Appendix H - TM 10.1

Groundwater Modeling

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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
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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].

[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-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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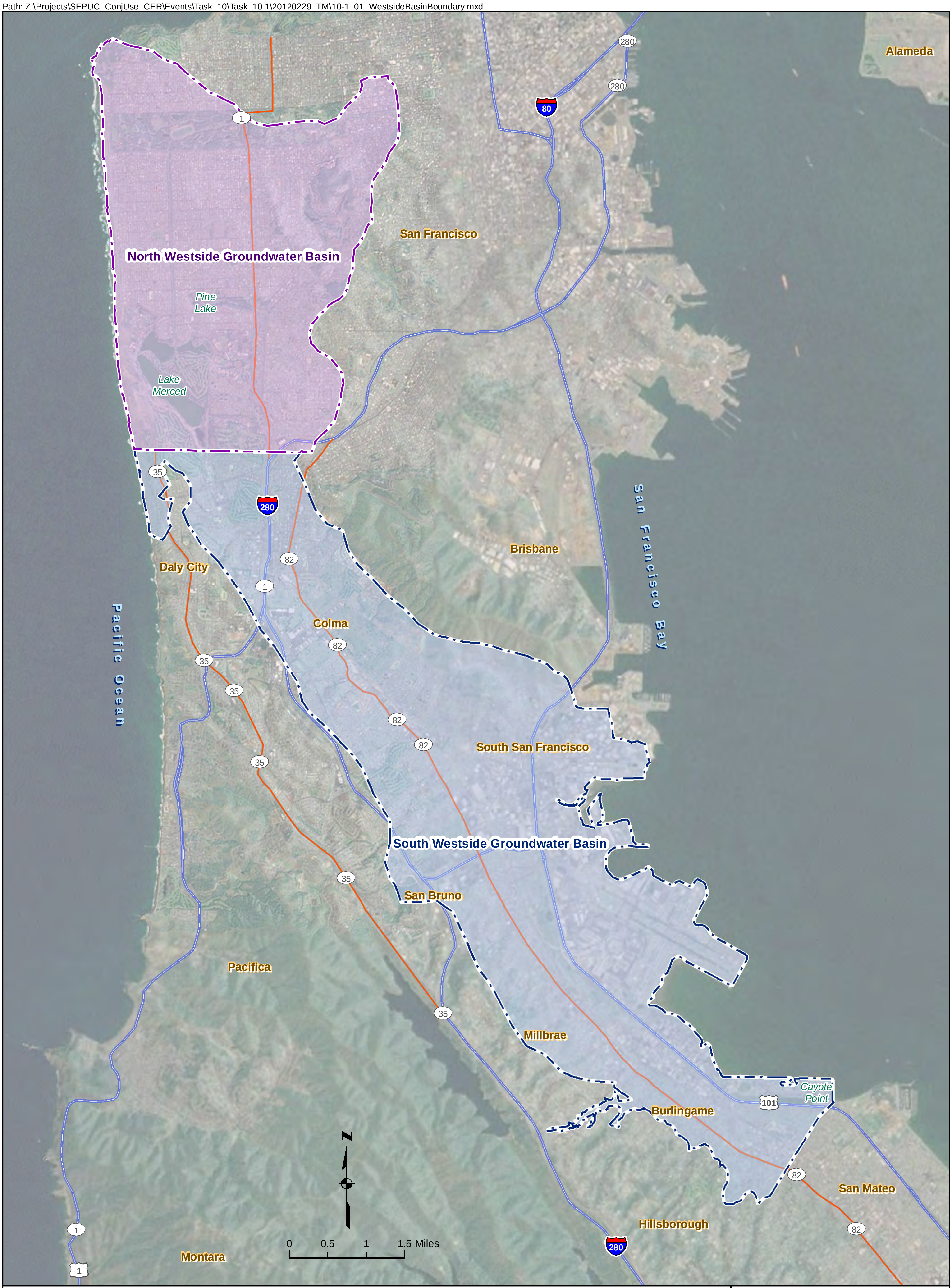

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WESTSIDE GROUNDWATER
BASIN BOUNDARY
NORTH AND SOUTH WESTSIDE BASINS

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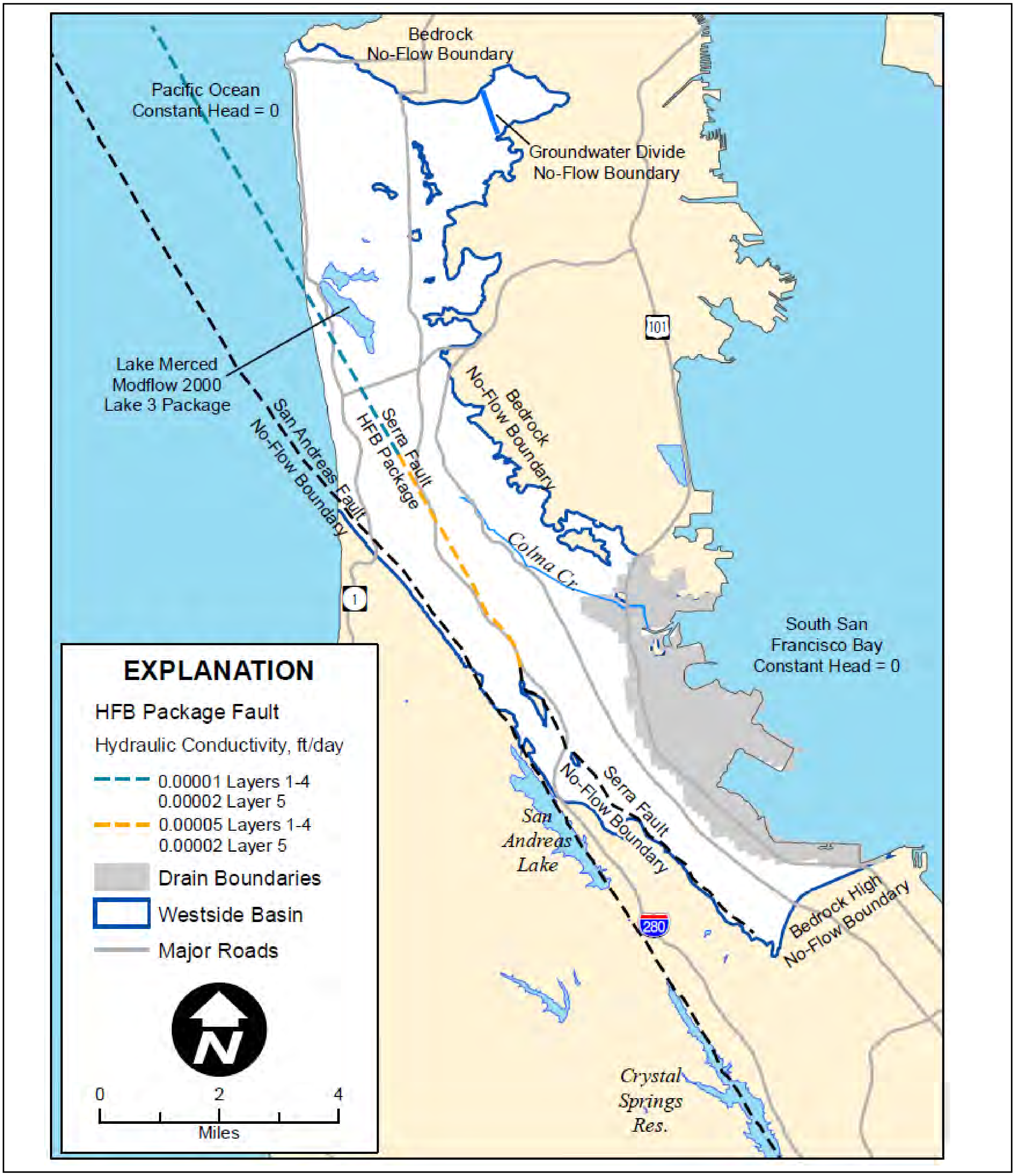
Figure
10.1-1

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

Date
April 2012



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

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San Francisco Public Utilities Commission

Westside Basin Groundwater-Flow Model Boundary

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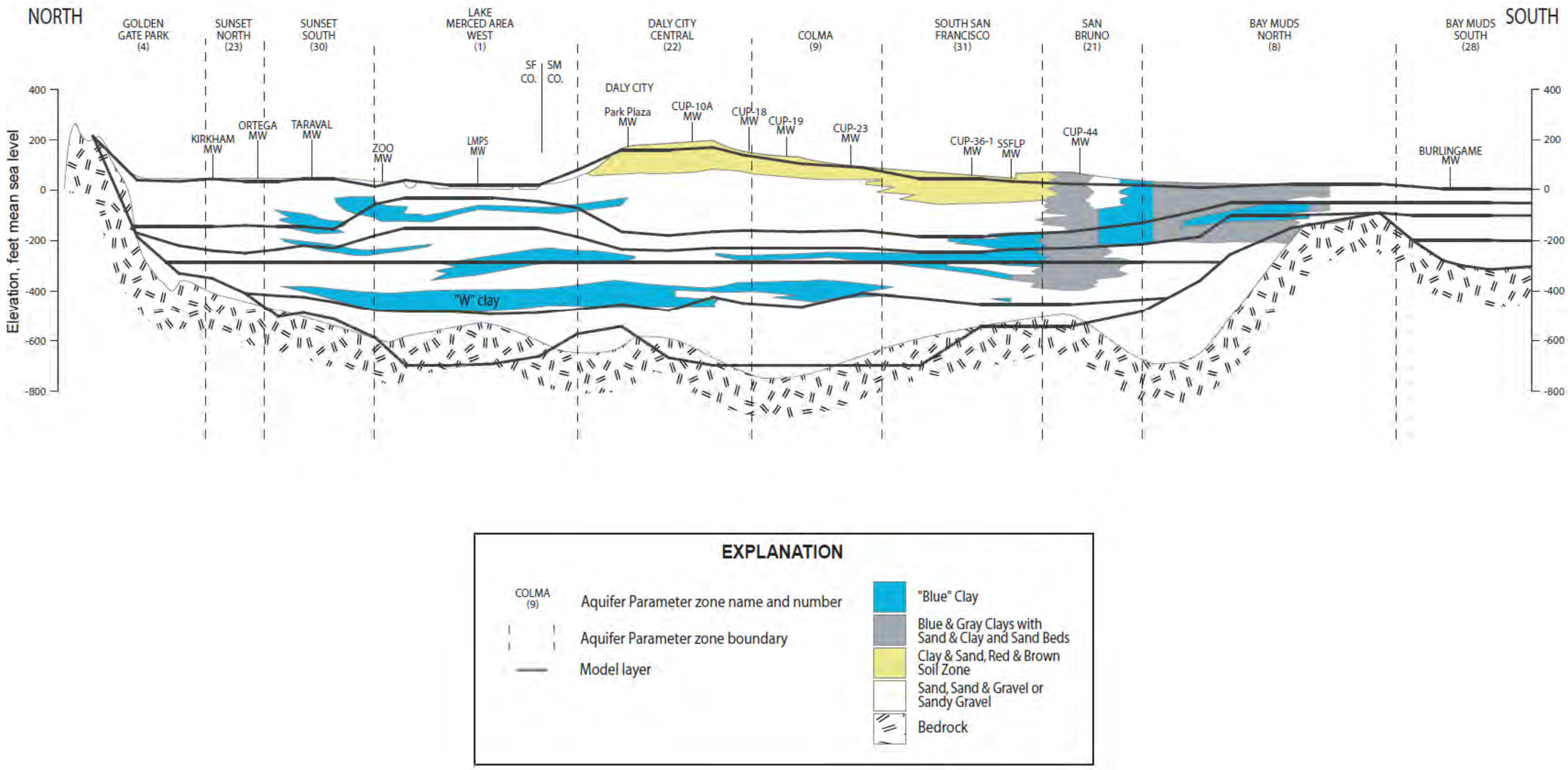
Figure 10.1-2



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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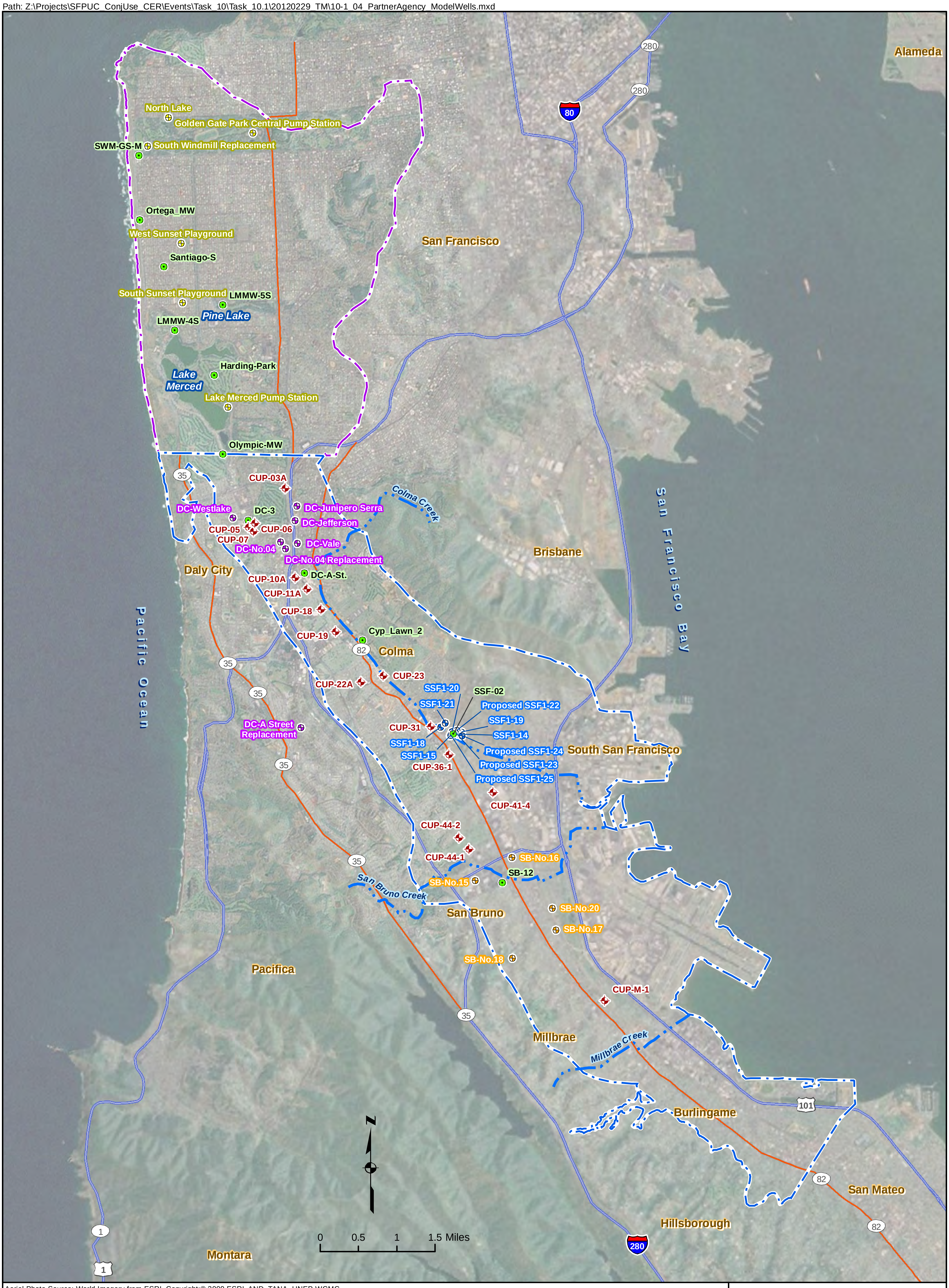

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Legend

- 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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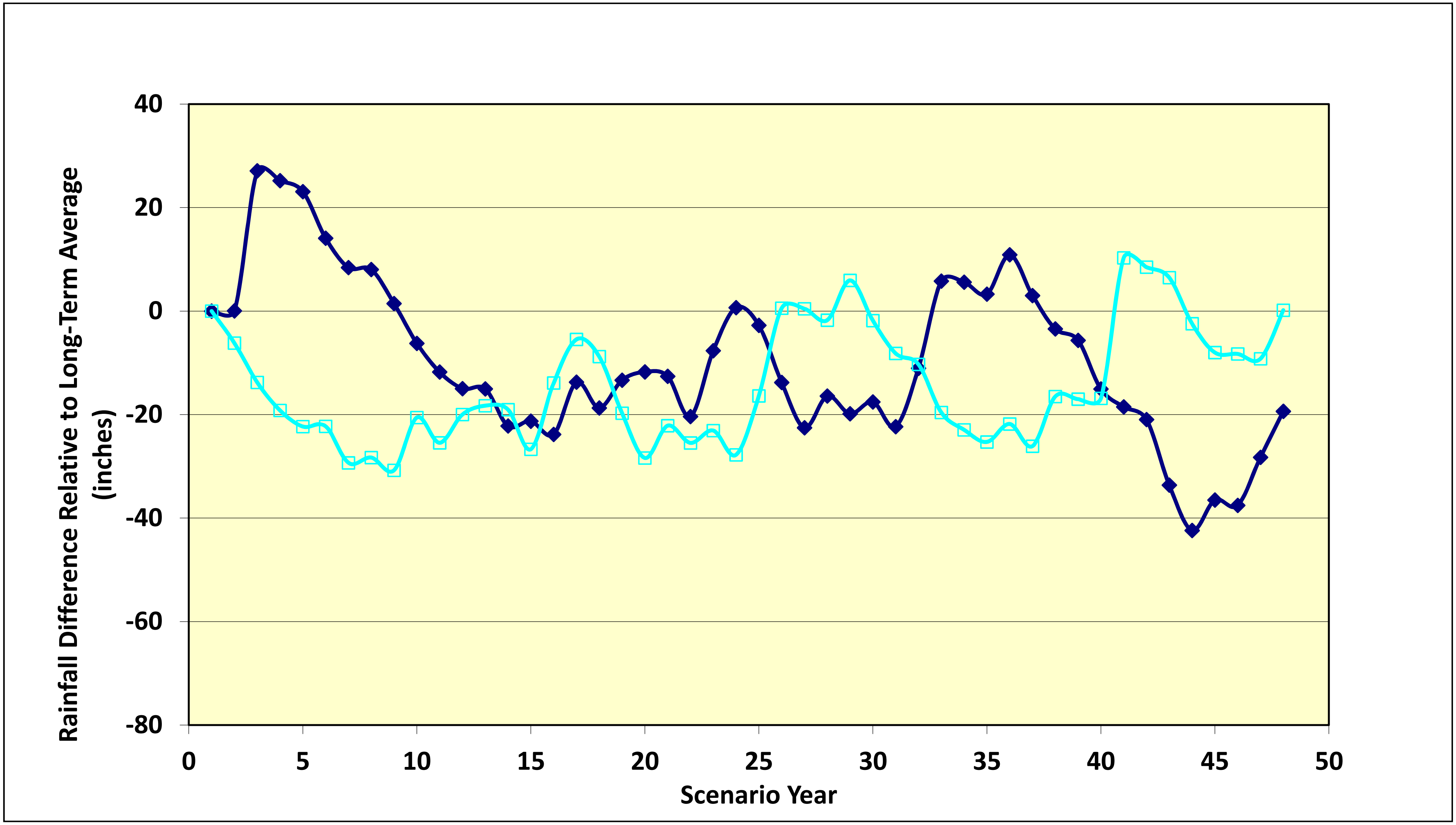
Figure **10.1-4**

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

Date April 2012



Cumulative Rainfall (inches):

Rearranged Hydrologic Sequence

Historical 1958 to 2005 Precipitation Data

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San Francisco Public Utilities Commission

Cumulative Rainfall Departure Curve Analysis for Historical and Rearranged Hydrological Sequence

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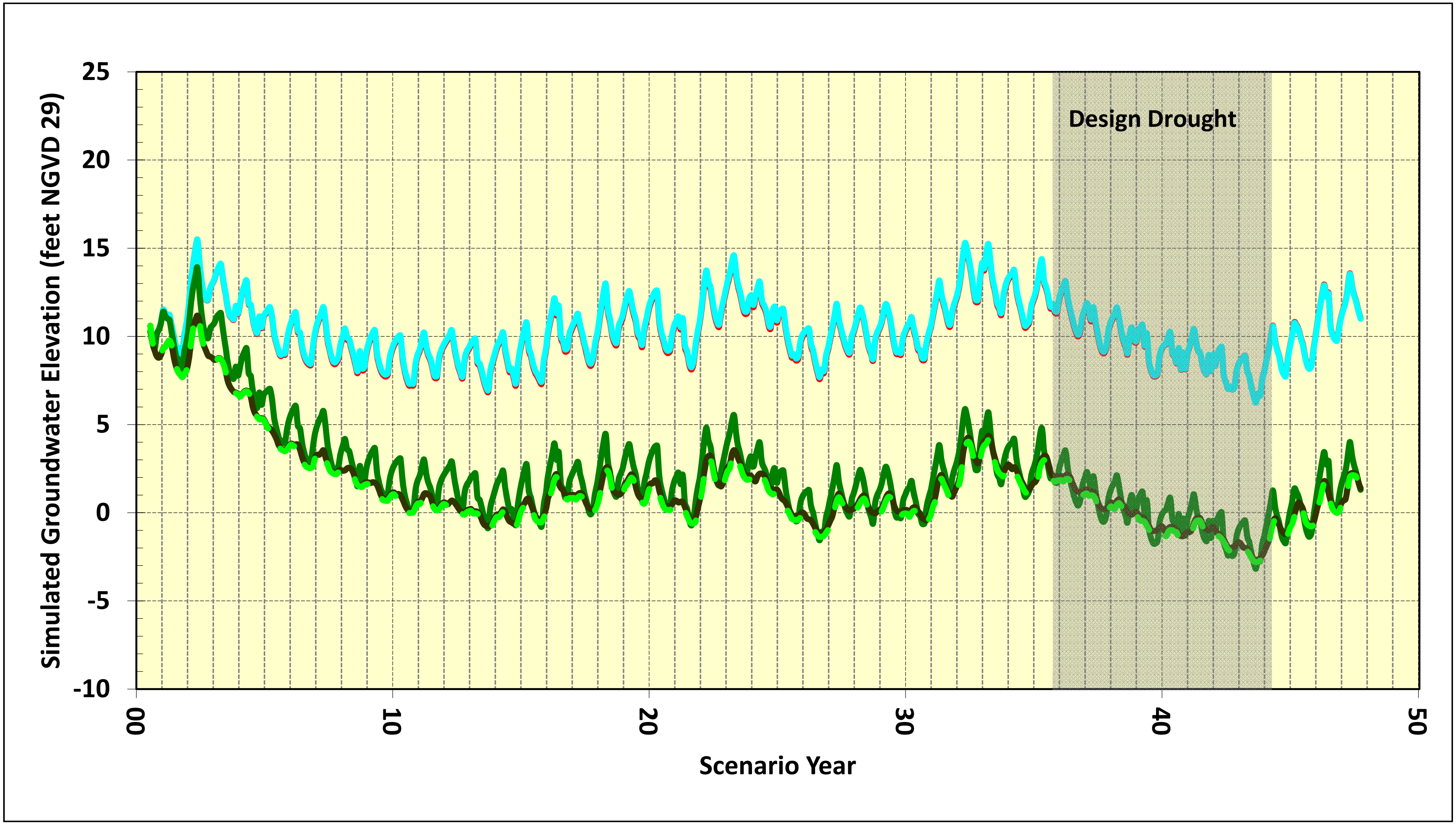
April 2012
Figure 10.1-5



Model Heads:

Scenario 1 | Scenario 2 | Scenario 3a
Scenario 3b | Scenario 4

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San Francisco Public Utilities Commission

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

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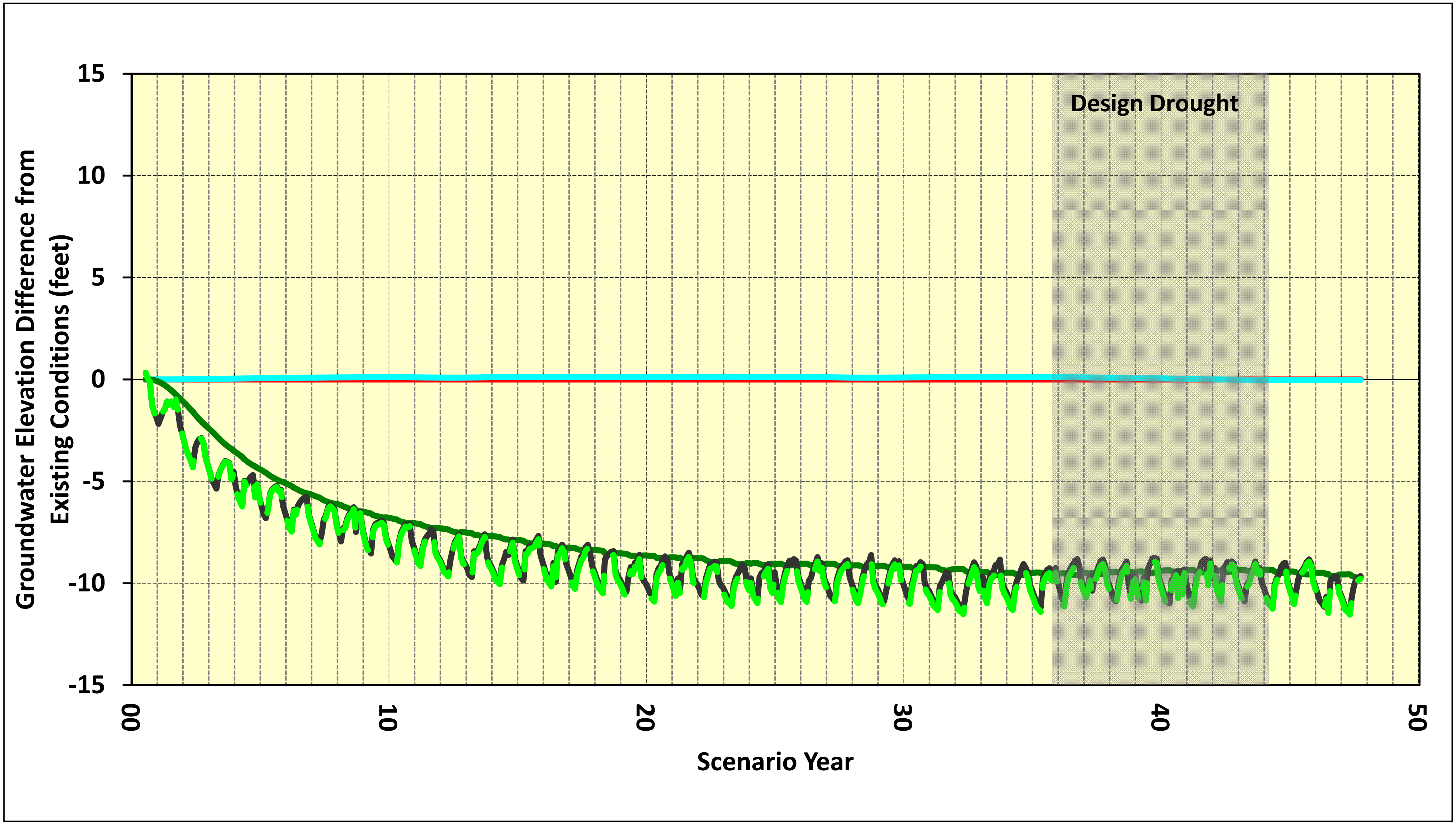
Figure 10.1-6



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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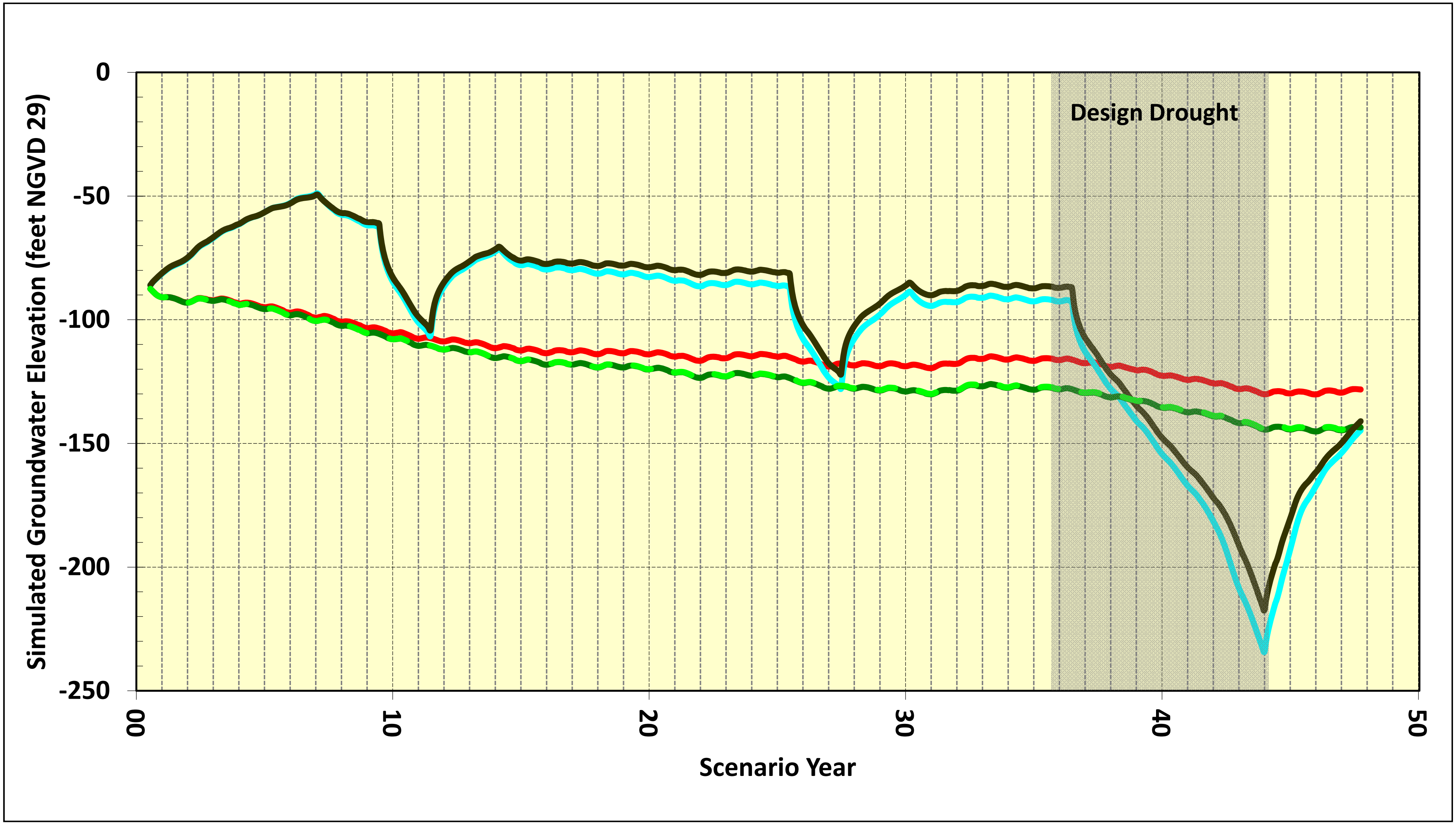
Figure 10.1-7



Model Heads:

Scenario 1 | Scenario 2 | Scenario 3a
Scenario 3b | Scenario 4

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

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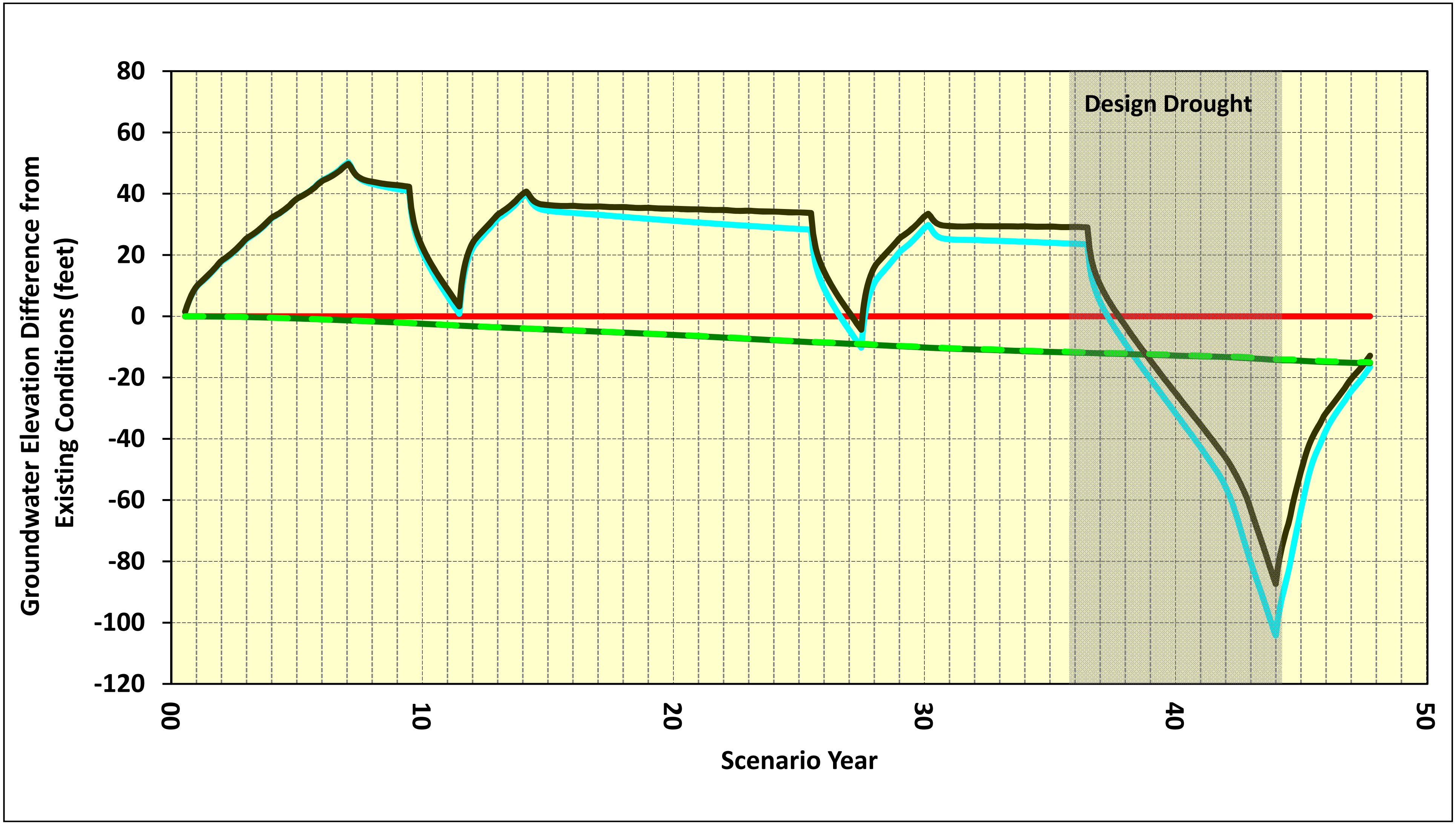
Figure 10.1-8



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 DC-A St (Model Layer 4)

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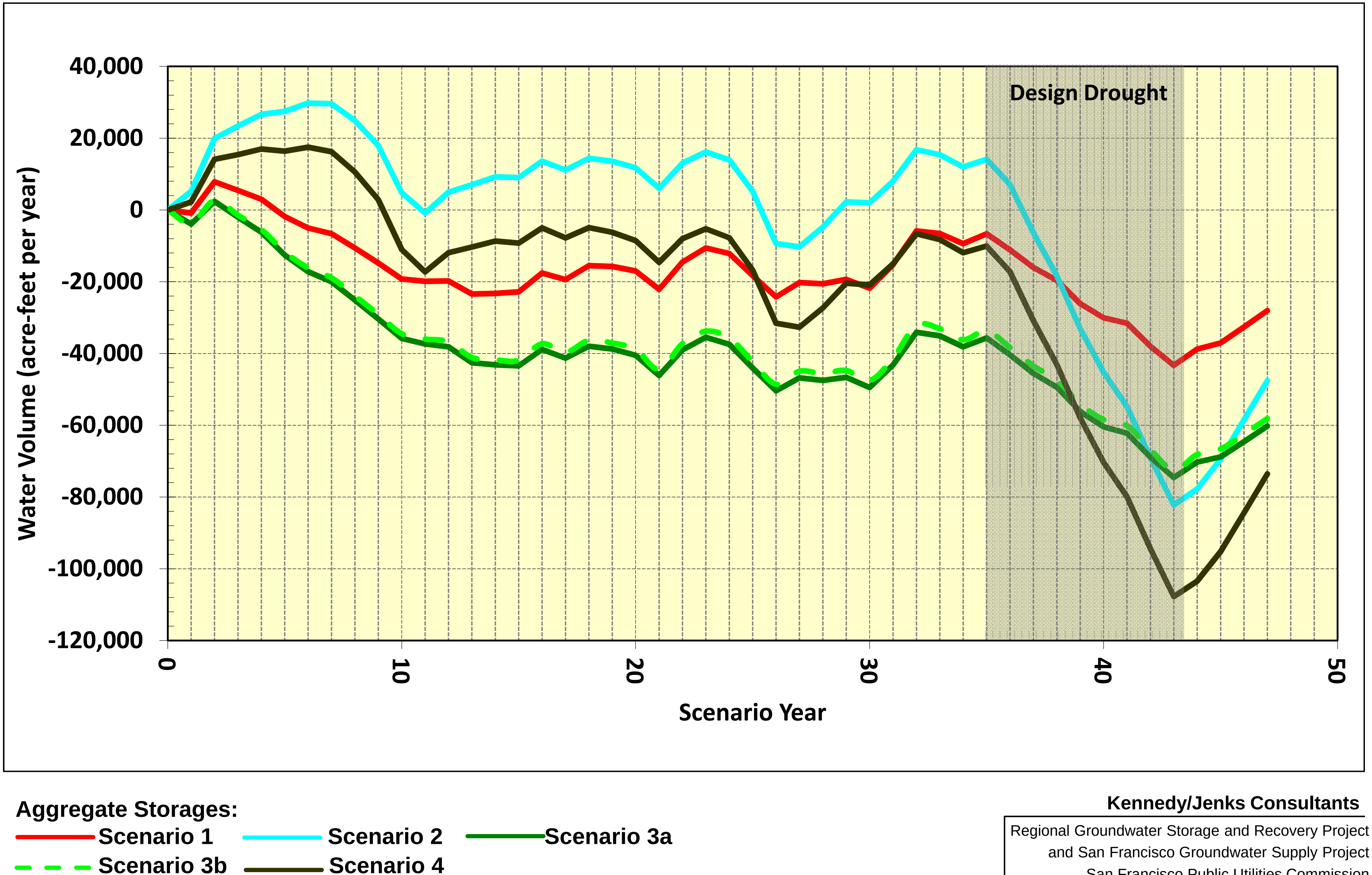
Figure 10.1-9



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Model-Simulated Aggregate Change in Groundwater Storage

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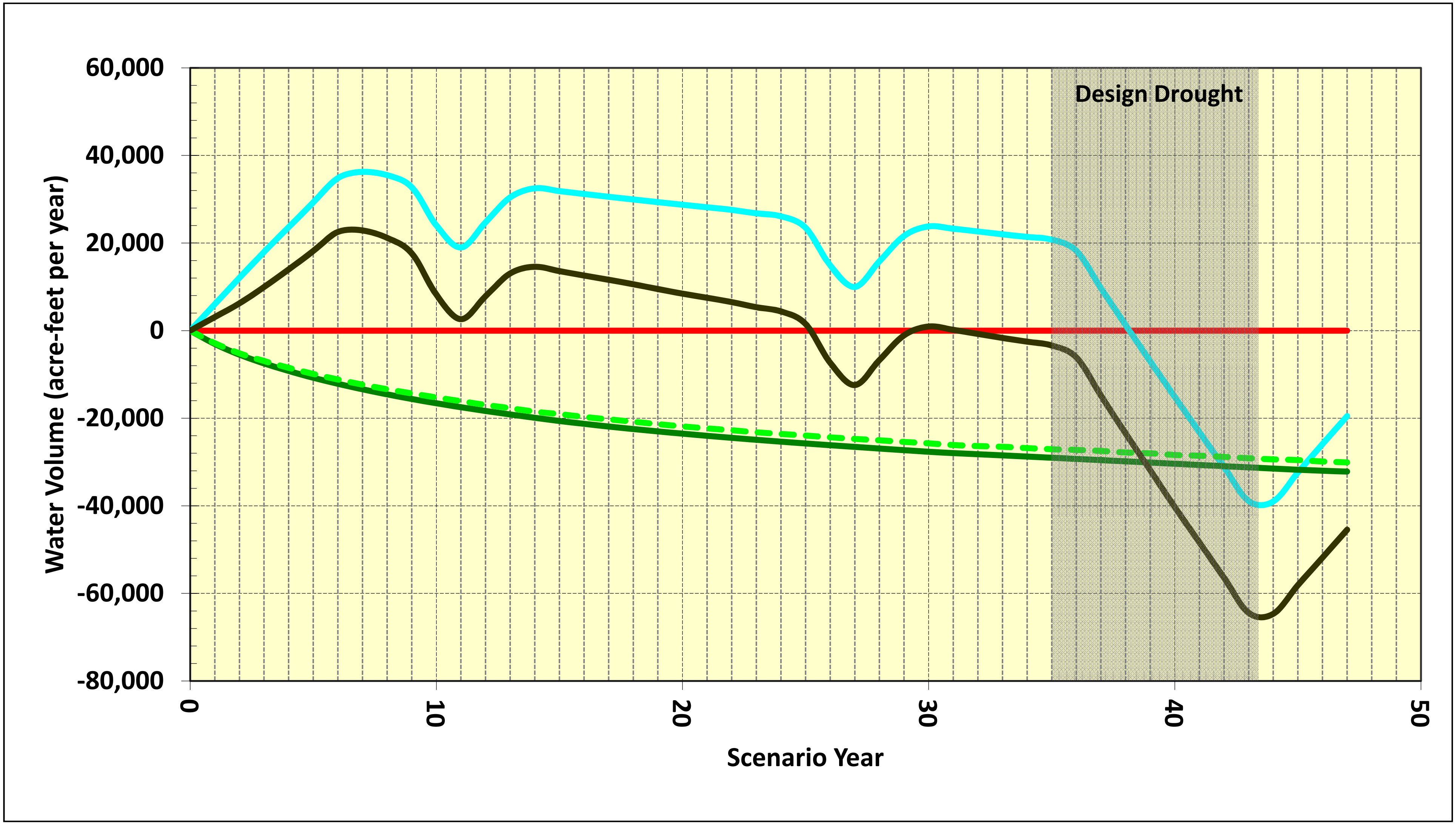
Figure 10.1-10



Aggregate Storages:
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

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

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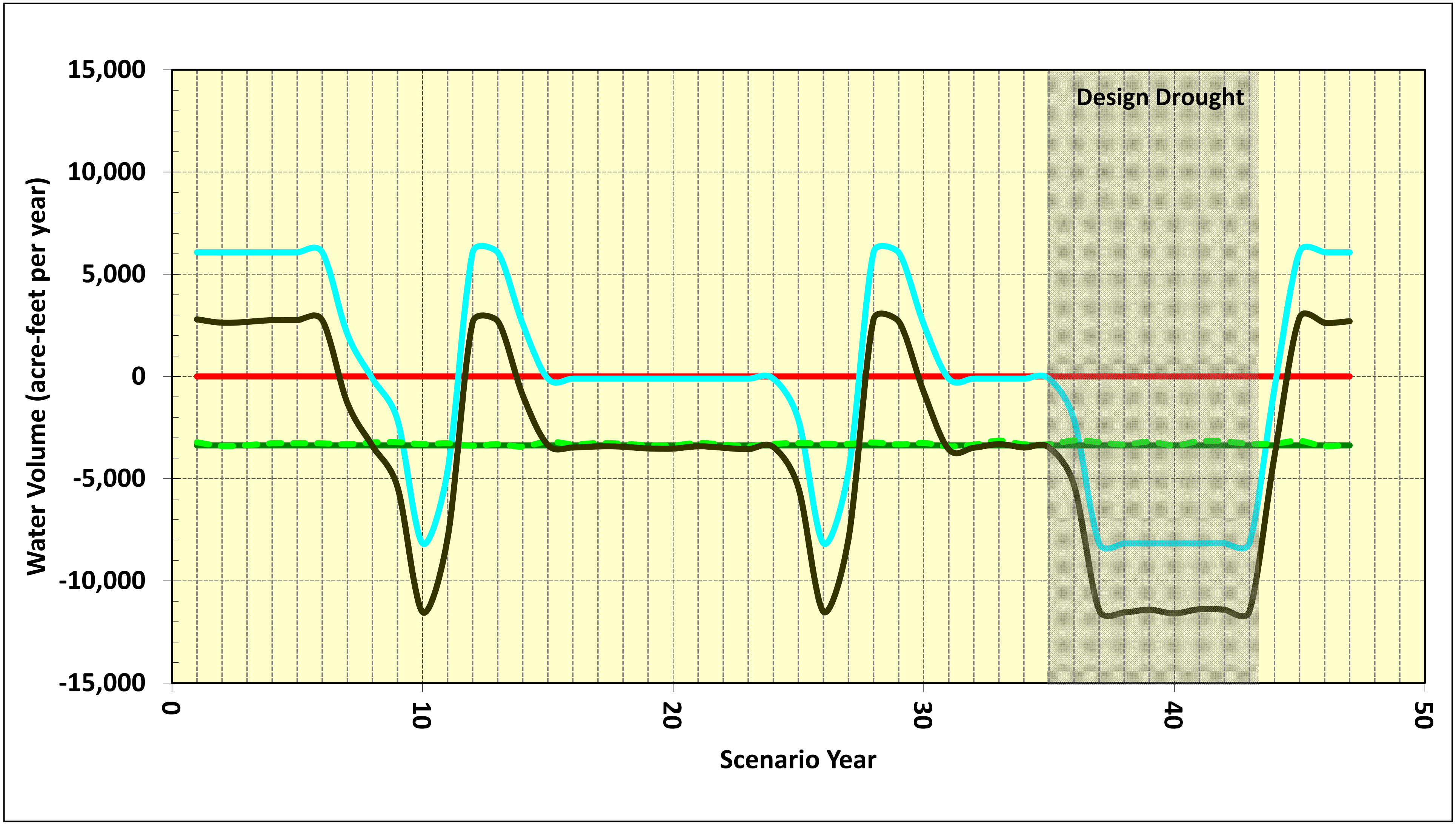
Figure 10.1-11



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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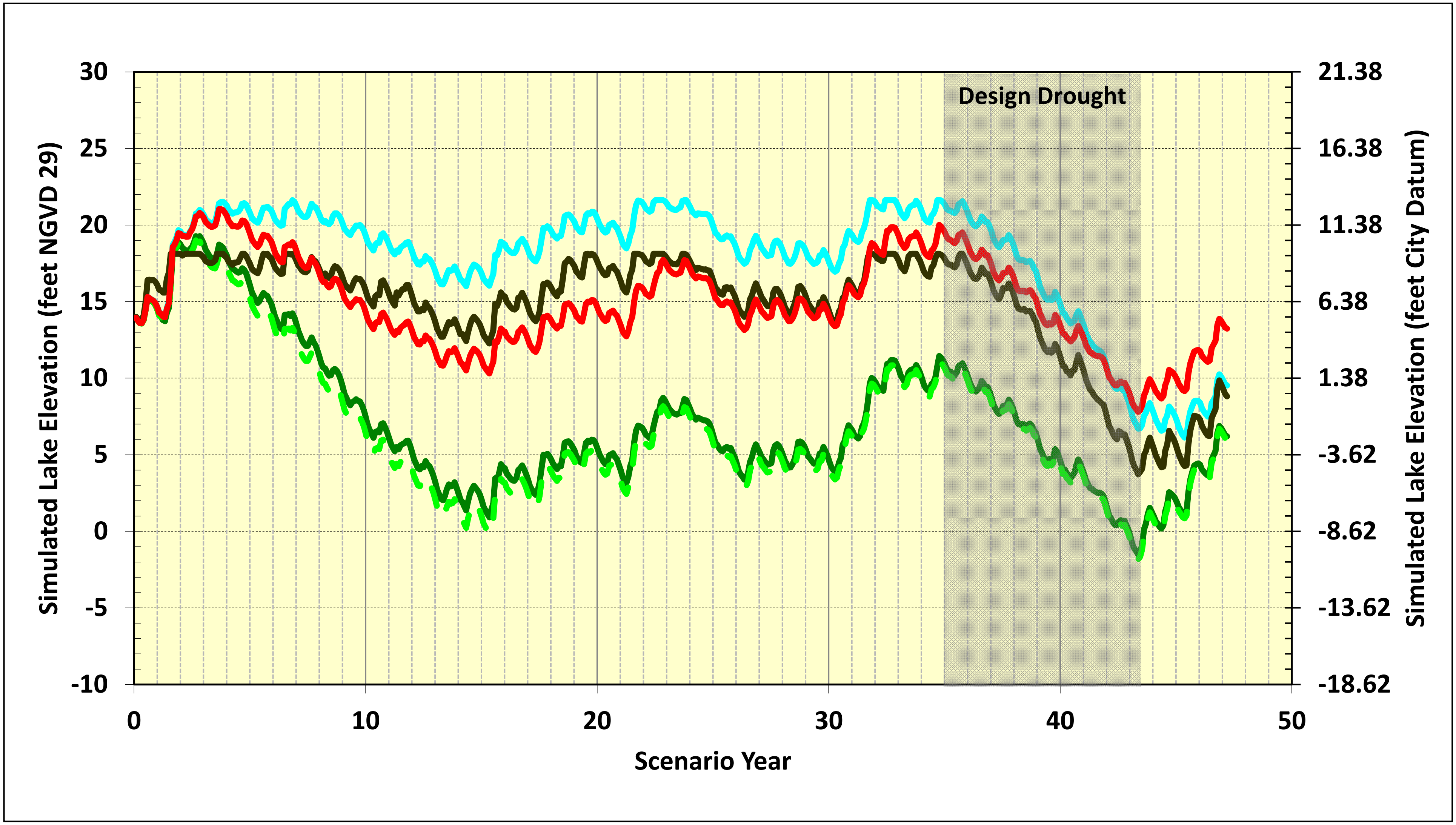
Figure 10.1-12



Model Lake Elevations:

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

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

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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)					Total
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
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.

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[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.

