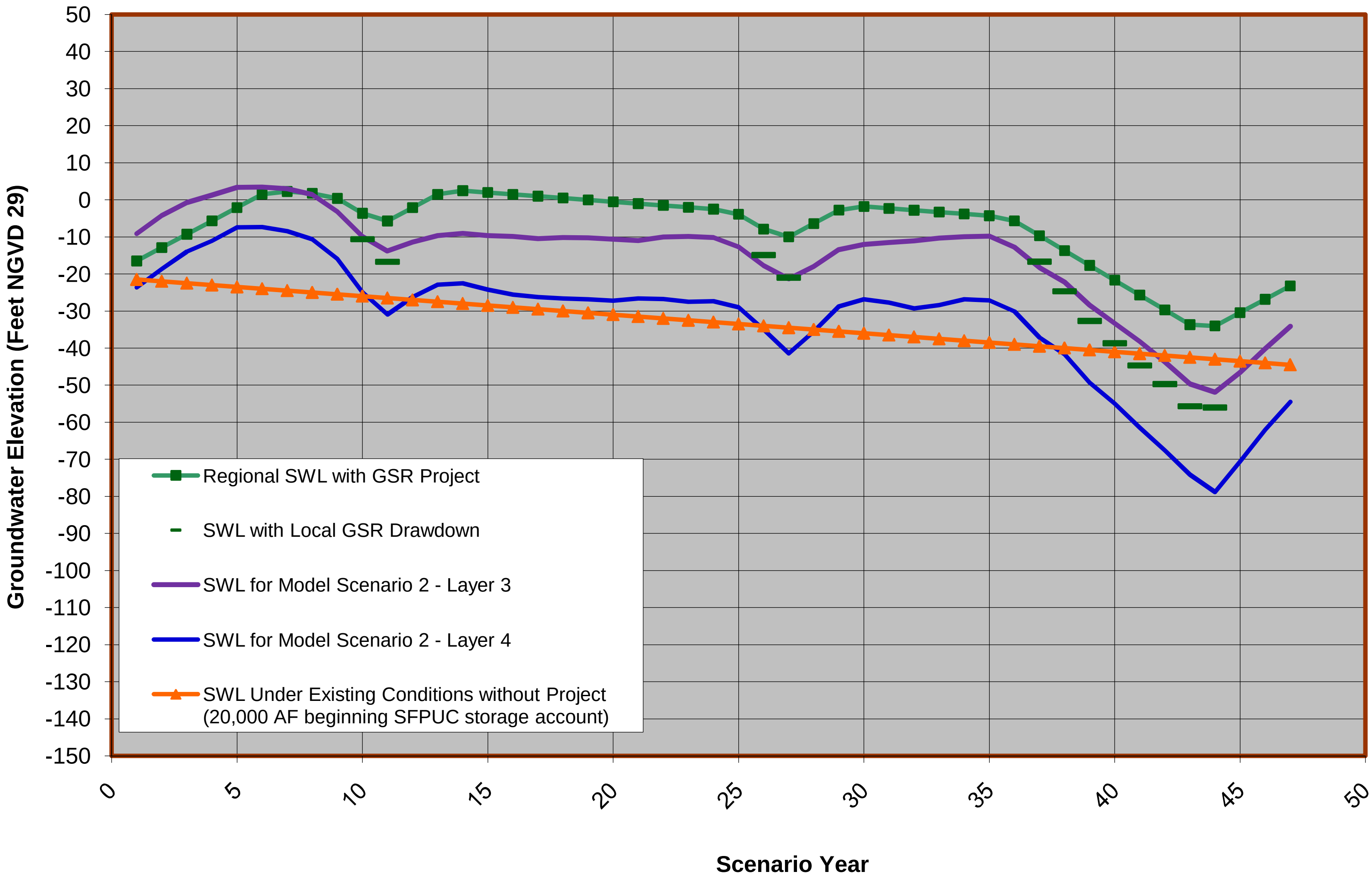


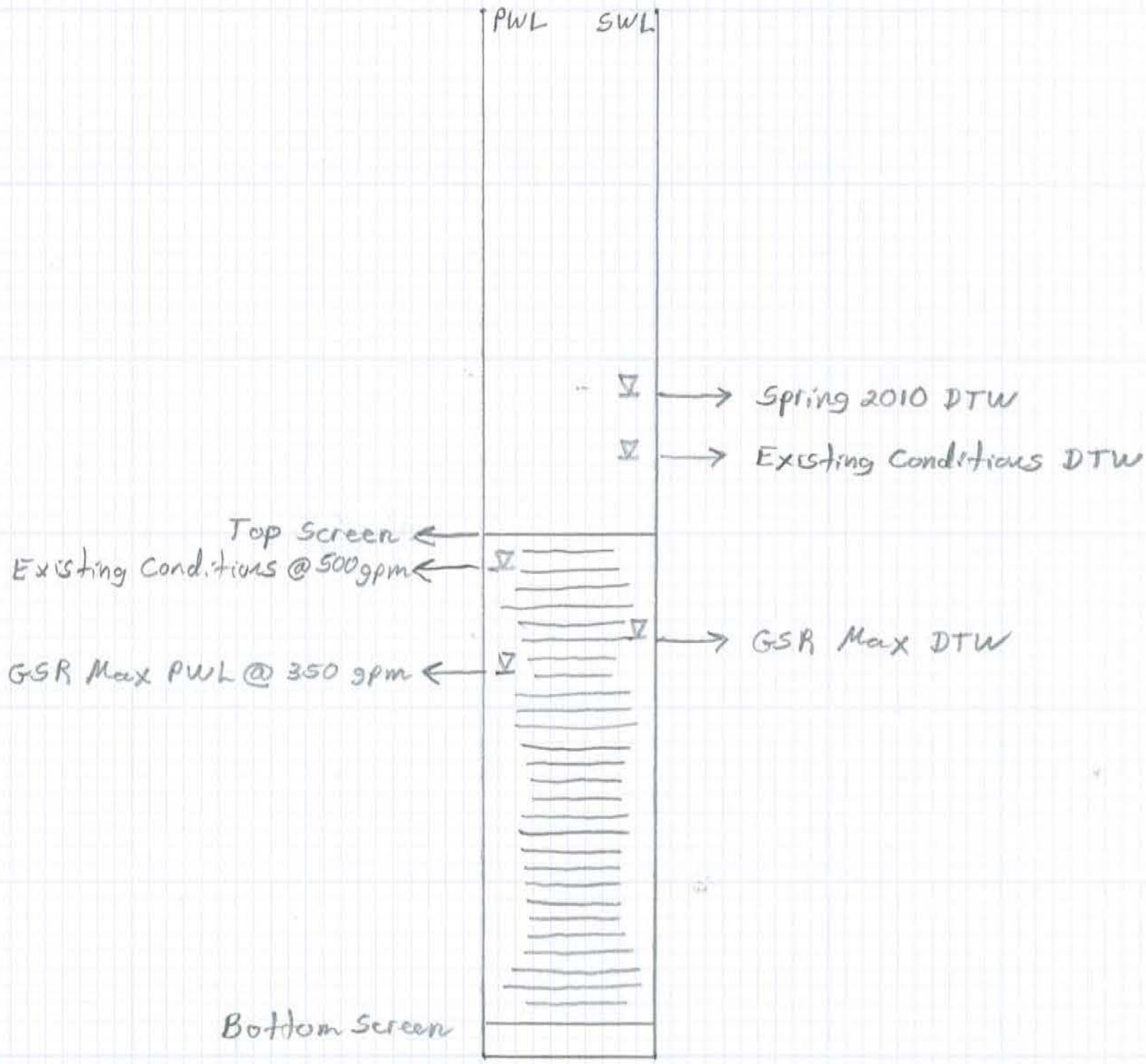
Figure C-23. Estimated Groundwater Elevations at San Francisco Club Well 2 for GSR Project (Scenario 2)



APPENDIX D

Form: Vta.(comp 11/93)
COMPUTATIONS

Job No.: ______ By: ______ Date: ______
Checked By: ______ Date: ______ Sheet No. ___ of ___
Subject: Typical Third Party Well
Intermediate Depth to Top Screen



Note: Schematic - Not to Scale

Form: Vta.(comp 11/93)