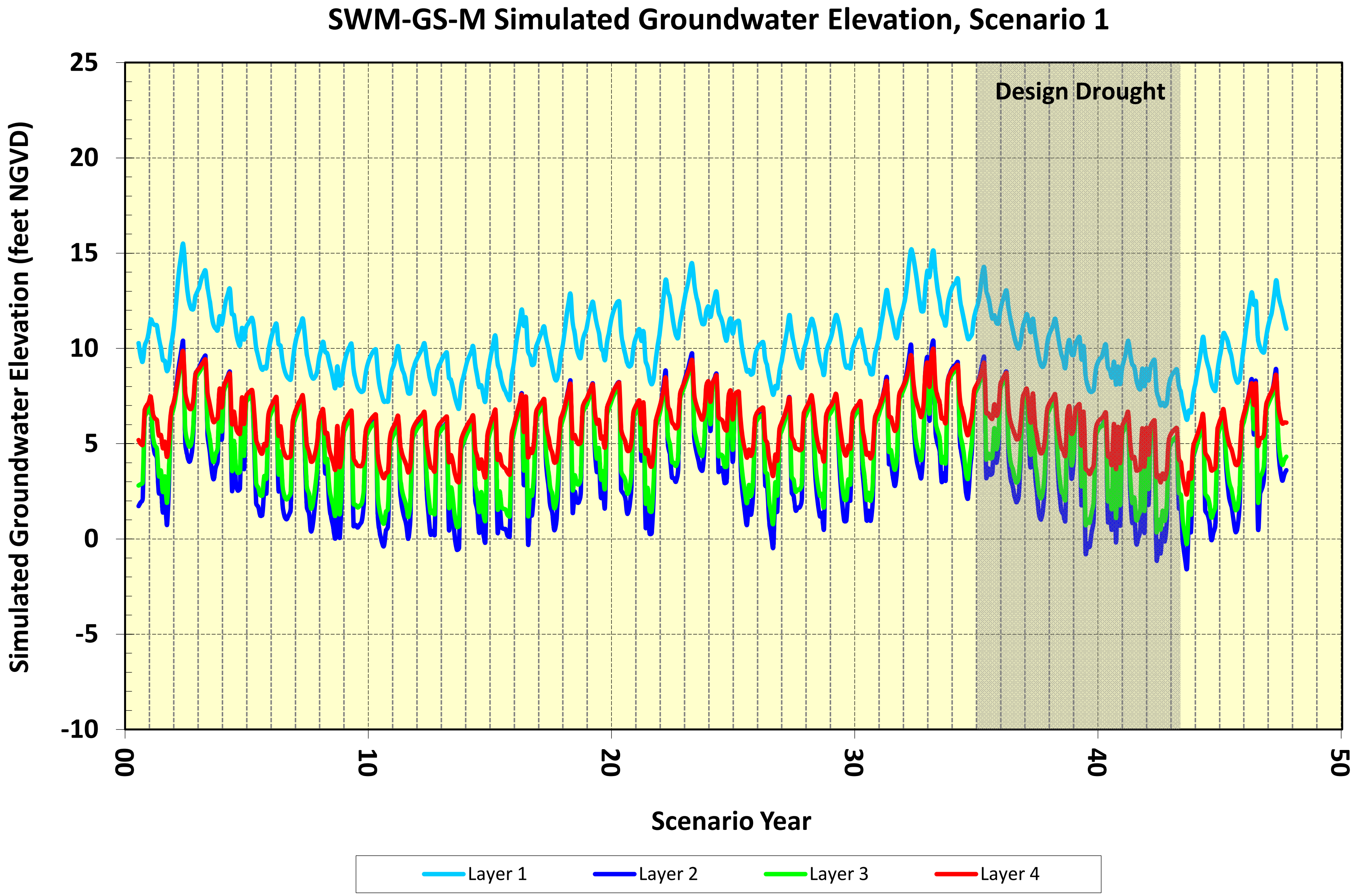
New Project wells installed by the SFPUC would be operated under the following circumstances:

- 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

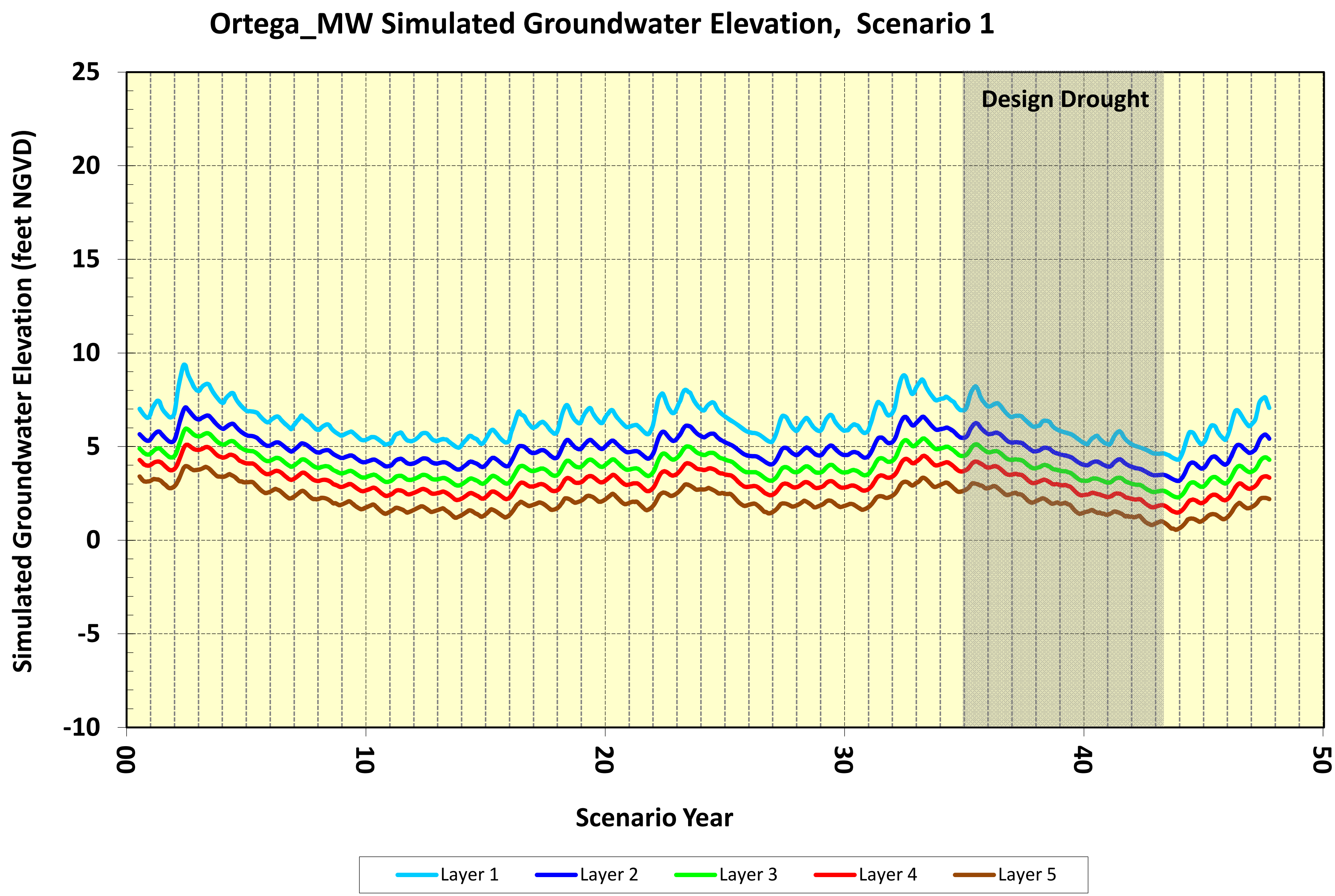
In these circumstances, new Project wells could be operated continuously or for shorter intervals, depending on the need for water. The primary purpose of the Project is to provide a dry year water supply during a multiple year drought. During these Take Periods, when groundwater is pumped to provide 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

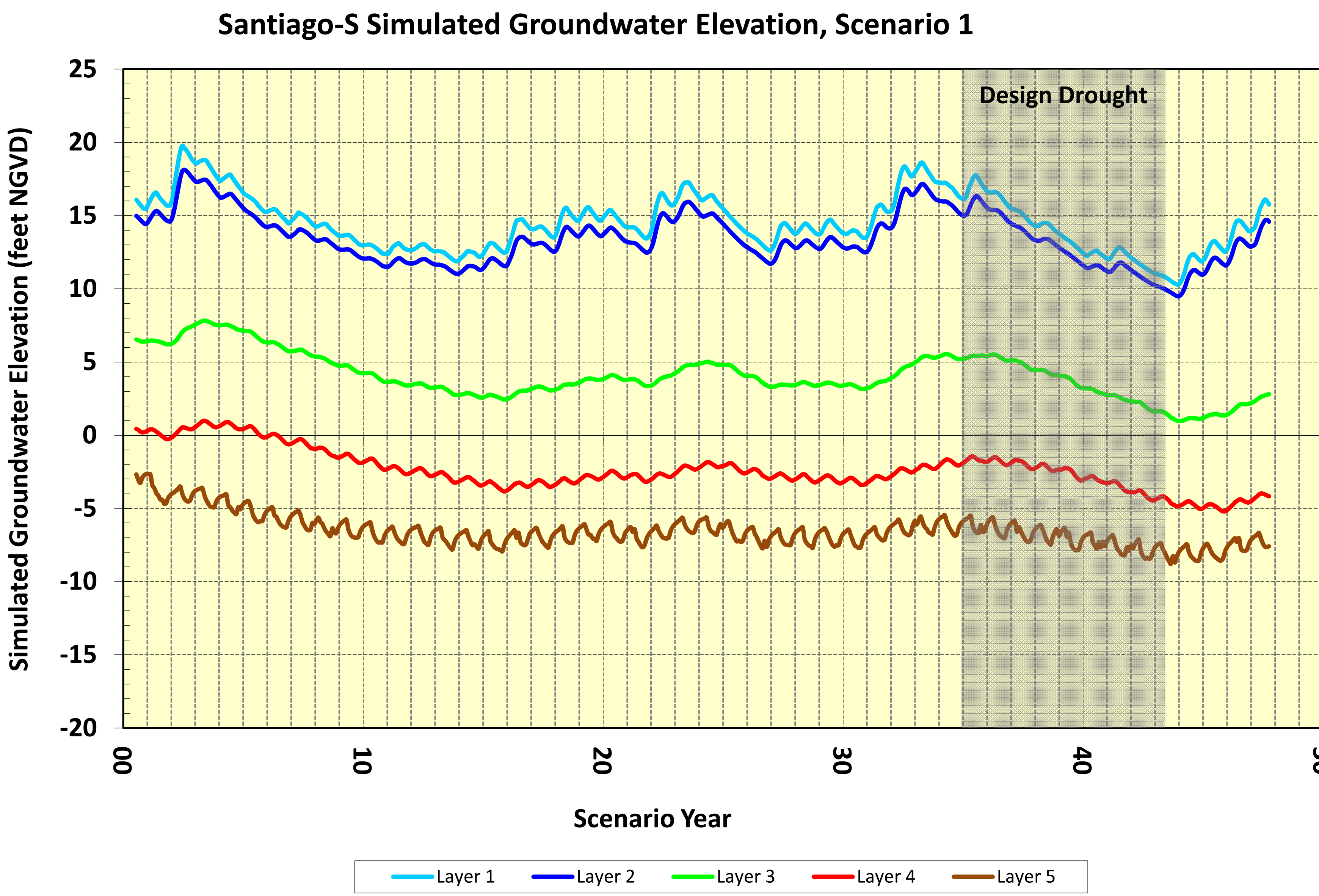
Model Scenario Hydrographs for Selected Locations



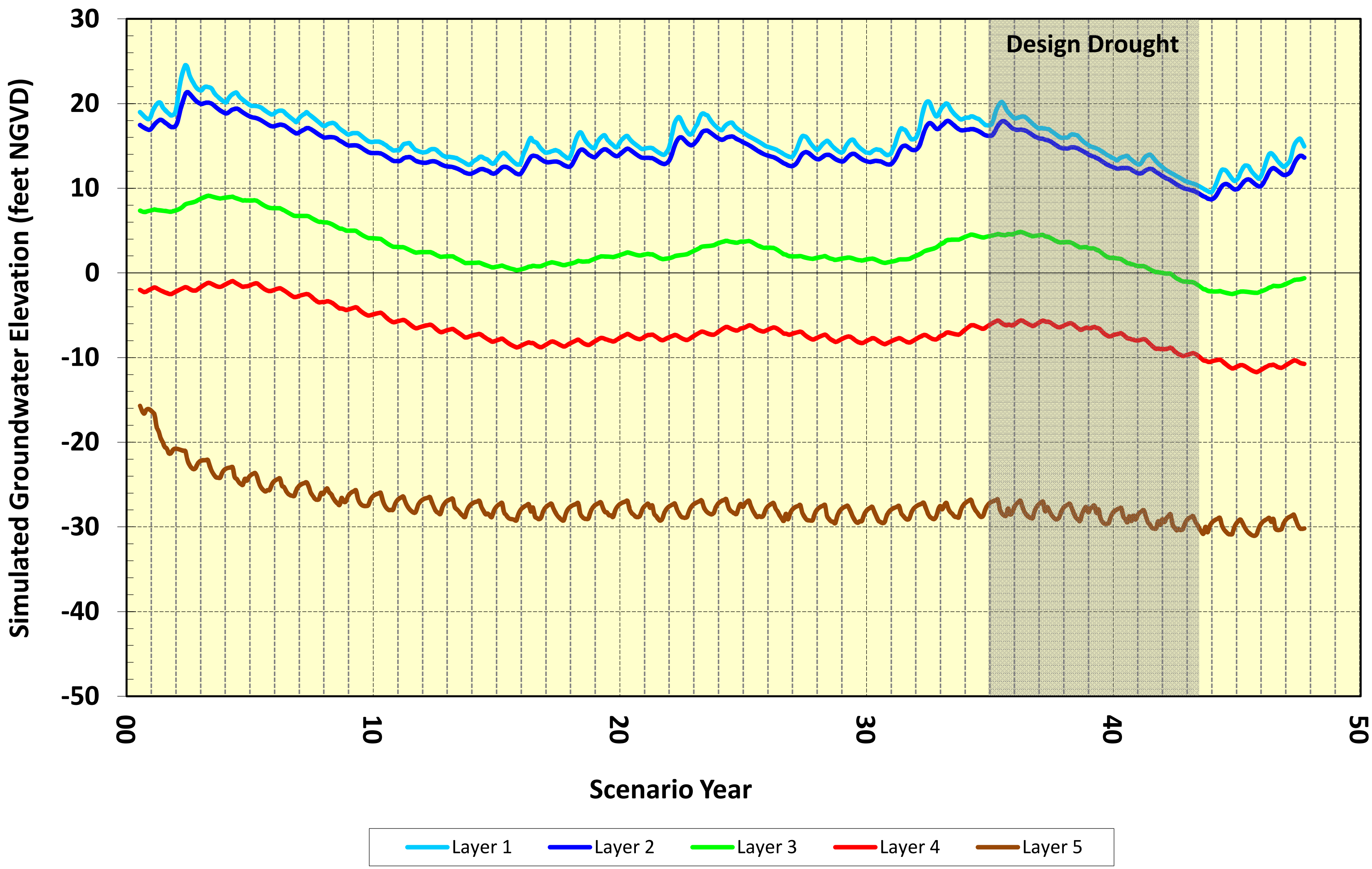
Note: At the location of SWM-GS-M, the model does not contain Model Layer 5.

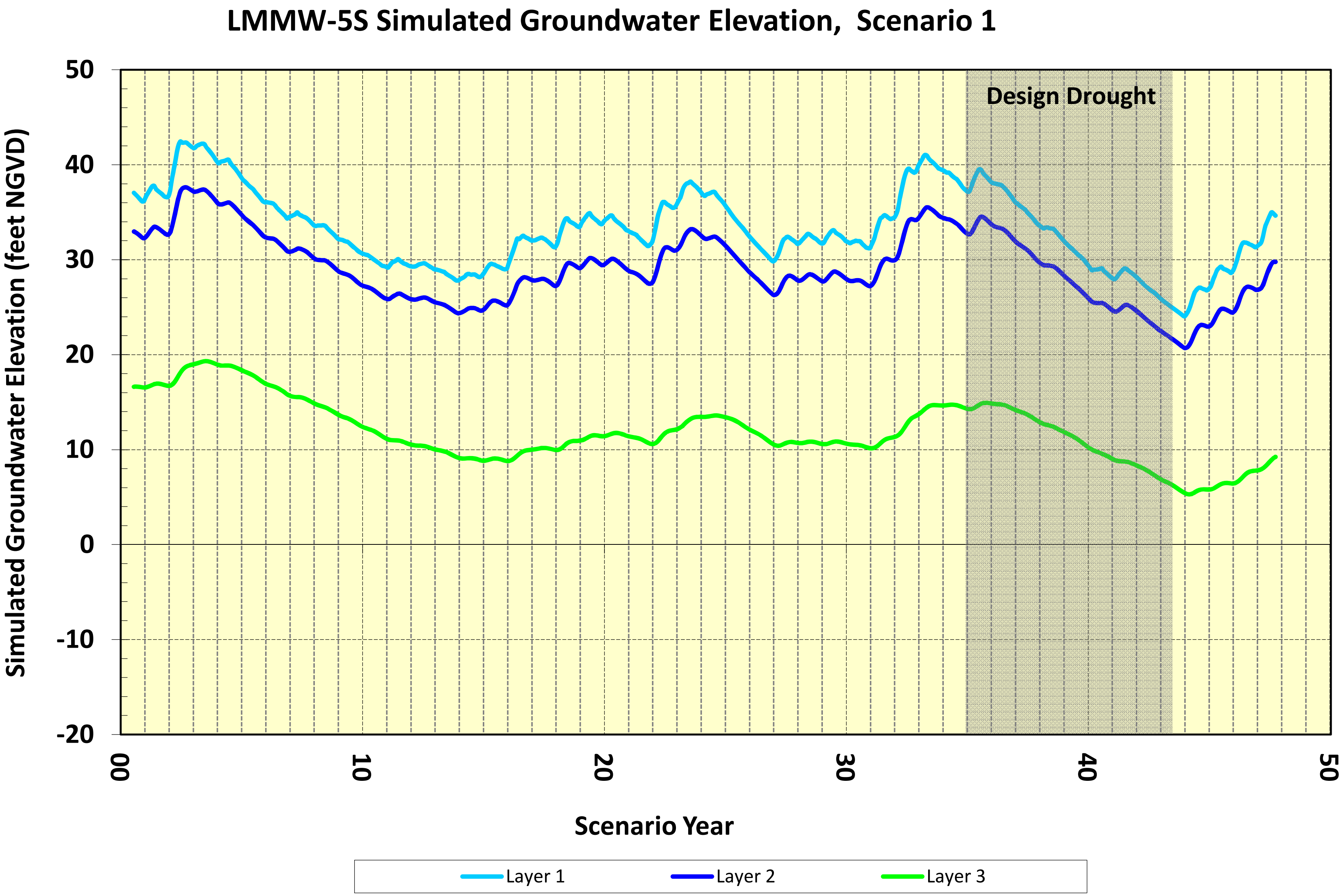


Ortega_MW Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

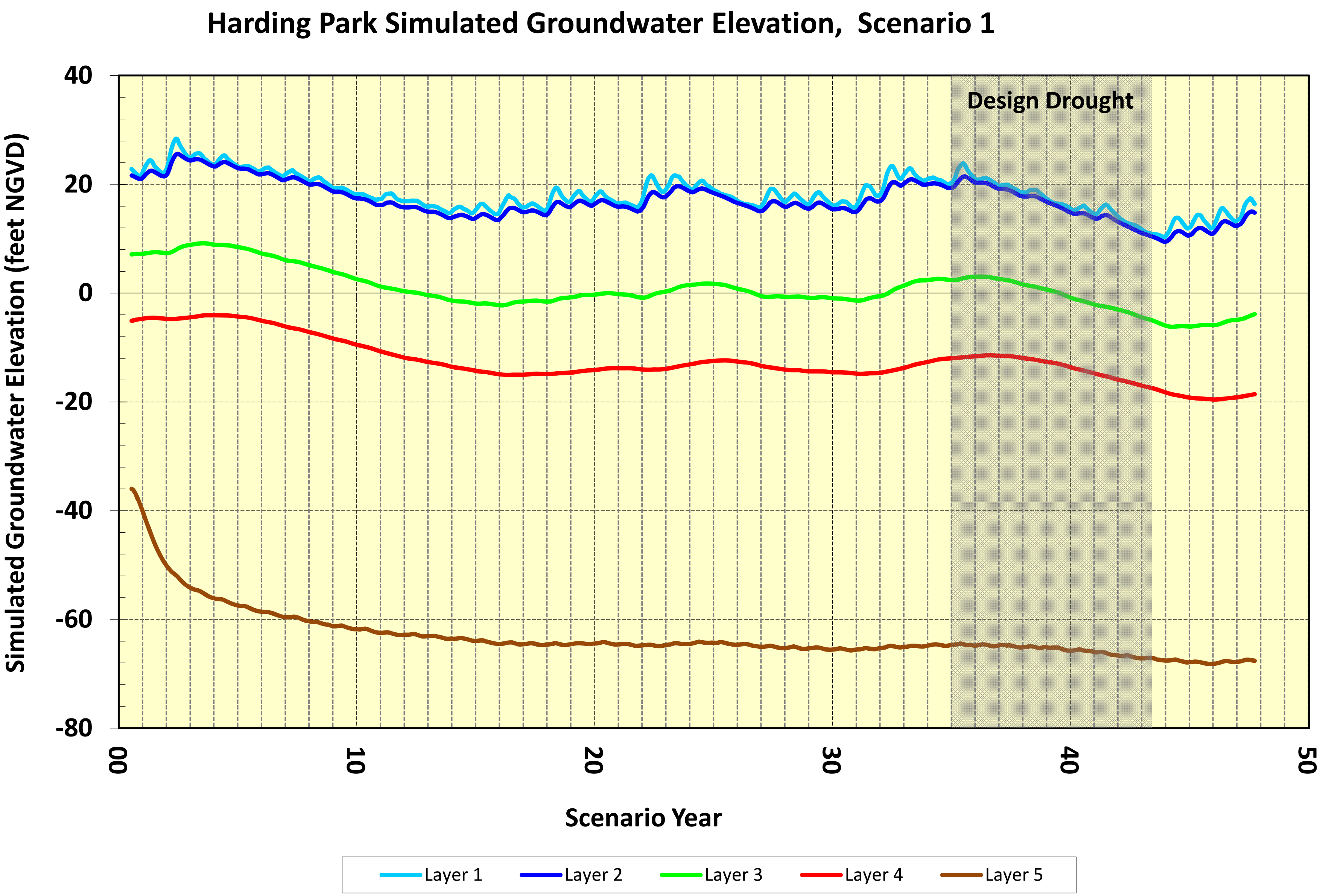

Santiago-S Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
-15
-20
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

LMMW-4S Simulated Groundwater Elevation, Scenario 1

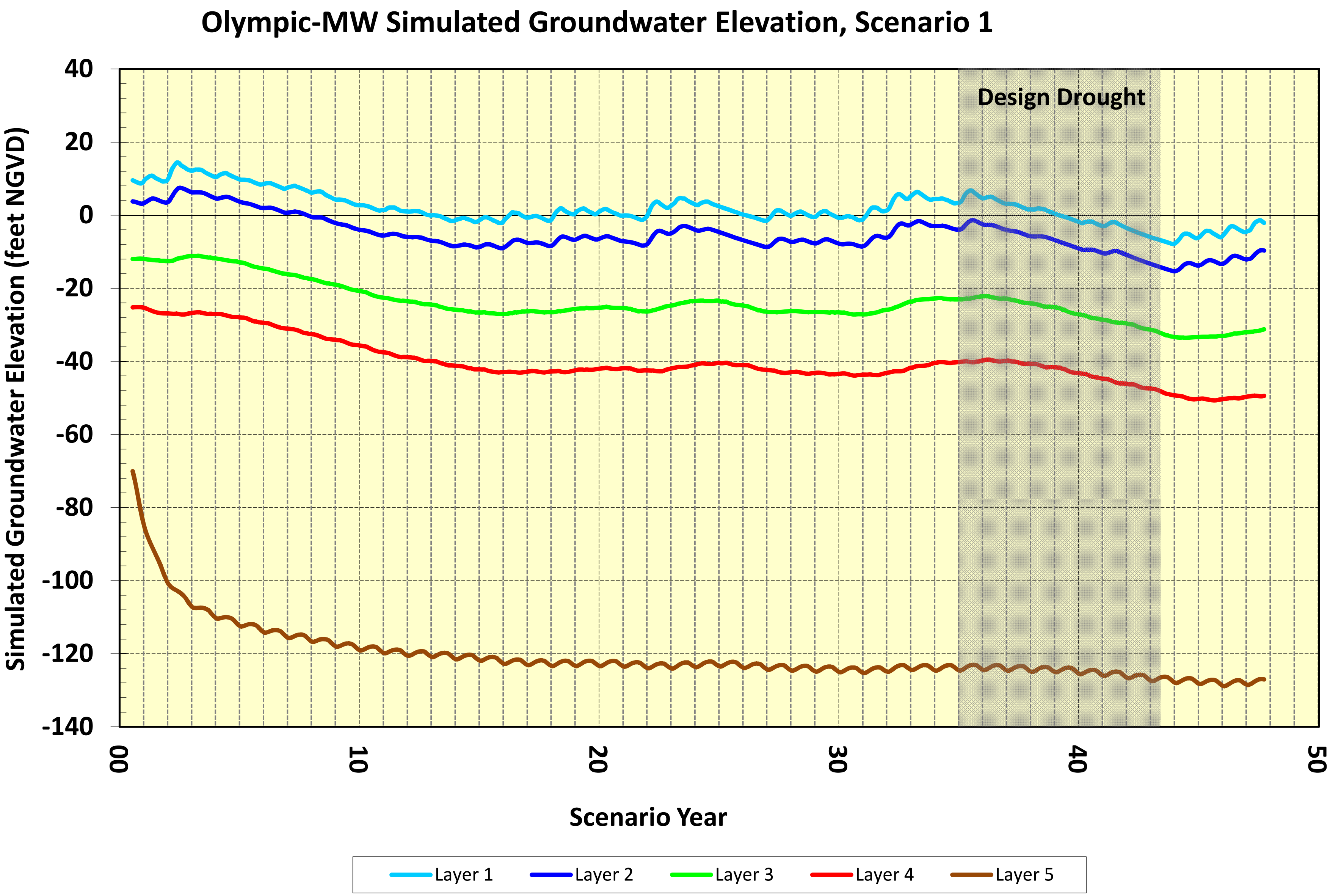




Note: At the location of LMMW-5S, the model does not contain Model Layers 4 and 5.

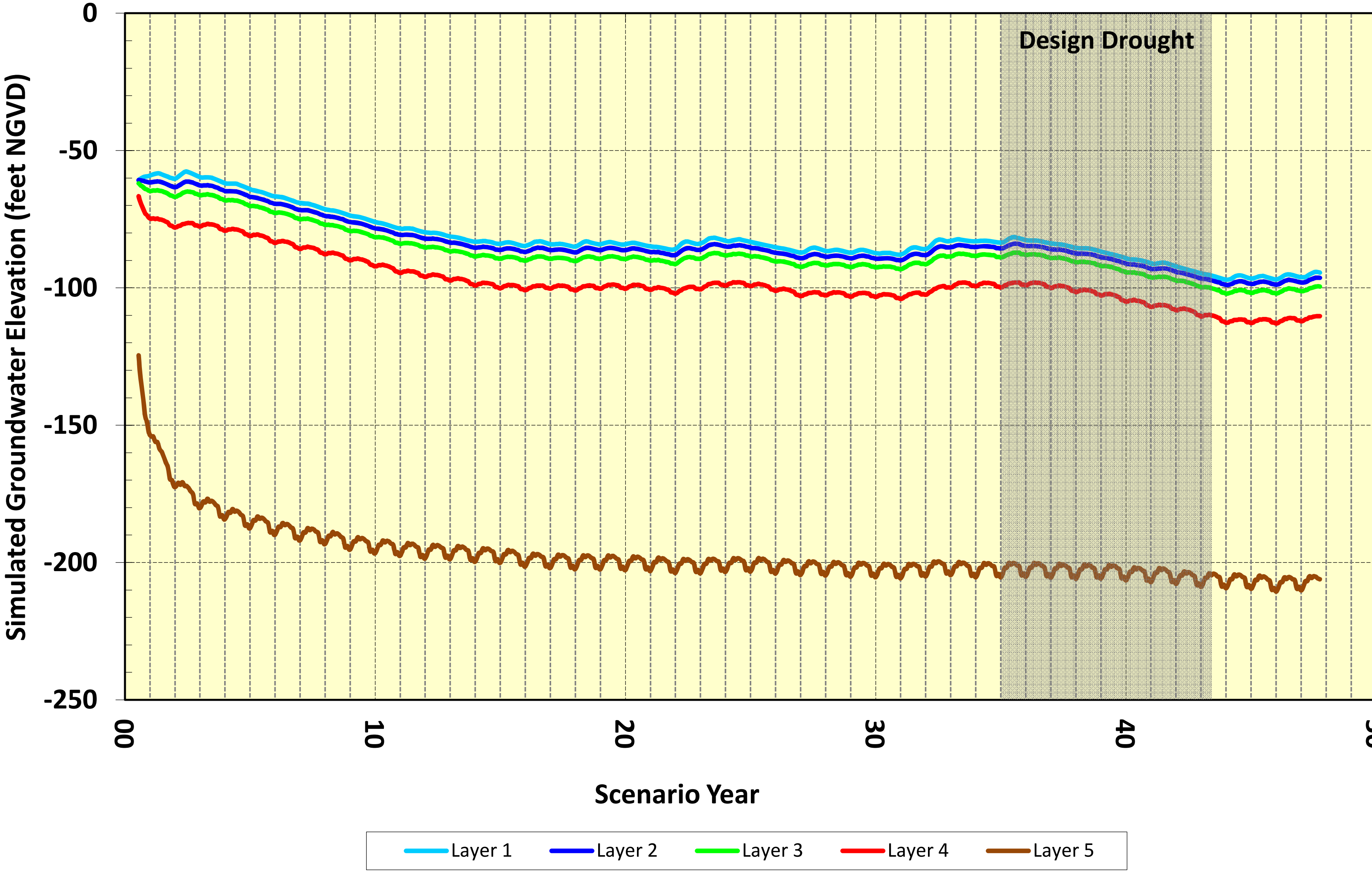


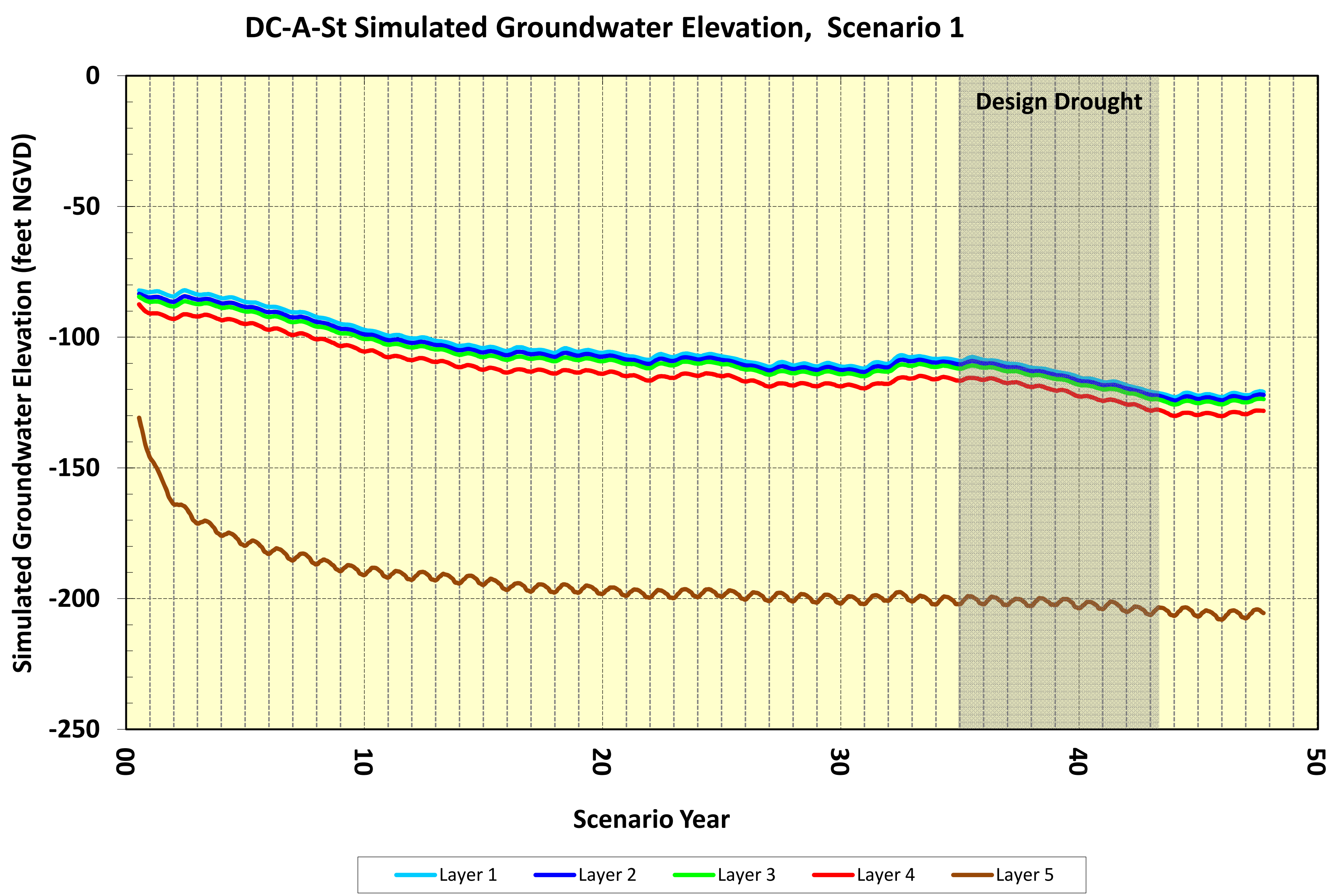
Harding Park Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



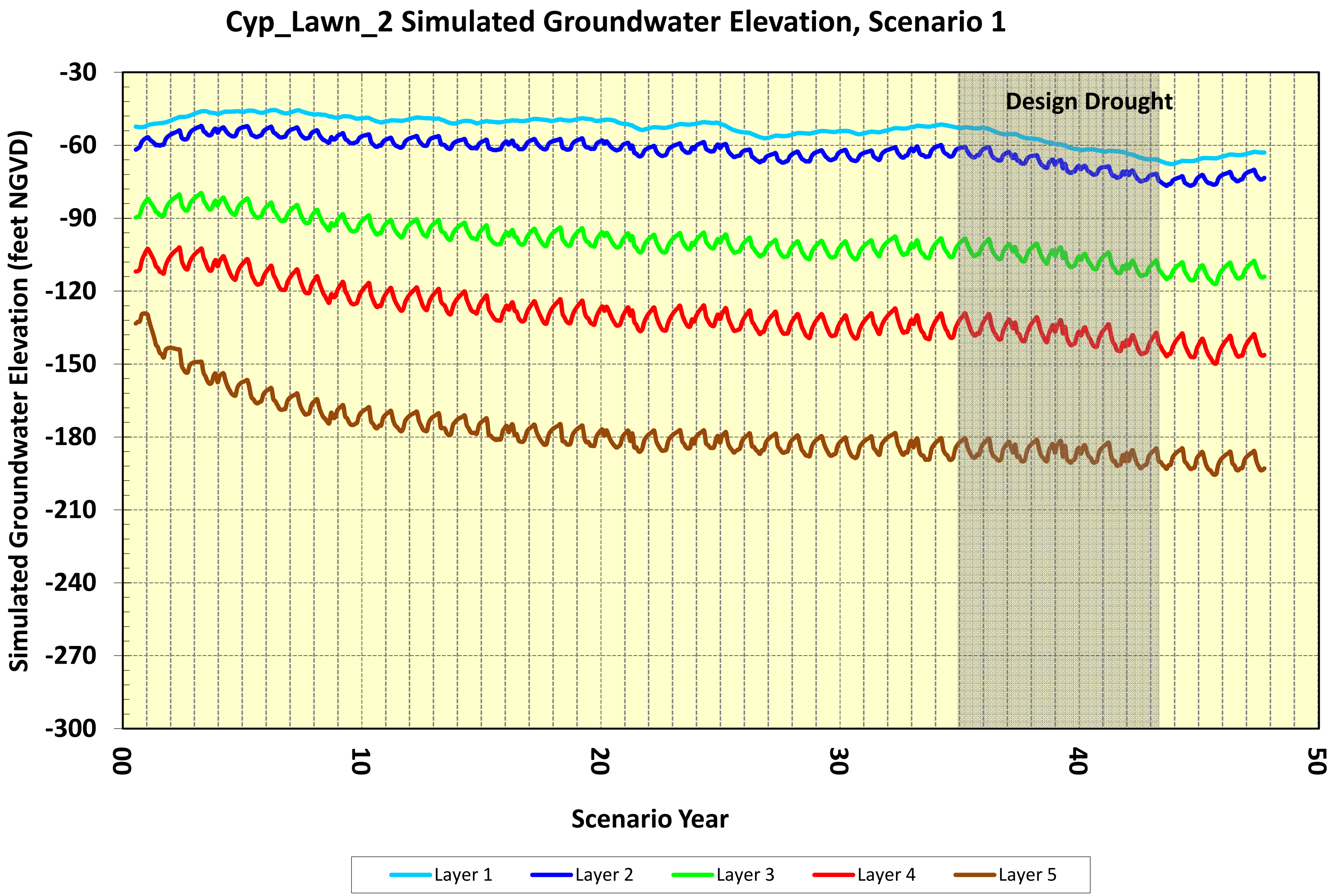
Olympic-MW Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
-100
-120
-140
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

DC-3 Simulated Groundwater Elevation, Scenario 1

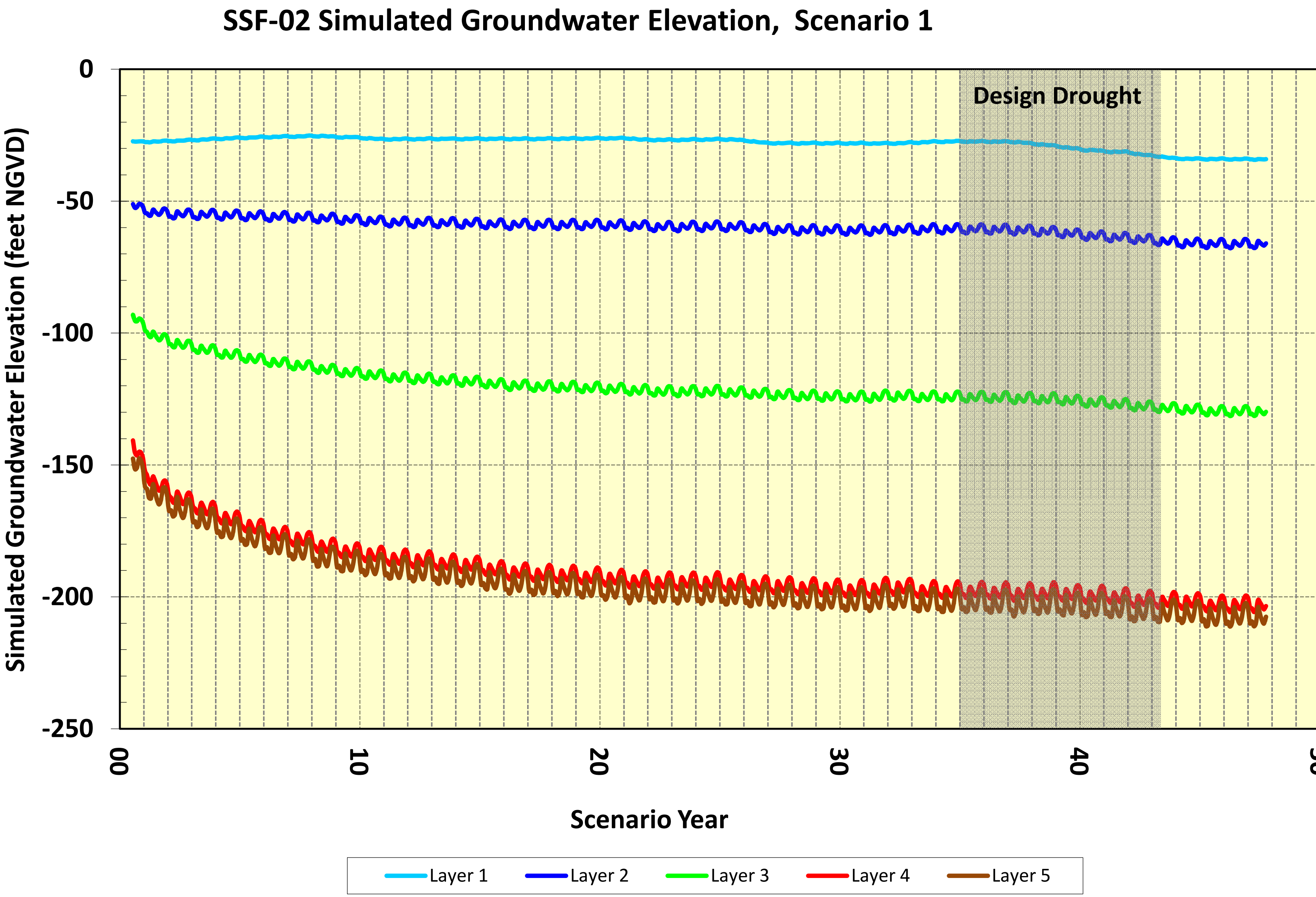


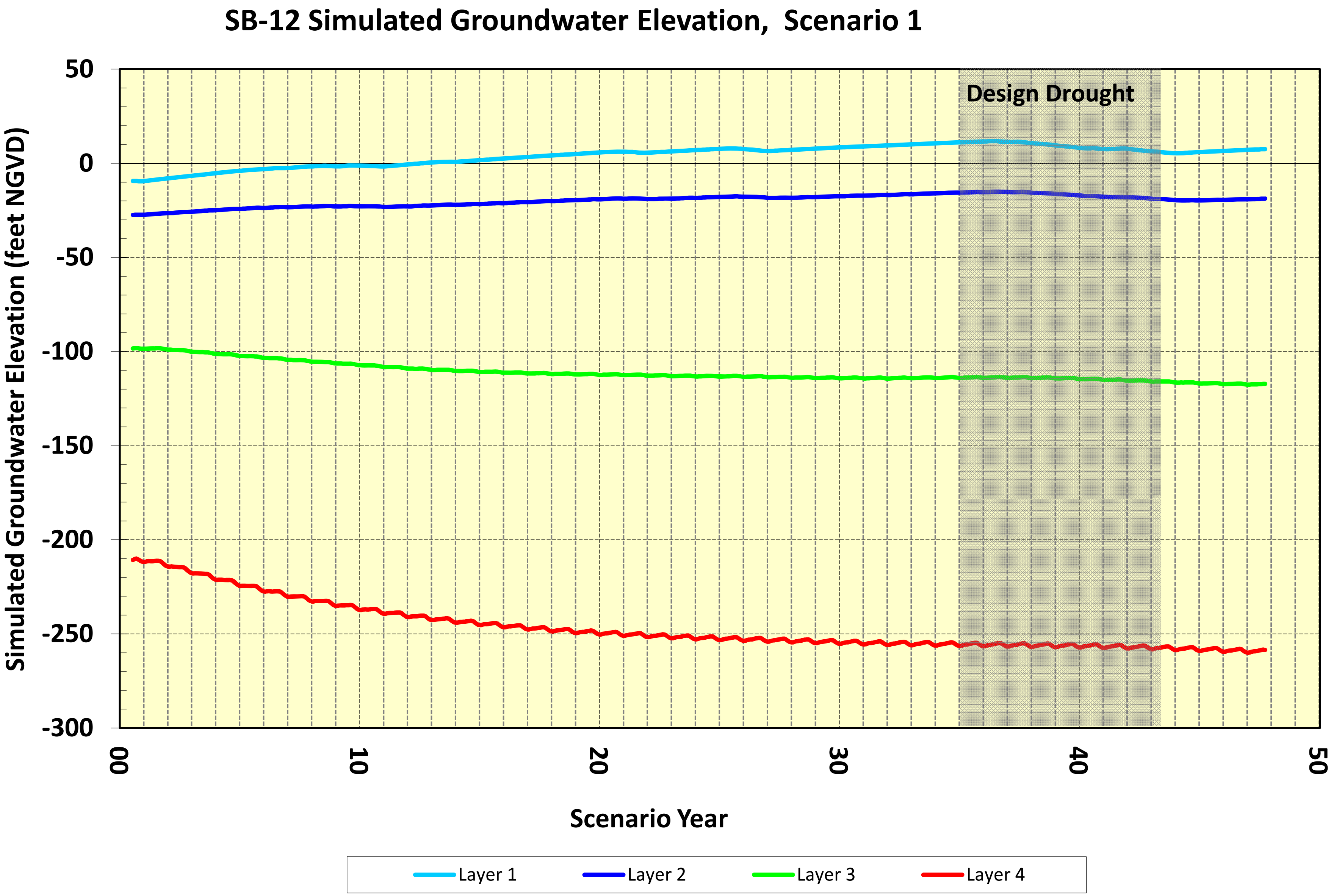


DC-A-St Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

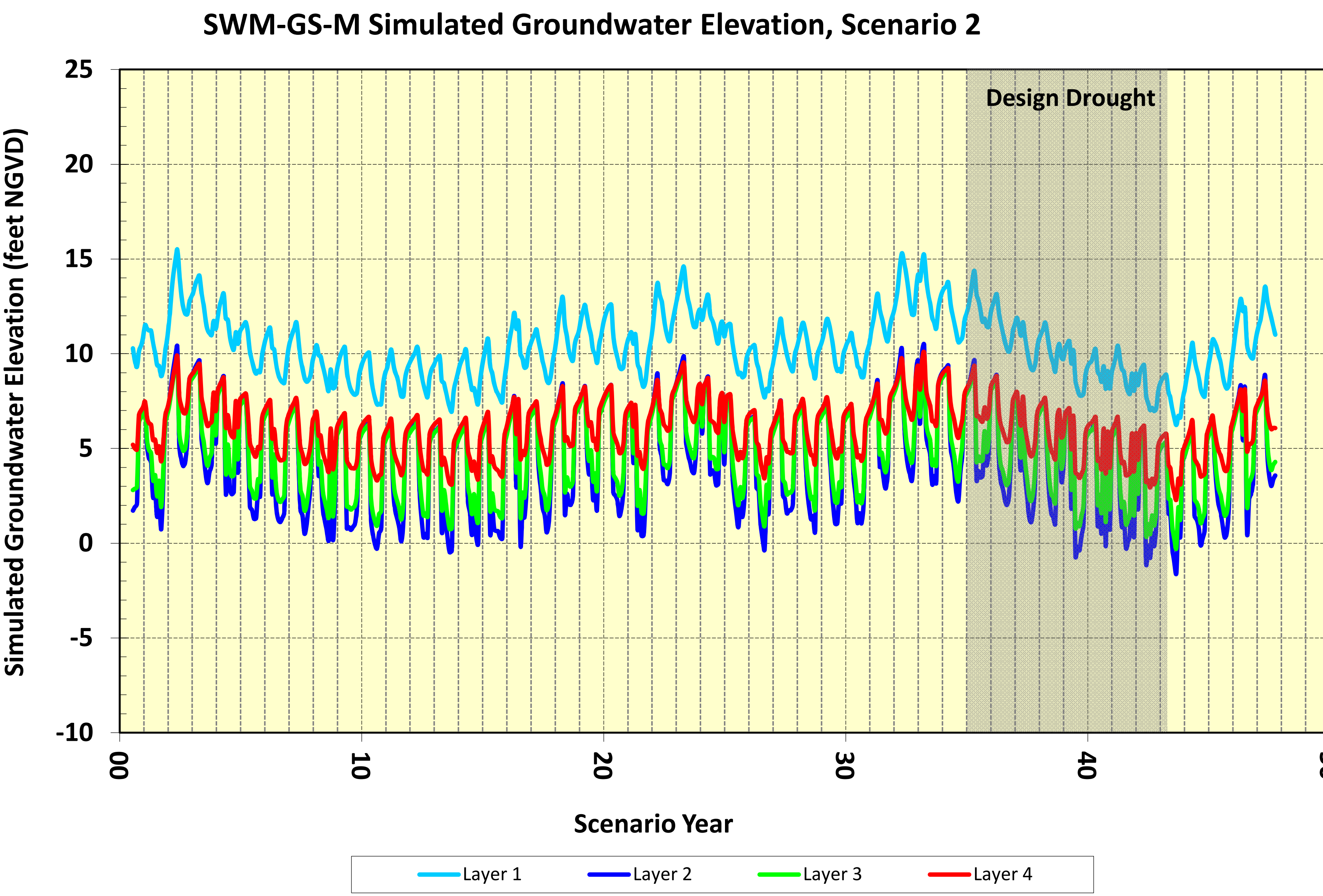


Cyp_Lawn_2 Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
-30
-60
-90
-120
-150
-180
-210
-240
-270
-300
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

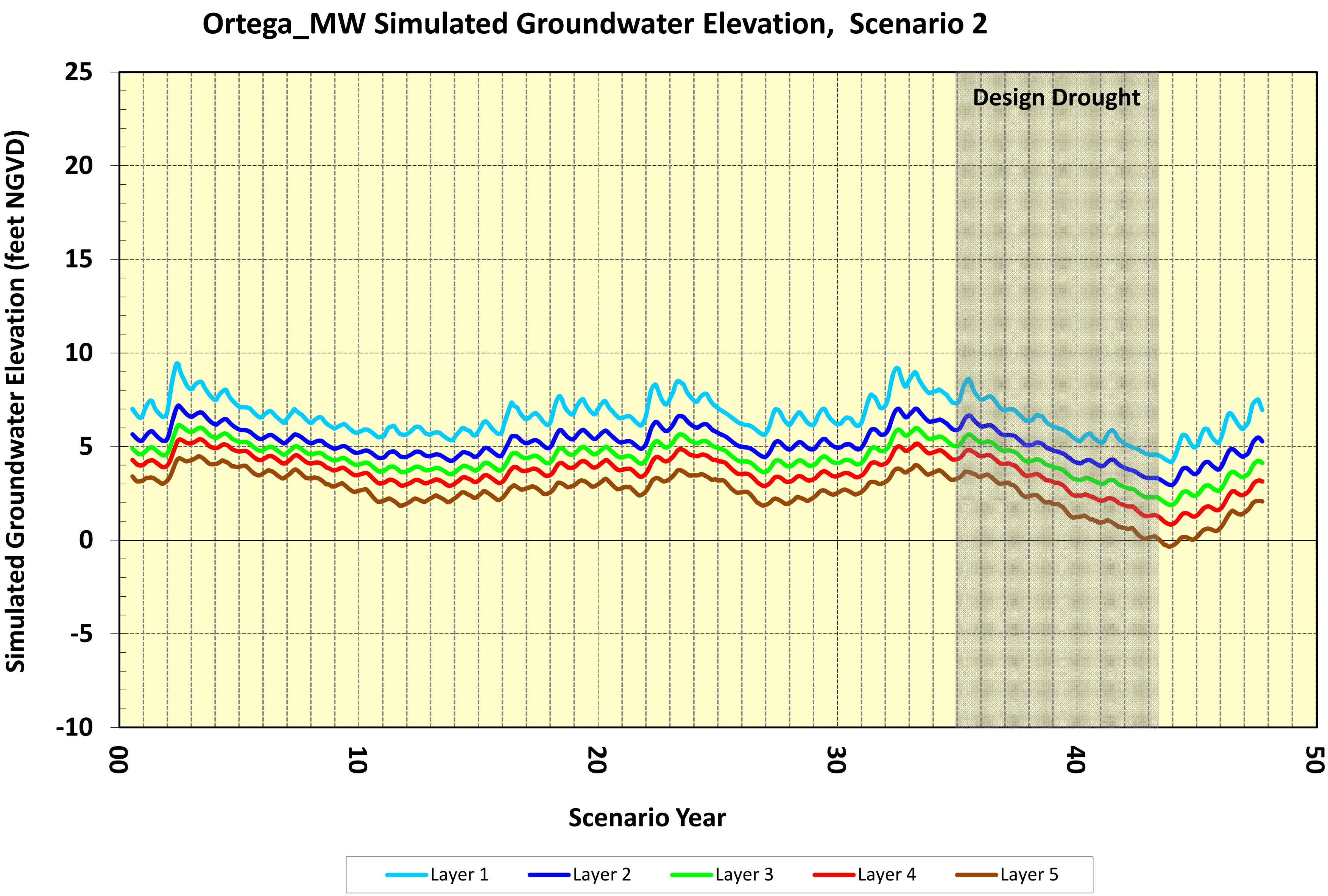

SSF-02 Simulated Groundwater Elevation, Scenario 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



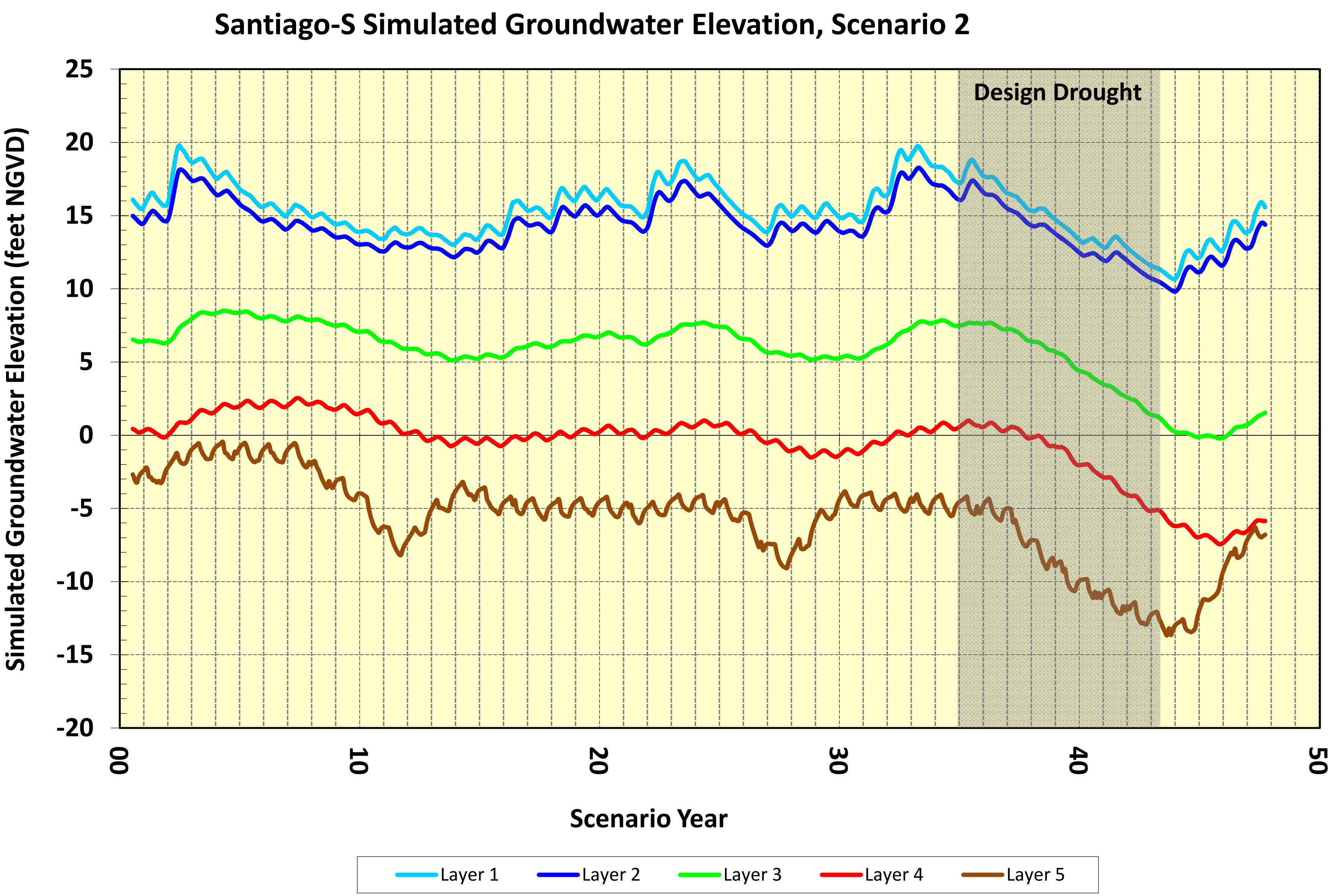
Note: At the location of SB-12, the model does not contain Model Layer 5.

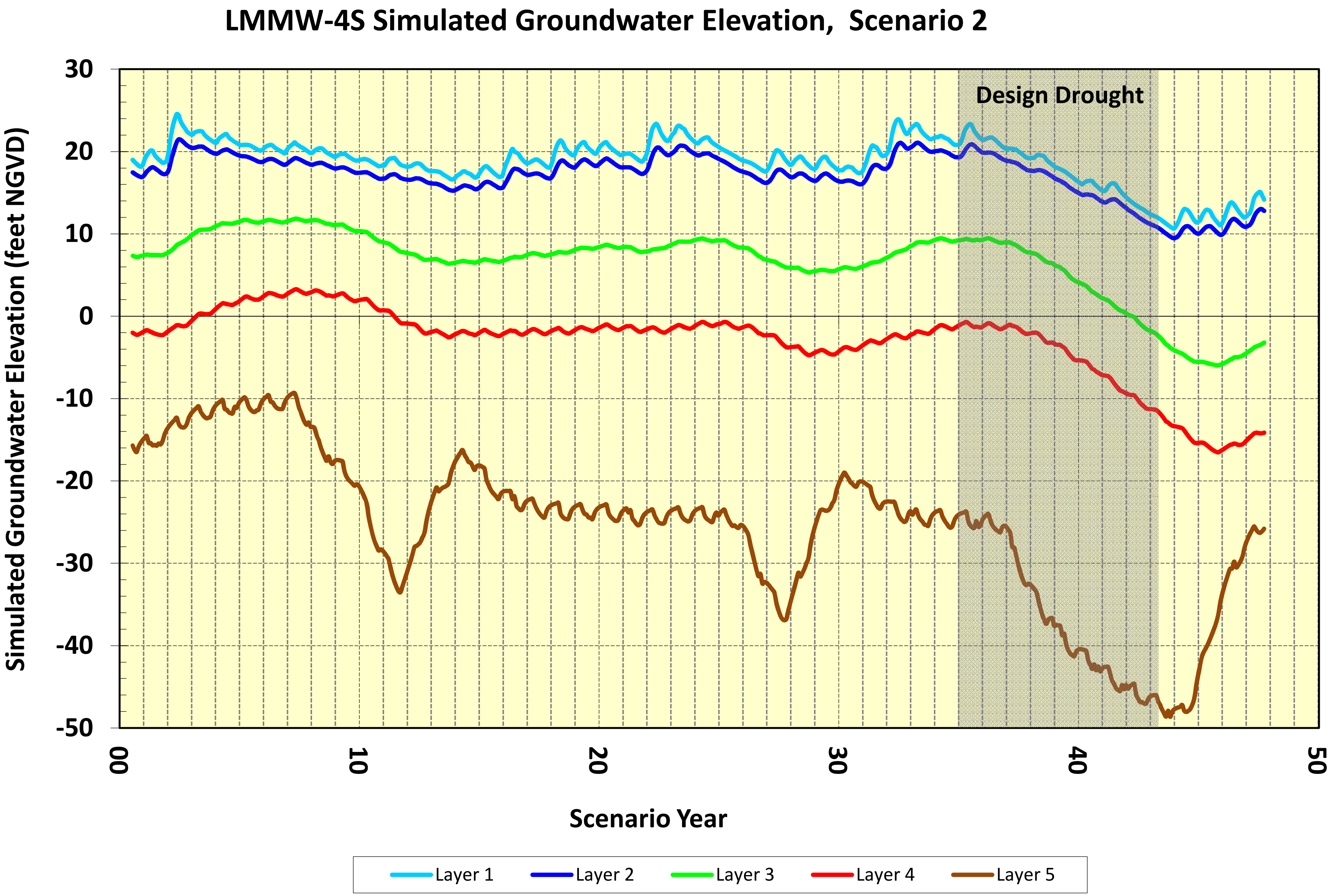


Note: At the location of SWM-GS-M, the model does not contain Model Layer 5.

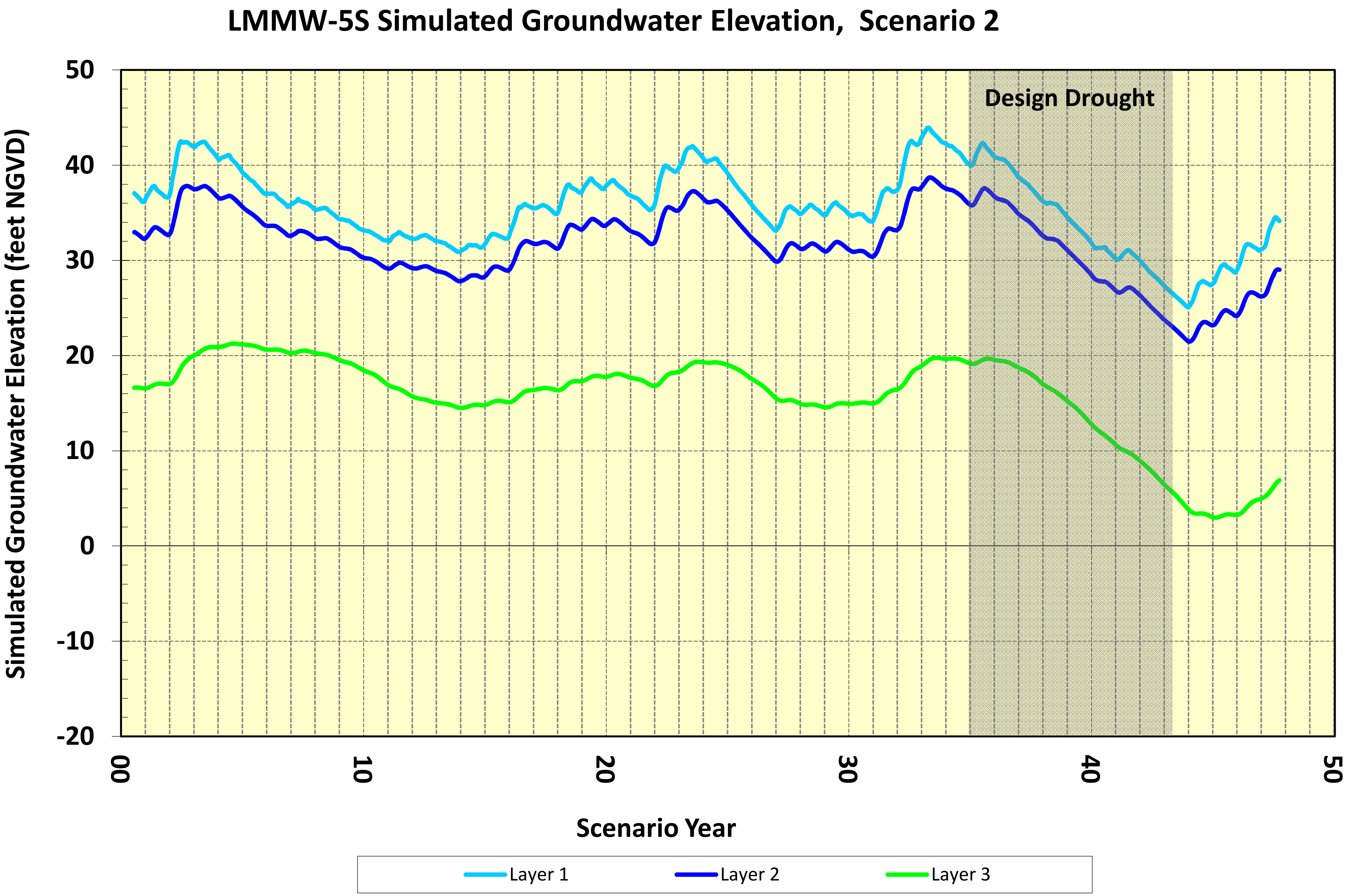


Ortega_MW Simulated Groundwater Elevation, Scenario 2
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

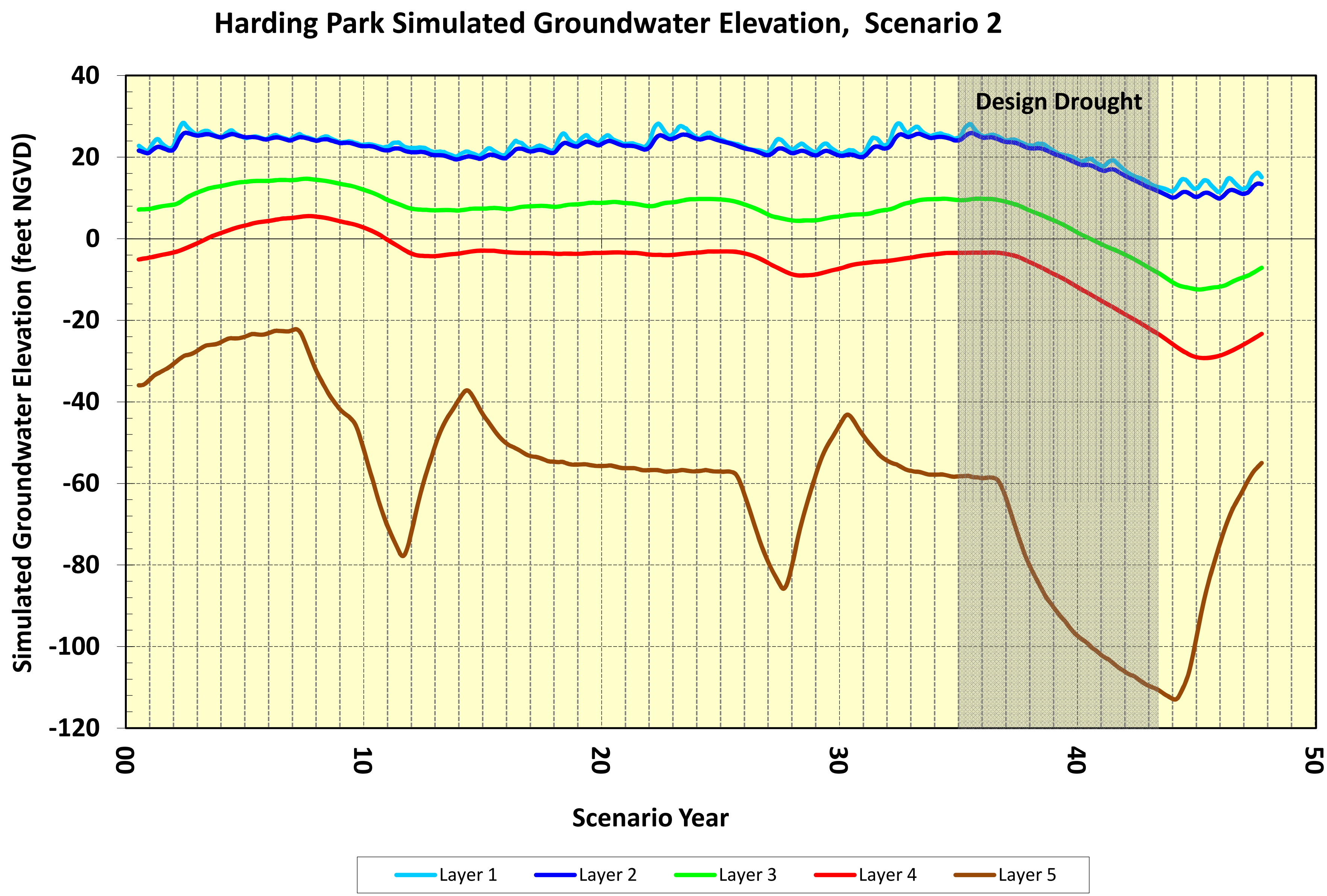

Santiago-S Simulated Groundwater Elevation, Scenario 2
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
-15
-20
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

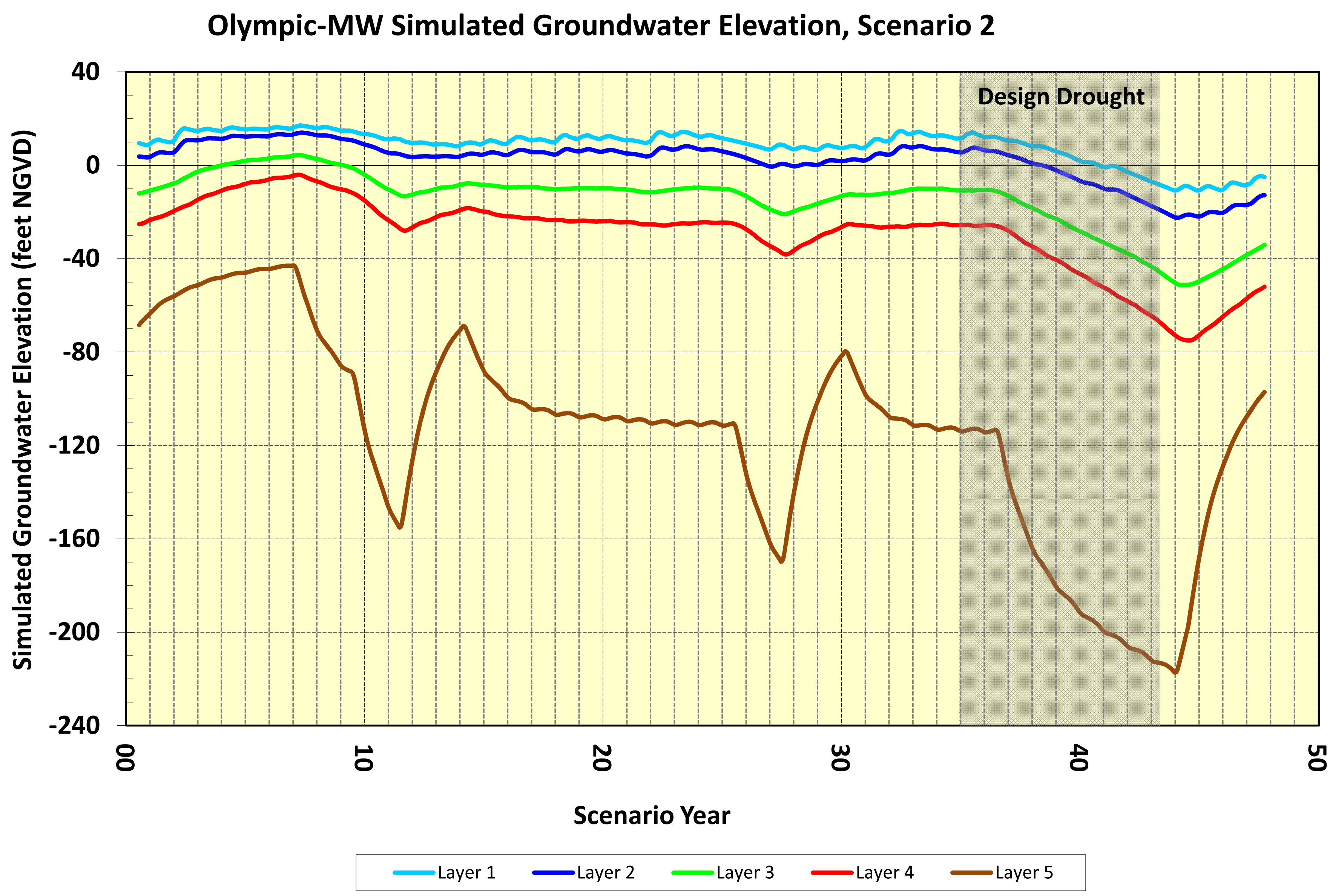


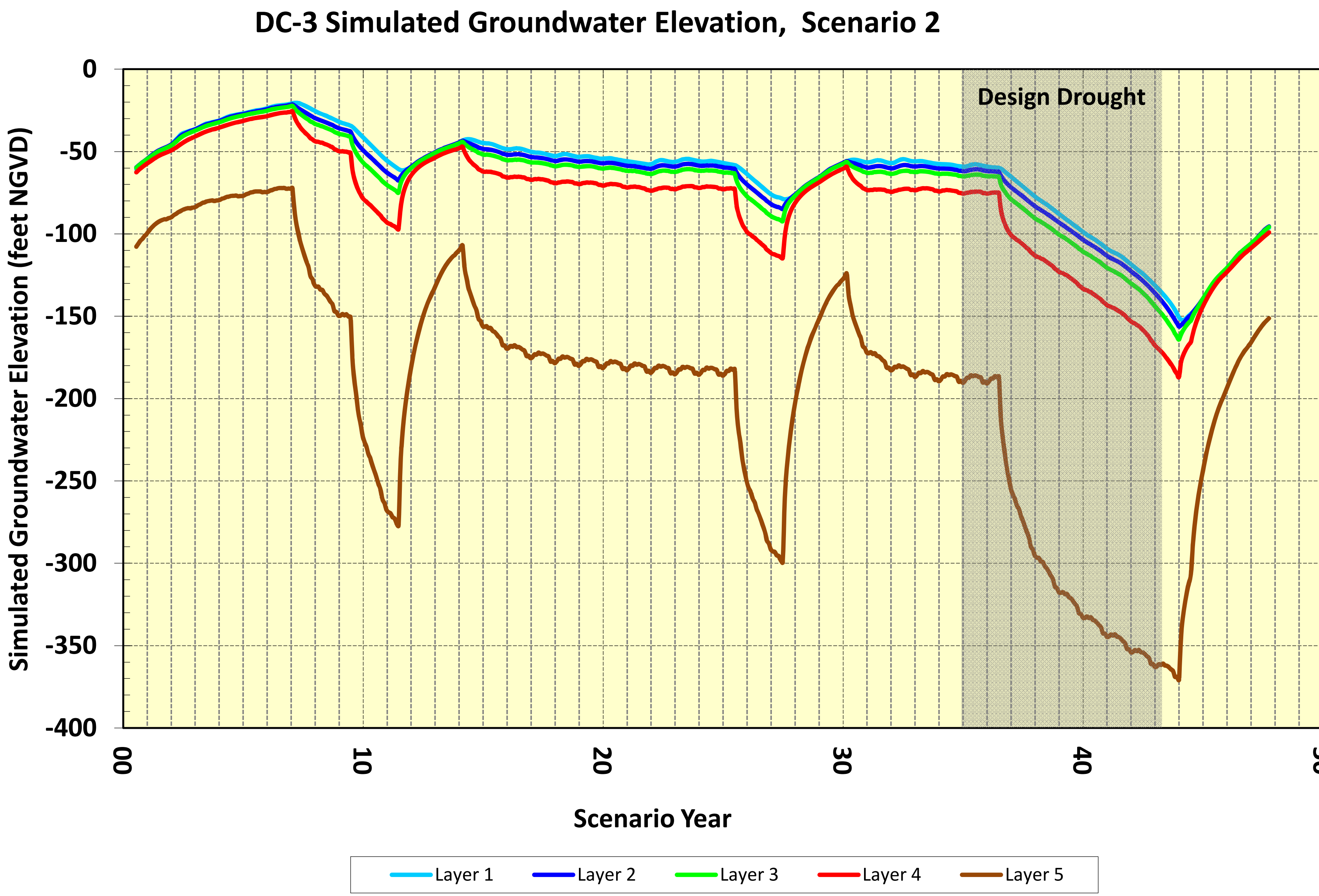
LMMW-4S Simulated Groundwater Elevation, Scenario 2
Design Drought
Simulated Groundwater Elevation (feet NGVD)
30
20
10
0
-10
-20
-30
-40
-50
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



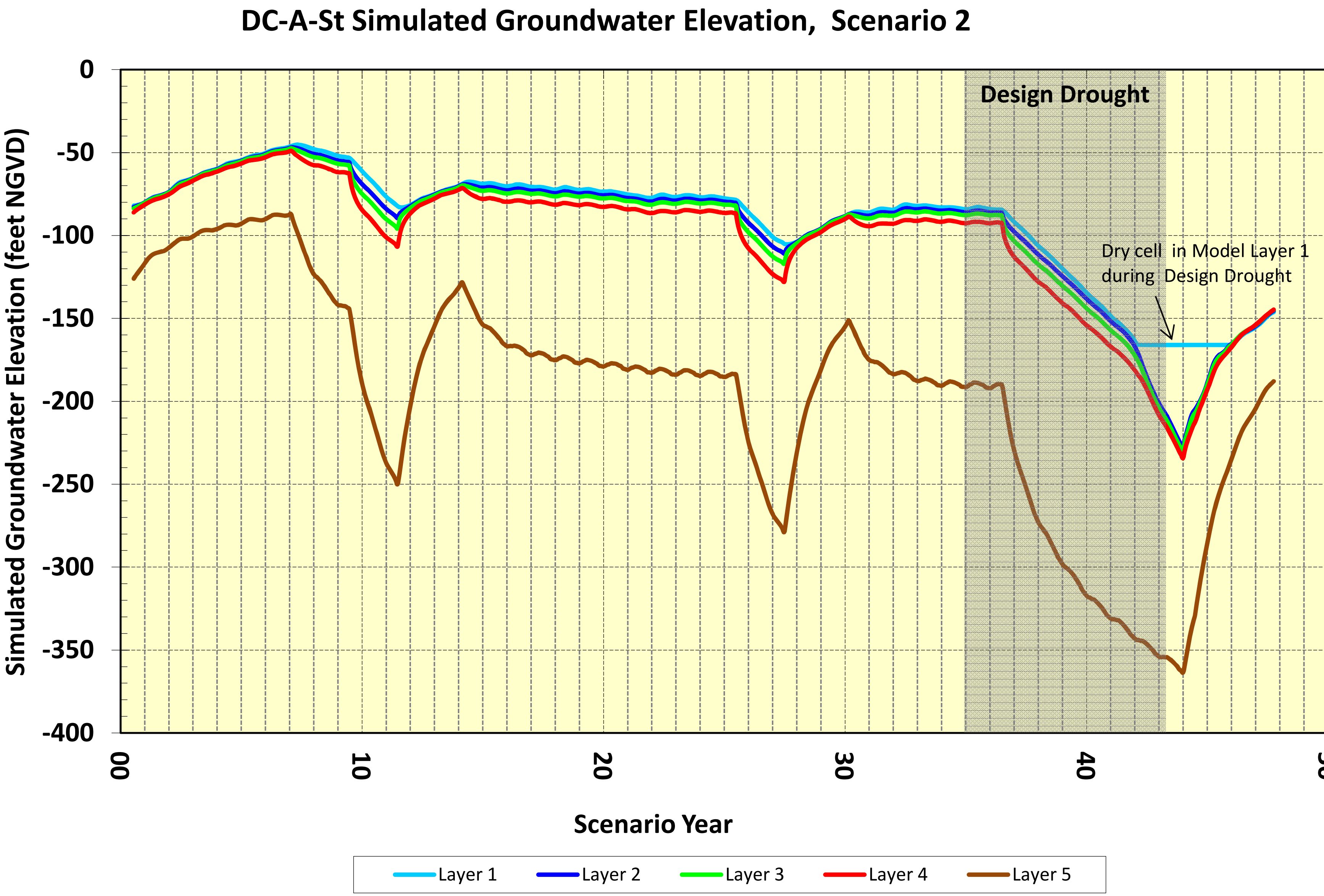
Note: At the location of LMMW-5S, the model does not contain Model Layers 4 and 5.


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

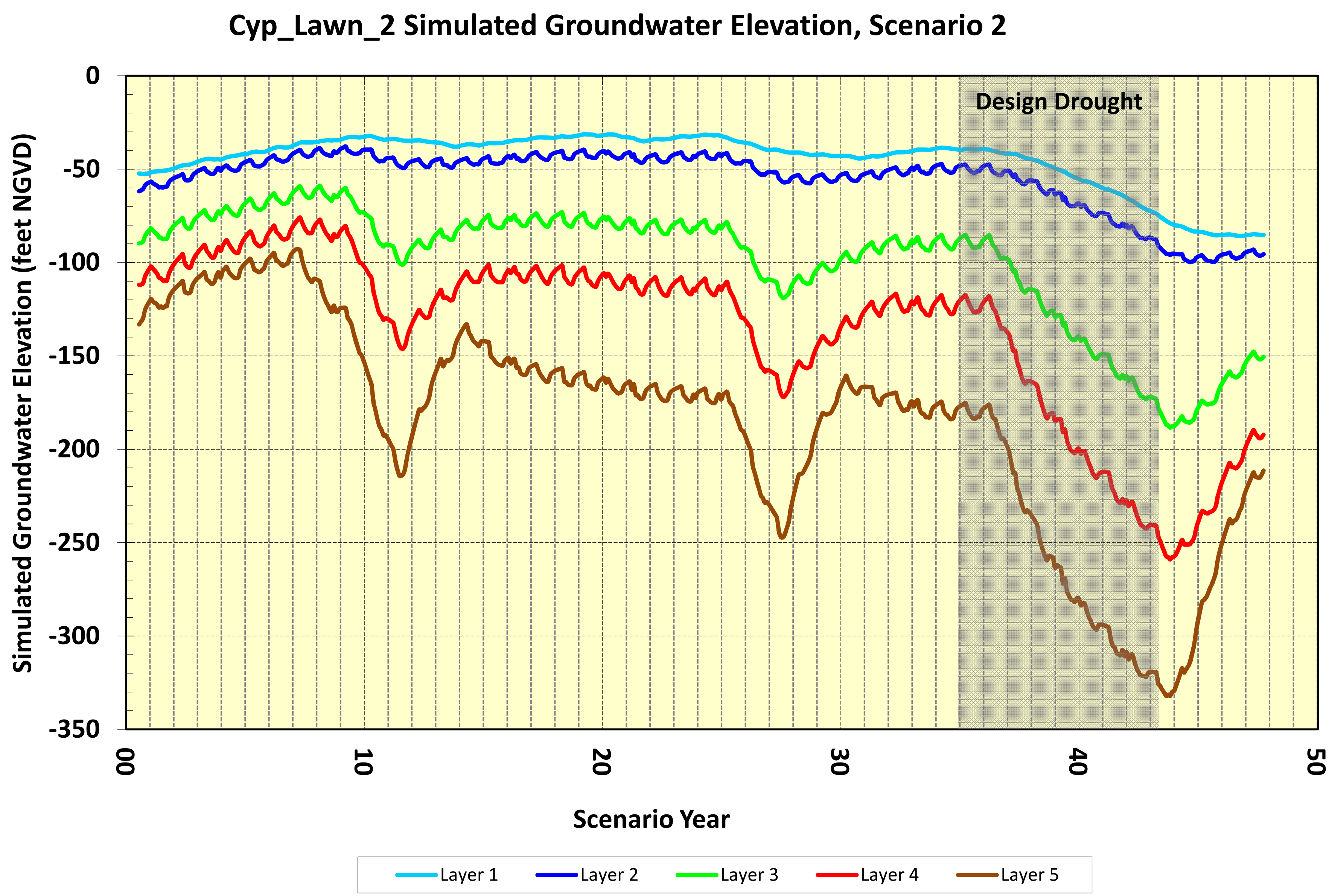

Olympic-MW Simulated Groundwater Elevation, Scenario 2
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
0
-40
-80
-120
-160
-200
-240
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

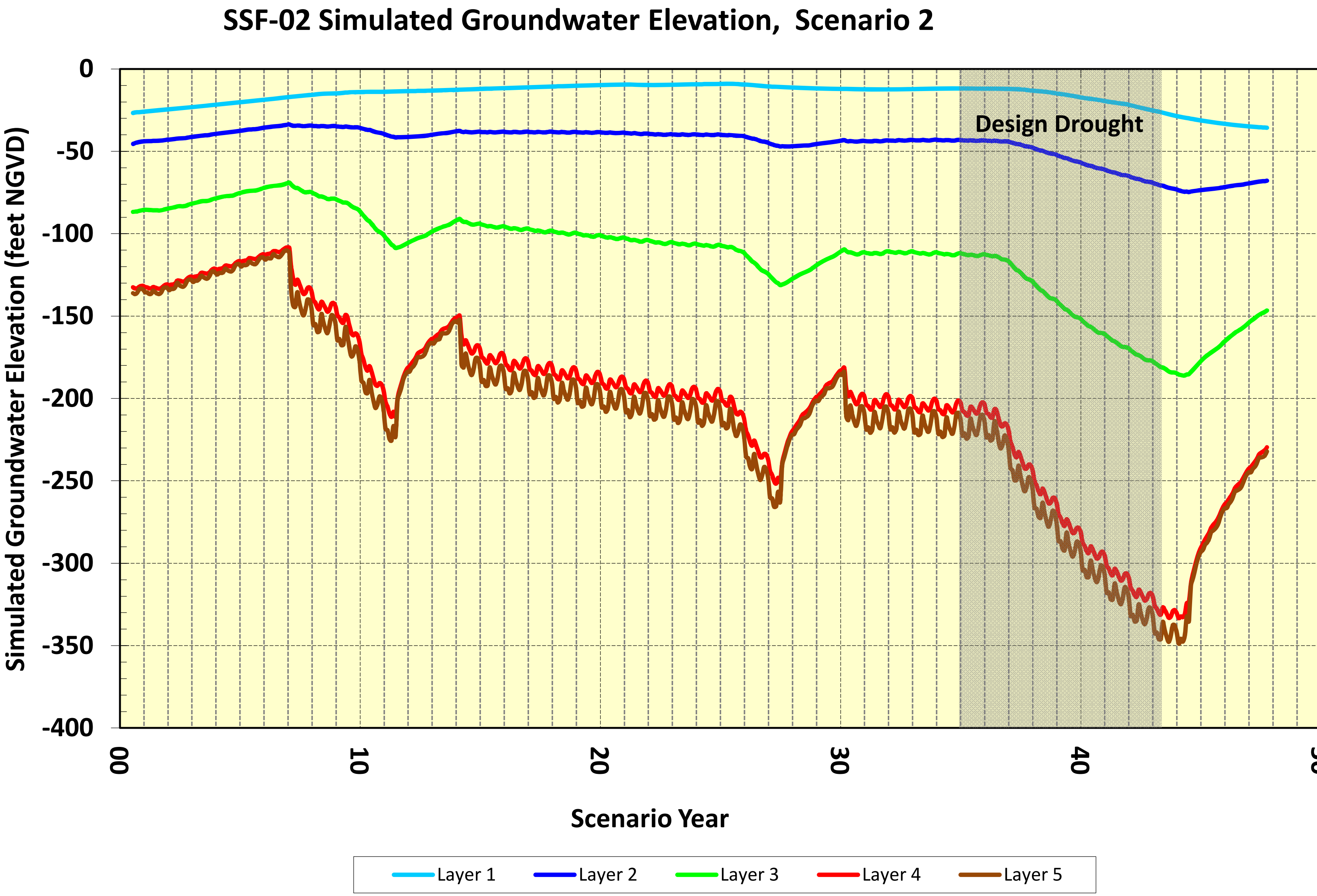


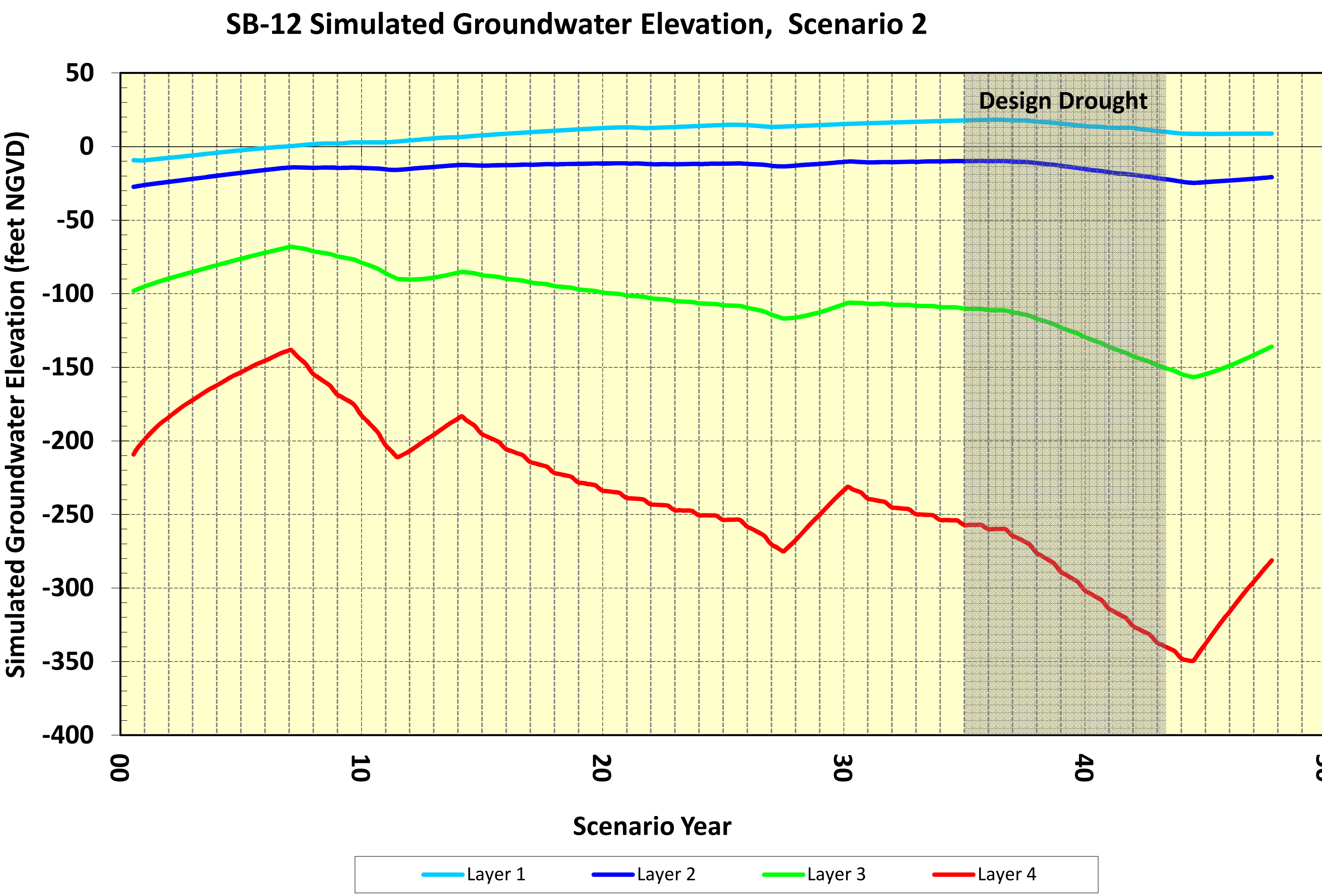
DC-3 Simulated Groundwater Elevation, Scenario 2
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



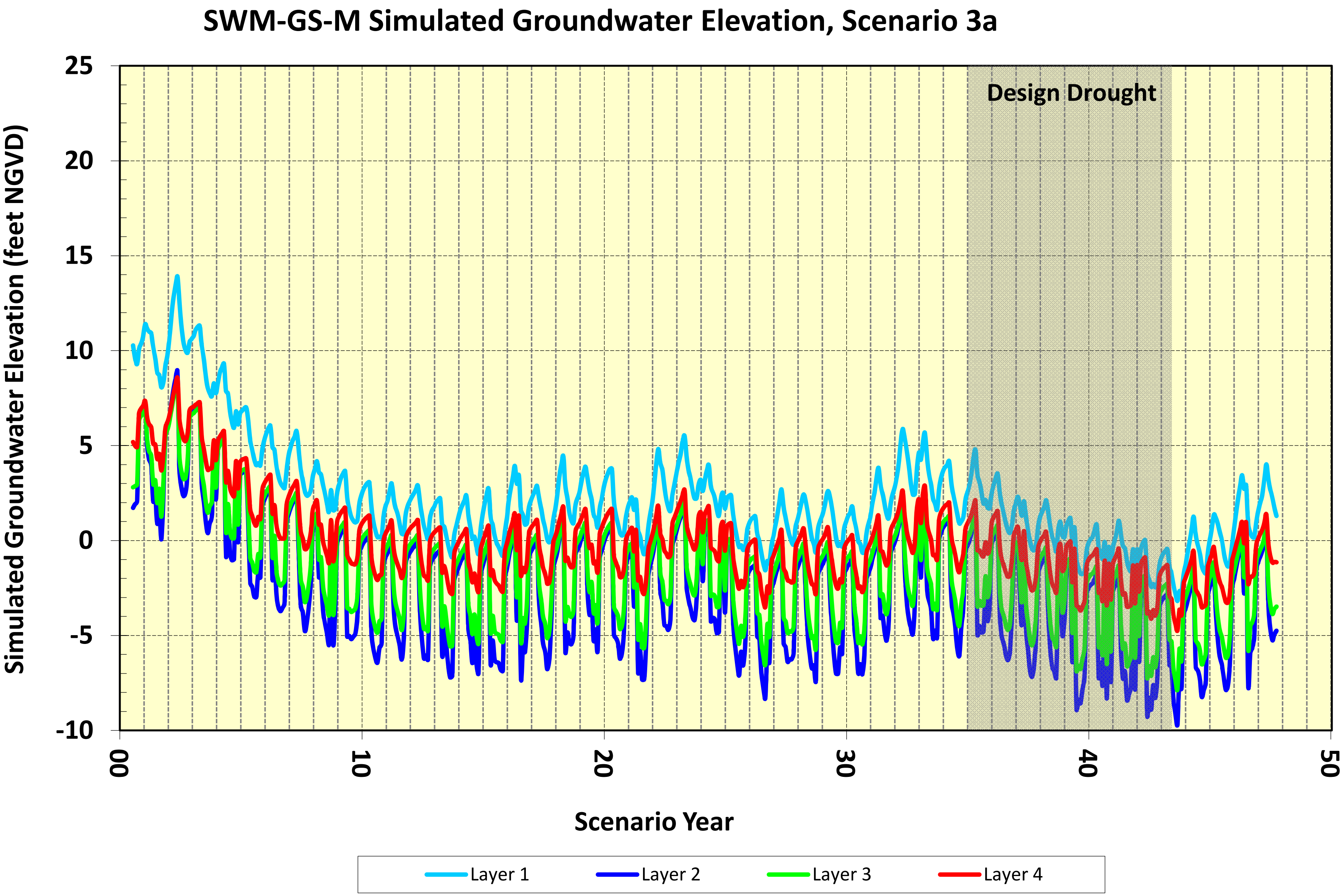
DC-A-St Simulated Groundwater Elevation, Scenario 2
Design Drought
Dry cell in Model Layer 1
during Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


Cyp_Lawn_2 Simulated Groundwater Elevation, Scenario 2
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

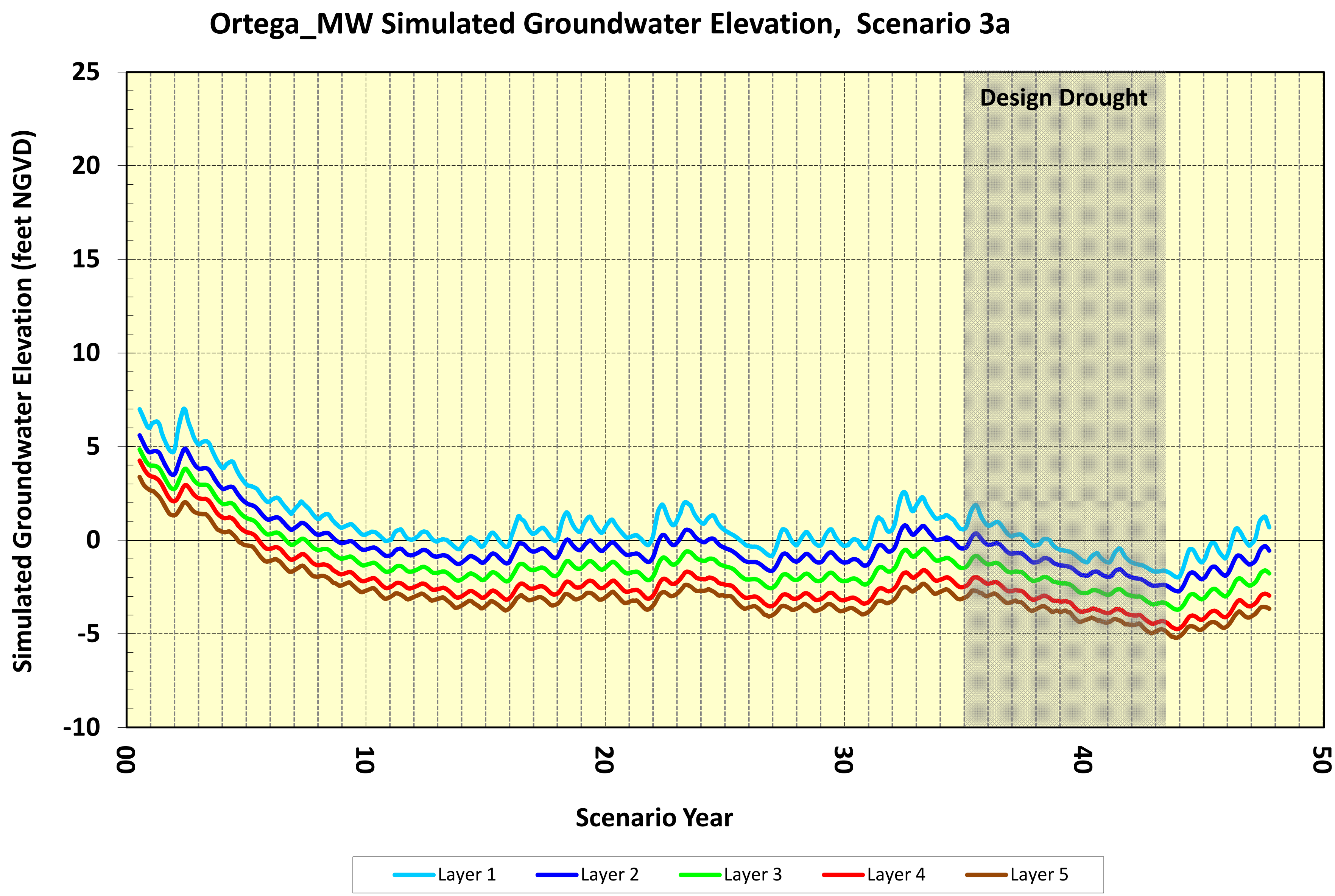

SSF-02 Simulated Groundwater Elevation, Scenario 2
Simulated Groundwater Elevation (feet NGVD)
Scenario Year
Design Drought
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



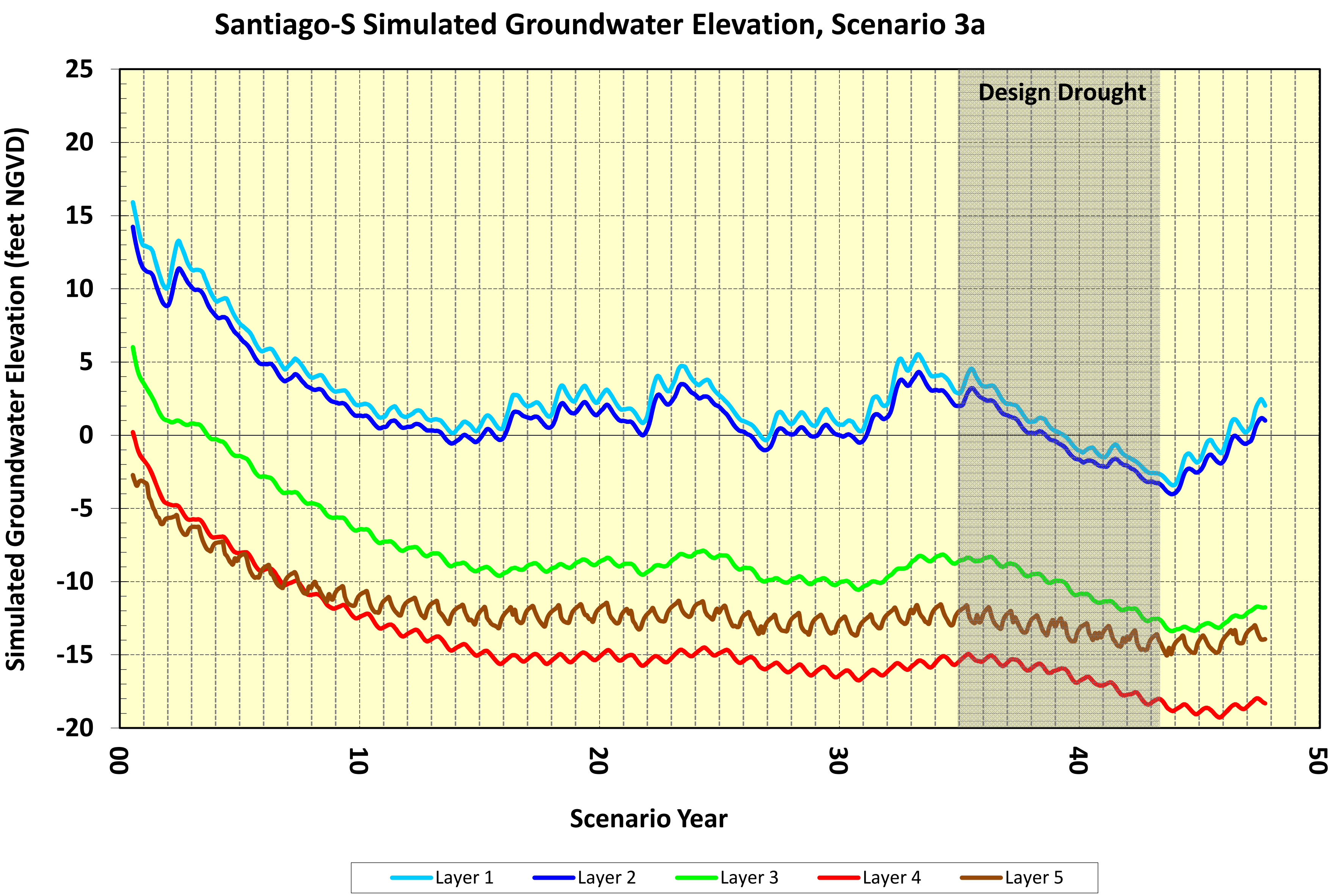
Note: At the location of SB-12, the model does not contain Model Layer 5.

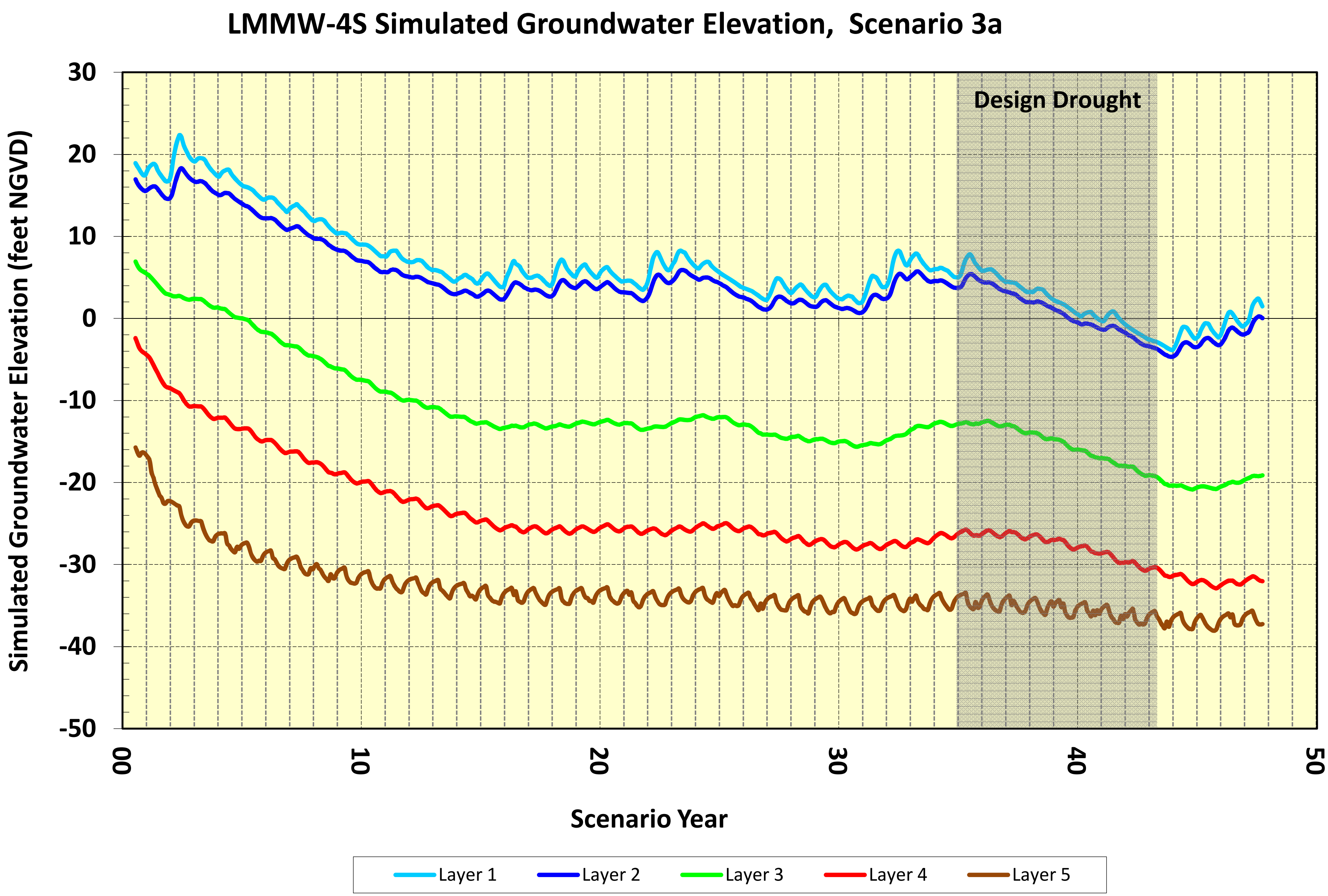


Note: At the location of SWM-GS-M, the model does not contain Model Layer 5.