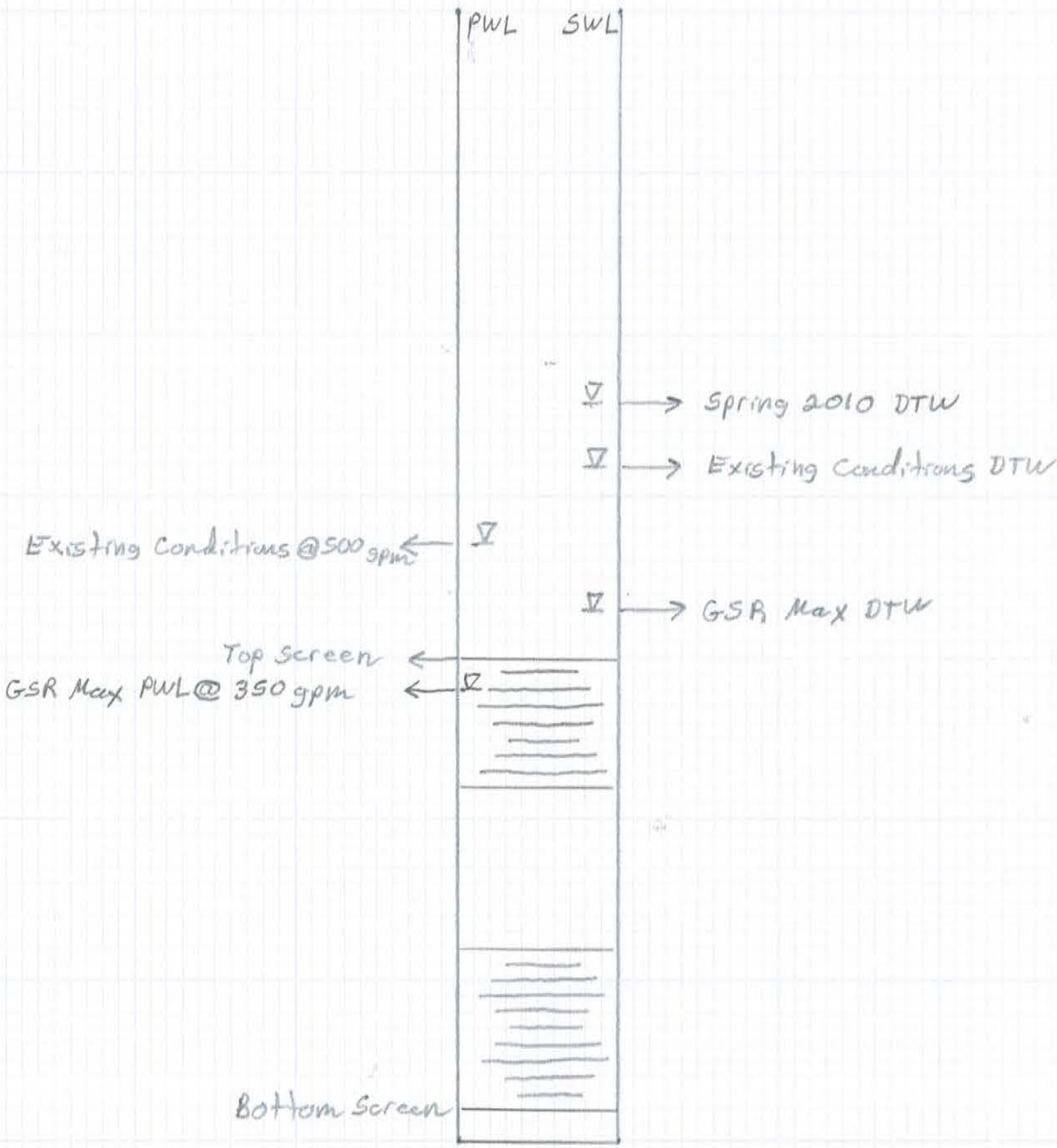
COMPUTATIONS

Job No.:________ By:________ Date:________

Checked By:________ Date:________ Sheet No.____ of____

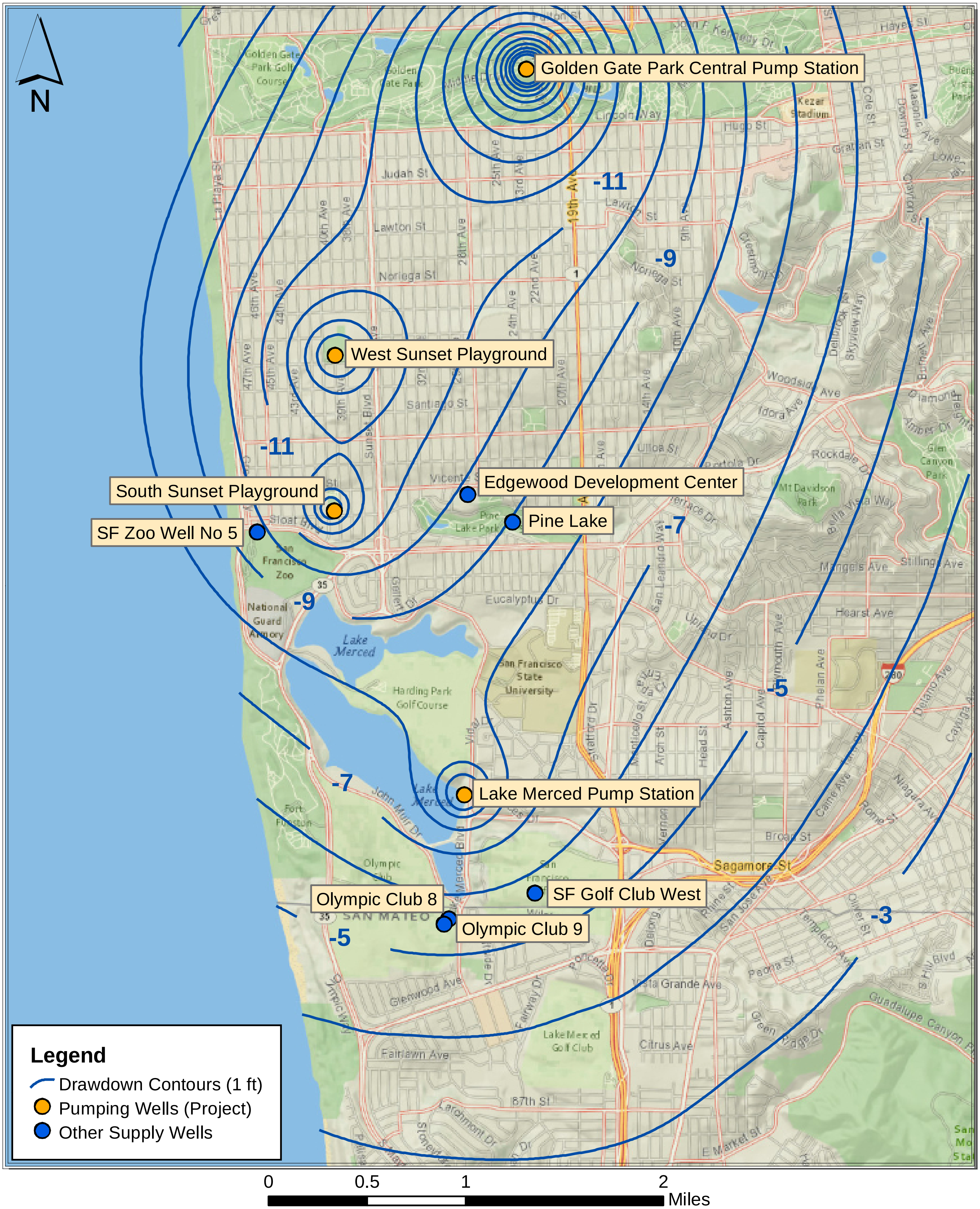
Subject: Typical Third Party Well
Deep Depth to Top Screen