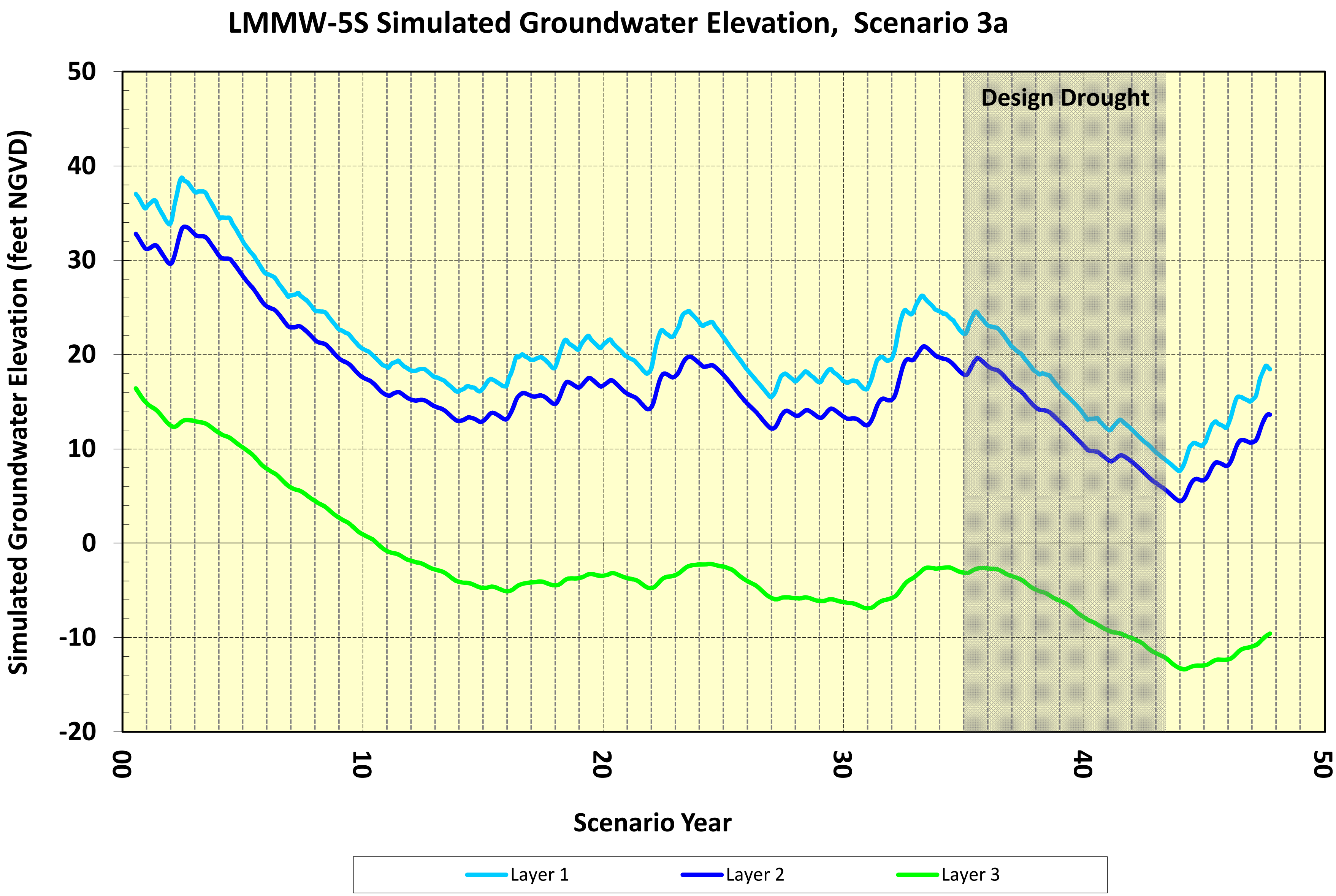


Ortega_MW Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

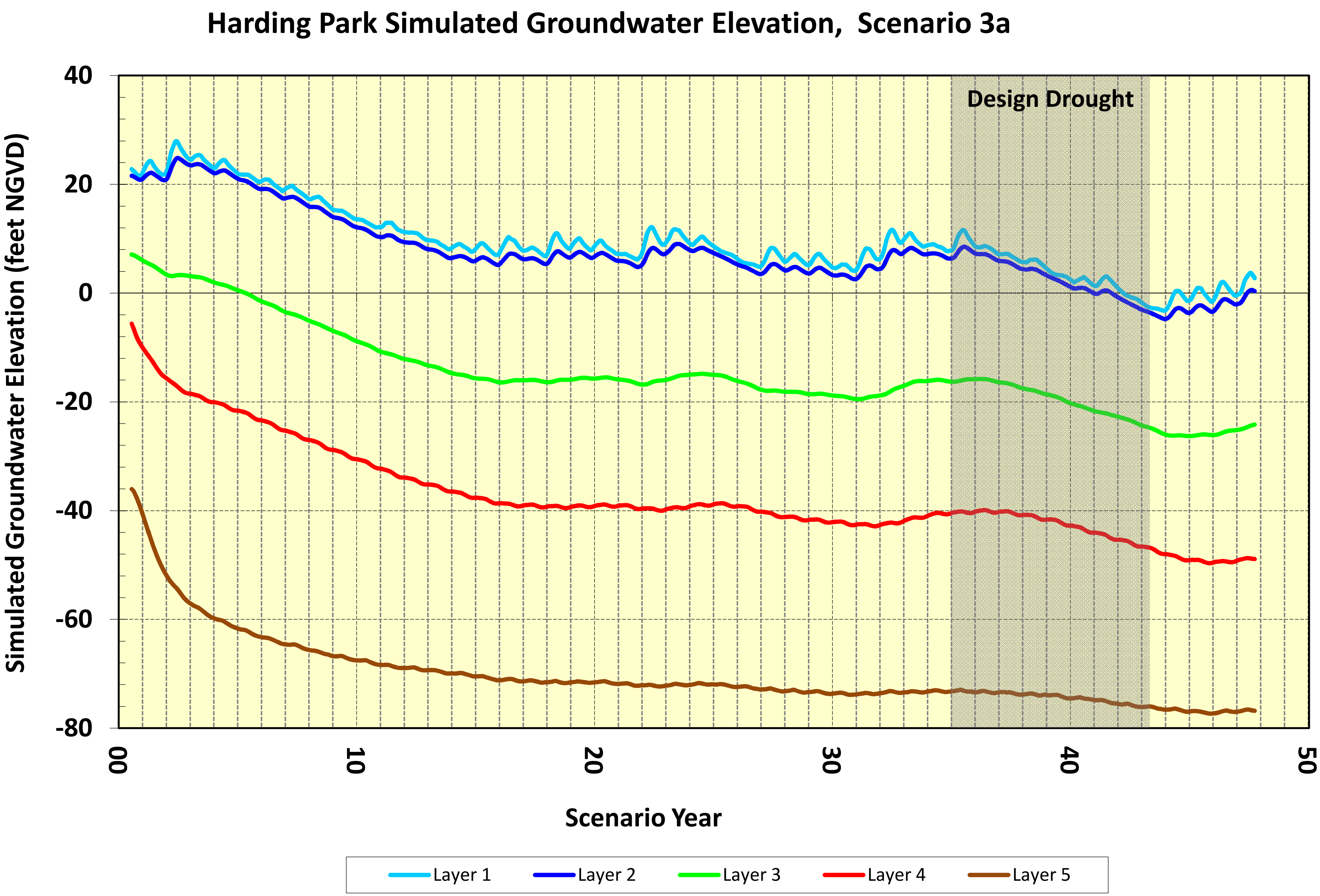

Santiago-S Simulated Groundwater Elevation, Scenario 3a
Design Drought
25
20
15
10
5
0
-5
-10
-15
-20
Simulated Groundwater Elevation (feet NGVD)
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



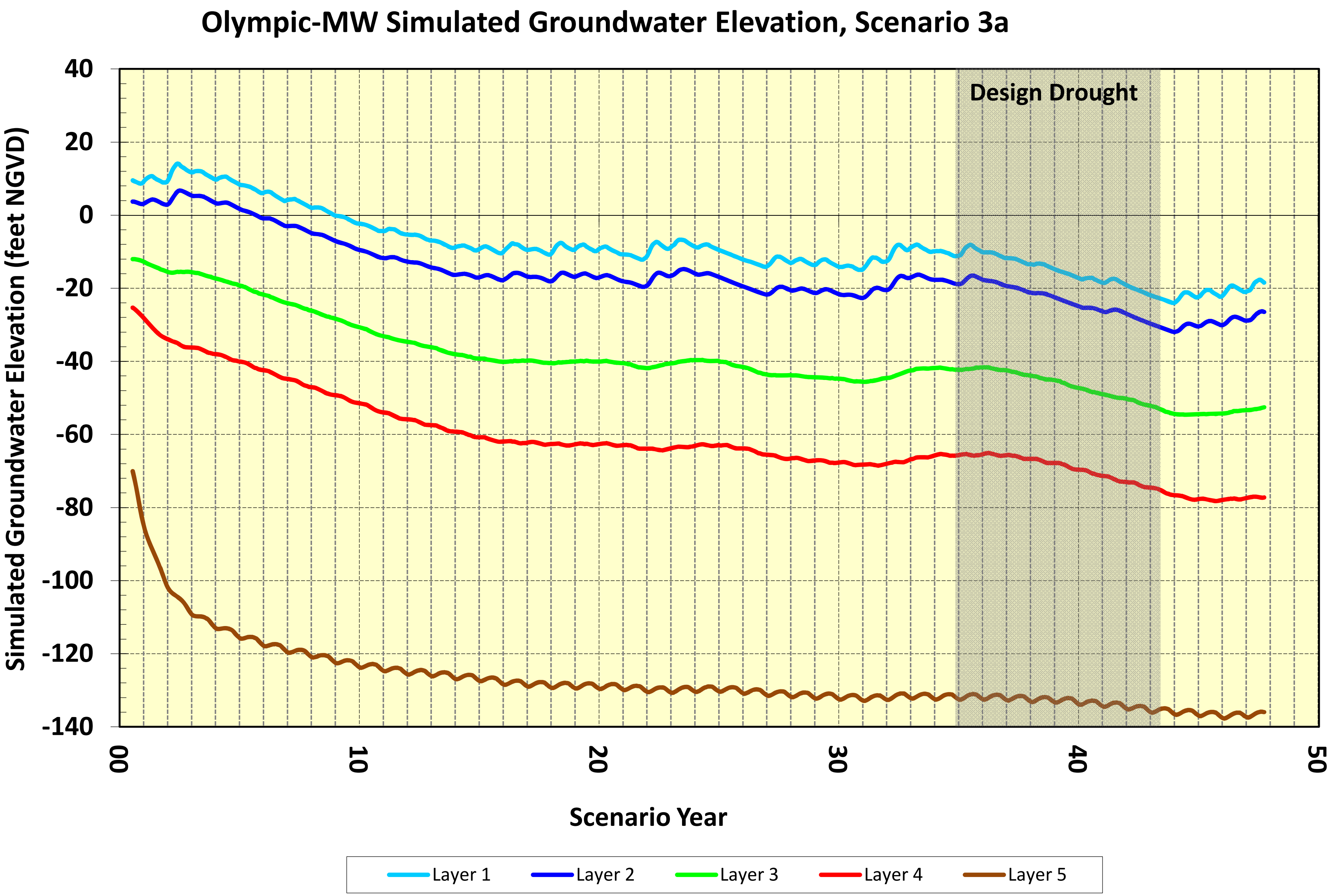
LMMW-4S Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
30
20
10
0
-10
-20
-30
-40
-50
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



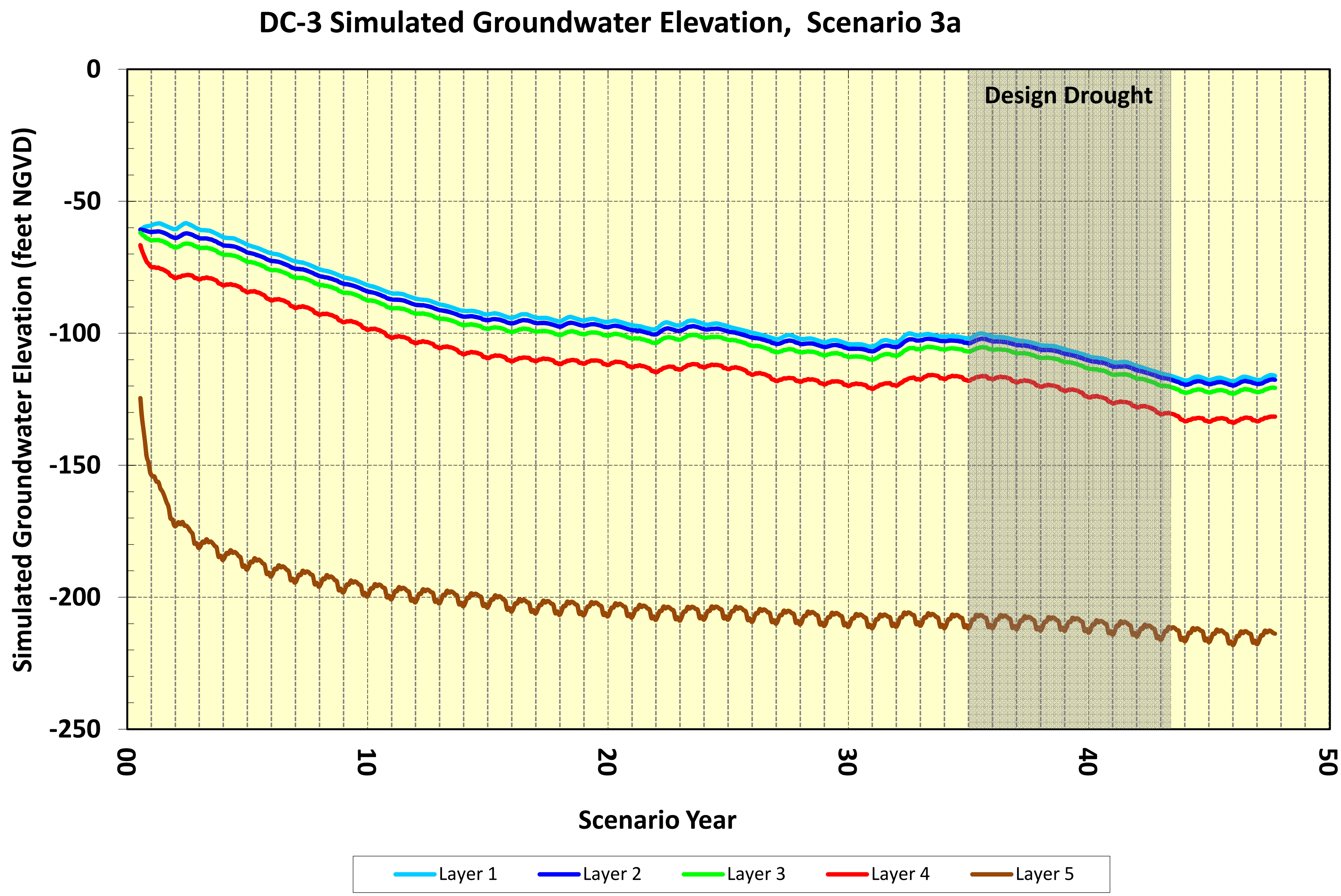
Note: At the location of LMMW-5S, the model does not contain Model Layers 4 and 5.



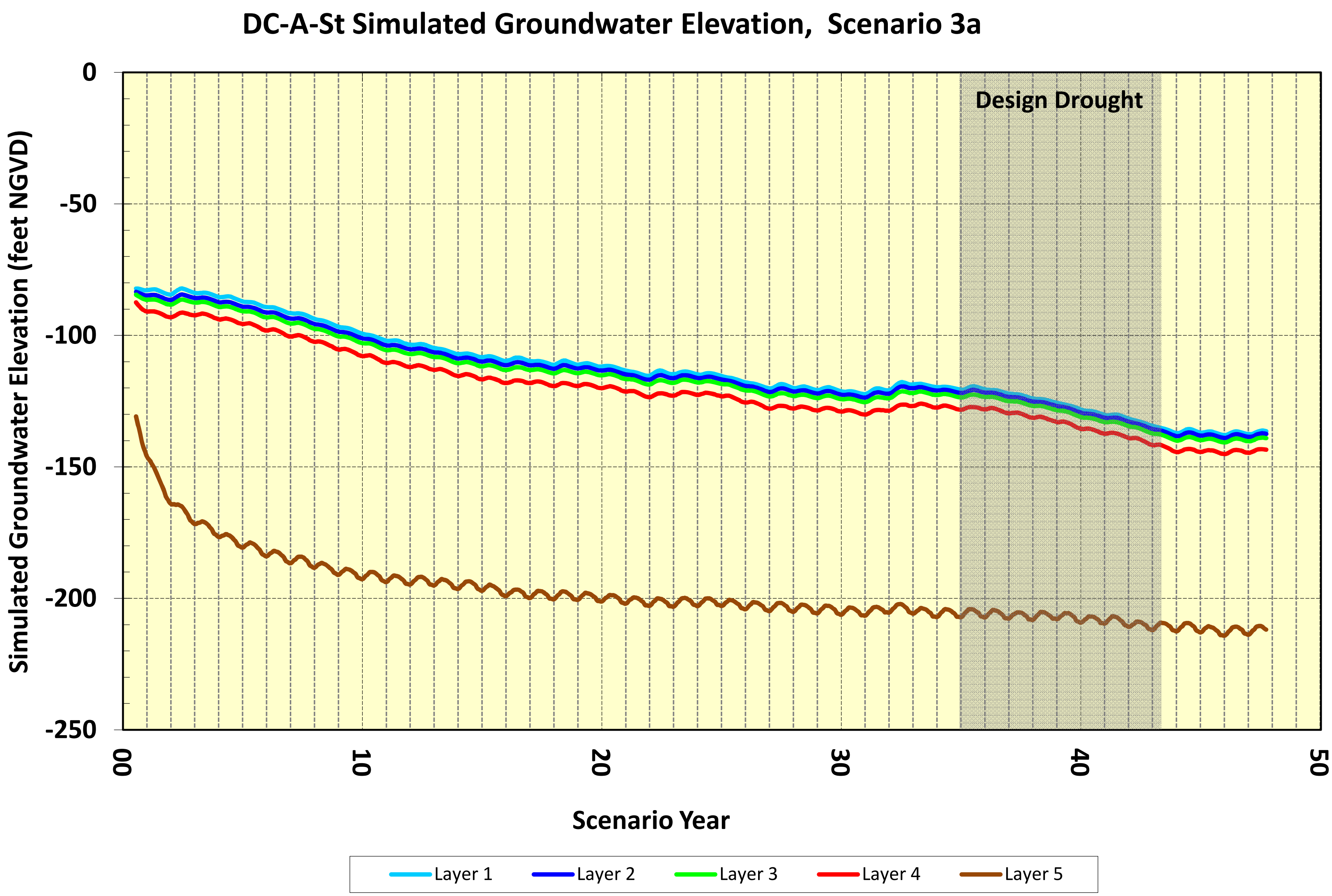
Harding Park Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

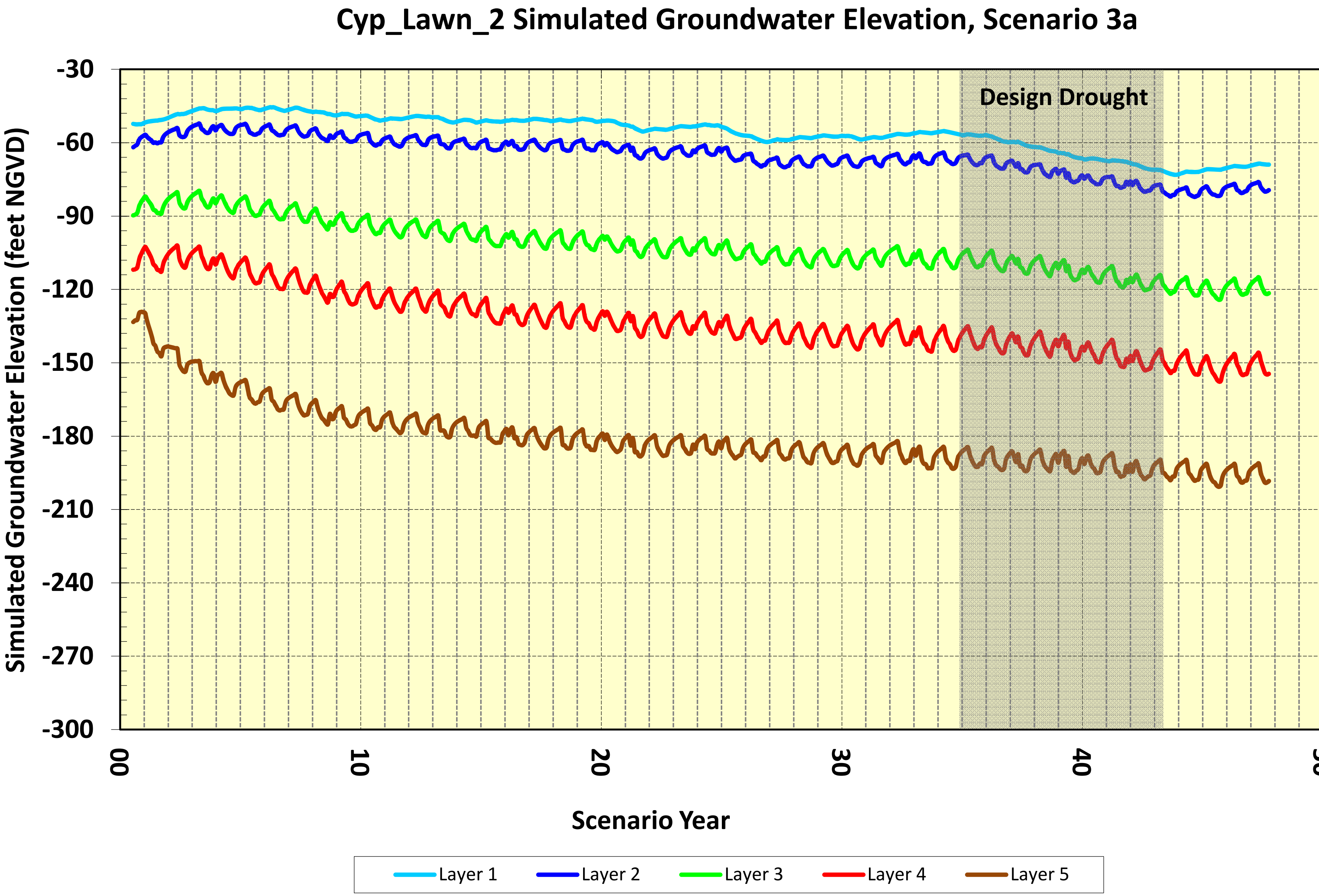


Olympic-MW Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
-100
-120
-140
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

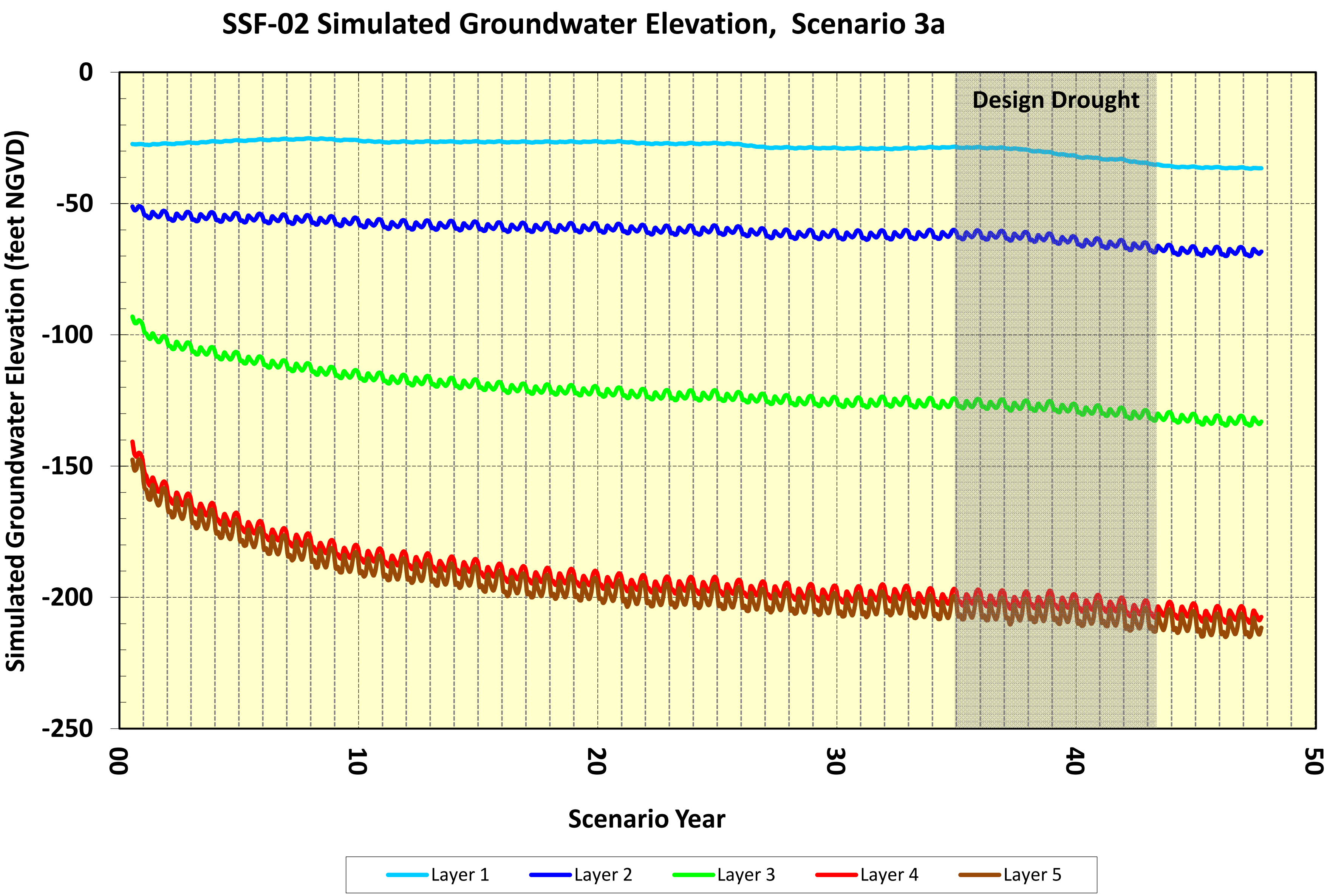


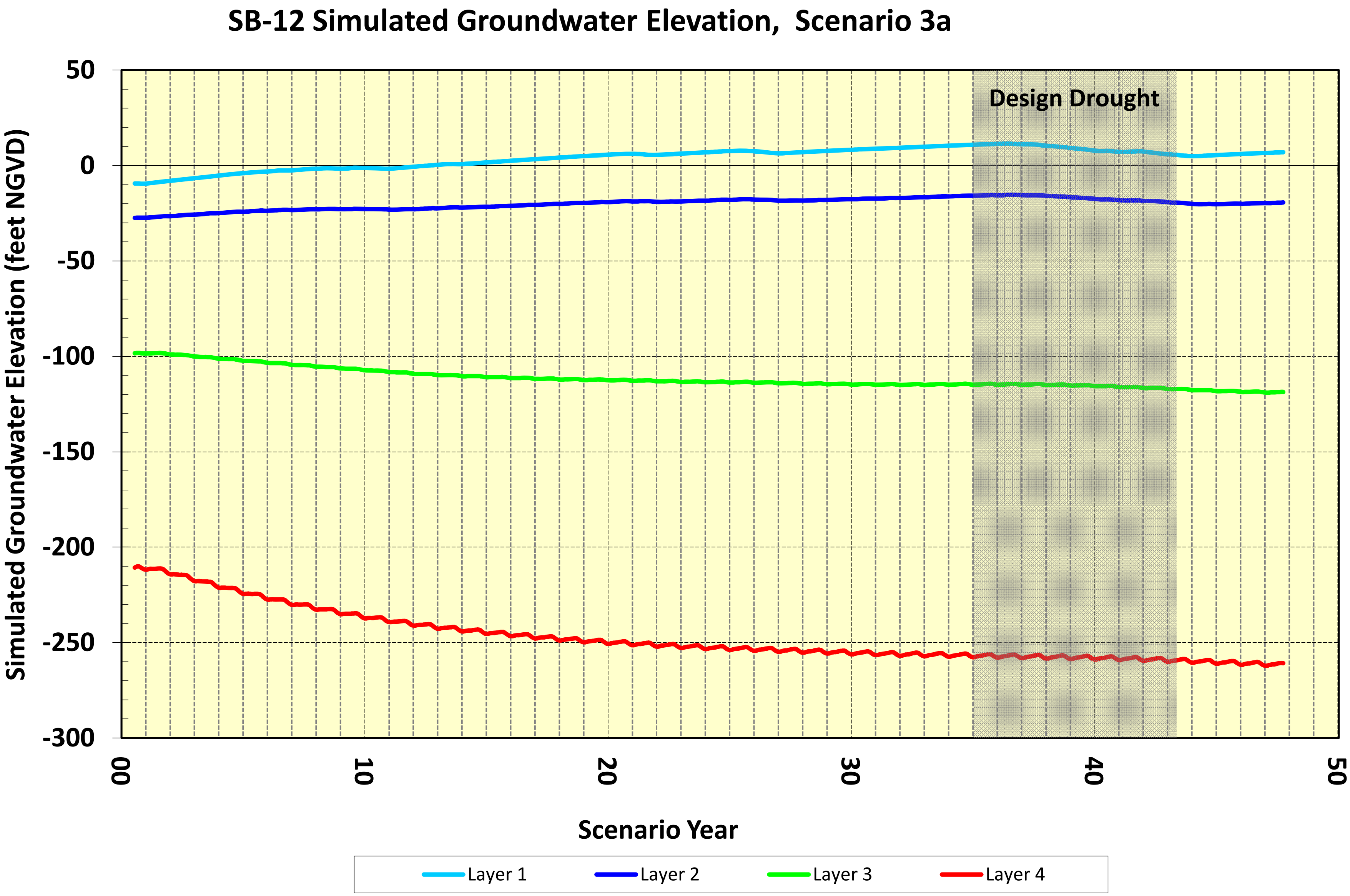
DC-3 Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


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

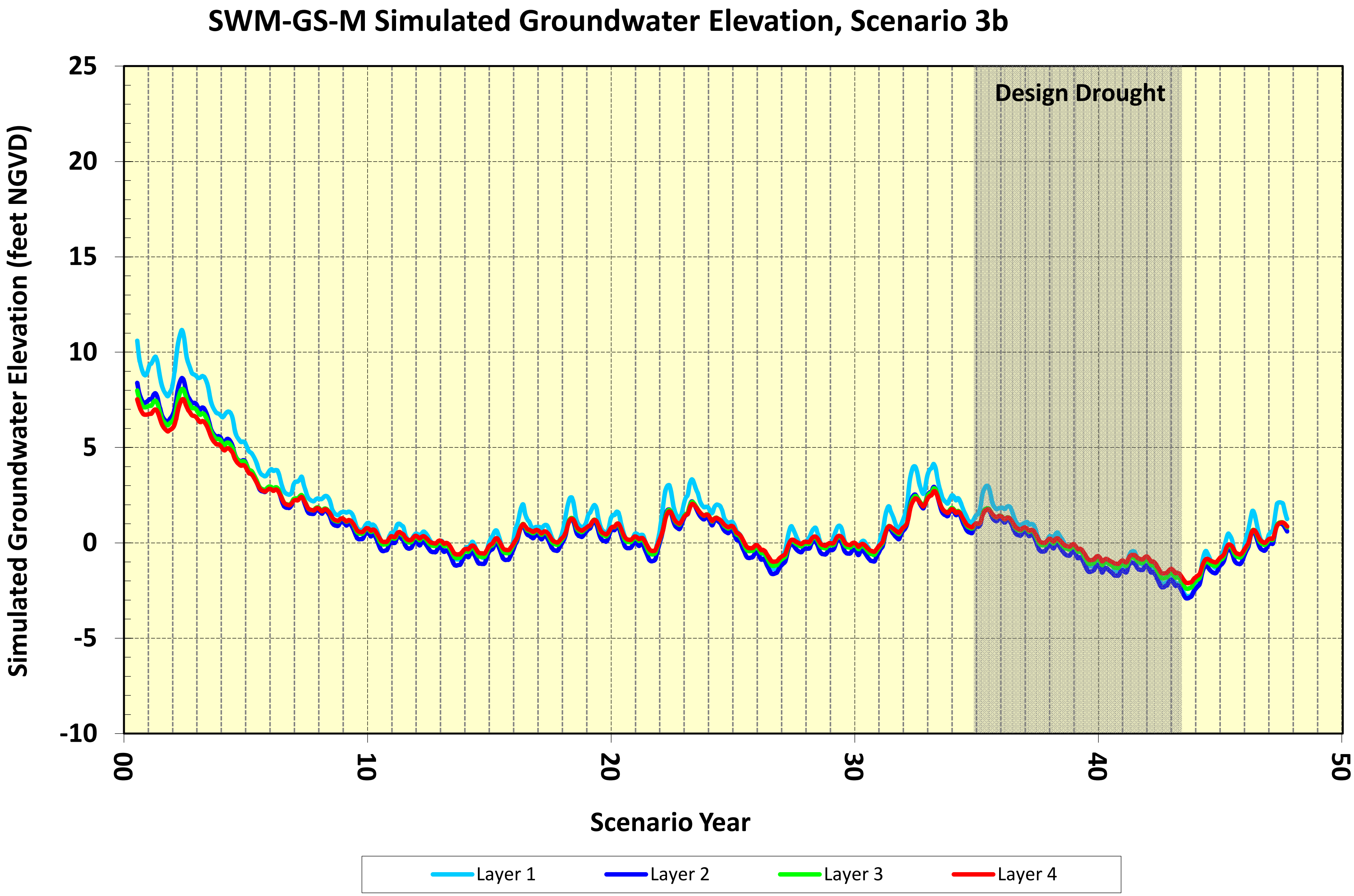


Cyp_Lawn_2 Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
-30
-60
-90
-120
-150
-180
-210
-240
-270
-300
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

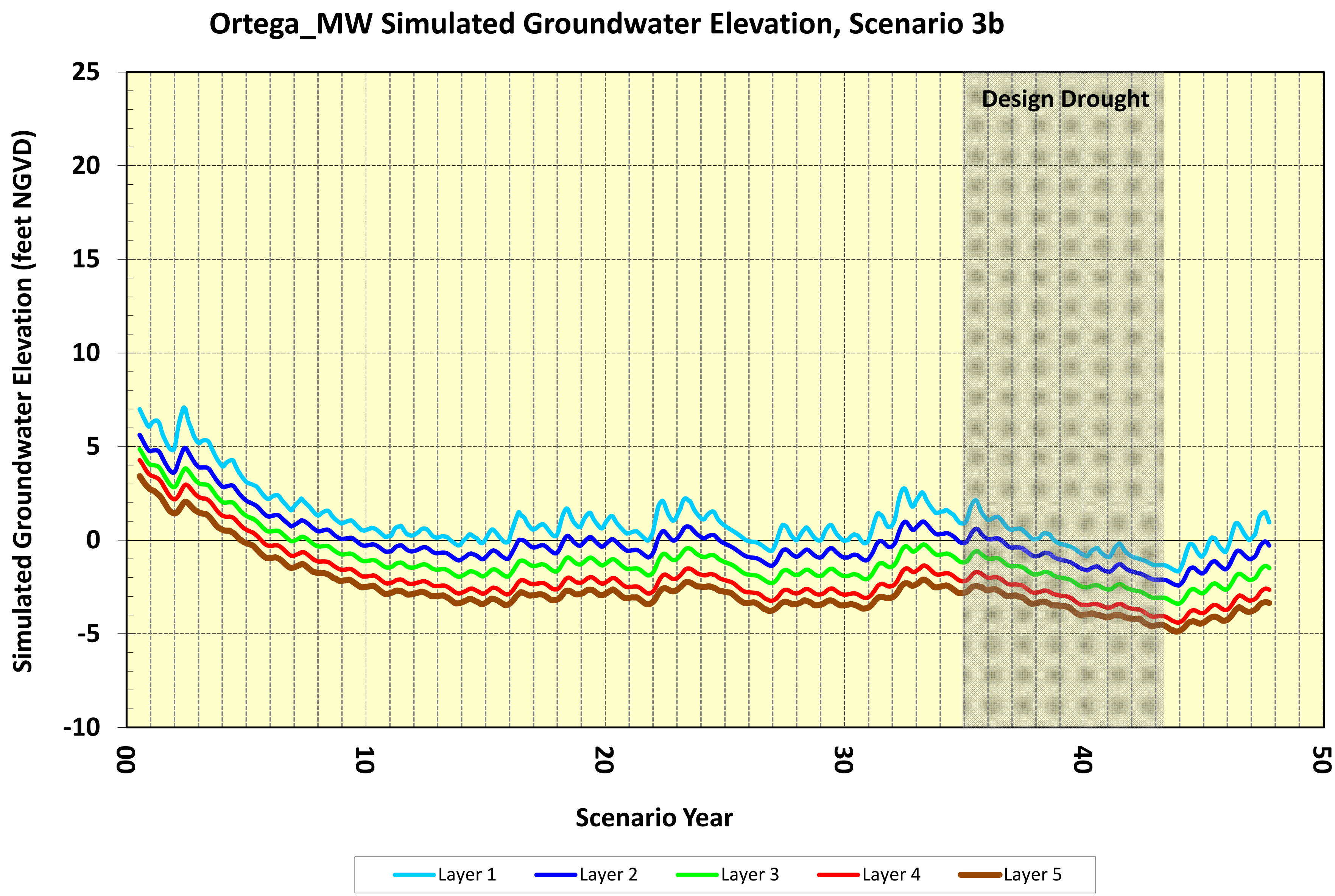

SSF-02 Simulated Groundwater Elevation, Scenario 3a
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



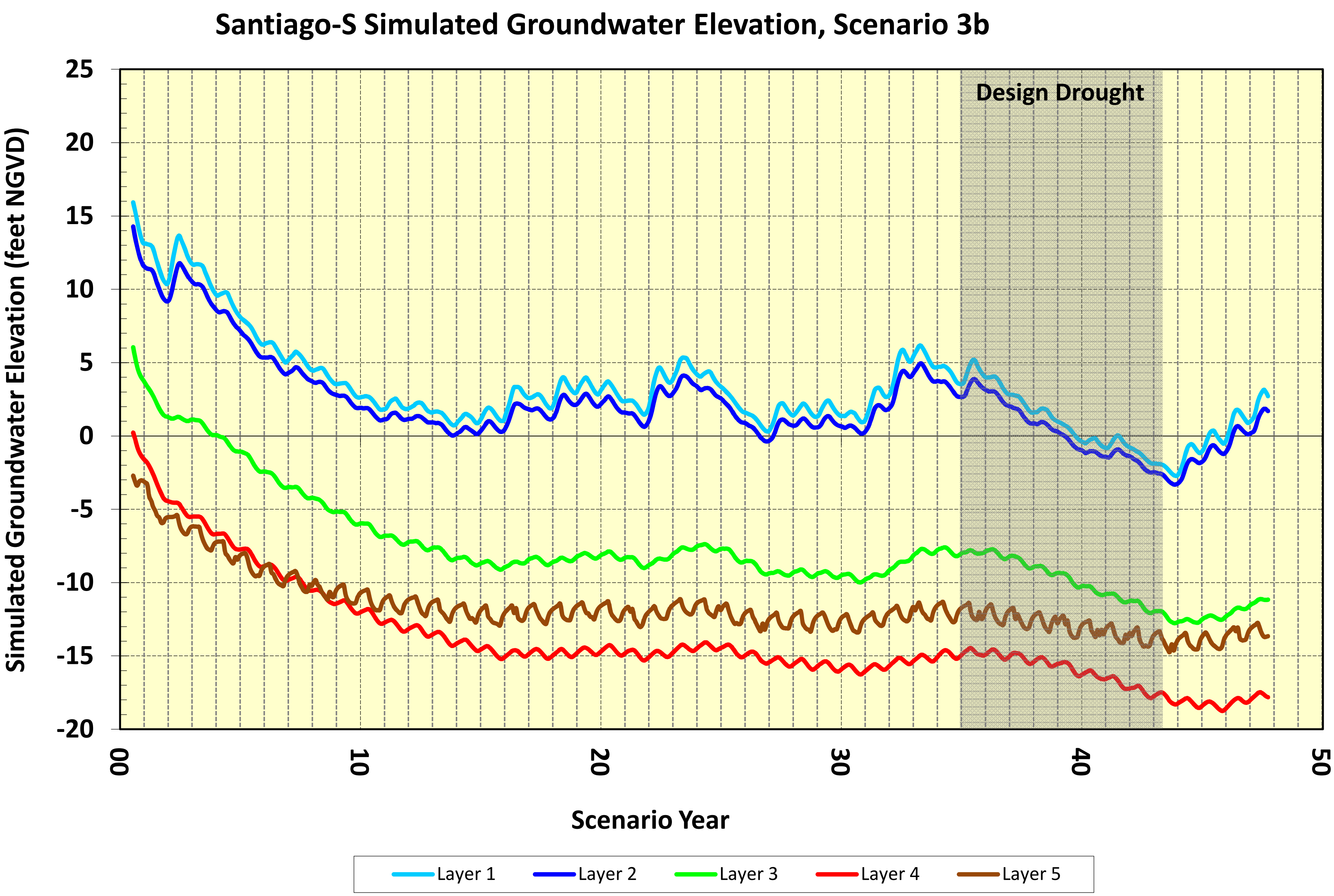
Note: At the location of SB-12, the model does not contain Model Layer 5.

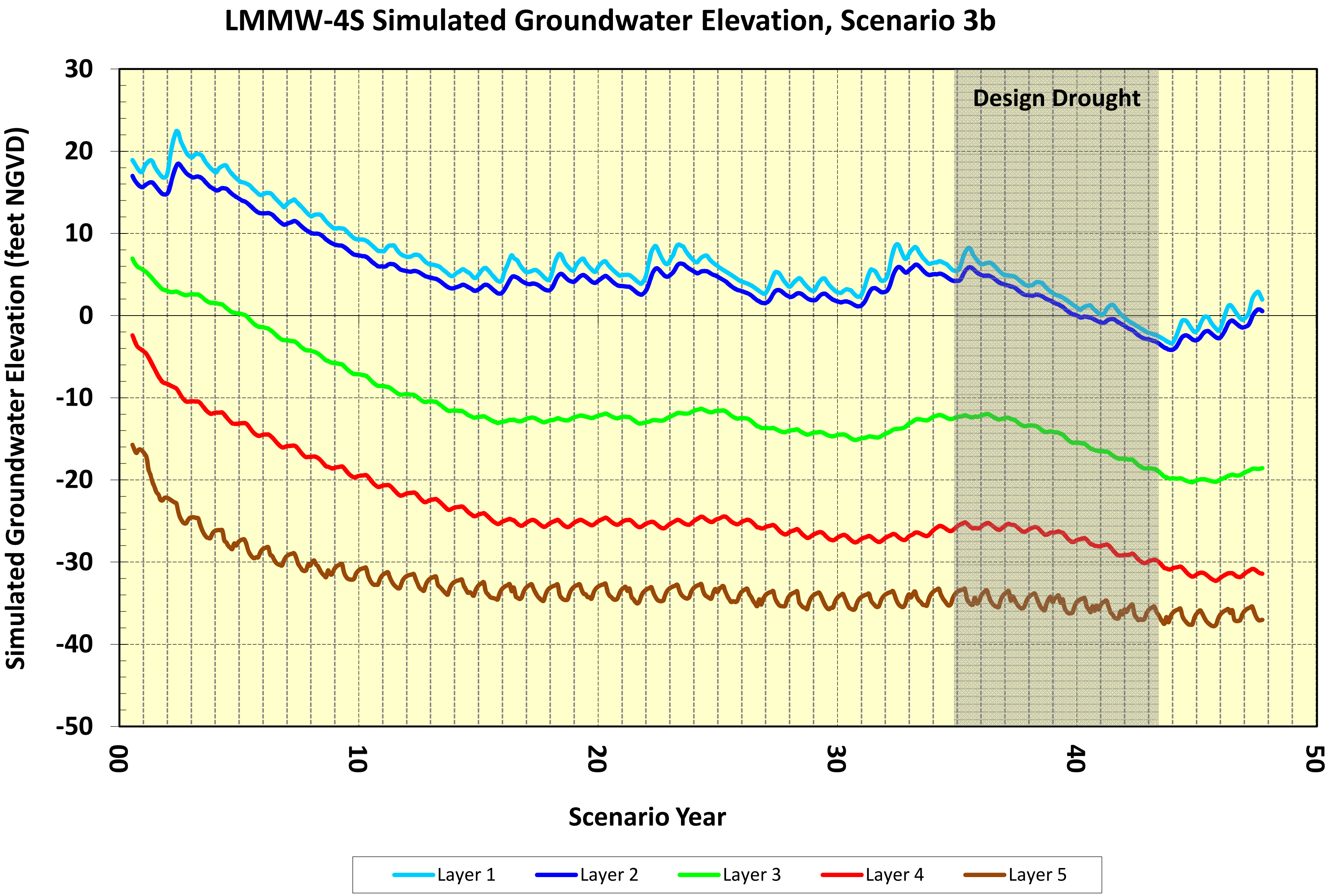


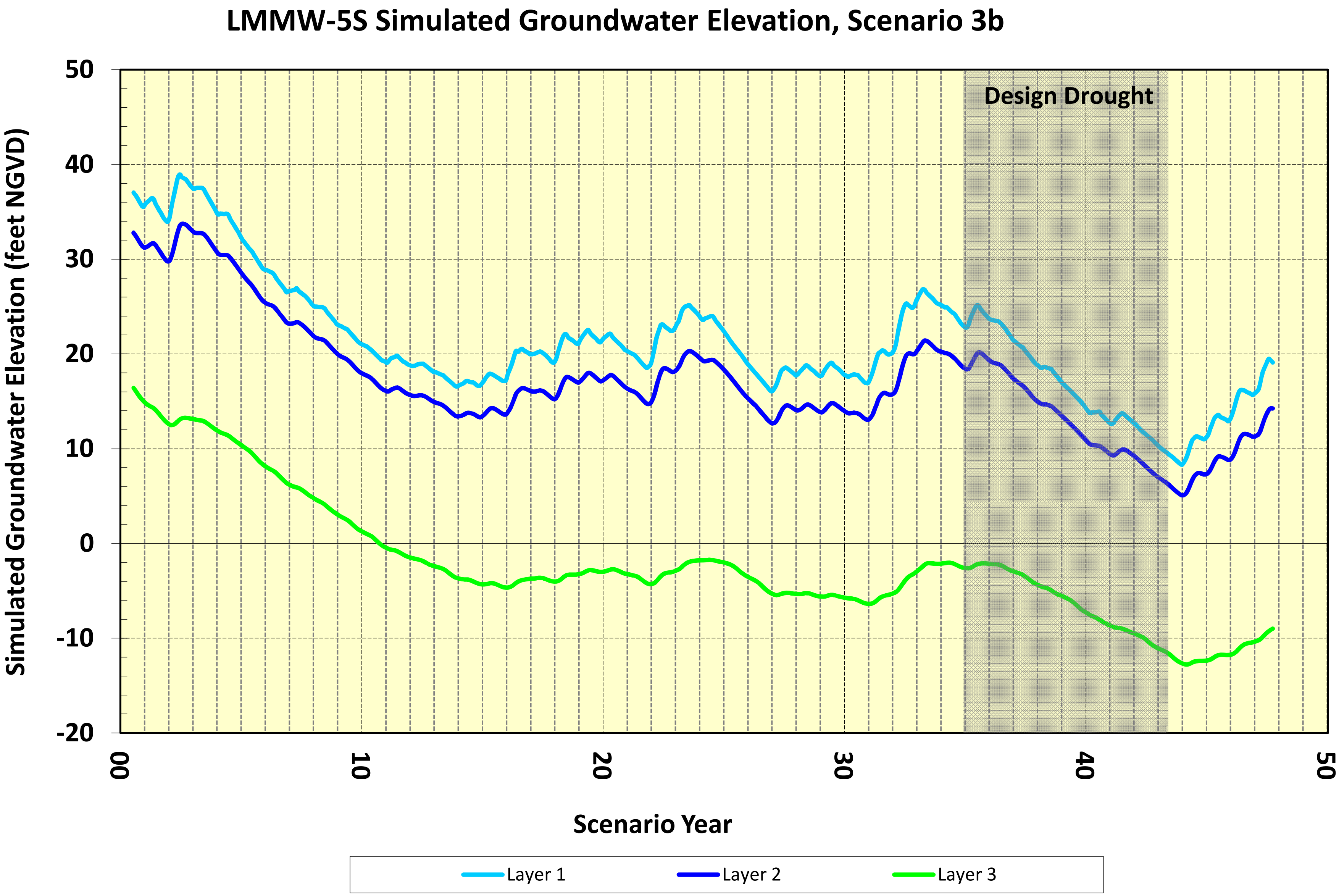
Note: At the location of SWM-GS-M, the model does not contain Model Layer 5.



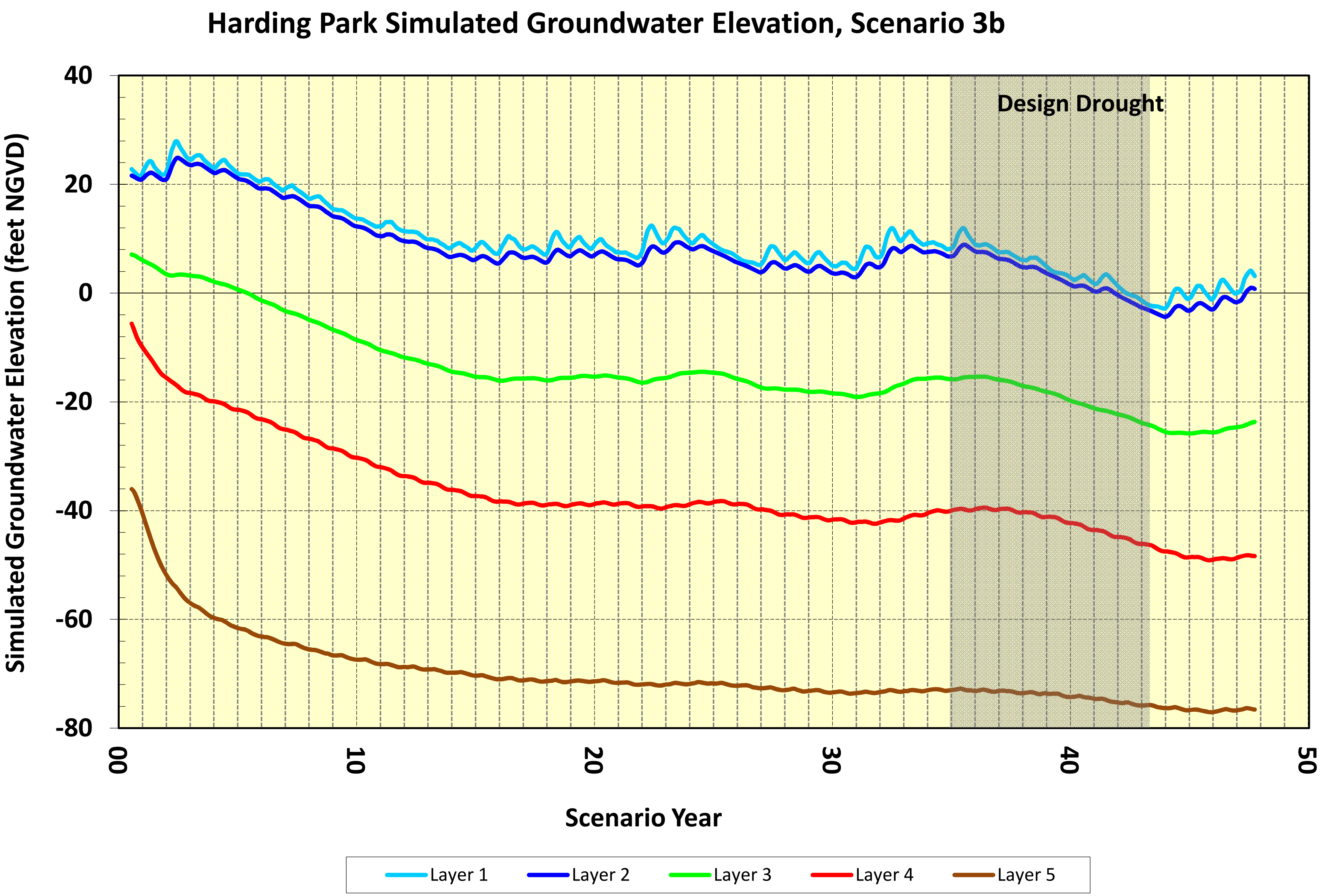
Ortega_MW Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


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

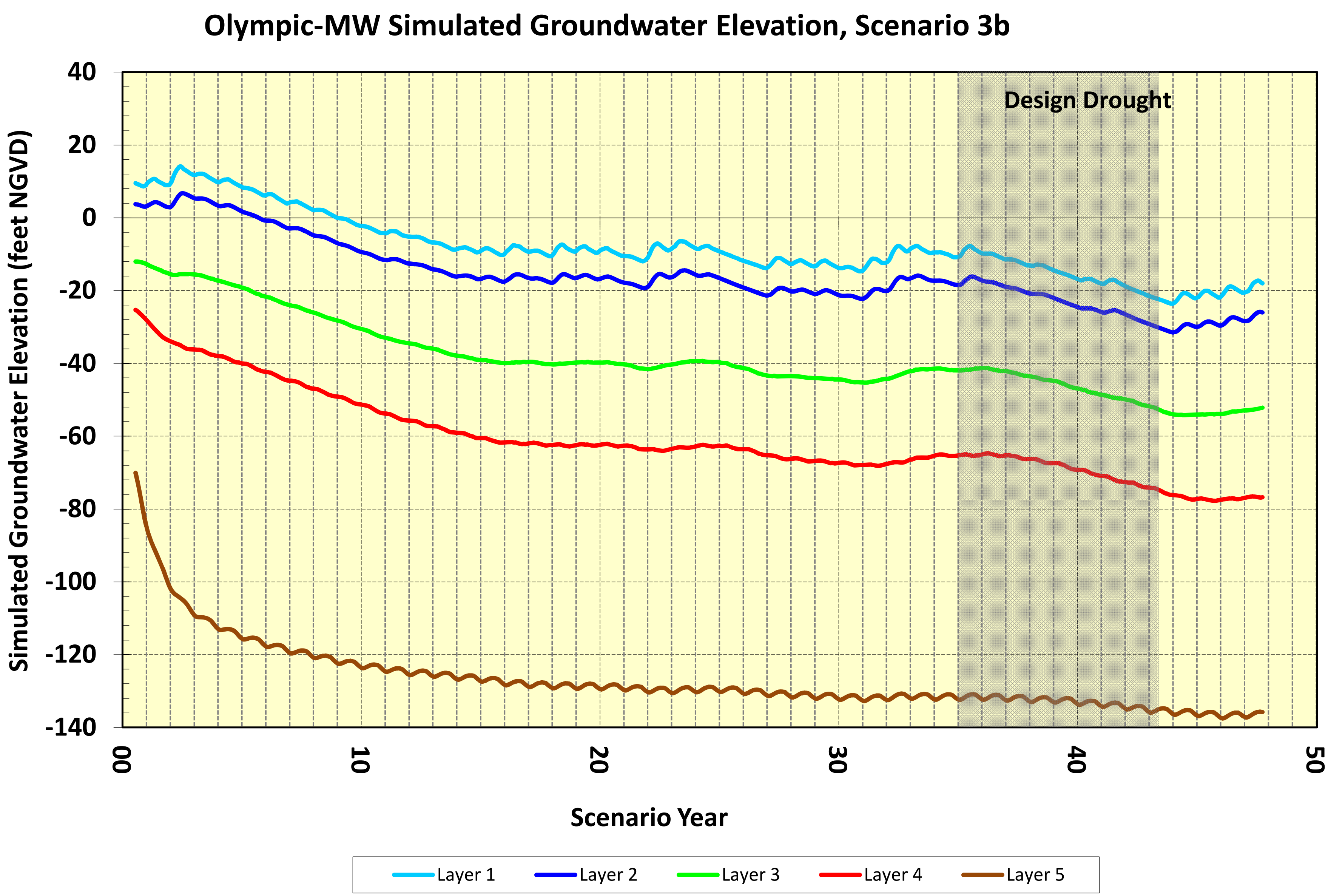

LMMW-4S Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
Scenario Year
30
20
10
0
-10
-20
-30
-40
-50
00
10
20
30
40
50
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



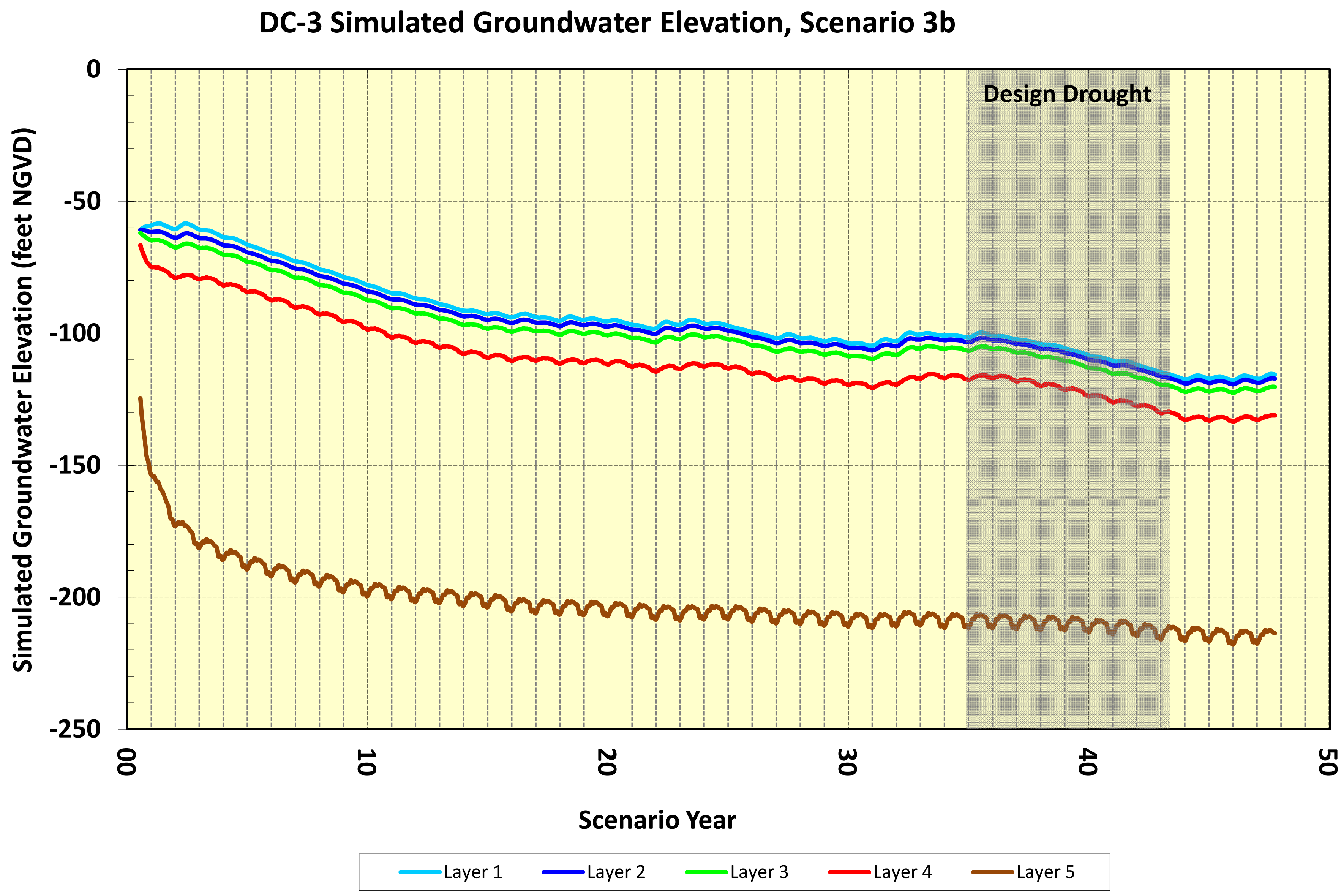
Note: At the location of LMMW-5S, the model does not contain Model Layers 4 and 5.



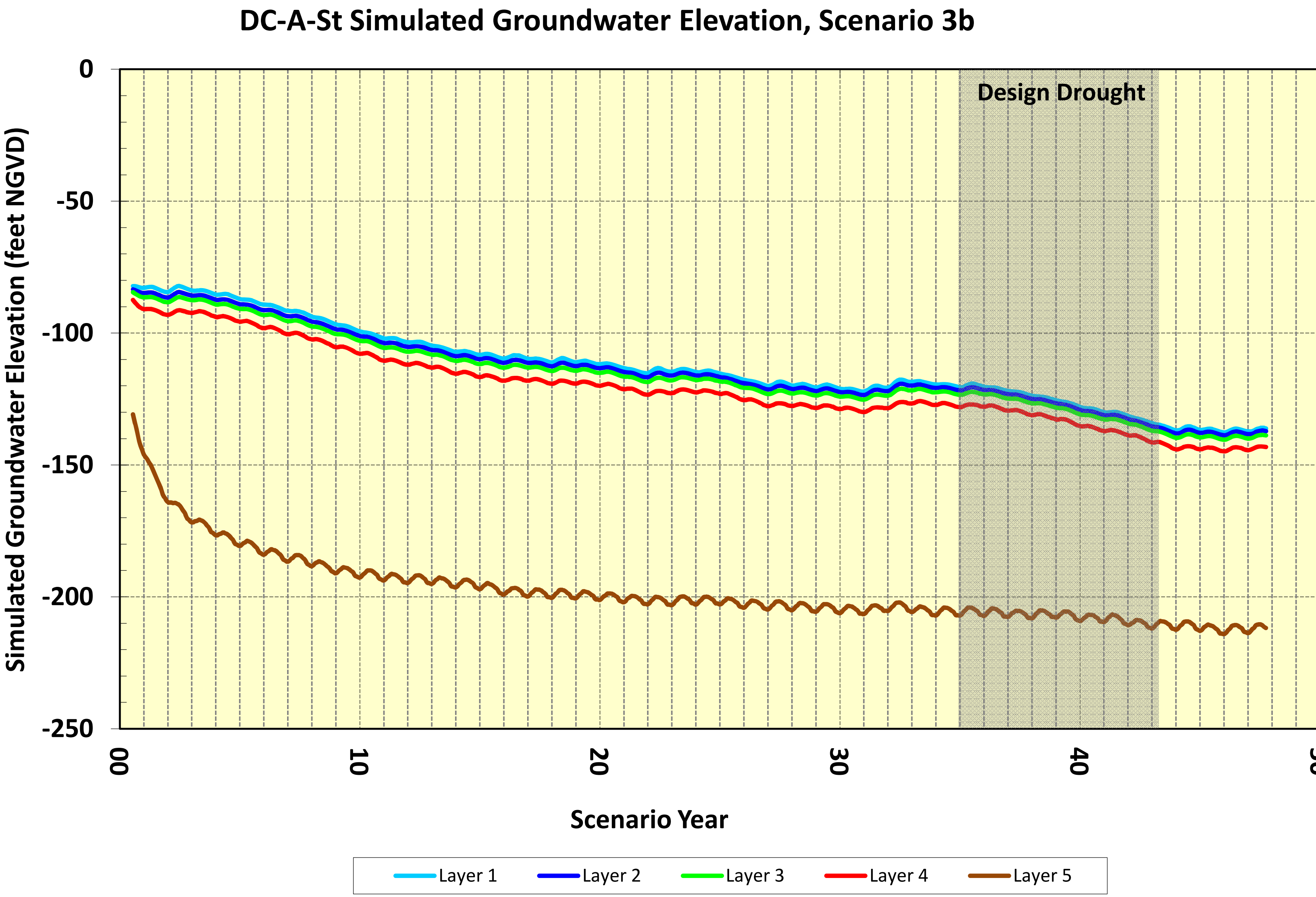
Harding Park Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



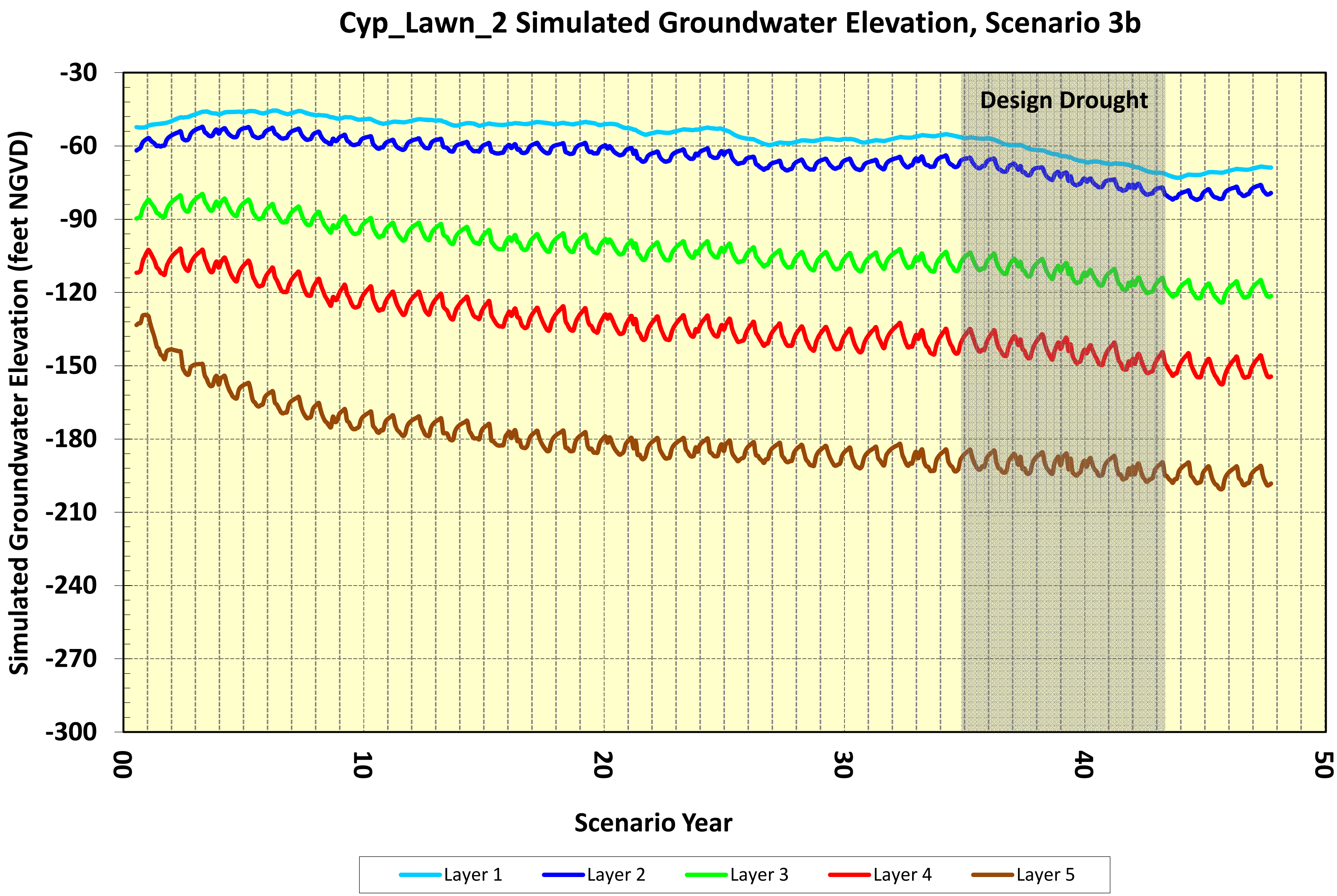
Olympic-MW Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
-100
-120
-140
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5



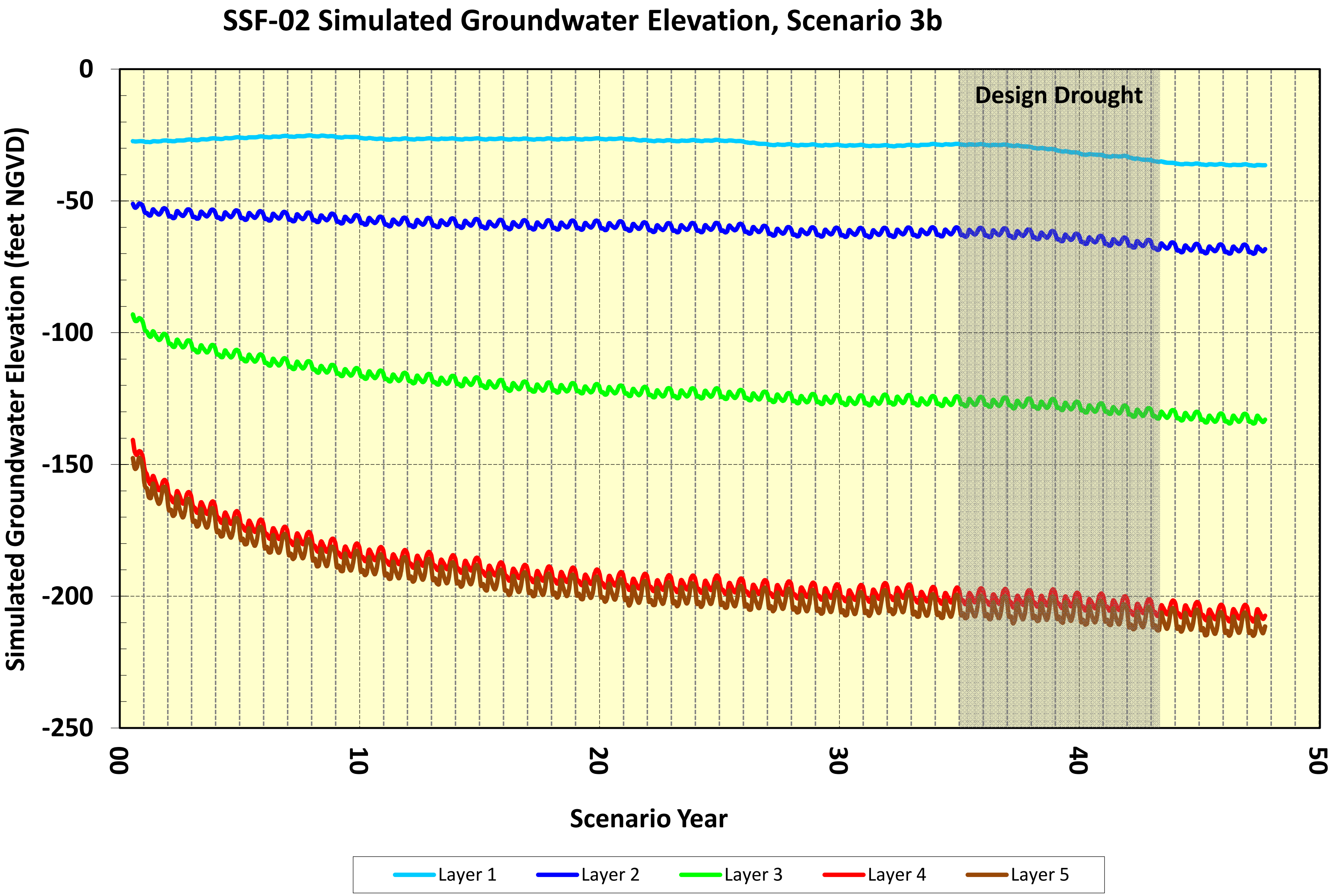
DC-3 Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

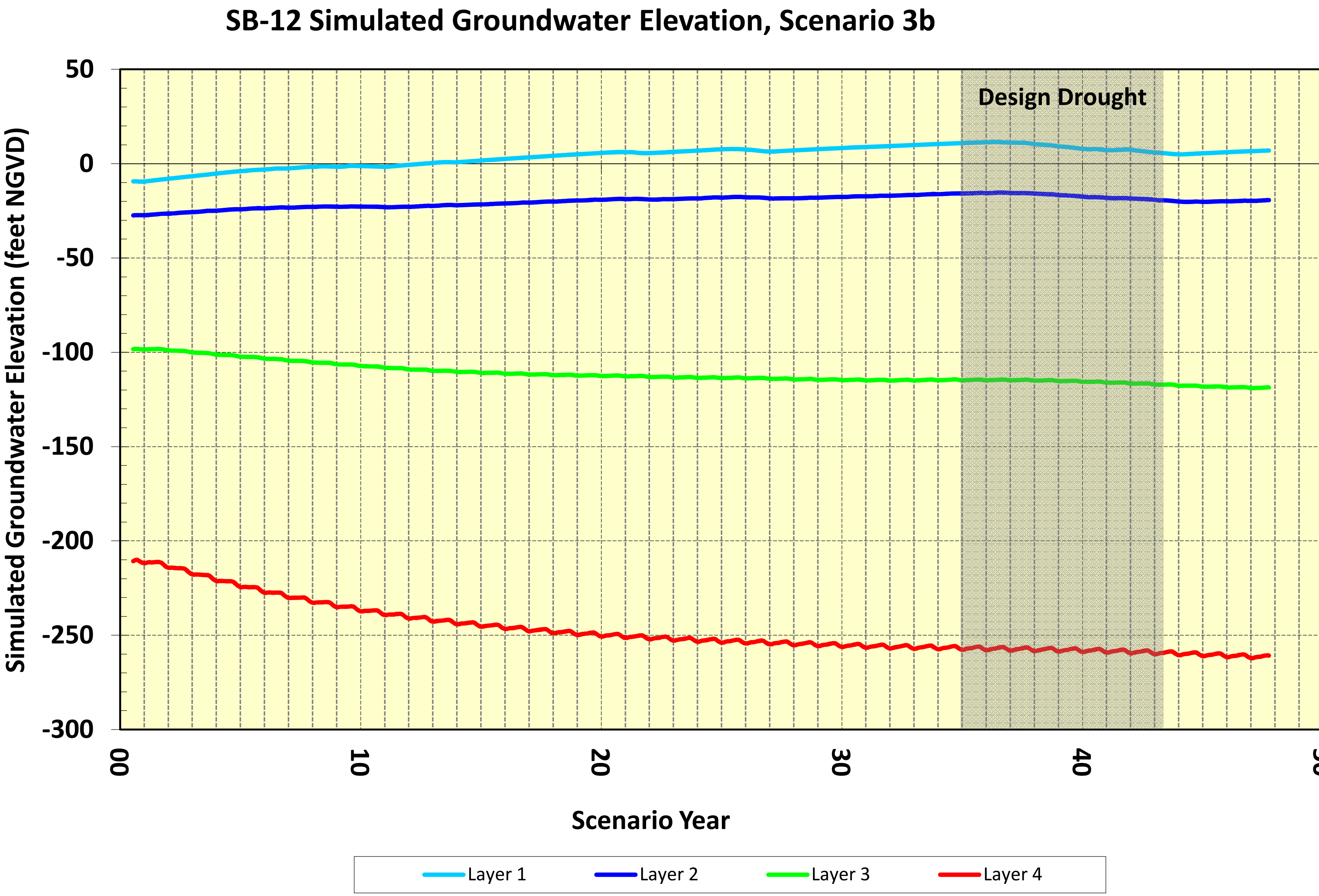


DC-A-St Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

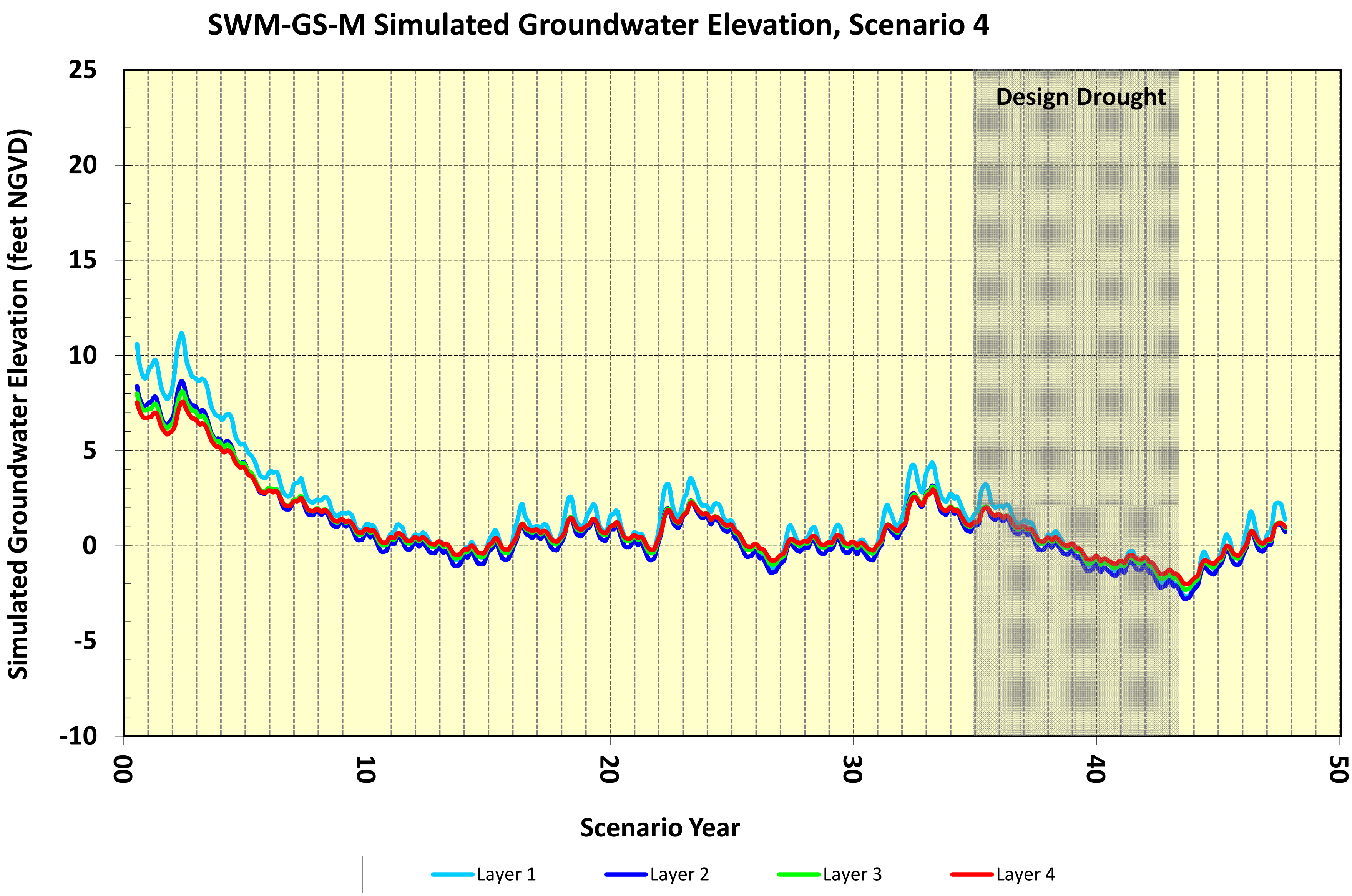


Cyp_Lawn_2 Simulated Groundwater Elevation, Scenario 3b
Design Drought
Simulated Groundwater Elevation (feet NGVD)
-30
-60
-90
-120
-150
-180
-210
-240
-270
-300
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


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

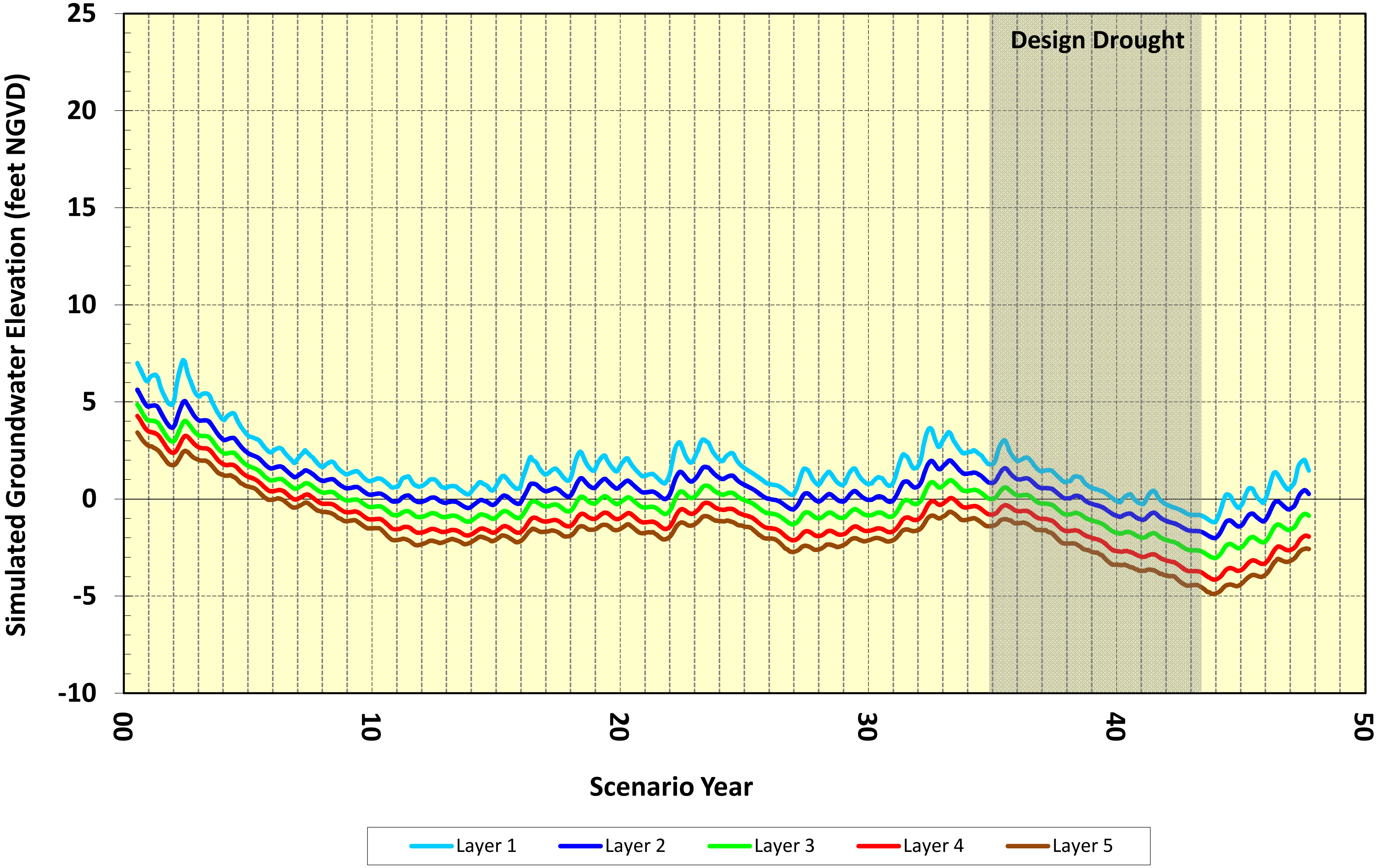


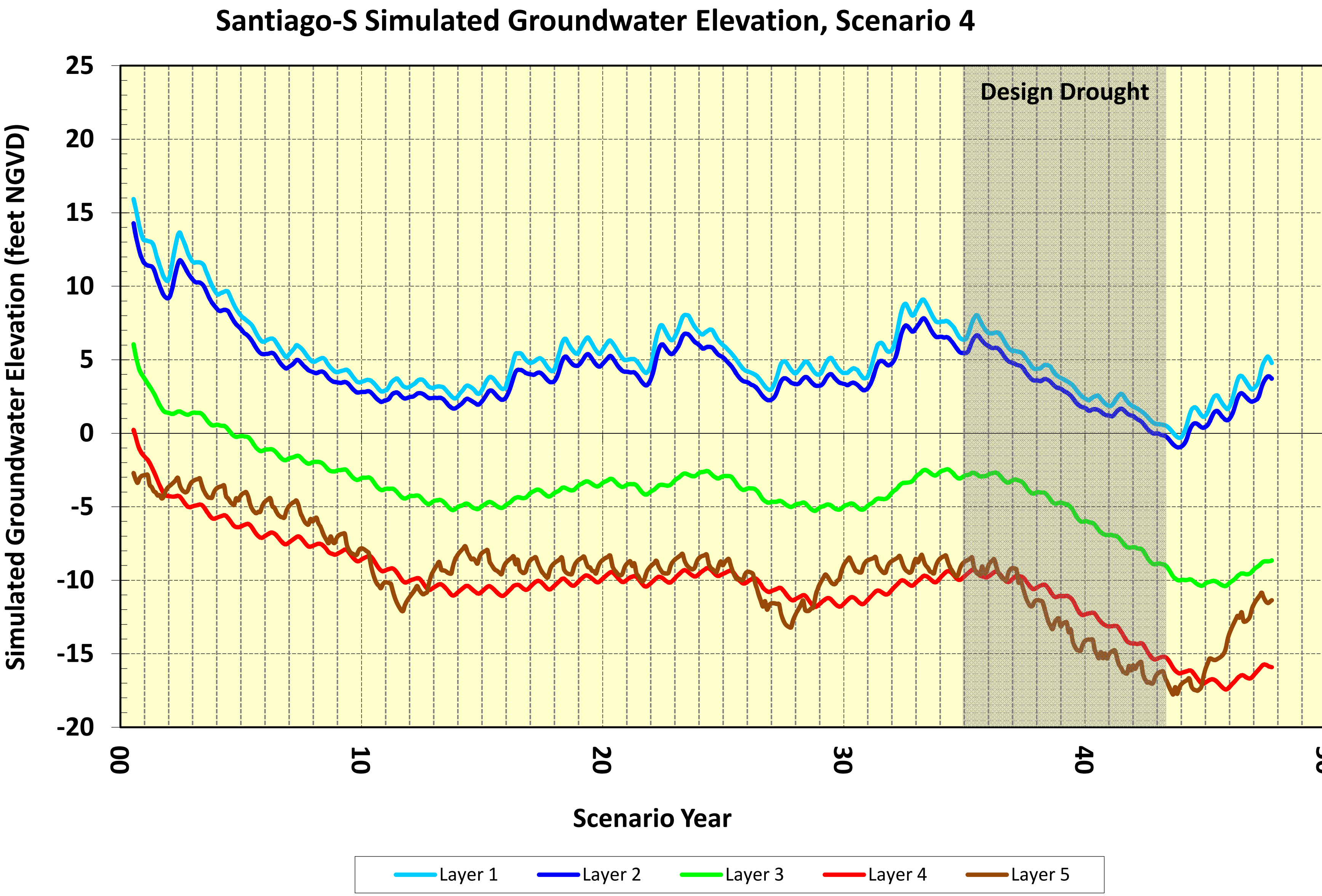
Note: At the location of SB-12, the model does not contain Model Layer 5.



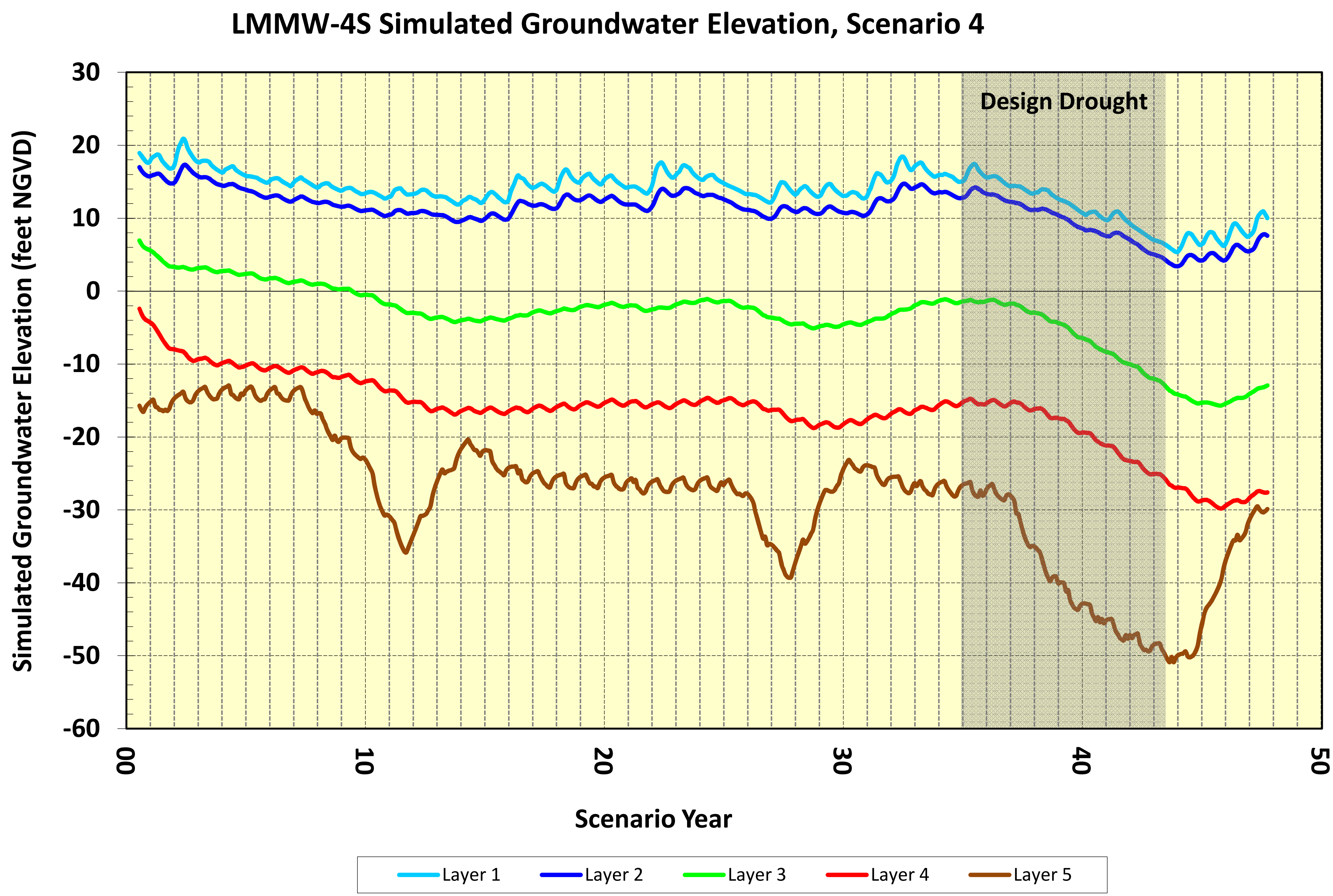
Note: At the location of SWM-GS-M, the model does not contain Model Layer 5.

Ortega_MW Simulated Groundwater Elevation, Scenario 4

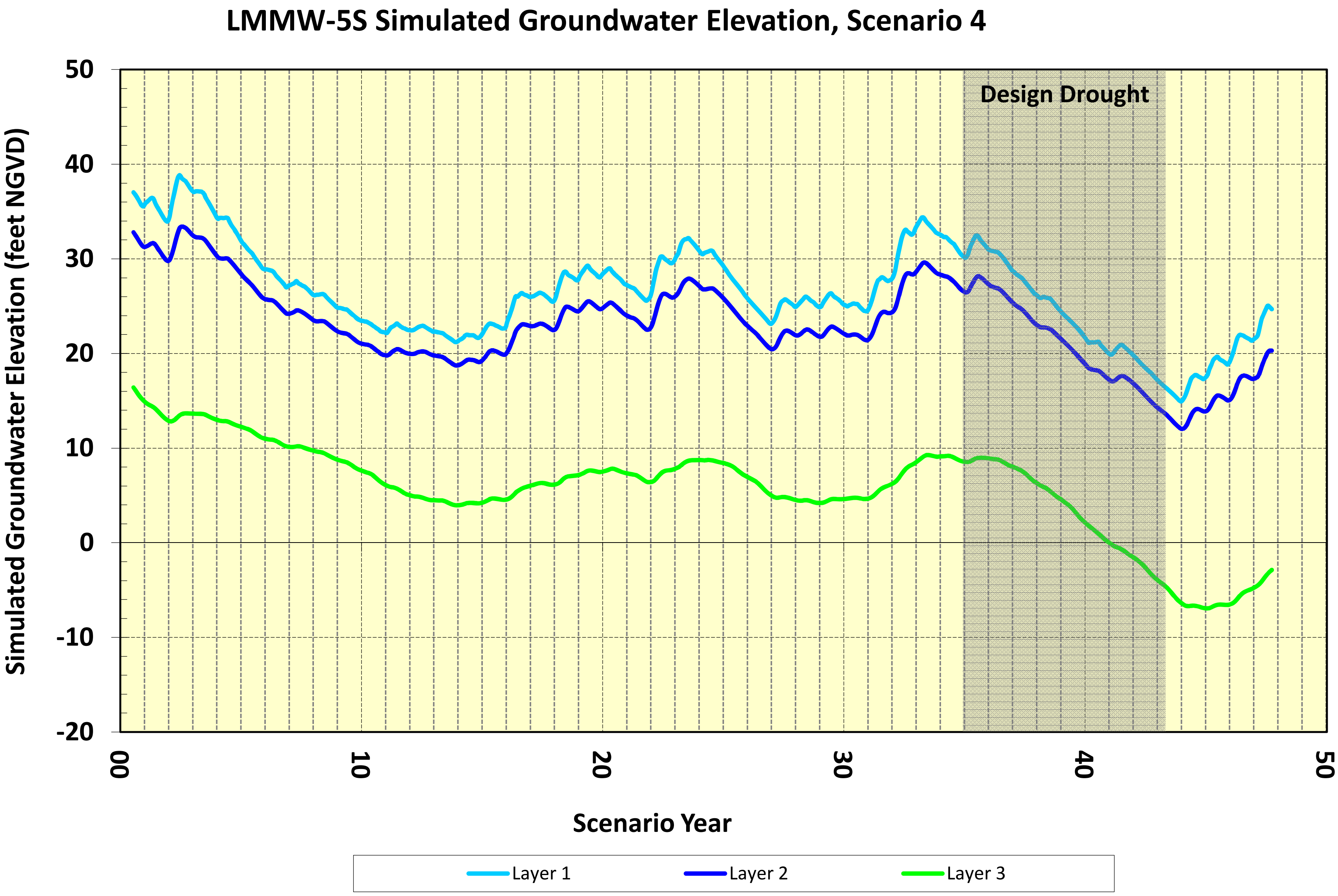




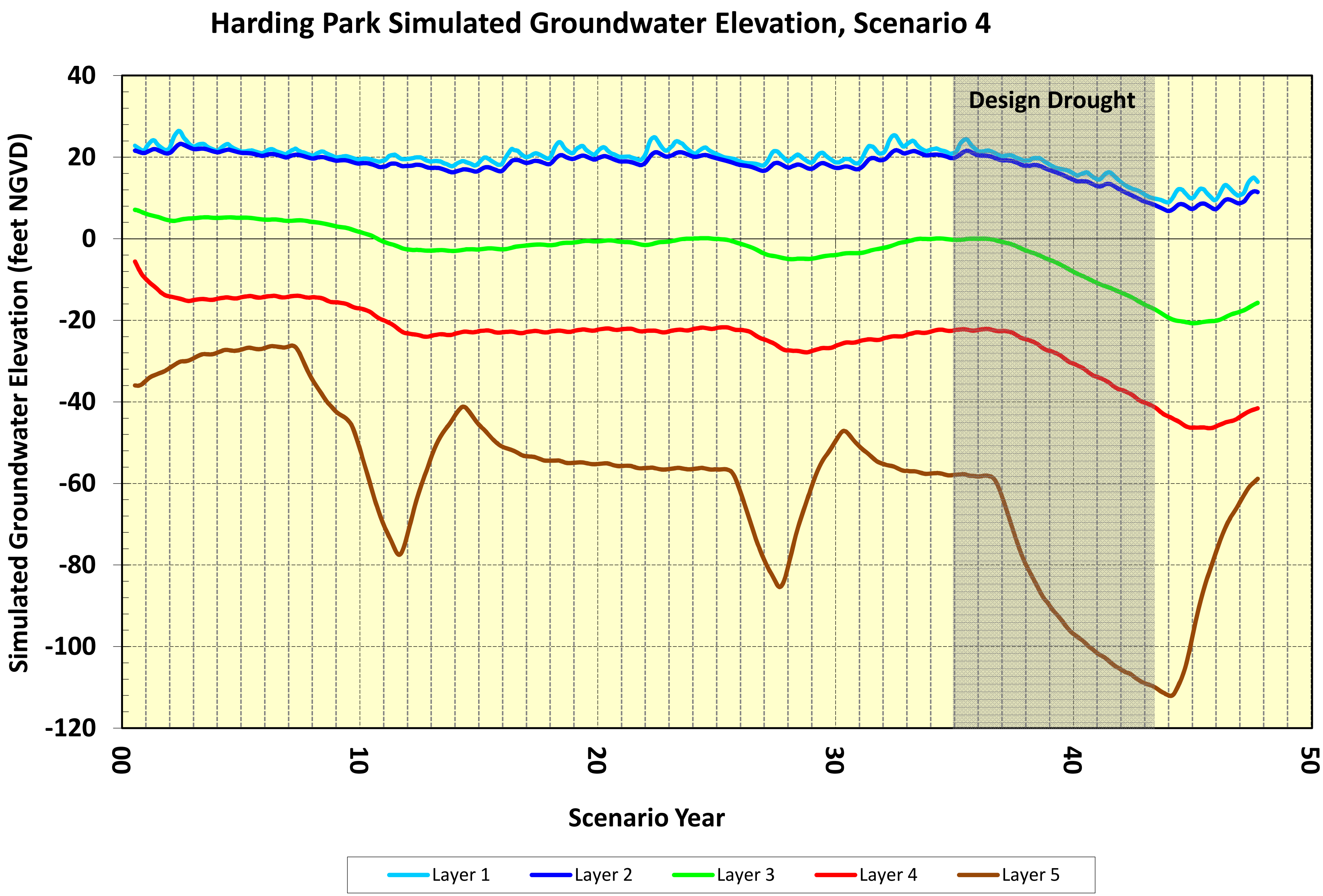
Santiago-S Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
-15
-20
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

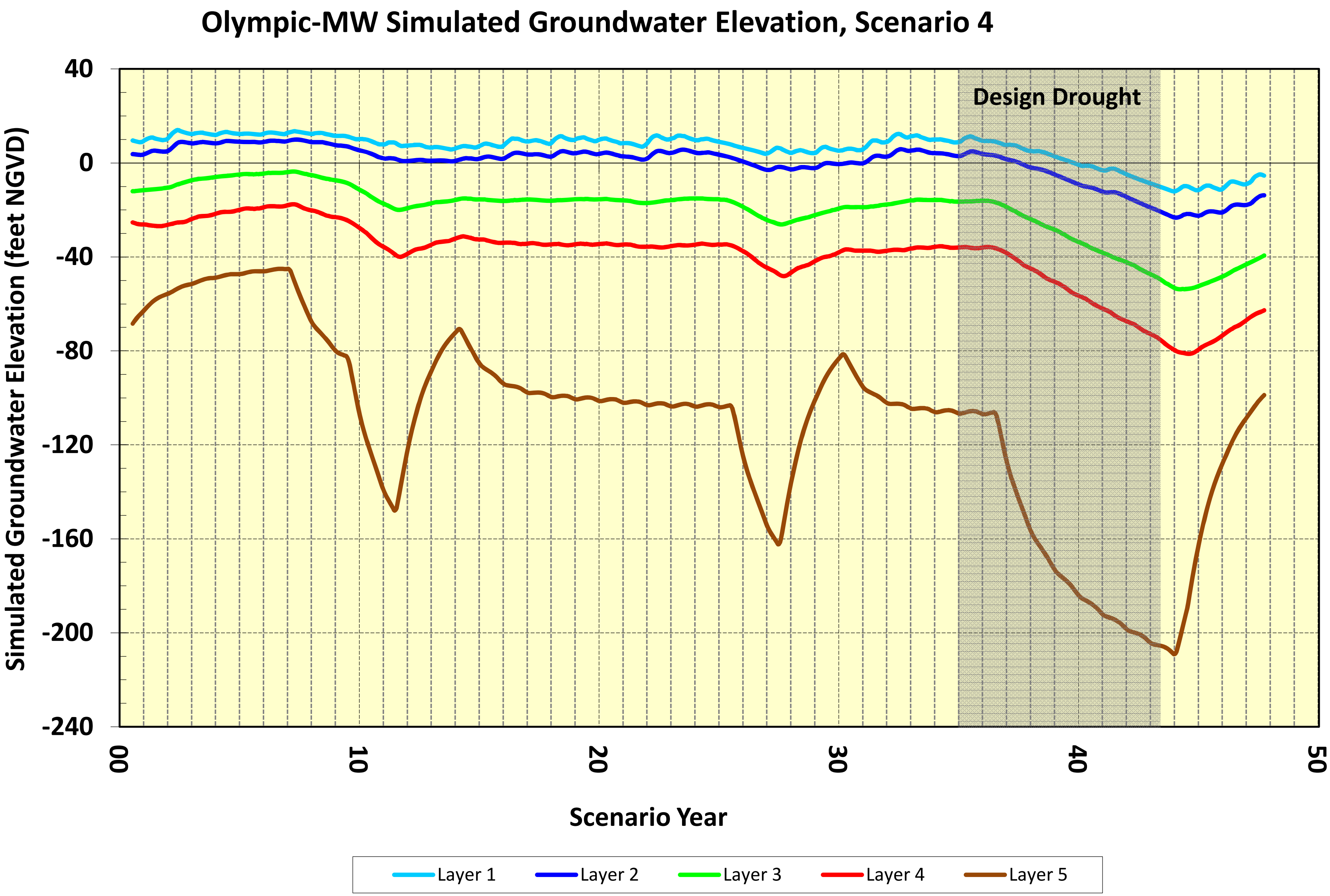


LMMW-4S Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
30
20
10
0
-10
-20
-30
-40
-50
-60
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

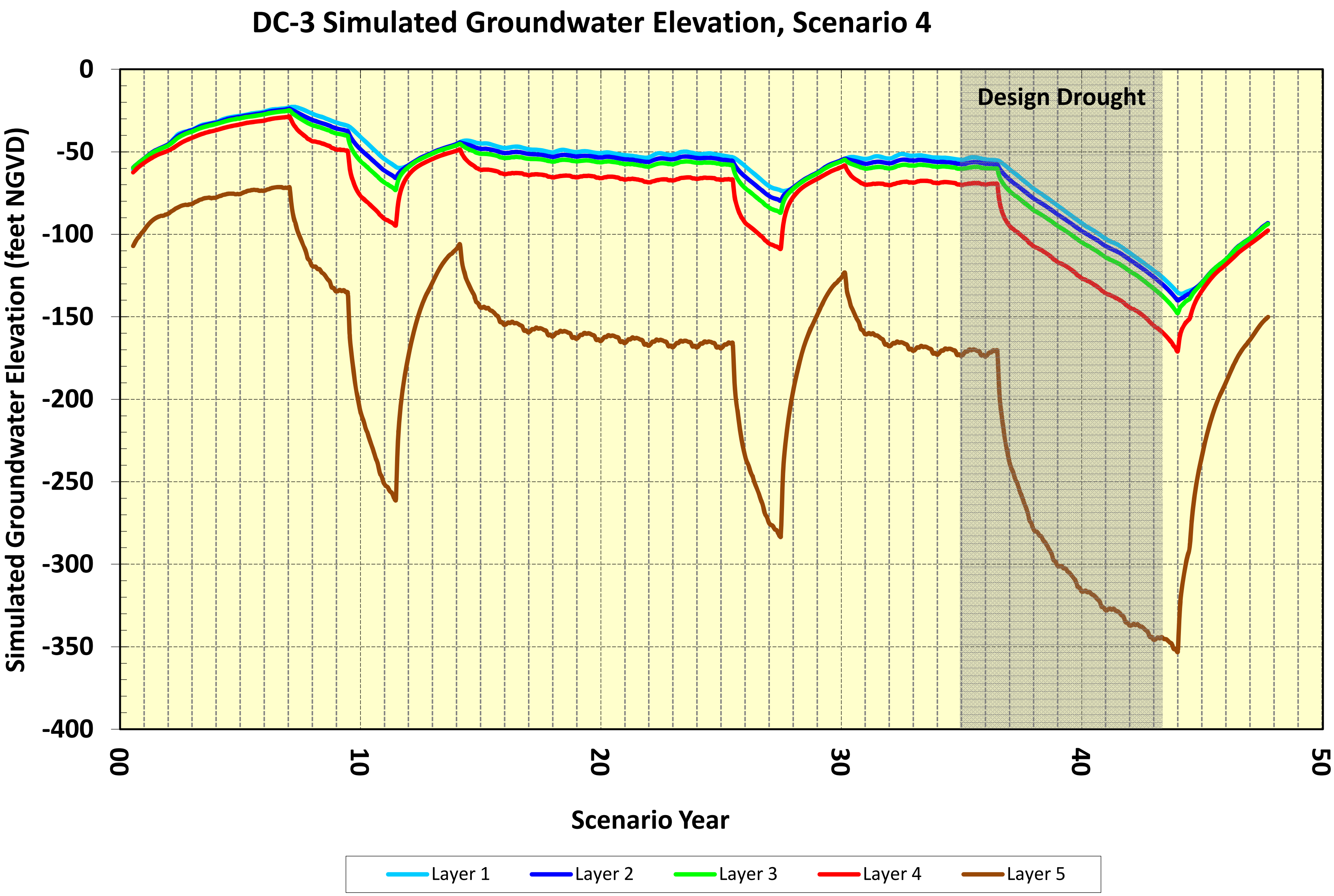


Note: At the location of LMMW-5S, the model does not contain Model Layers 4 and 5.