FUGRO



Note: Schematic - Not to Scale

APPENDIX E



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LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure No
Drawdown Following 1 Year of Pumping
Scenario A Four Project Wells Pumping

X:\2010 Job Files\10-077\Task 10 8a\GIS\Figure 2 ScenarioB_dd.mxd

LUHDORFF & SCALMANINI CONSULTING ENGINEERS

Figure No
Drawdown Following 1 Year of Pumping
Scenario B Six Project Wells Pumping

APPENDIX F

Appendix F-1
Third Party Well Construction Details

WELL	GROUND ELEVATION (ft NGVD)	TOP OF SAND PACK (ft bgs)	TOP OF SCREEN (ft bgs)
Elk Glen Well	172	60	170
SF Zoo Well No. 5	32	130	160
Pine Lake [1]	83	48	98
Edgewood Development Center [1]	158	30 (liner)	120 (liner)
Olympic Club 8	61	50	200
Olympic Club 9	78	230	260
SF Golf Club West	148	50	360
City of Daly City Westlake (DC2)	110	255	340
Lake Merced Golf Club No. 1			
Lake Merced Golf Club No. 2			
Lake Merced Golf Club No. 3		50	294

NOTES:

1 - Information obtained by Jeff Gilman, SFPUC Water Enterprise. Well also known as Stern Grove W-2.

Table F-2
Third Party Well Pump Data [1]

WELL	Pump Make	Pump Model	Stages	Current or Design Capacity (gpm)	Other Information
SF Zoo Well No. 5	Goulds	12DHLC	4	1,160	Current capacity as observed in 2009 using Magmeter: 1,160 gpm (multiple observations).
Pine Lake	Flowserve	8MEL	10	250	Current capacity as observed in 2010.
Edgewood Development Center	Grundfos	25S50	26	25	Grundfos pump was noted in 1993 inspection for Groundwater Master Plan. Current pump is Goulds; assume to have similar head-capacity relationship for analysis of interference effects.
Olympic Club 8	Byron Jackson	11MQH	4	1,000	260 ft Column; Pump Intake at 270 ft.
Olympic Club 9	Byron Jackson	10GH	6	700	240 ft Column; Pump Intake at 248-250 ft.
SF Golf Club West	Byron Jackson	10MQH	9	700	345 ft Shaft and Oil Tubes on Work Order.
City of Daly City Westlake (DC2)	Byron Jackson	10MQL	9	500	Pump setting depth at 415 ft.
Lake Merced Golf Club No. 1	Not Available				
Lake Merced Golf Club No. 2	Not Available				
Lake Merced Golf Club No. 3	Not Available				

NOTES:

1 - Pump data obtained from SFPUC records and information requests to well owners. Contacts and site visits to Pine Lake and Edgewood Development Center by Jeff Gilman, SFPUC Water Enterprise.

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