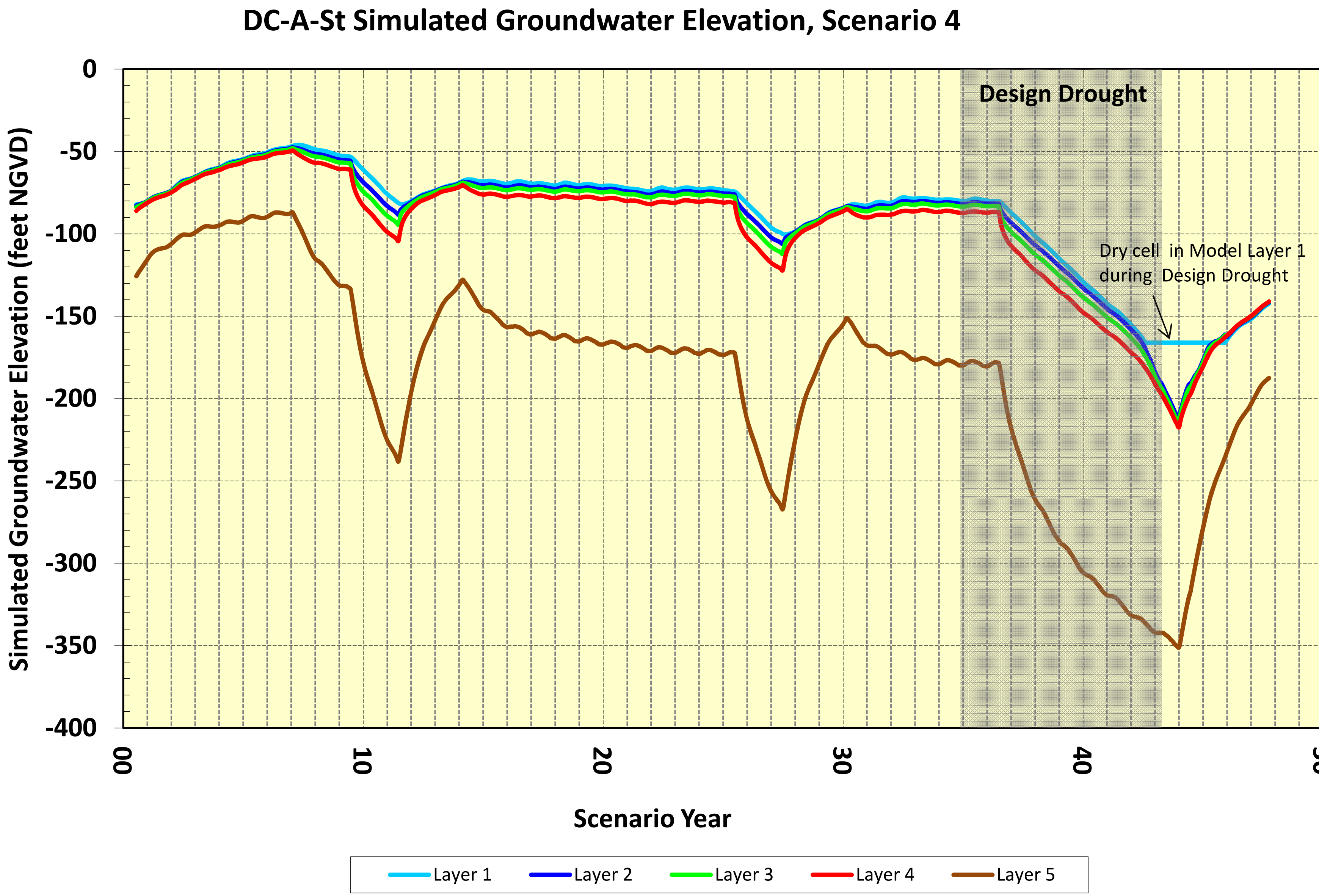

Harding Park Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
-100
-120
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

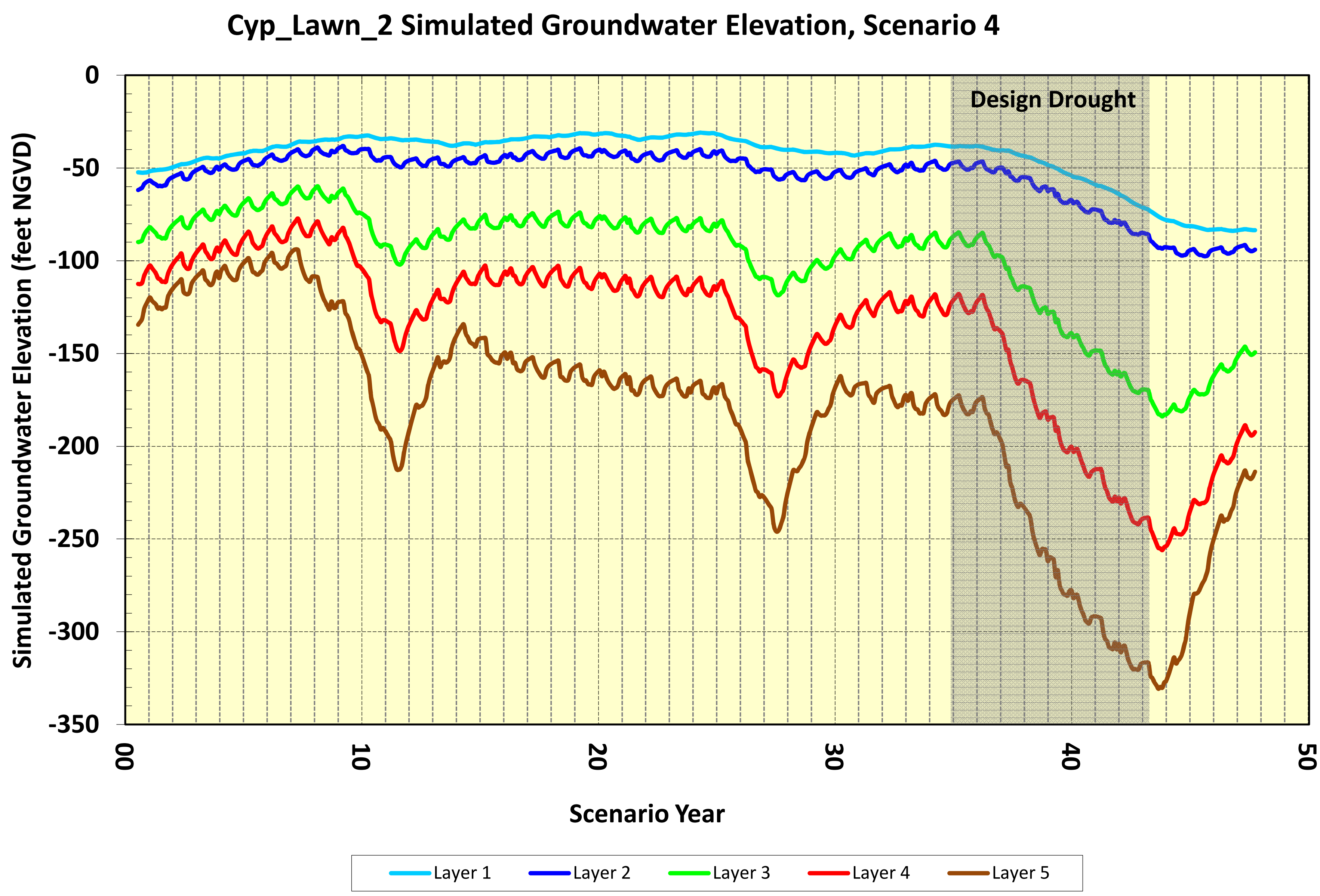


Olympic-MW Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
0
-40
-80
-120
-160
-200
-240
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

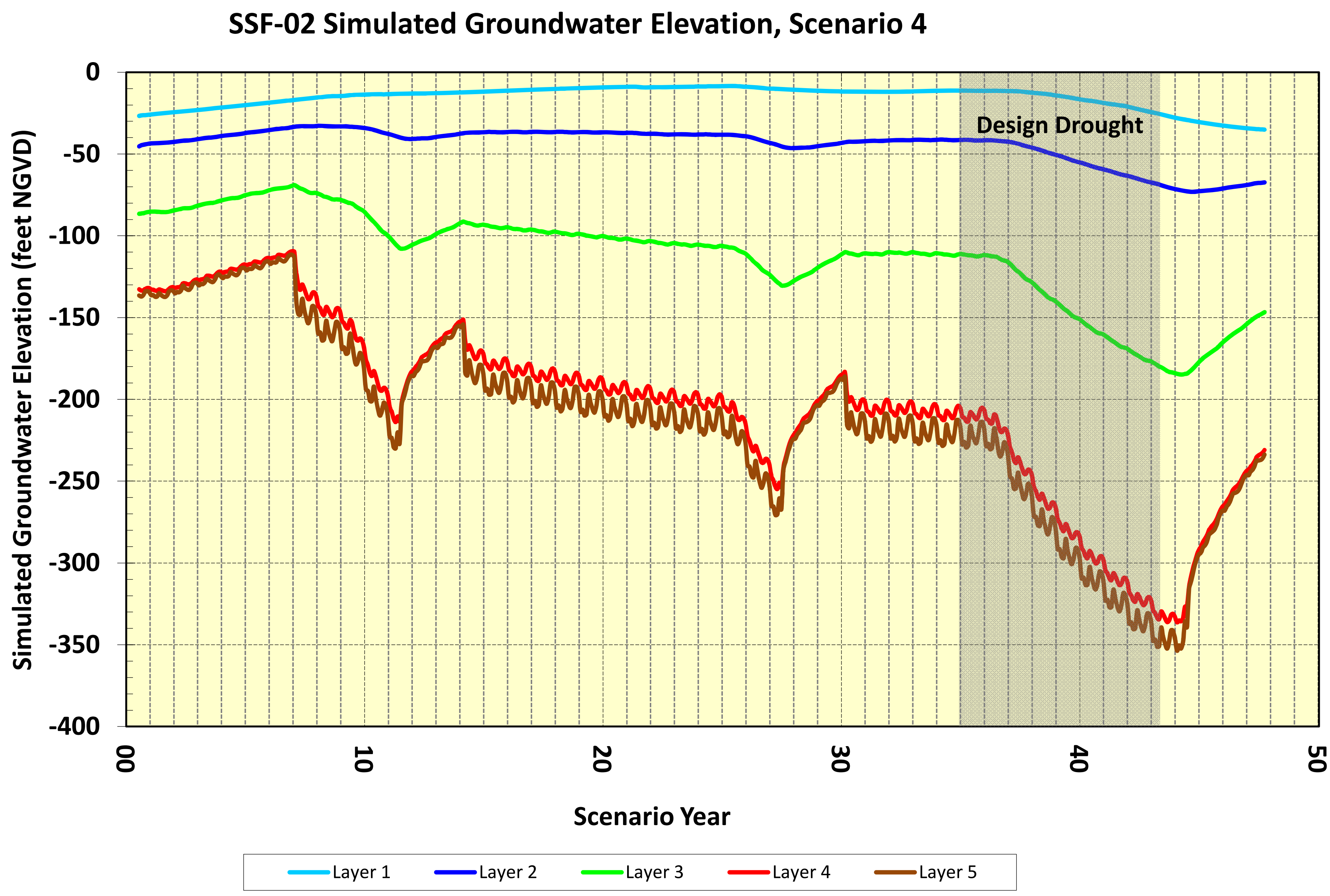


DC-3 Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5


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

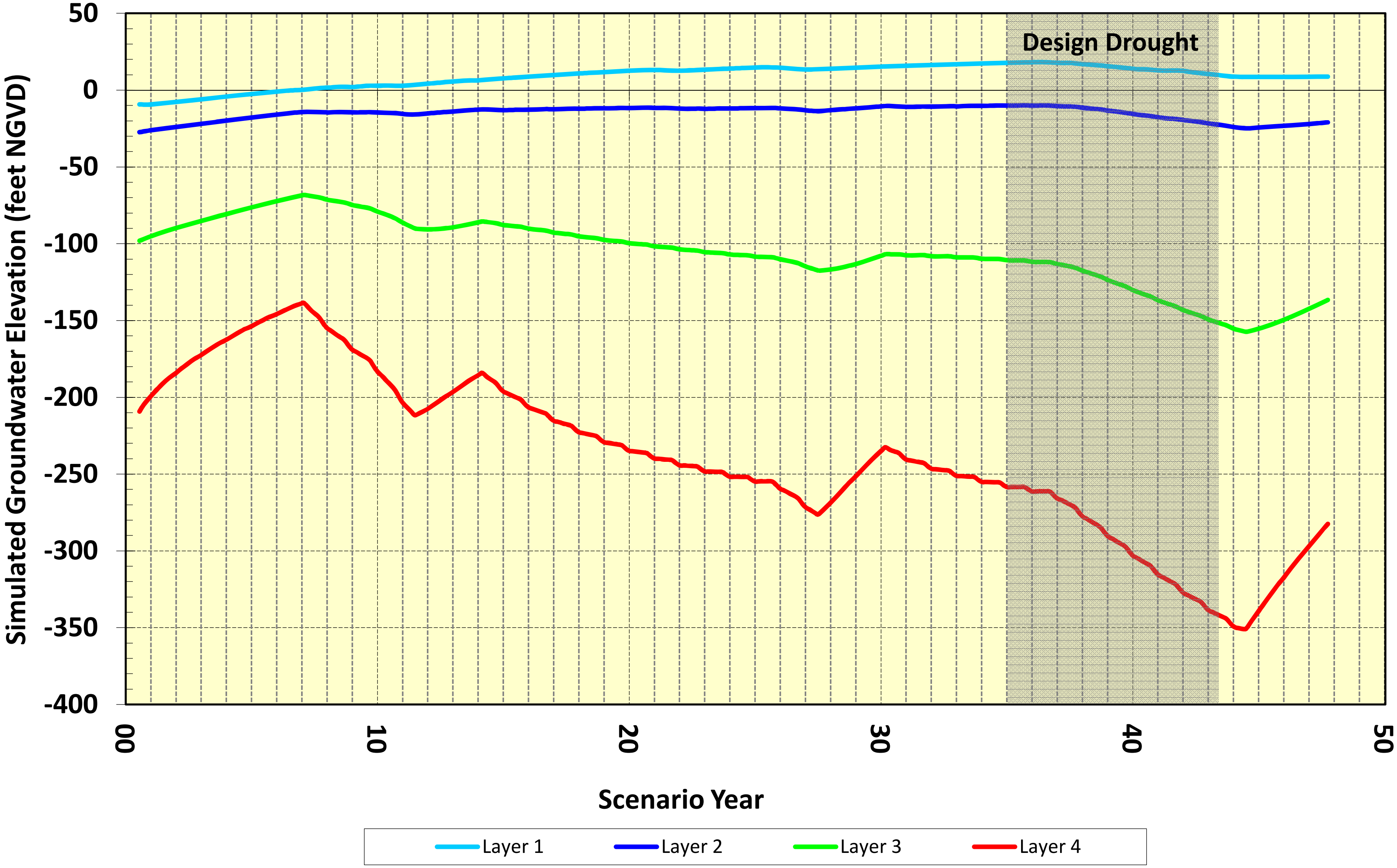


Cyp_Lawn_2 Simulated Groundwater Elevation, Scenario 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
00
10
20
30
40
50
Scenario Year
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

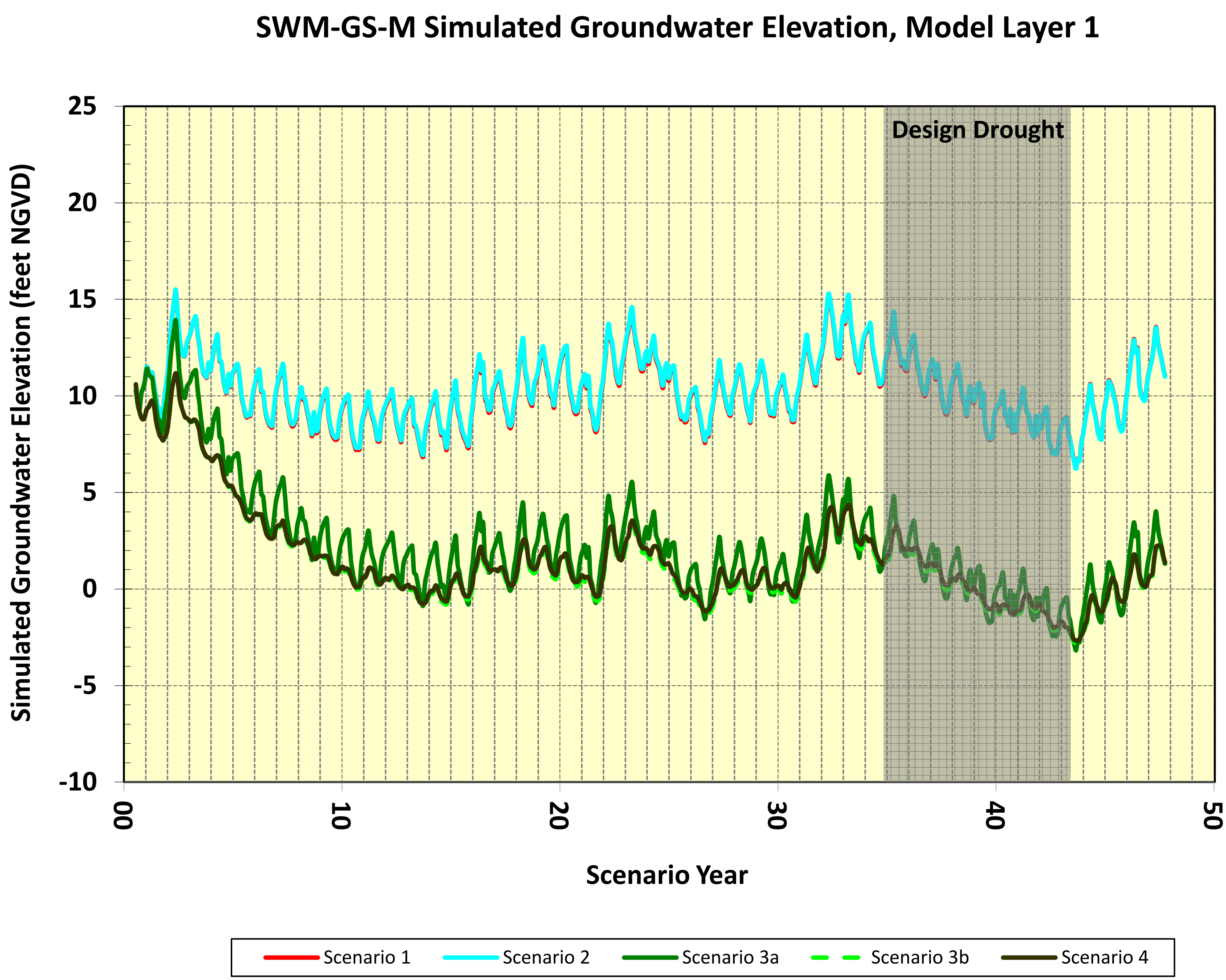


SSF-02 Simulated Groundwater Elevation, Scenario 4
Simulated Groundwater Elevation (feet NGVD)
Scenario Year
Design Drought
0
-50
-100
-150
-200
-250
-300
-350
-400
00
10
20
30
40
50
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5

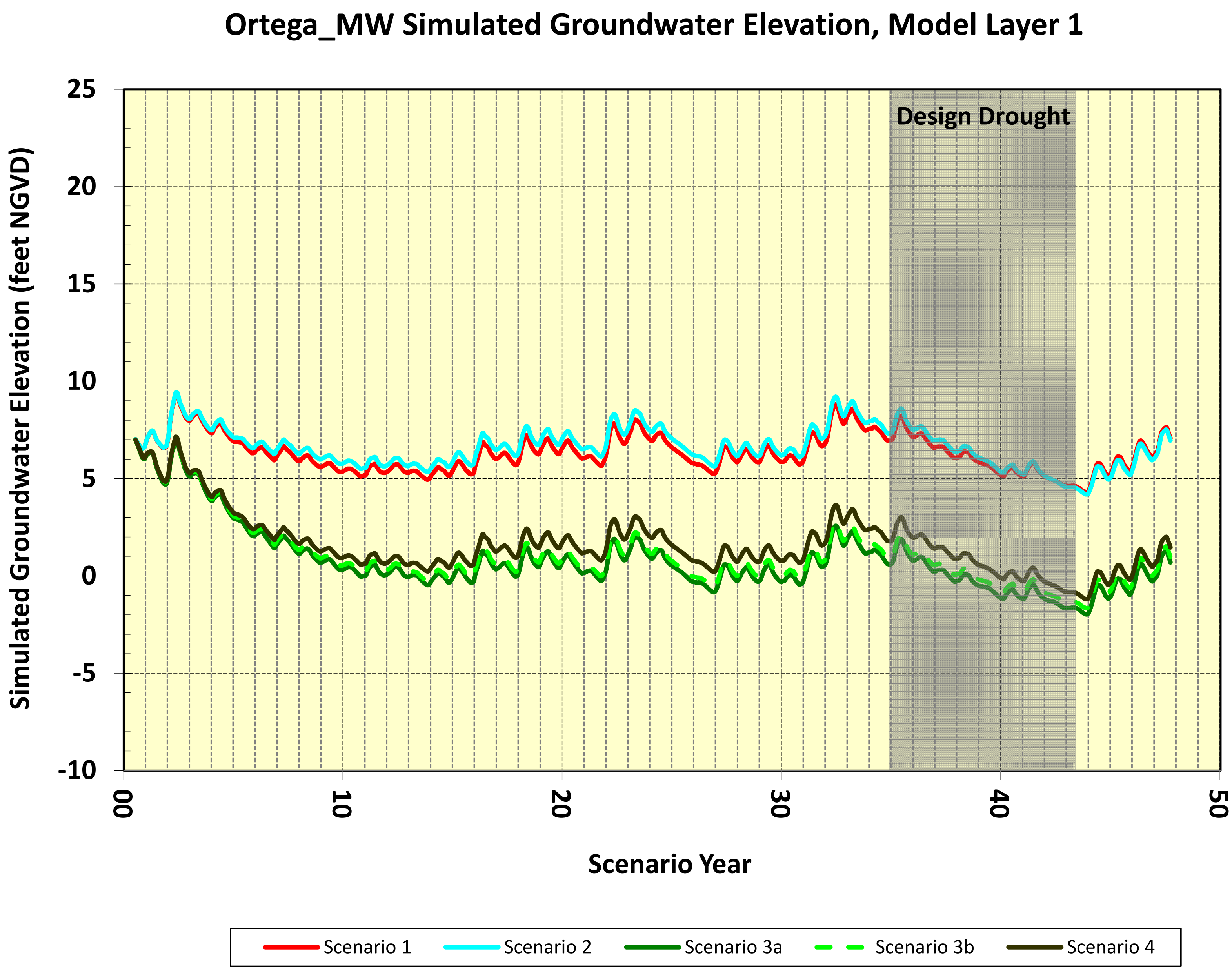
SB-12 Simulated Groundwater Elevation, Scenario 4

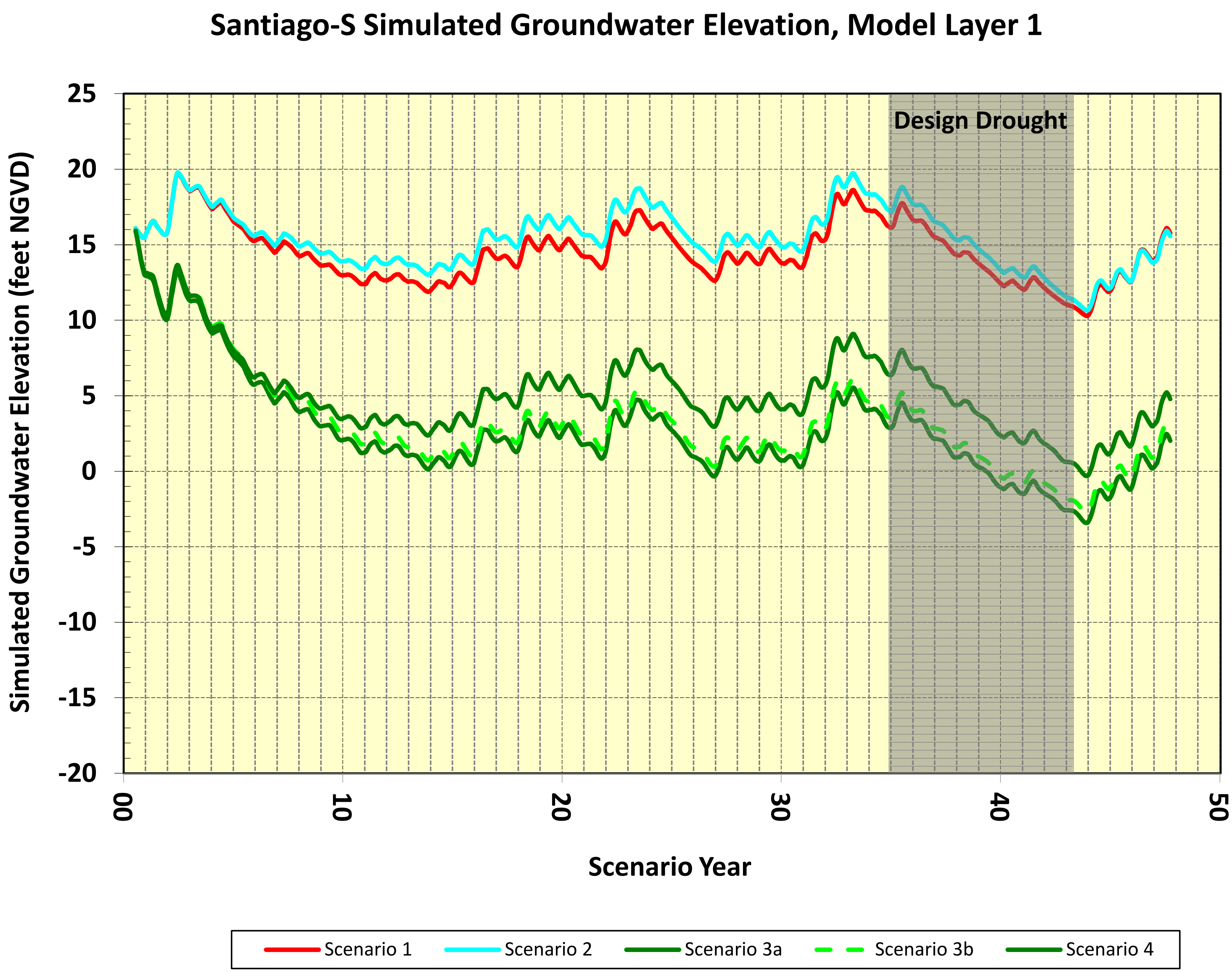


Note: At the location of LMMW-5S, the model does not contain Model Layers 4 and 5.

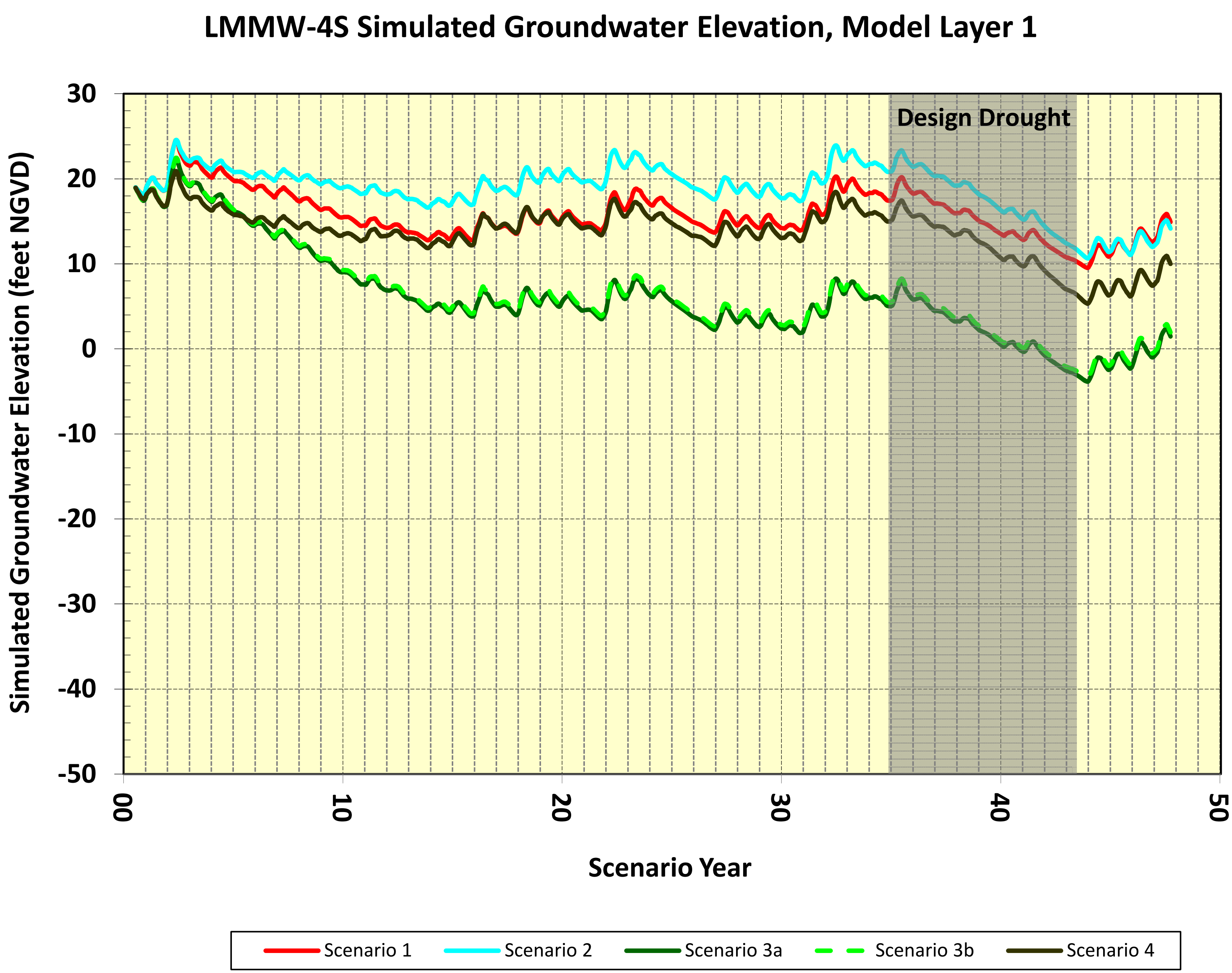


SWM-GS-M Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

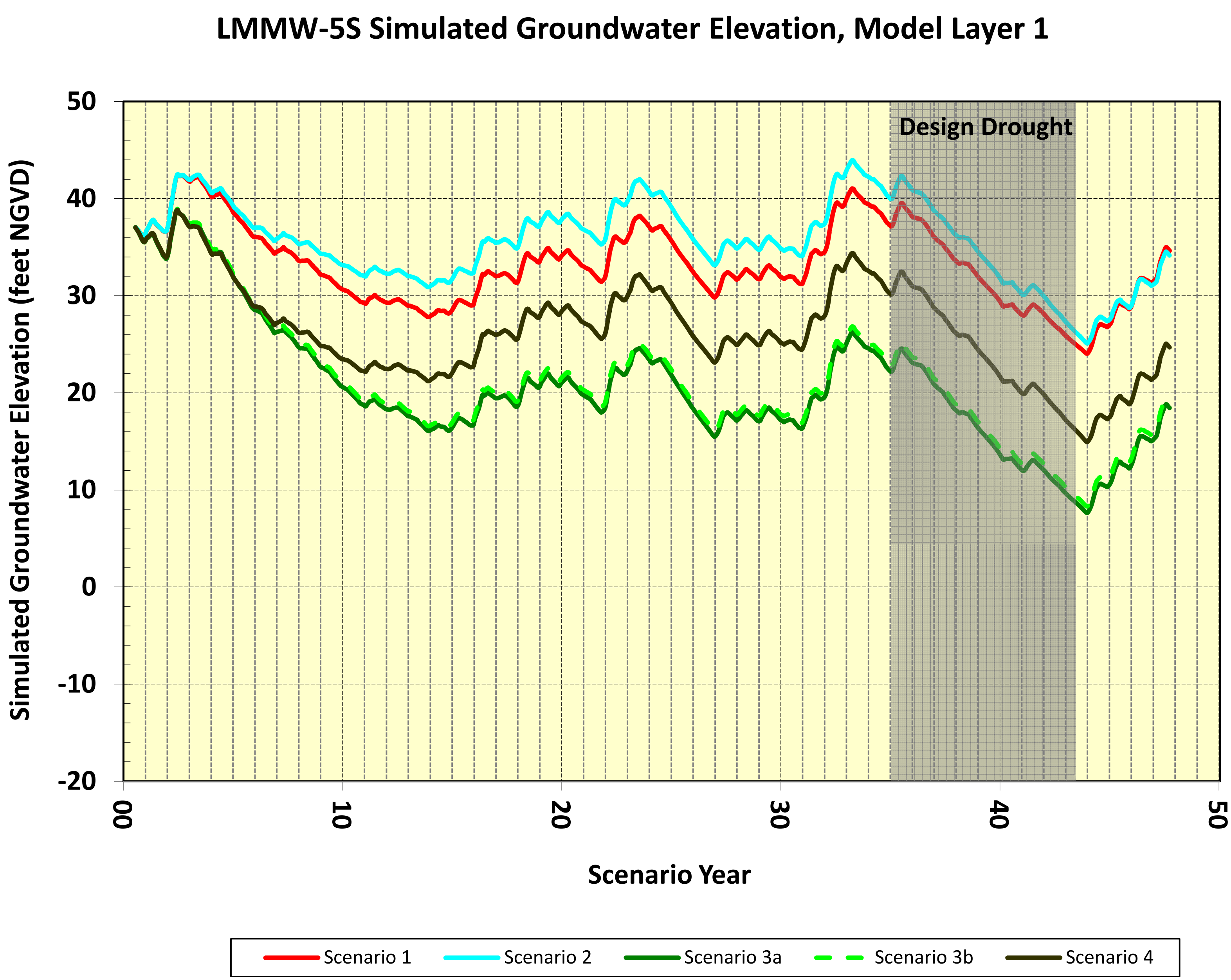

Ortega_MW Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

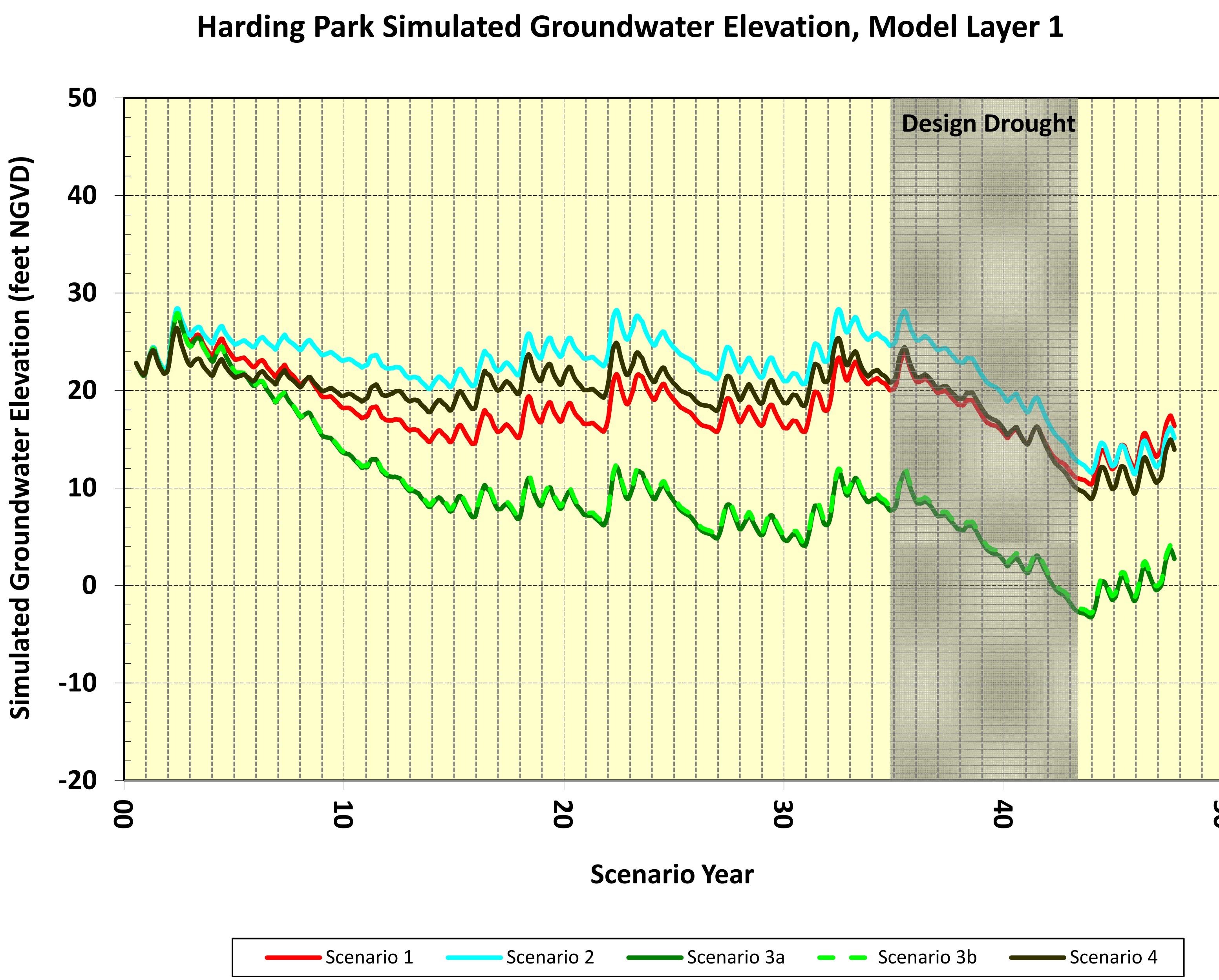


Santiago-S Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
-15
-20
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

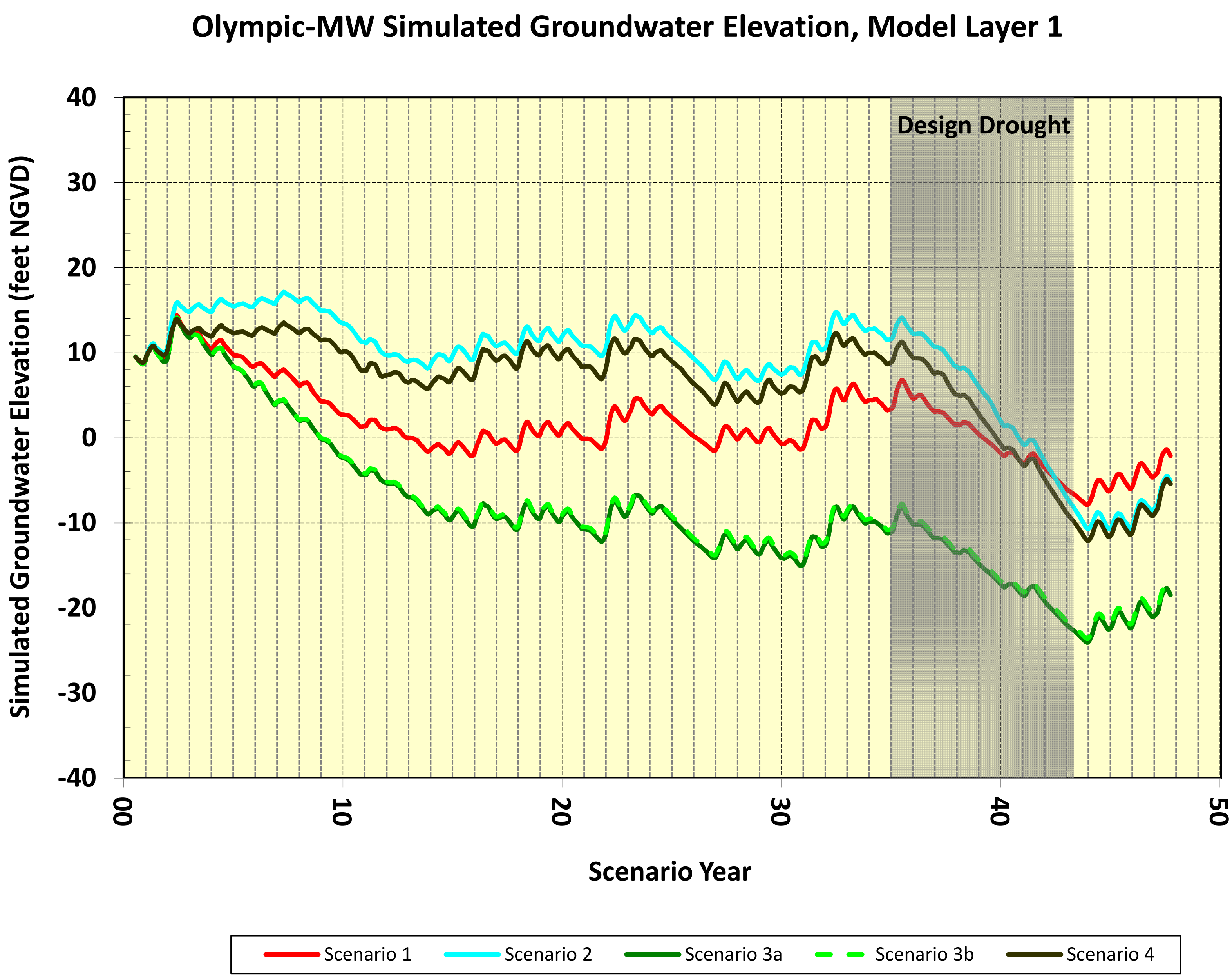


LMMW-4S Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
30
20
10
0
-10
-20
-30
-40
-50
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

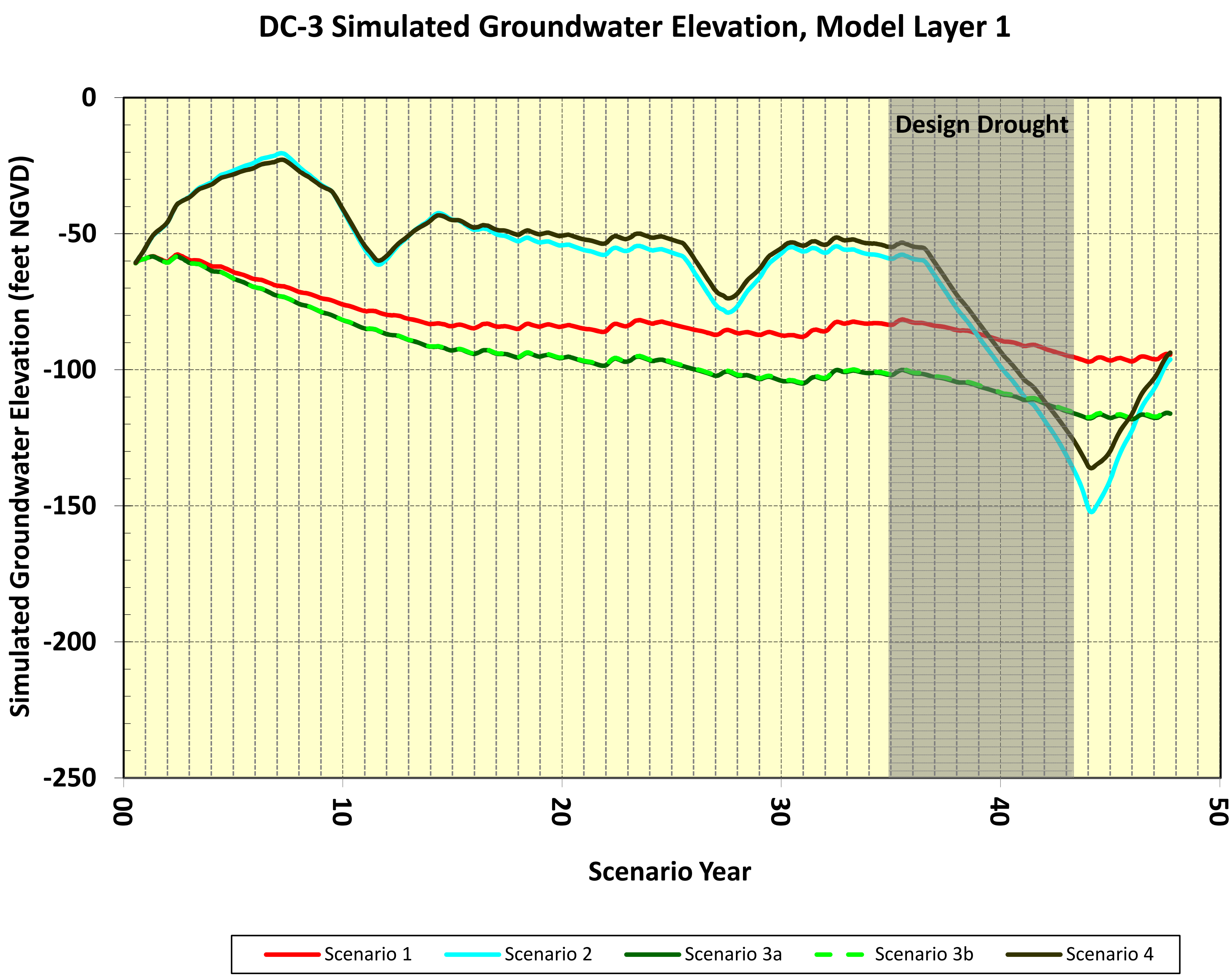

LMMW-5S Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
50
40
30
20
10
0
-10
-20
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

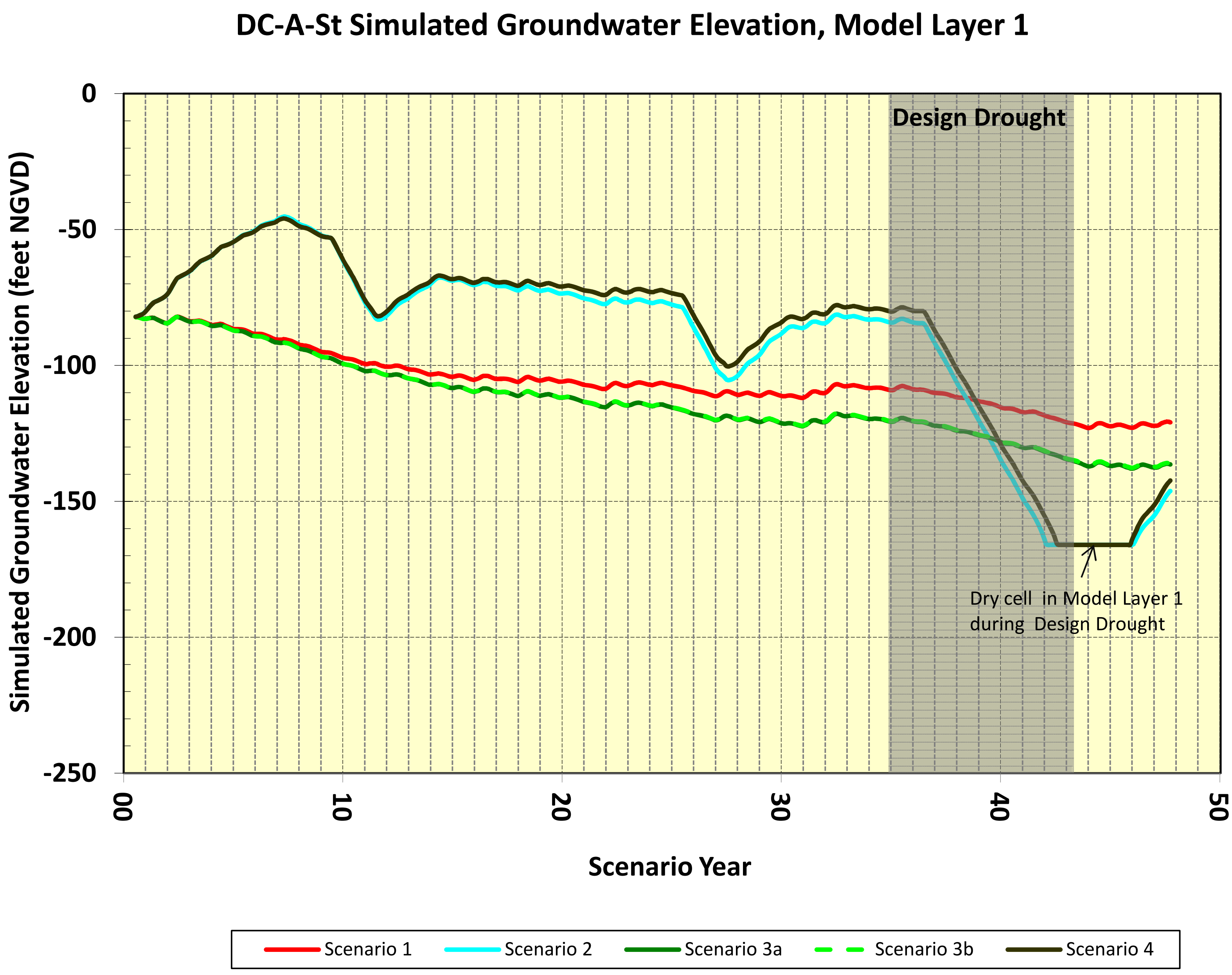


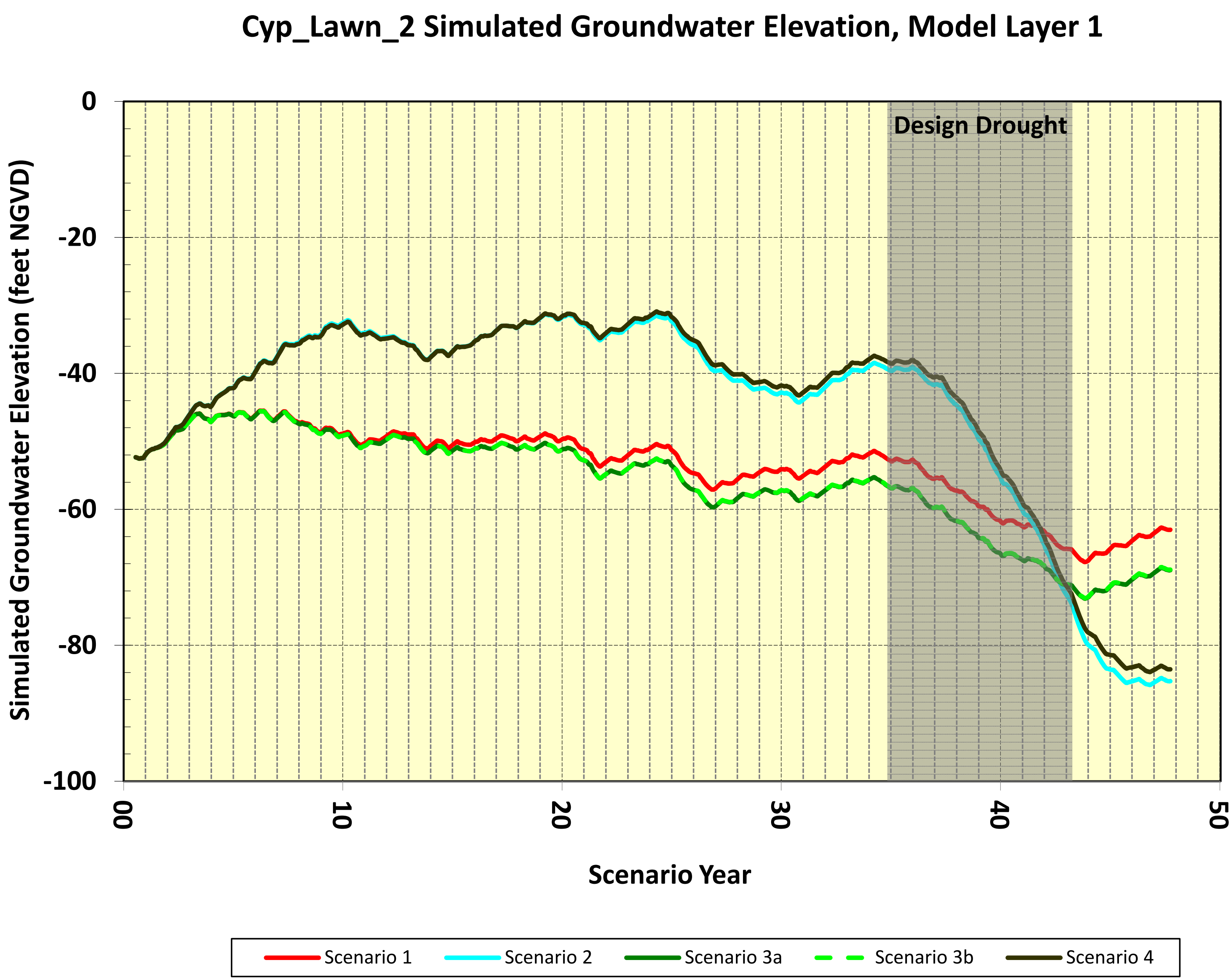
Harding Park Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
50
40
30
20
10
0
-10
-20
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



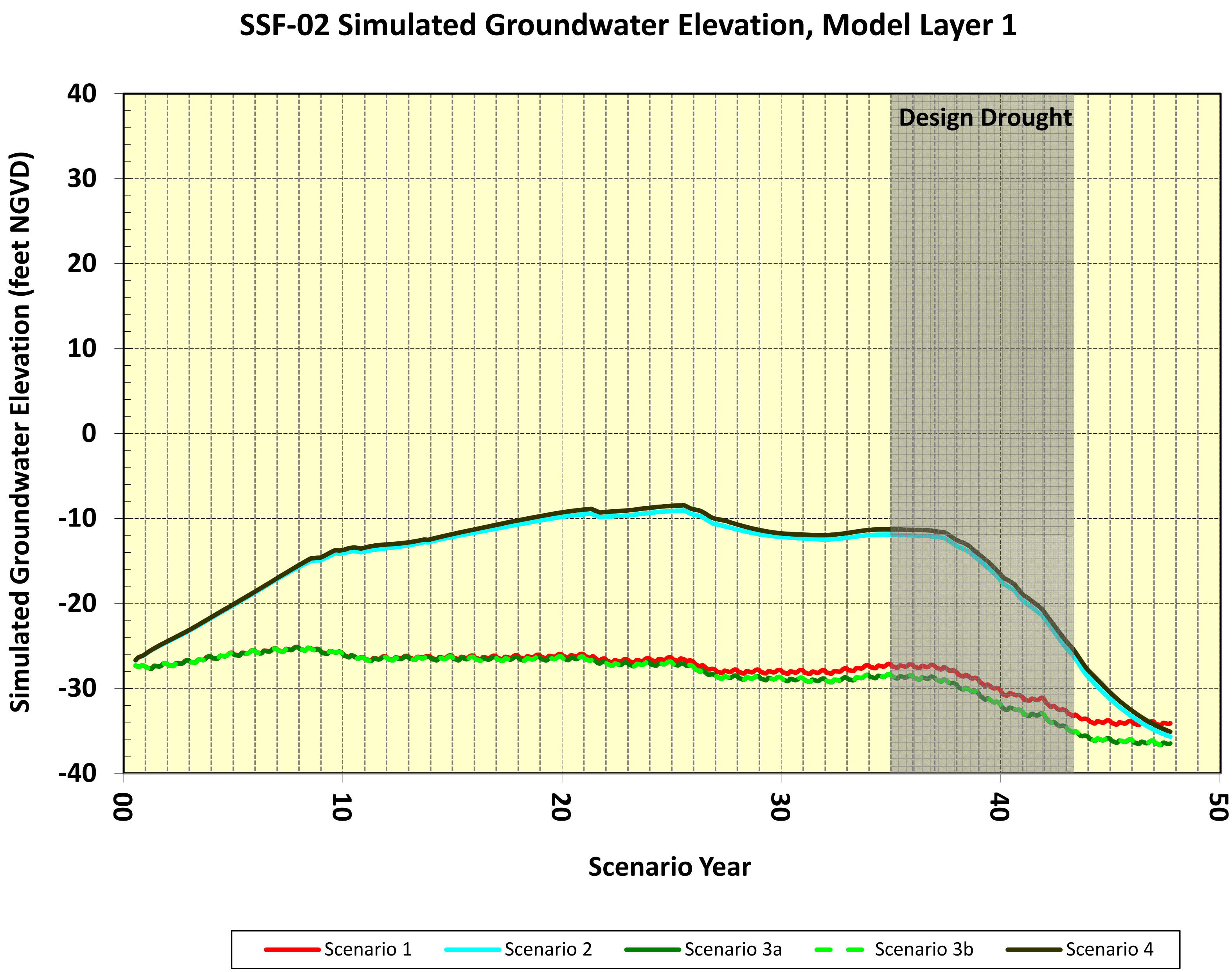
Olympic-MW Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
30
20
10
0
-10
-20
-30
-40
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


DC-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

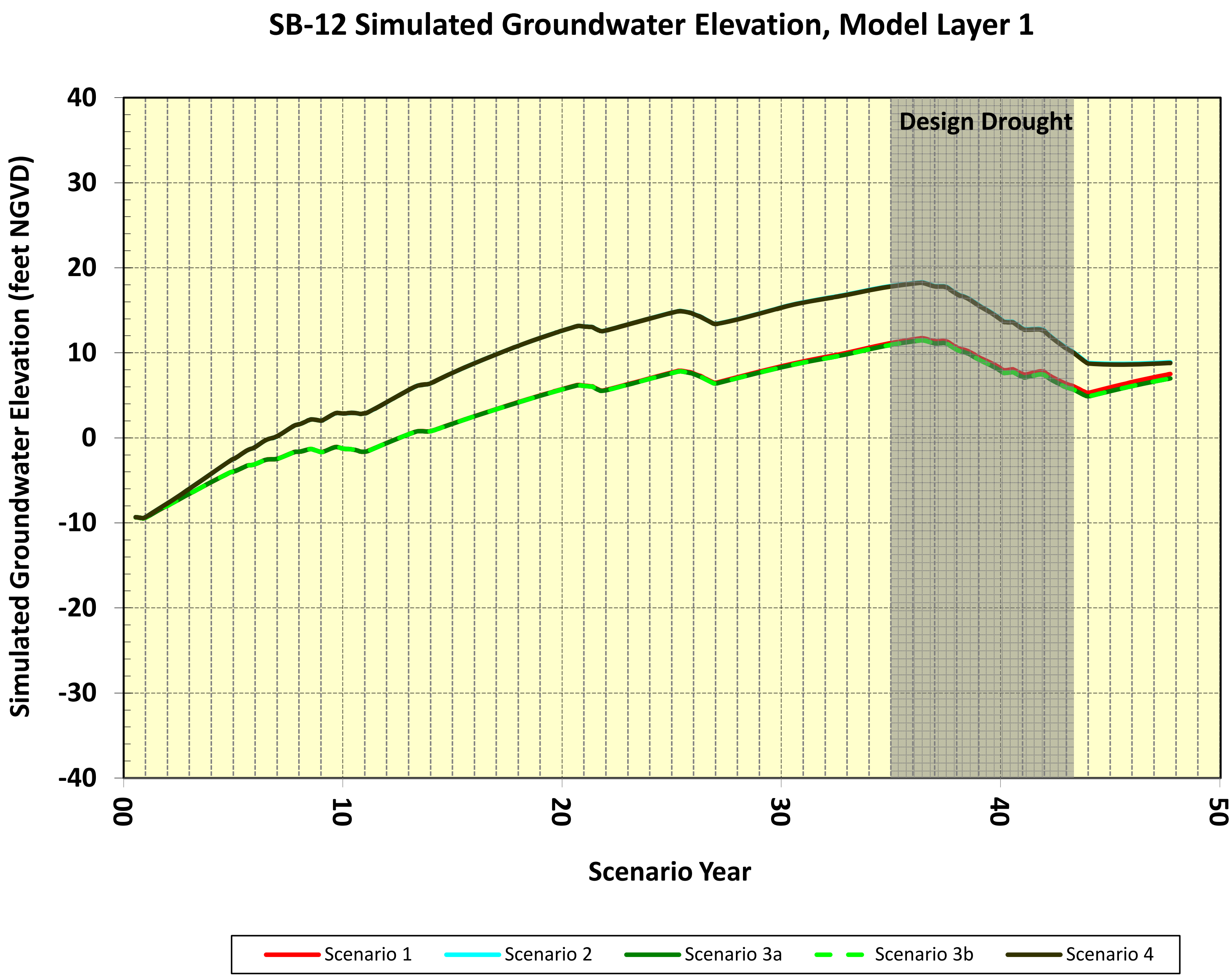

DC-A-St Simulated Groundwater Elevation, Model Layer 1
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
Design Drought
Dry cell in Model Layer 1
during Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

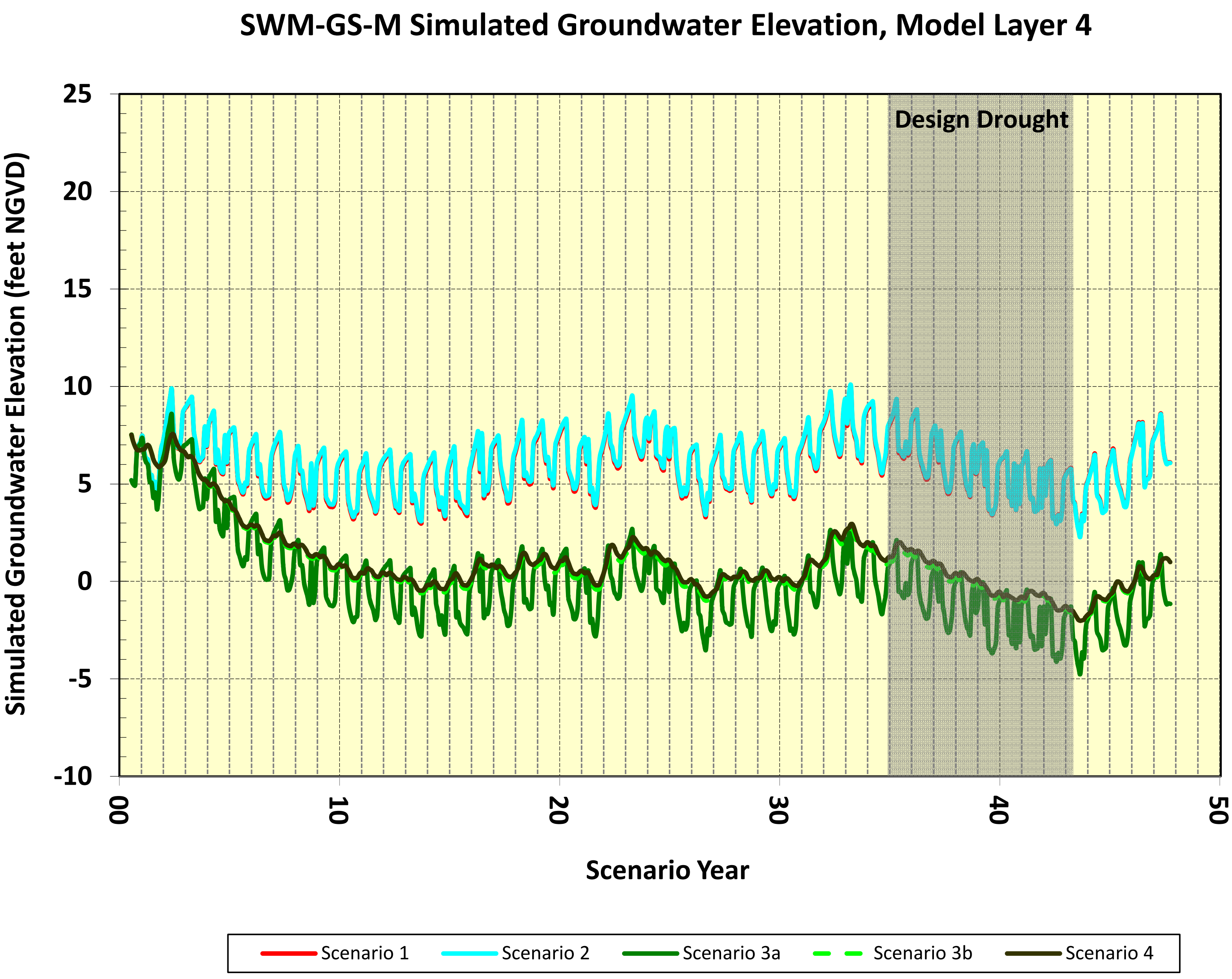


Cyp_Lawn_2 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-20
-40
-60
-80
-100
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

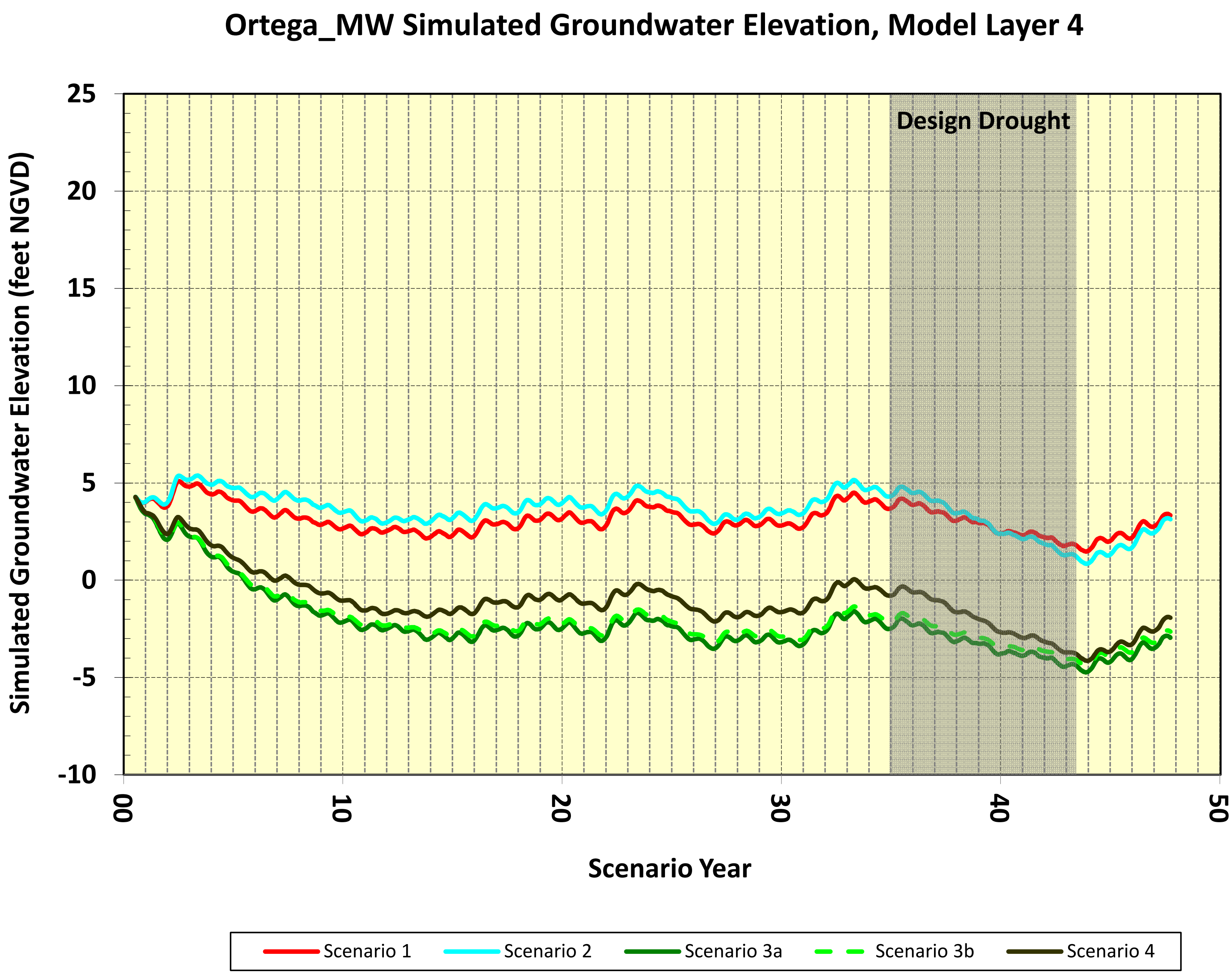


SSF-02 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
30
20
10
0
-10
-20
-30
-40
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

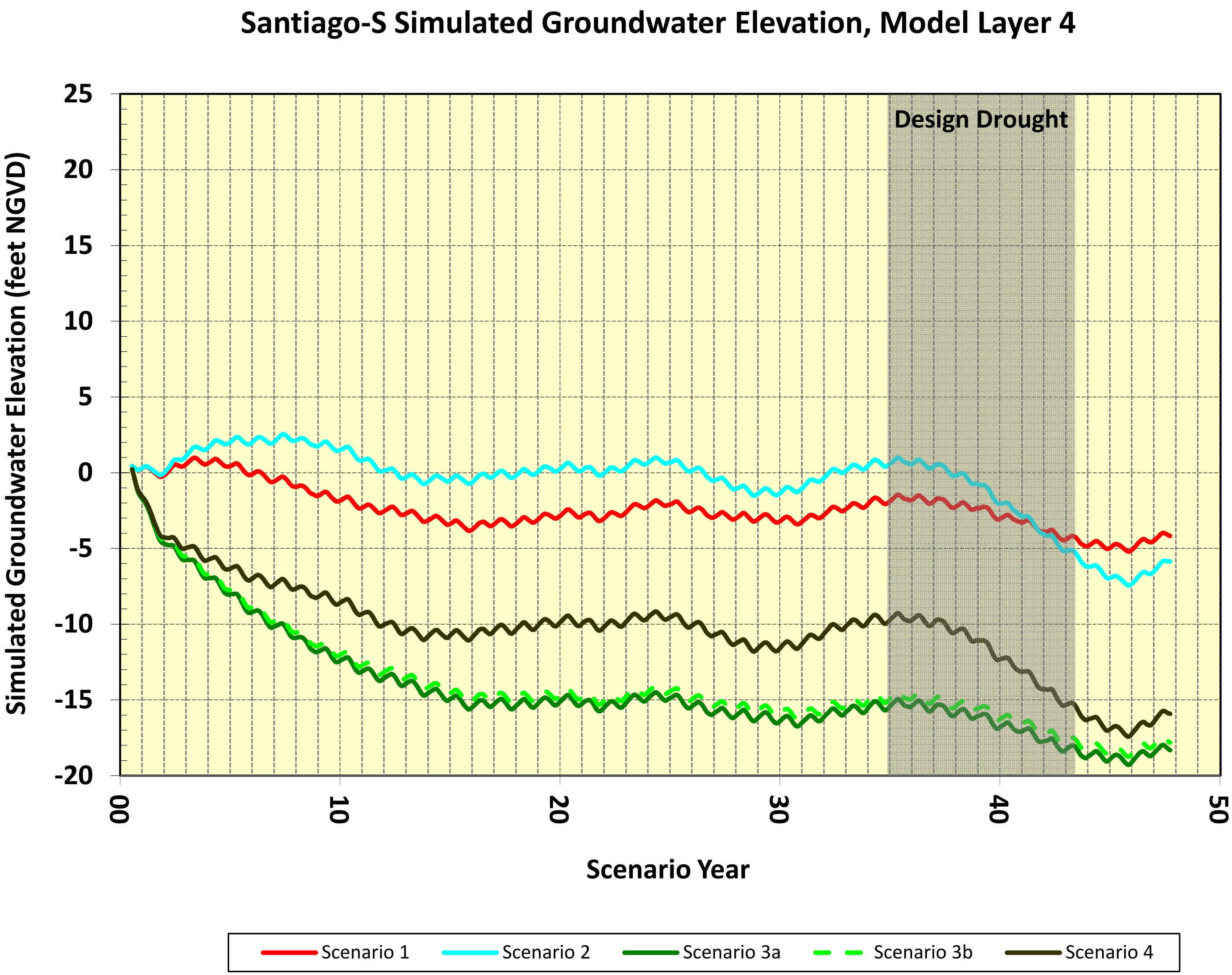

SB-12 Simulated Groundwater Elevation, Model Layer 1
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
30
20
10
0
-10
-20
-30
-40
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

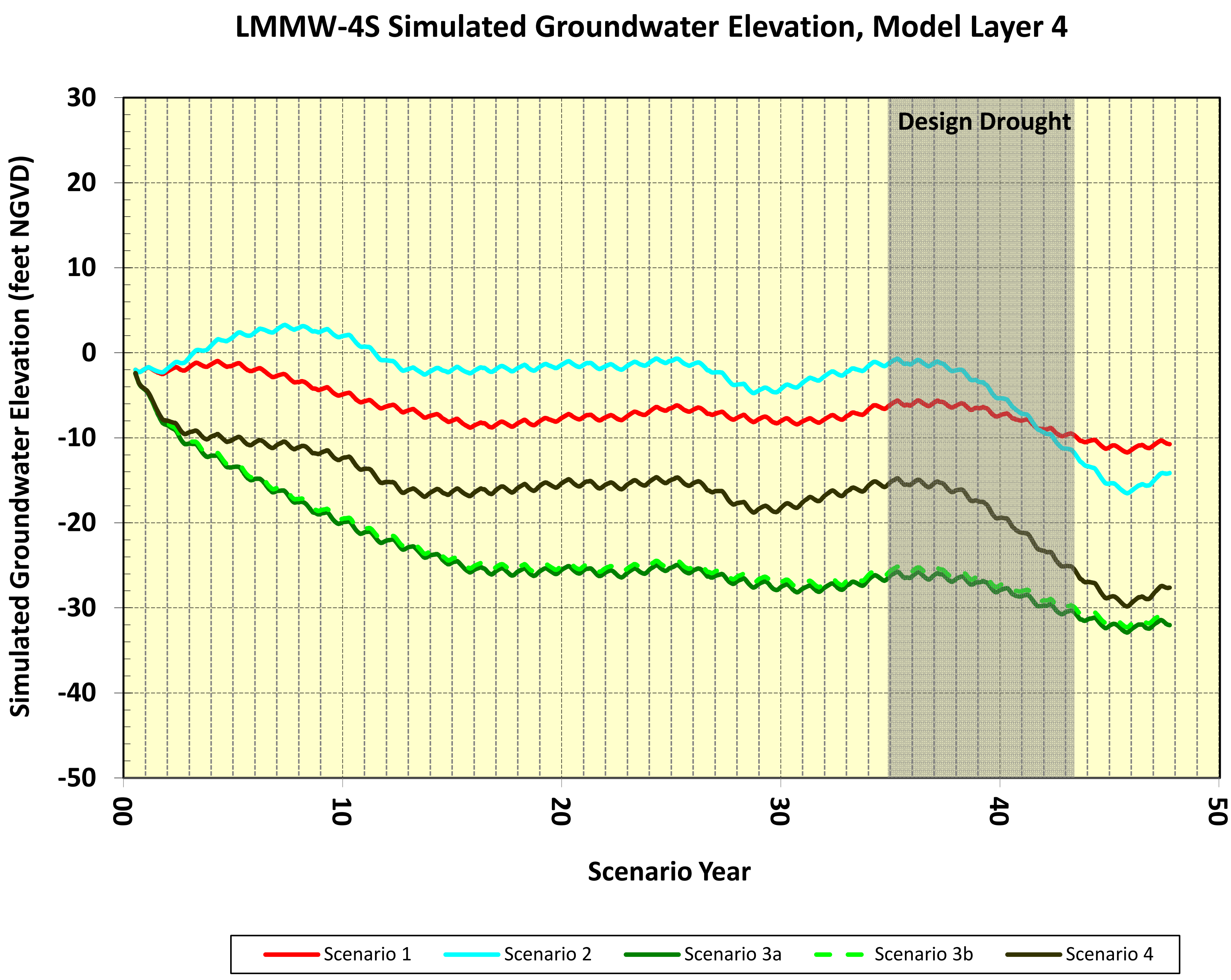


SWM-GS-M Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

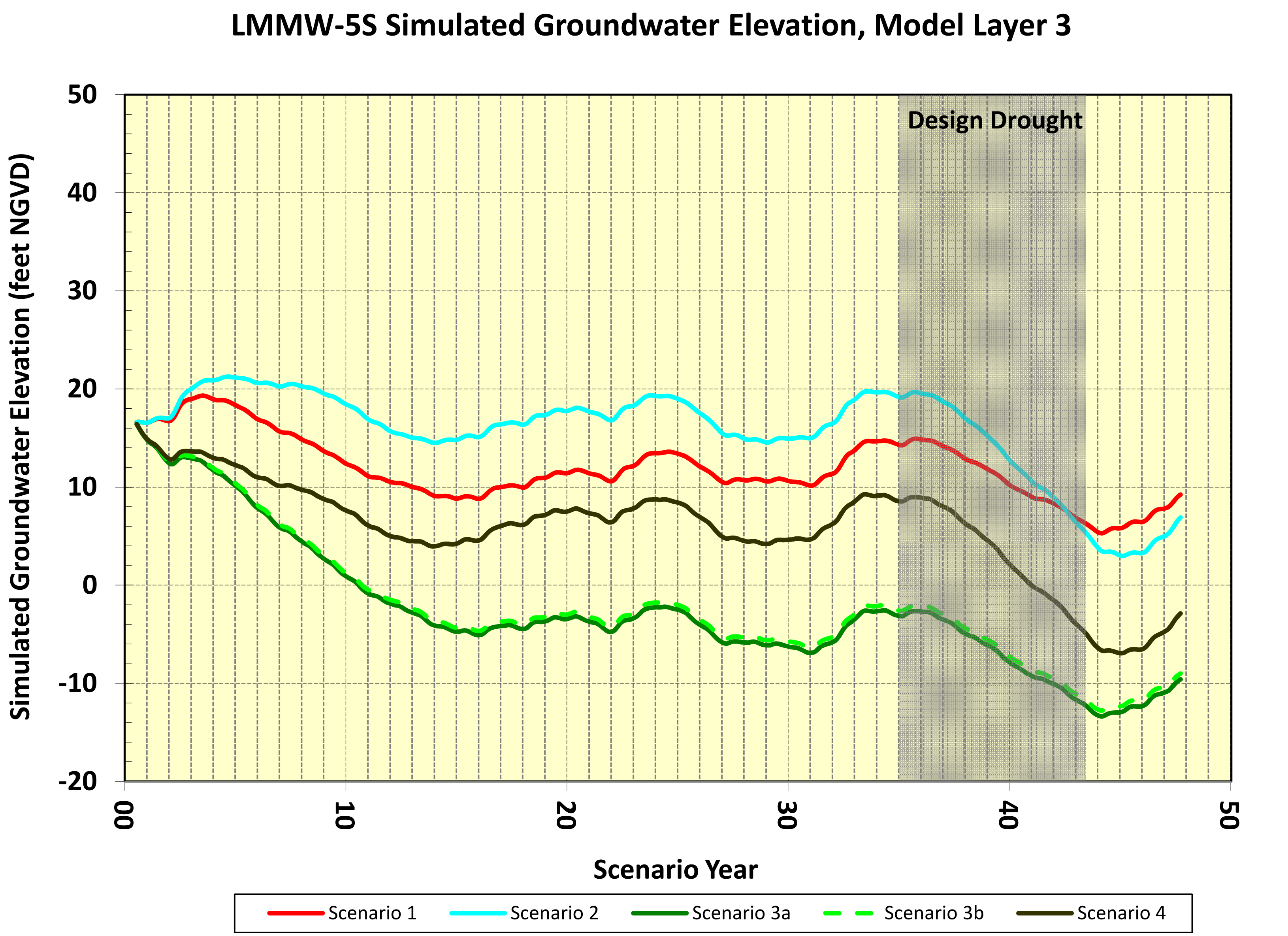


Ortega_MW Simulated Groundwater Elevation, Model Layer 4
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
Design Drought
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

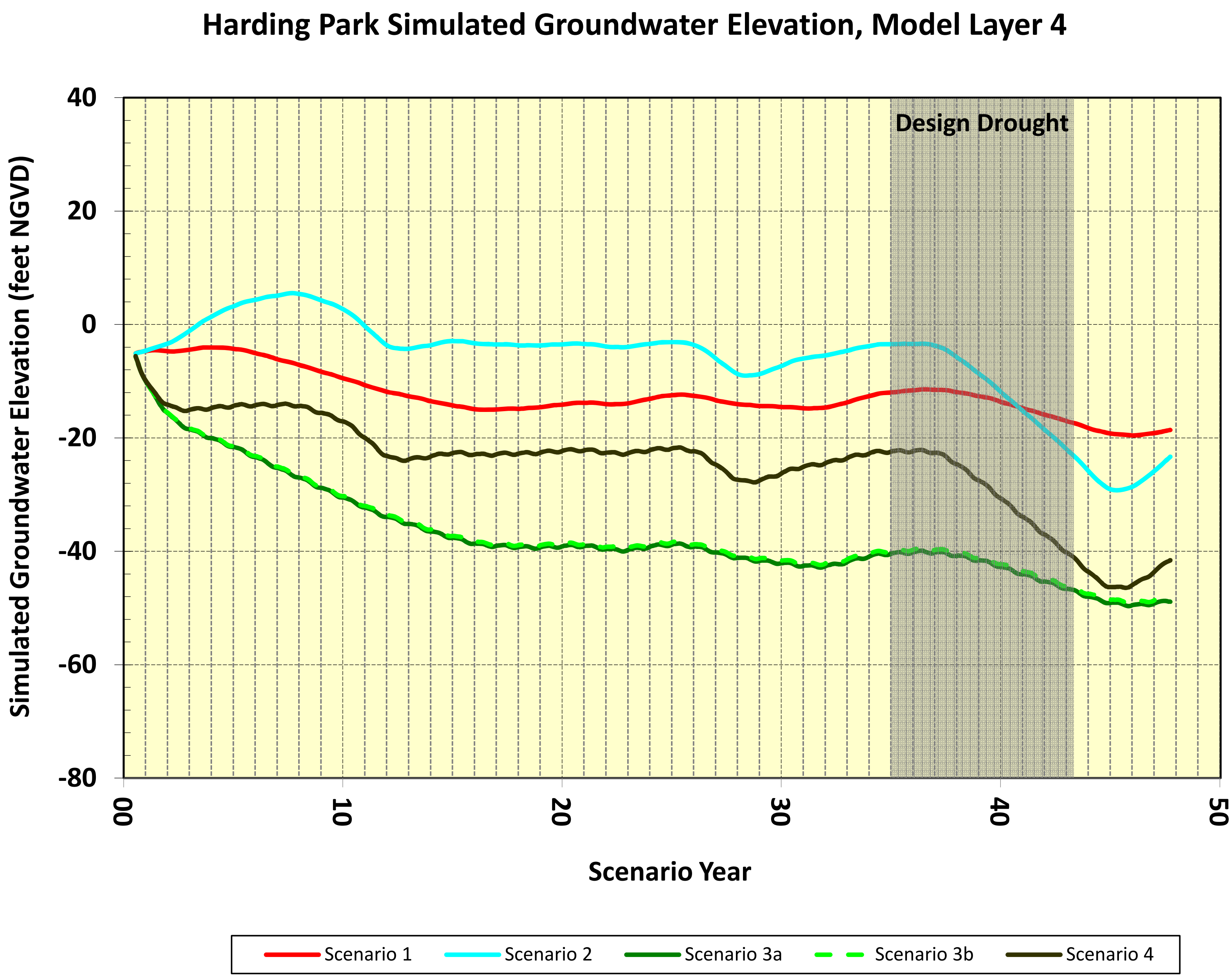

Santiago-S Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
25
20
15
10
5
0
-5
-10
-15
-20
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



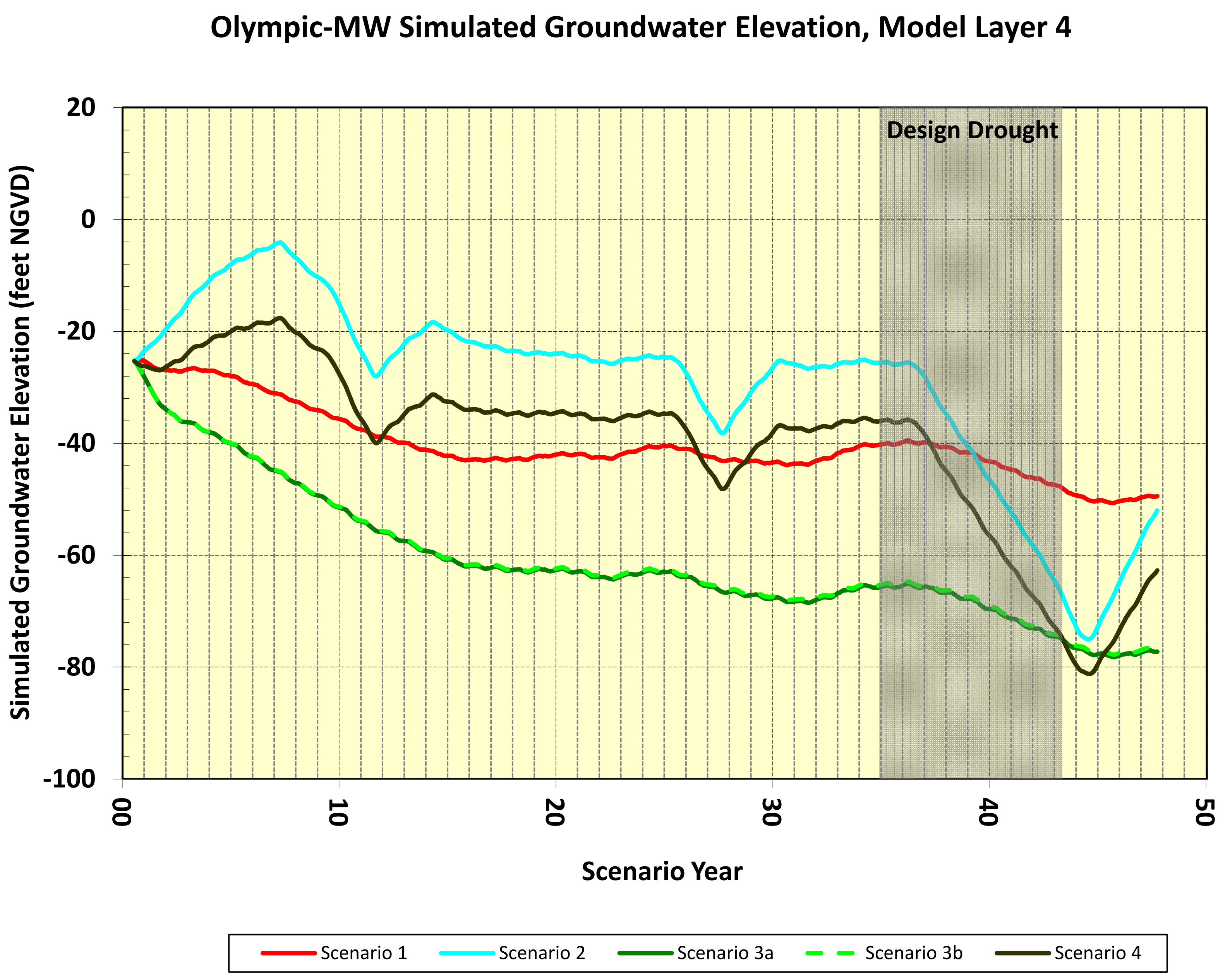
LMMW-4S Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
30
20
10
0
-10
-20
-30
-40
-50
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

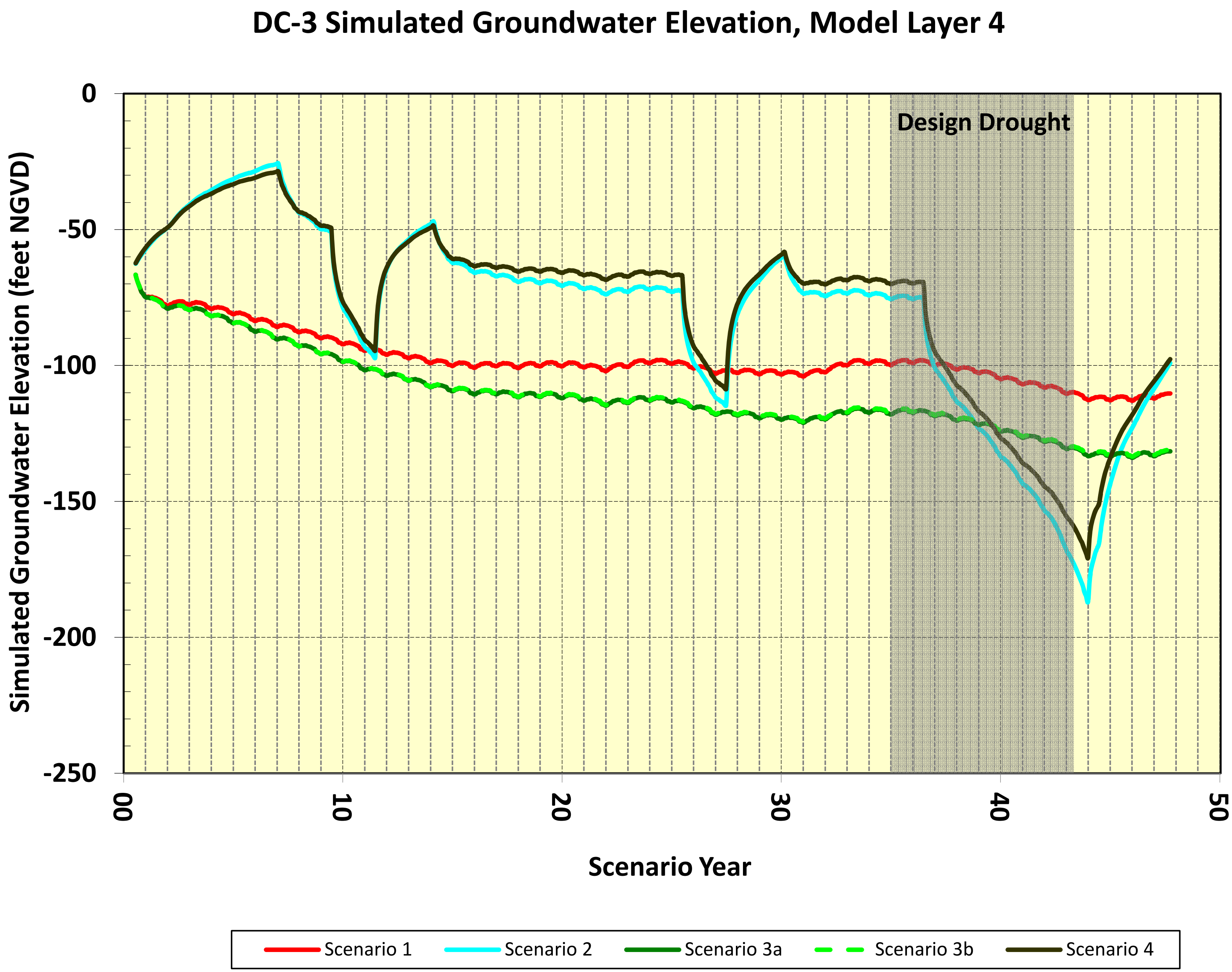


Note: At the location of LMMW-5S, the model does not contain layer 4. Layer 3 is presented in order to show the deepest layer response.

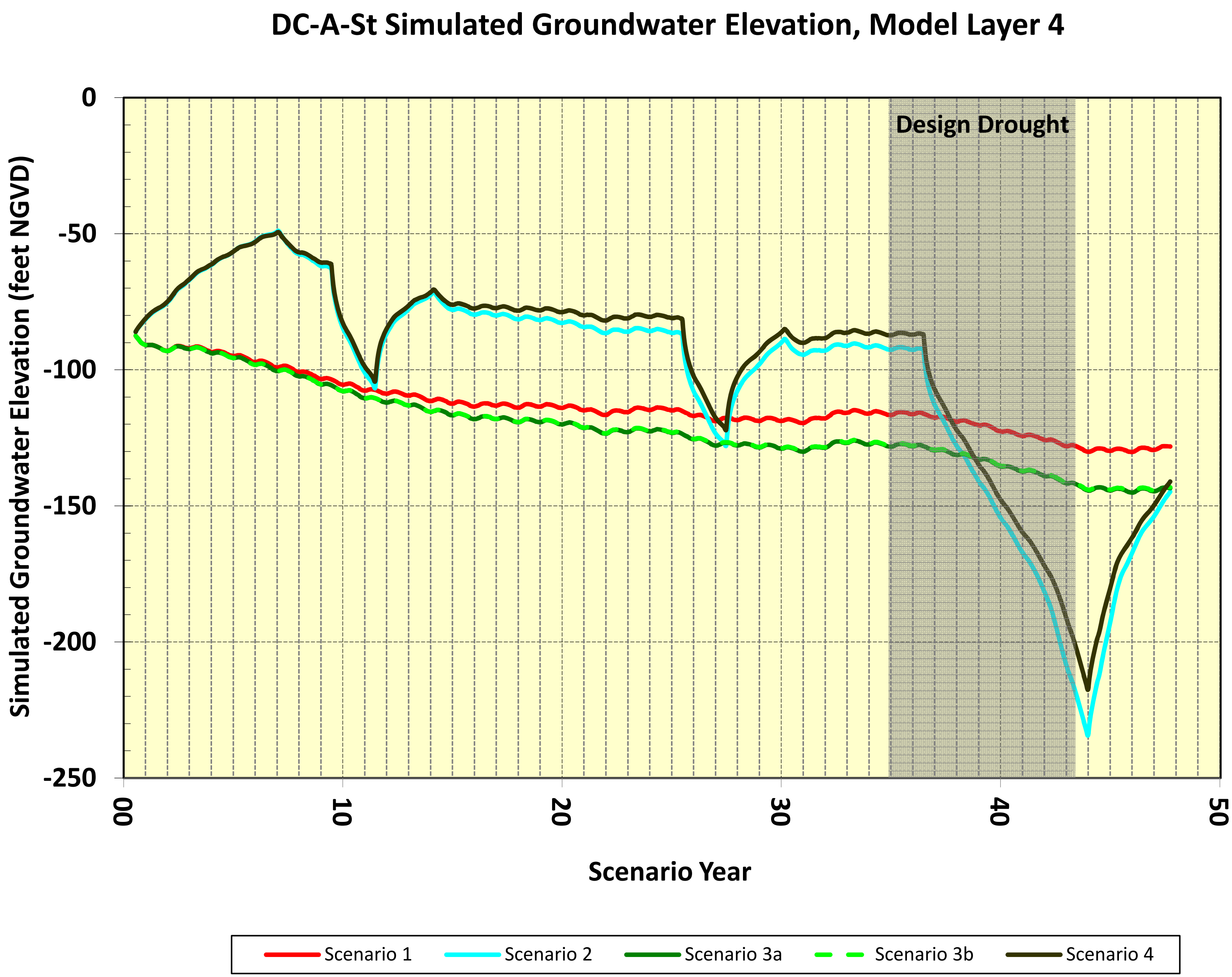


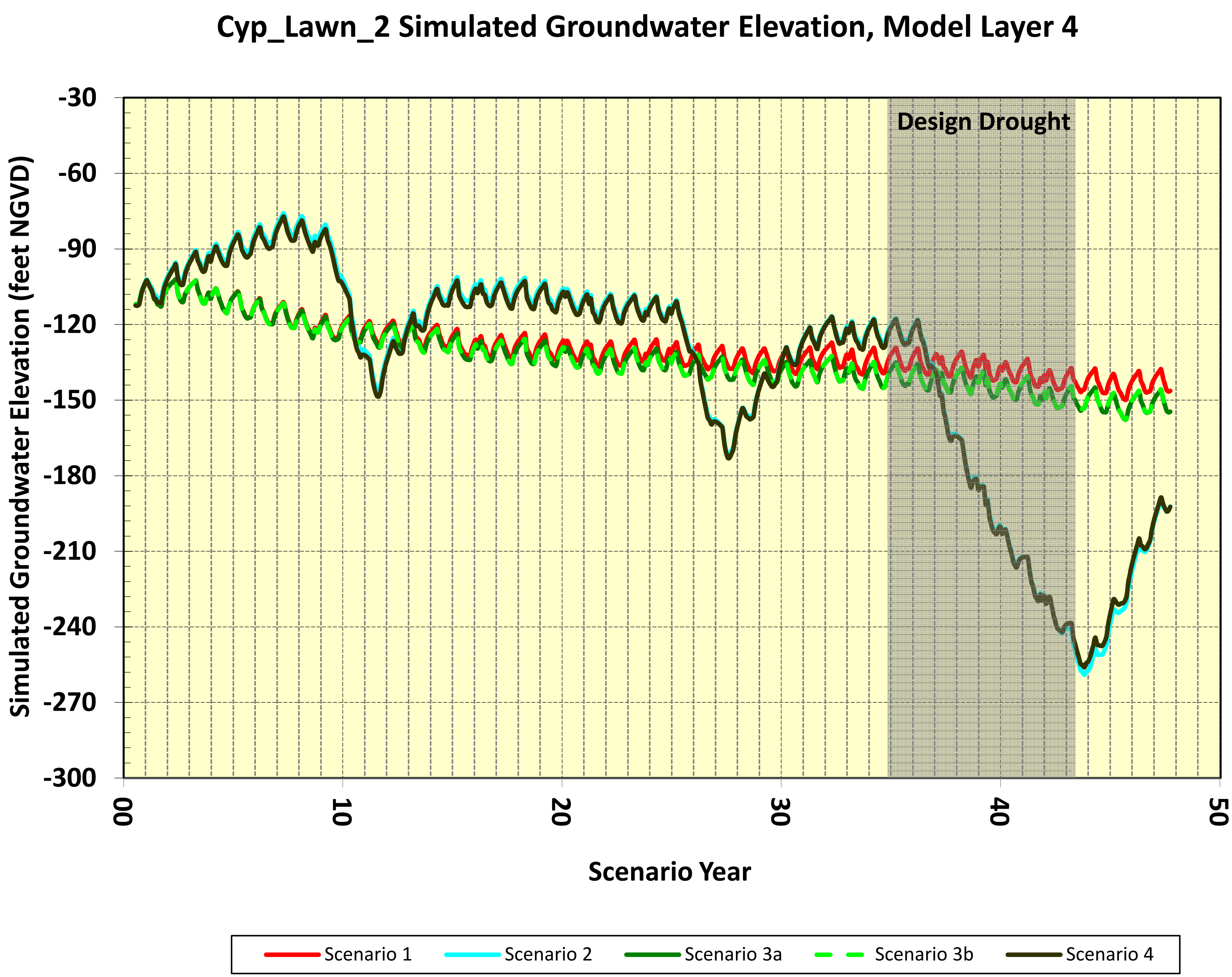
Harding Park Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
40
20
0
-20
-40
-60
-80
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4


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

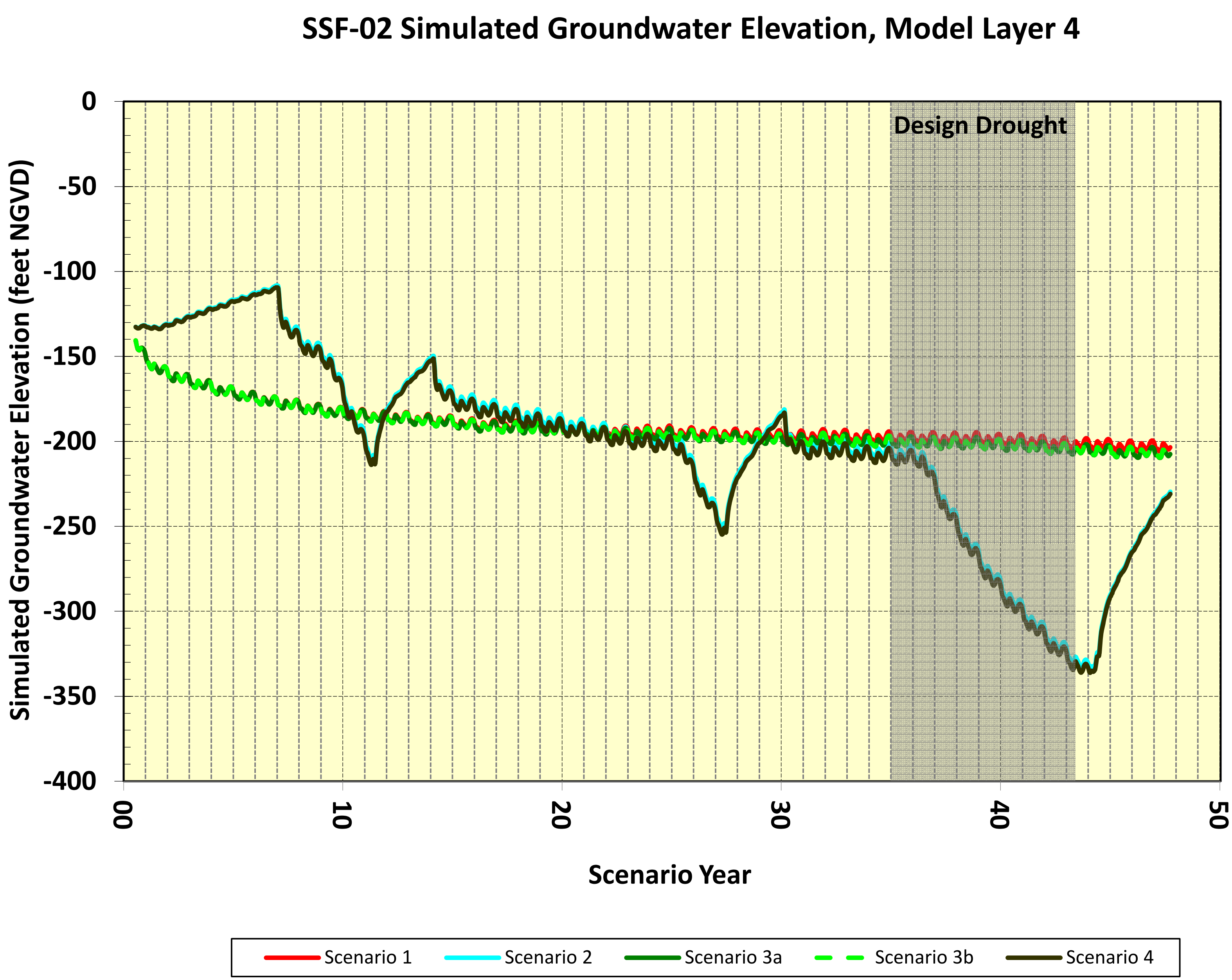


DC-3 Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

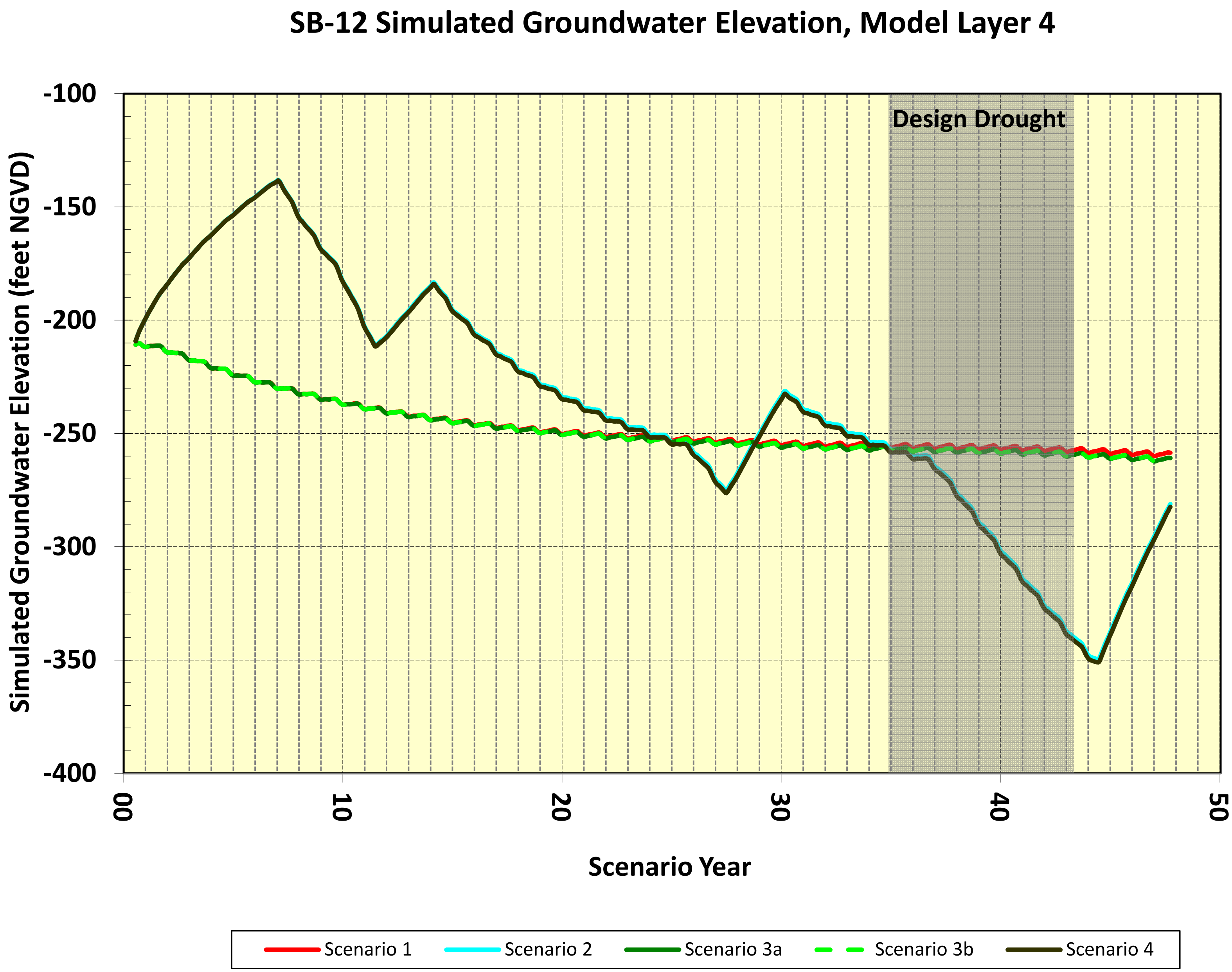

DC-A-St Simulated Groundwater Elevation, Model Layer 4
Design Drought
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
00
10
20
30
40
50
Scenario Year
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4



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
Simulated Groundwater Elevation (feet NGVD)
0
-50
-100
-150
-200
-250
-300
-350
-400
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
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

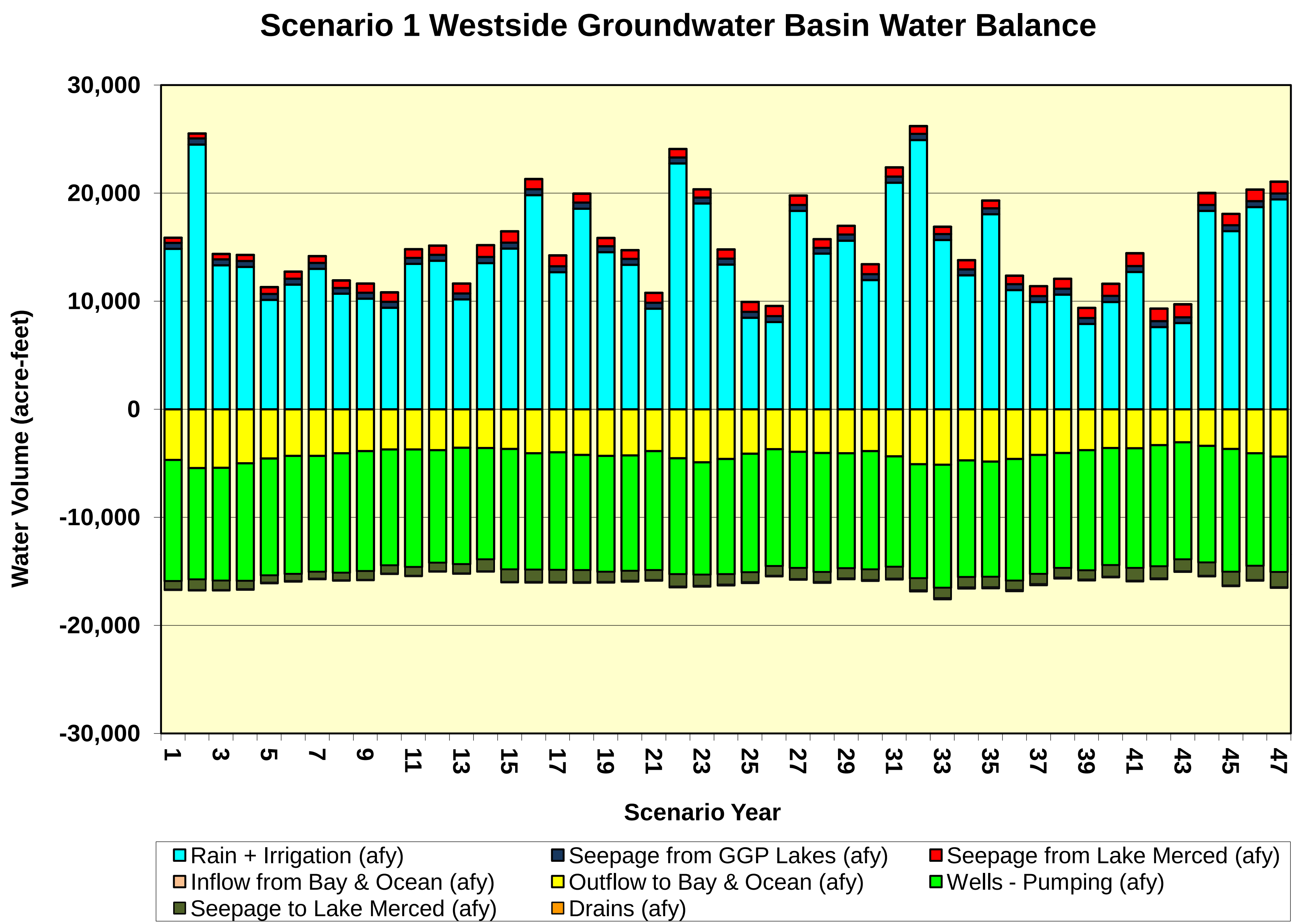
Model Scenario Water Balance Results – Westside Basin

Scenario 1 Westside Groundwater Basin Water Balance Summary

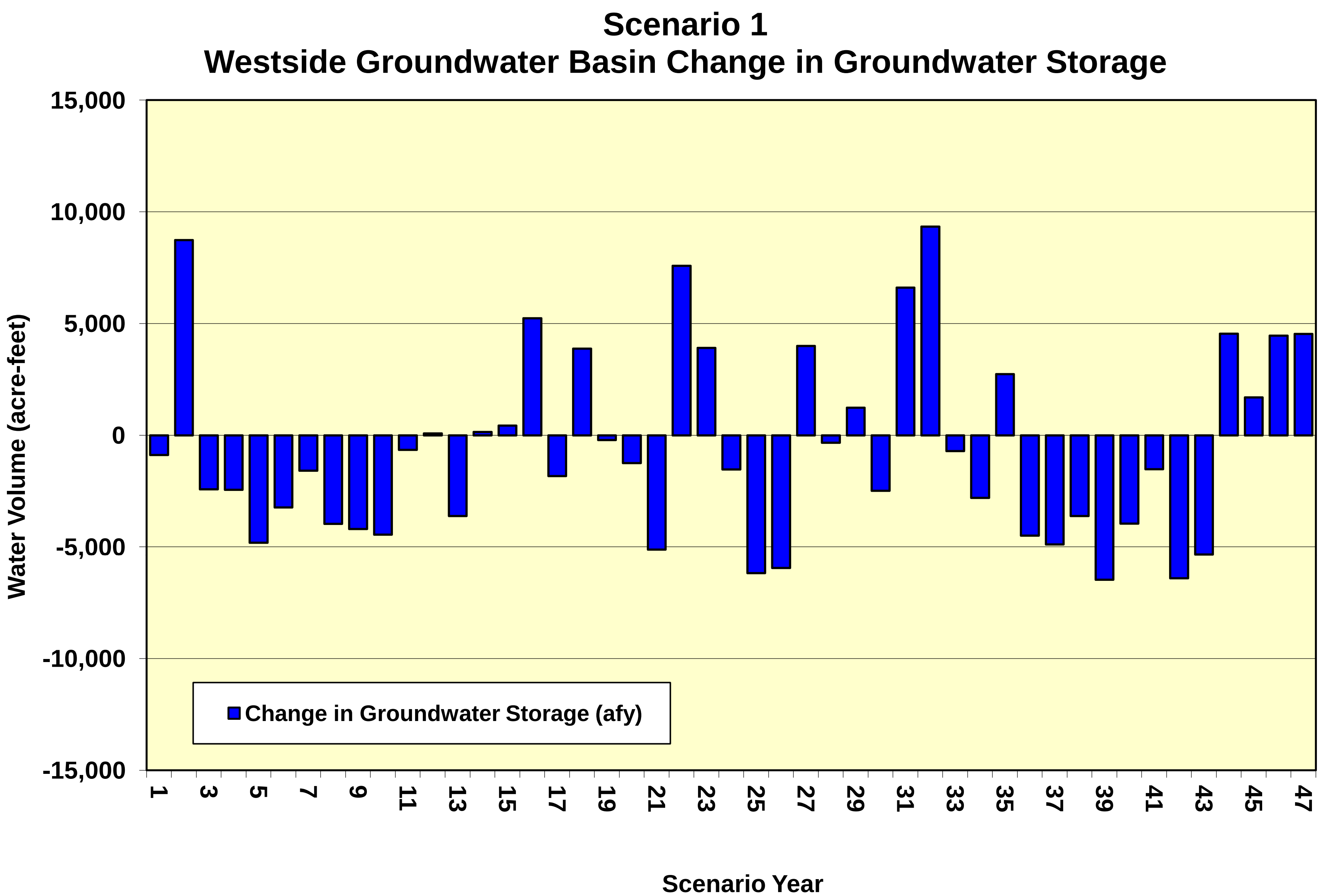
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	5	546	14,845	464	-4,684	-11,229	-753	-71	-877
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**

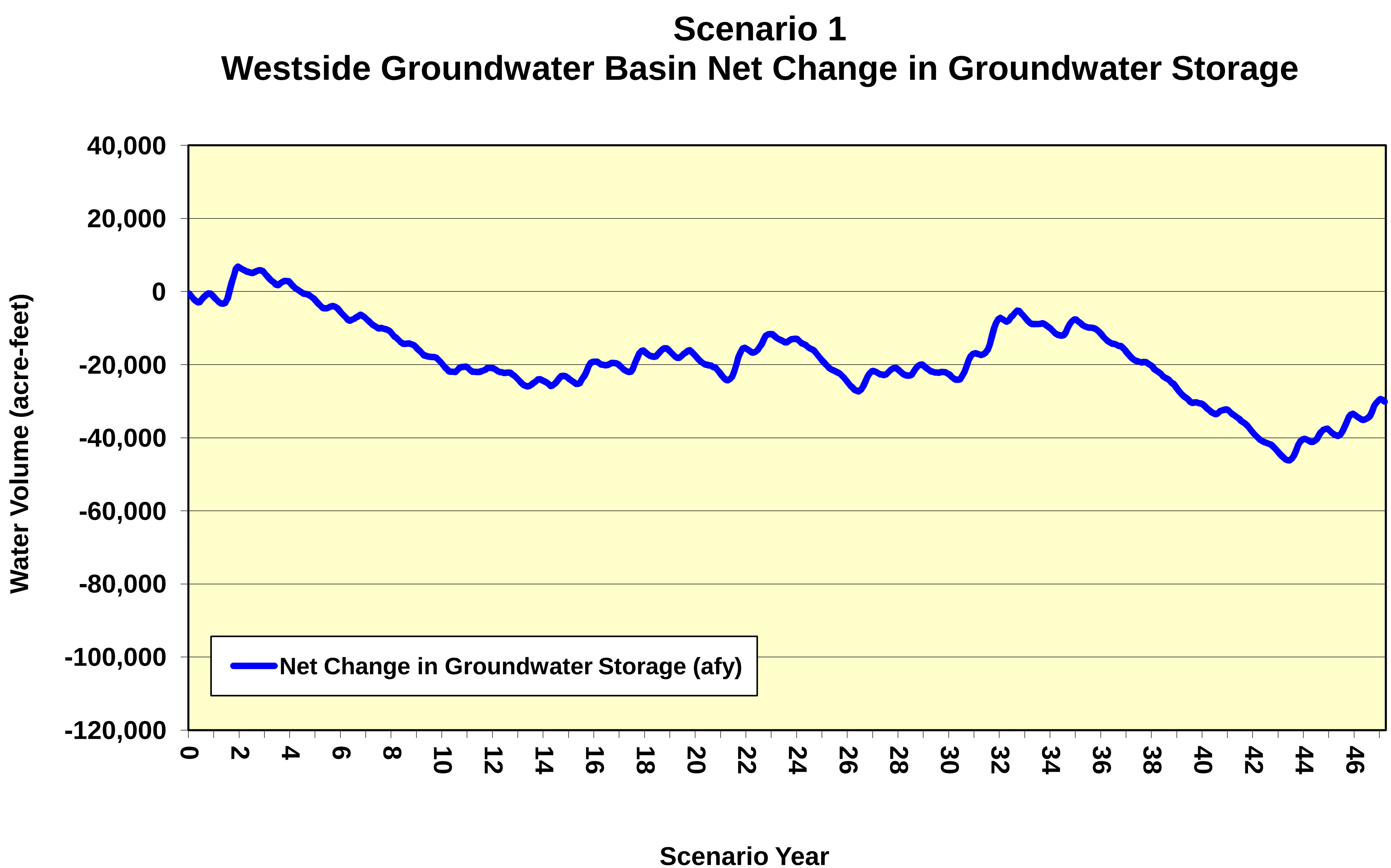
Key:
afy - acre-feet per year
GGP - Golden Gate Park

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

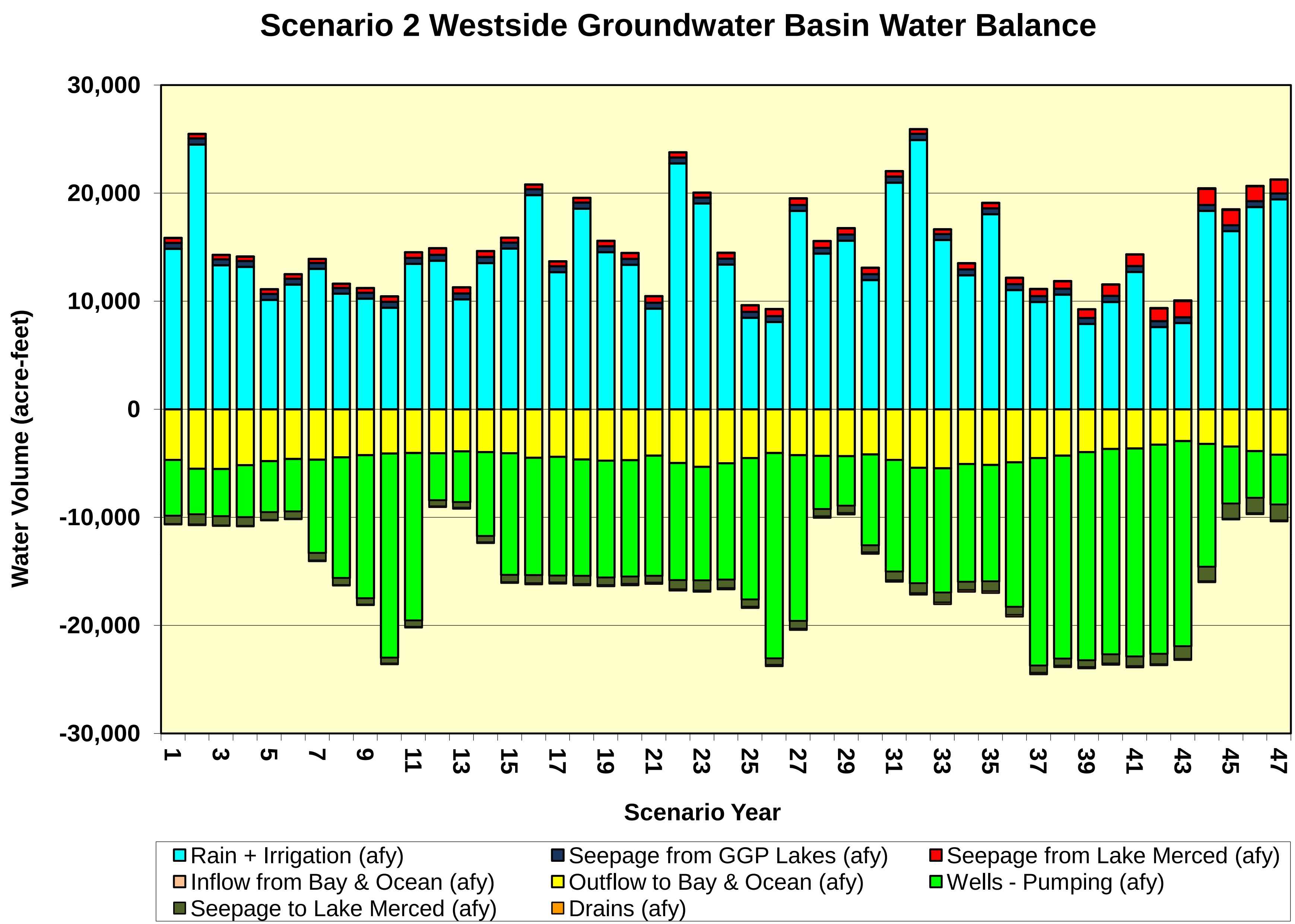

Scenario 1
Westside Groundwater Basin Net Change in Groundwater Storage
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
-100,000
-120,000
Water Volume (acre-feet)
Net Change in Groundwater Storage (afy)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
Scenario Year

Scenario 2 Westside Groundwater Basin Water Balance Summary

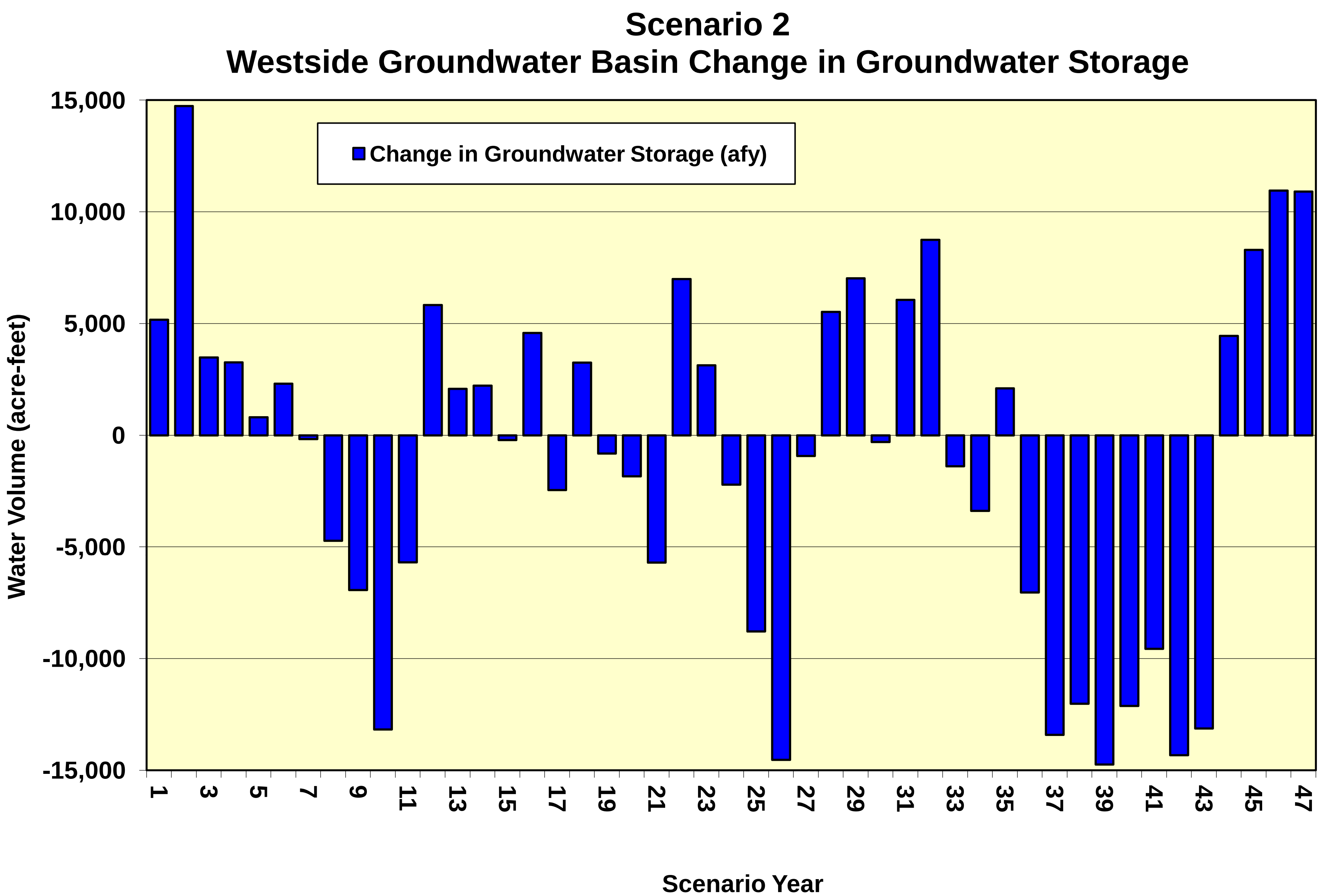
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	5	546	14,845	452	-4,698	-5,157	-754	-71	5,168
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**

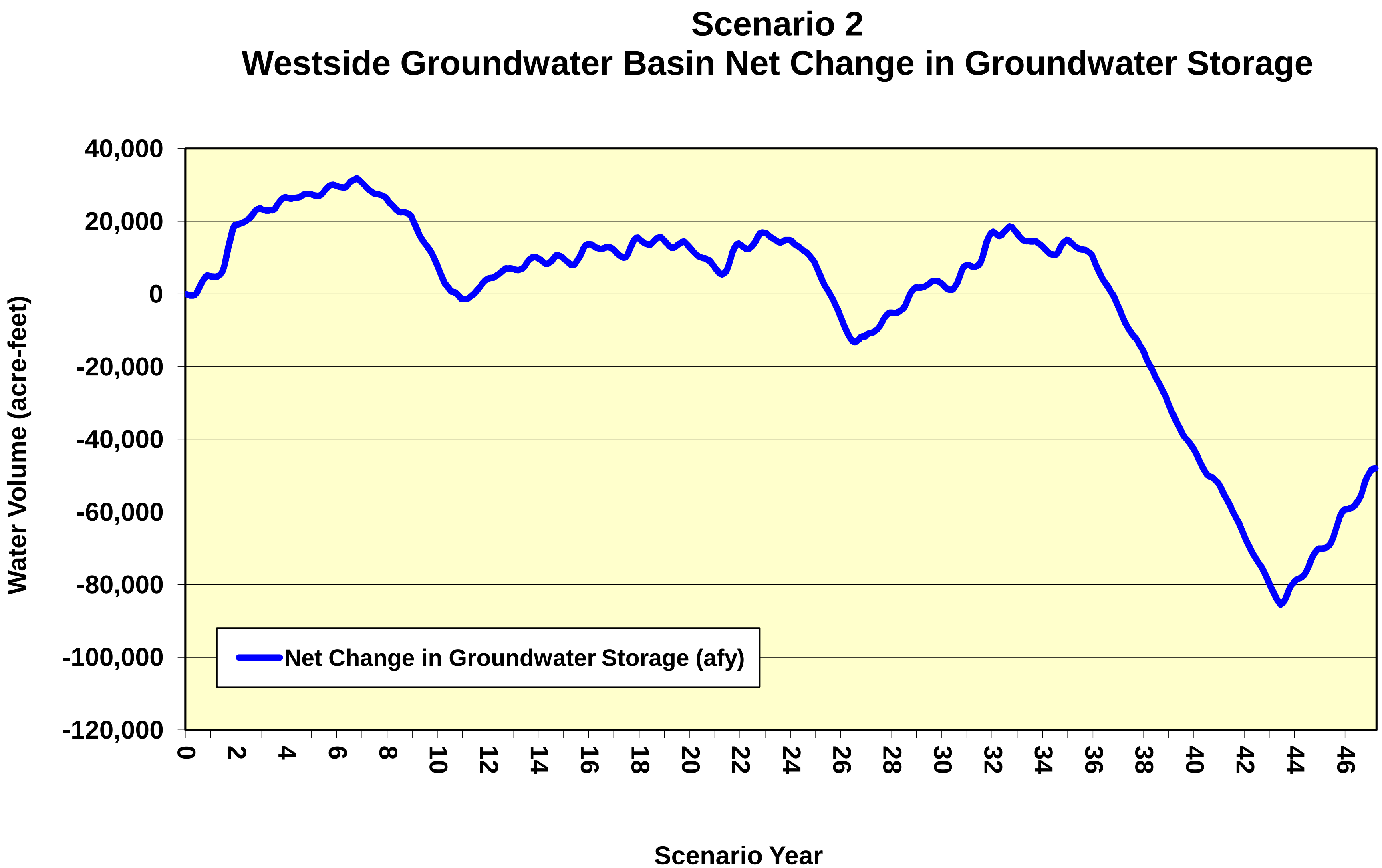
Key:
afy - acre-feet per year
GGP - Golden Gate Park

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



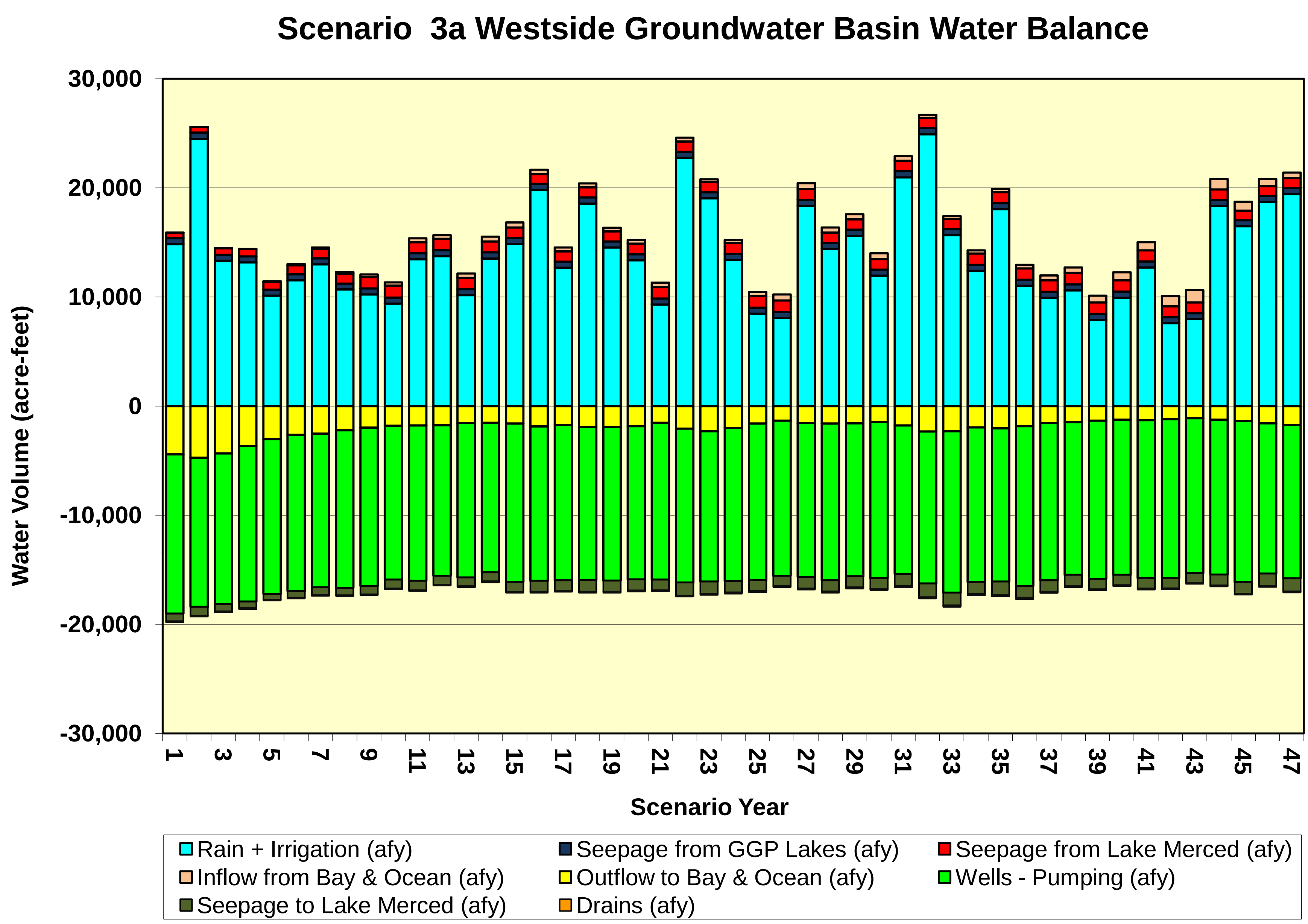
Scenario 2
Westside Groundwater Basin Net Change in Groundwater Storage
Water Volume (acre-feet)
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
-100,000
-120,000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
Scenario Year
Net Change in Groundwater Storage (afy)

Scenario 3a Westside Groundwater Basin Water Balance Summary

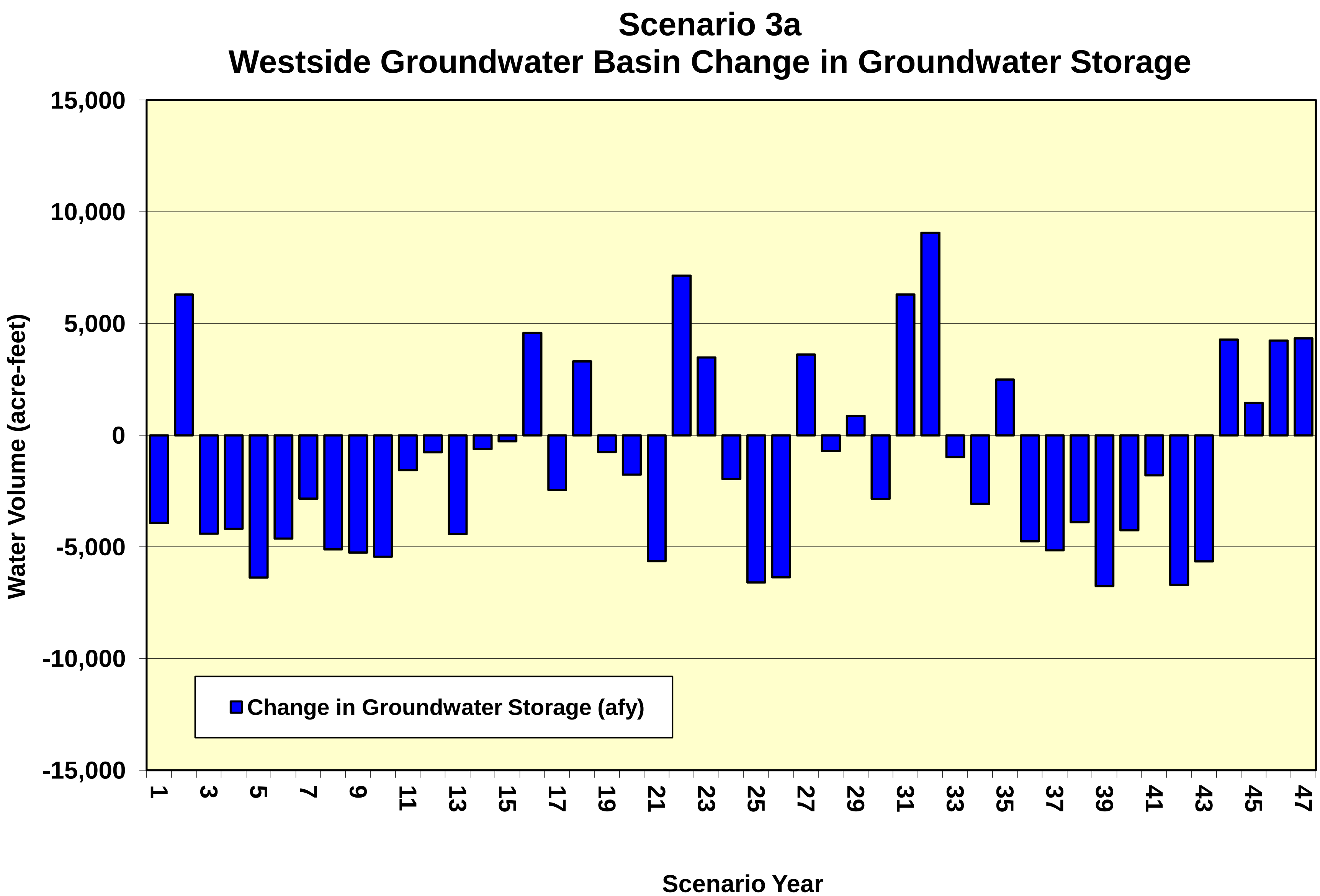
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	5	546	14,845	485	-4,415	-14,603	-712	-71	-3,919
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
Water Volume (acre-feet)
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Change in Groundwater Storage (afy)
1
3
5
7
9
11
13
15
17
19
21
23
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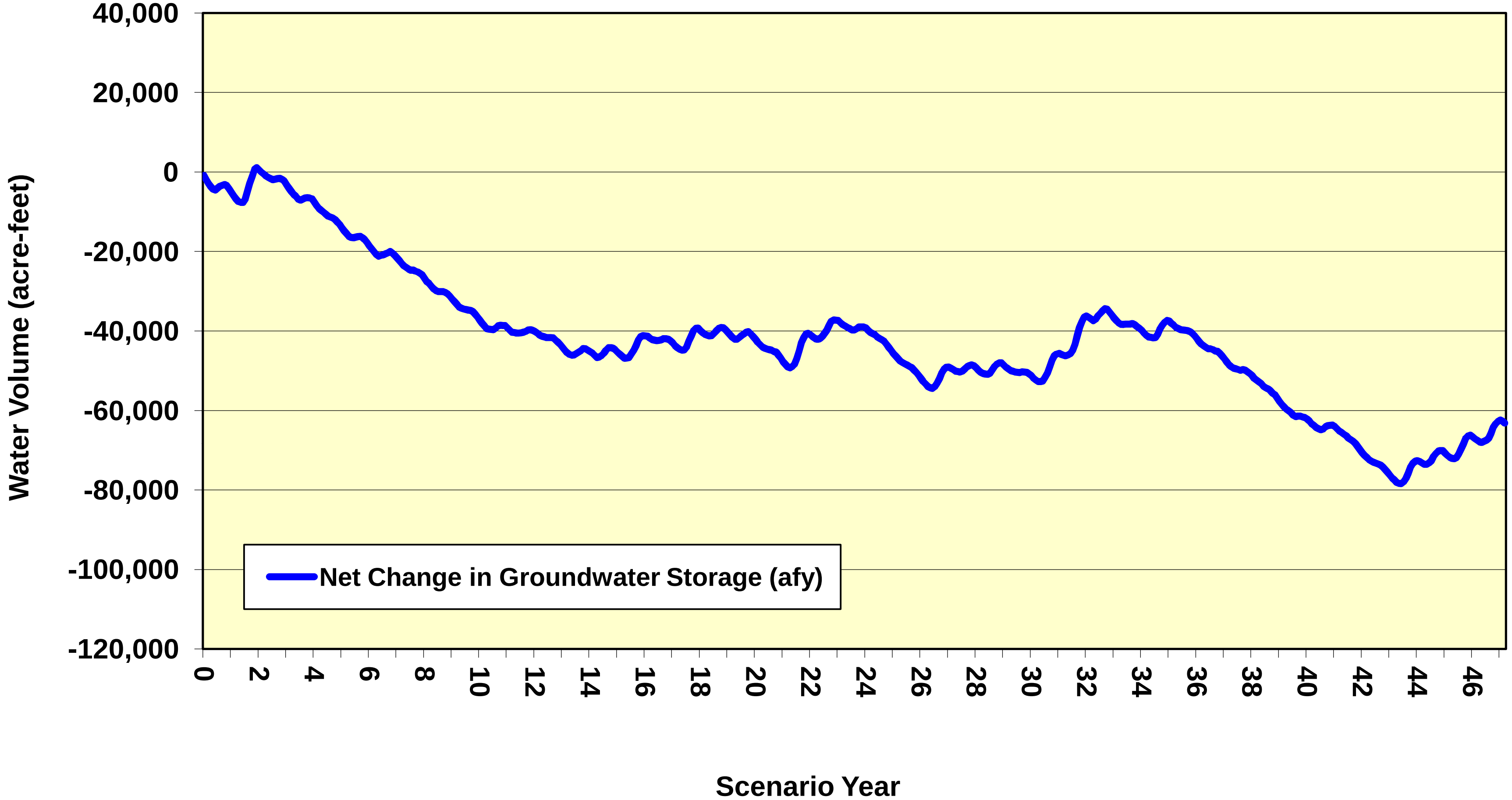
Scenario Year

Scenario 3a
Westside Groundwater Basin Net Change in Groundwater Storage

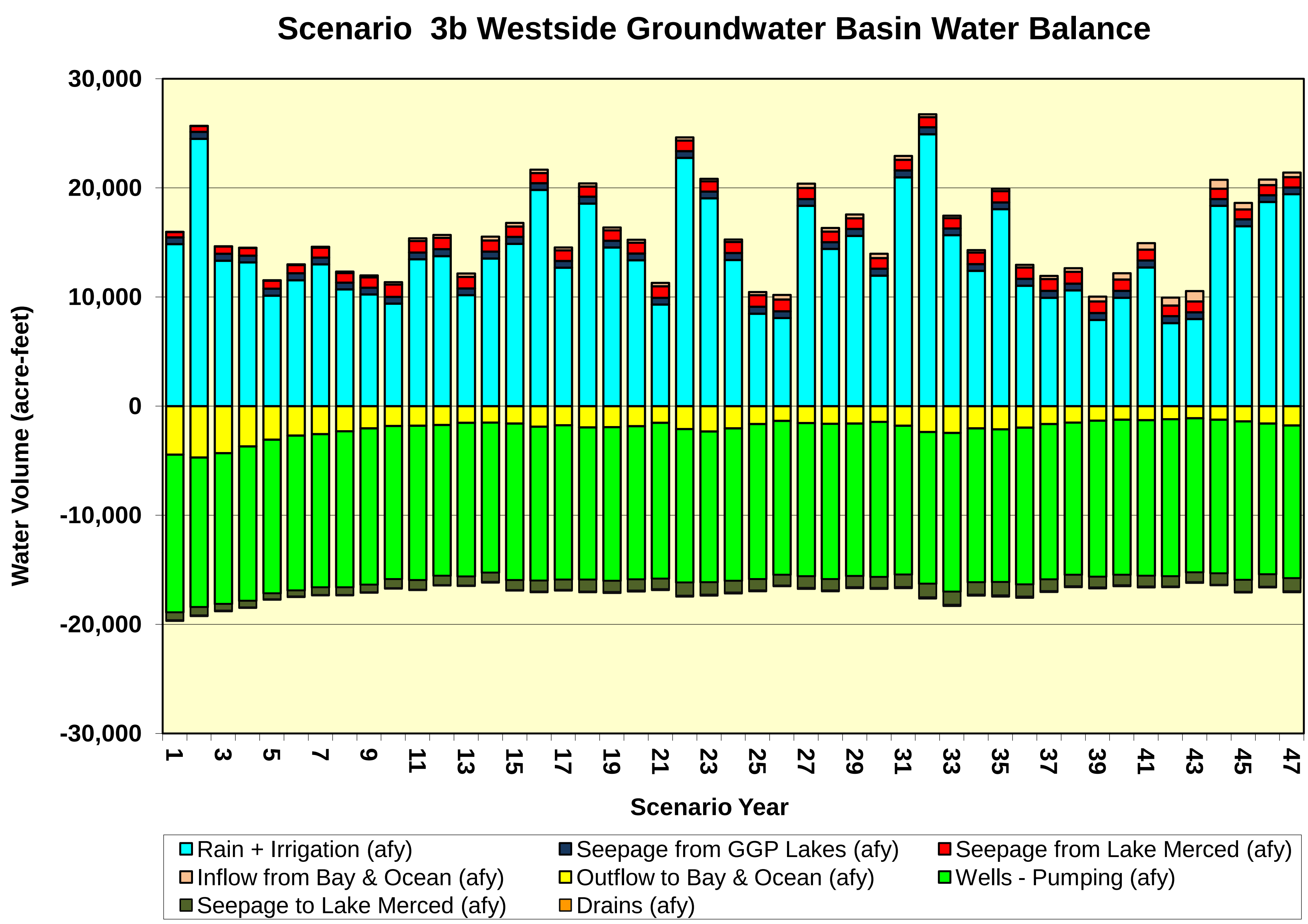


Scenario 3b Westside Groundwater Basin Water Balance Summary

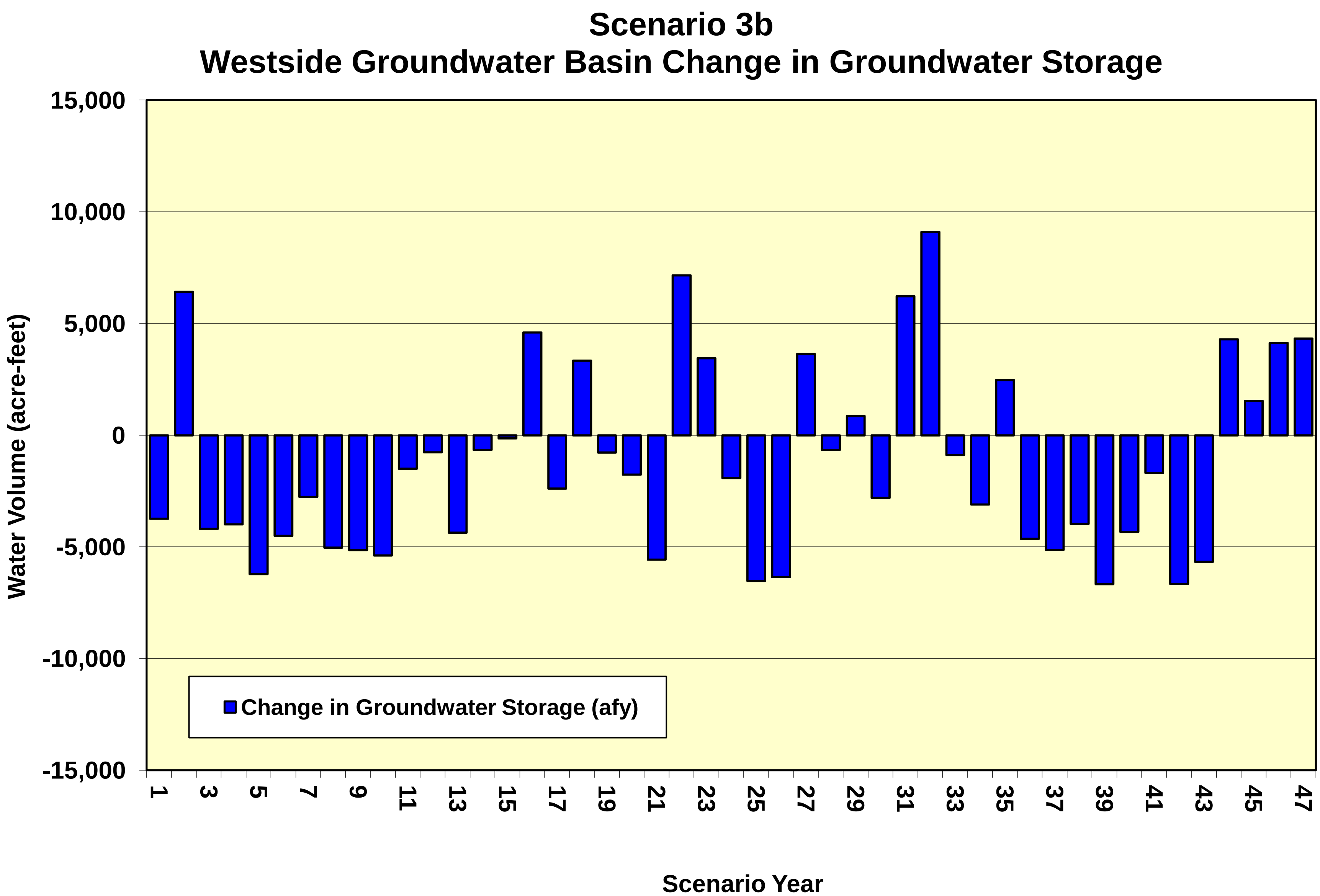
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	5	626	14,845	485	-4,455	-14,452	-713	-71	-3,730
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
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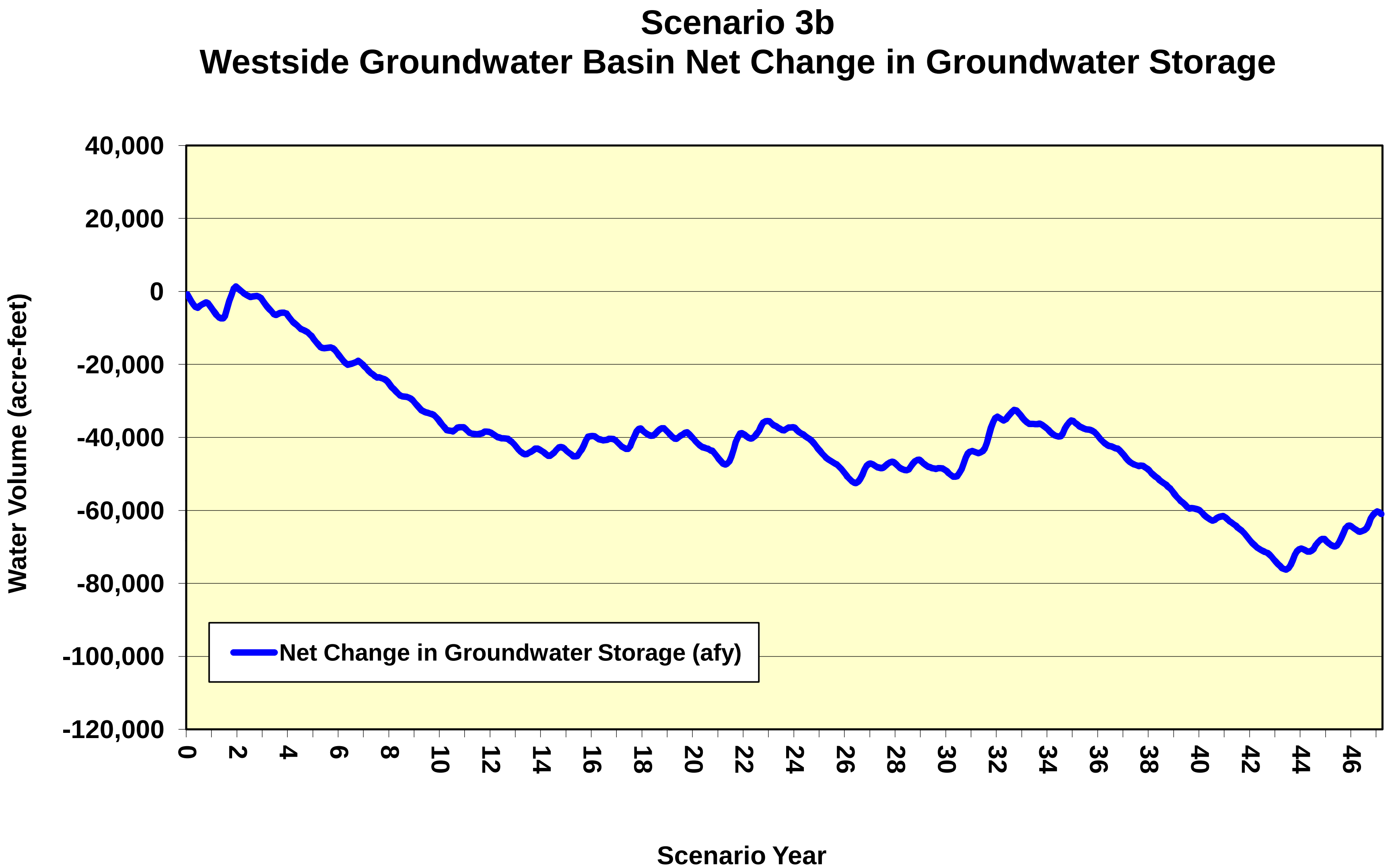
Scenario Year



Scenario 3b
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
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46
Scenario Year
Net Change in Groundwater Storage (afy)

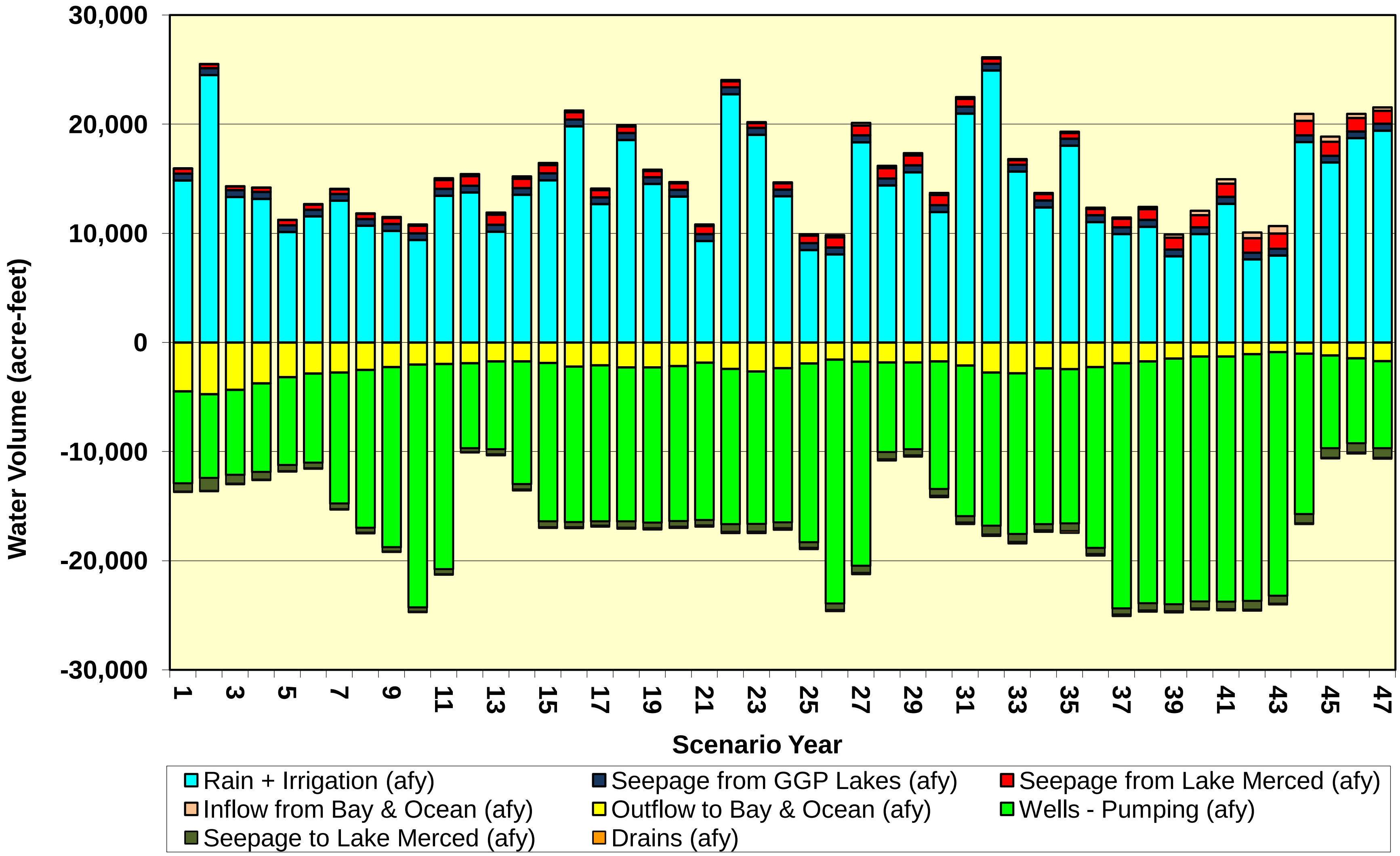
Scenario 4 Westside Groundwater Basin Water Balance Summary

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**

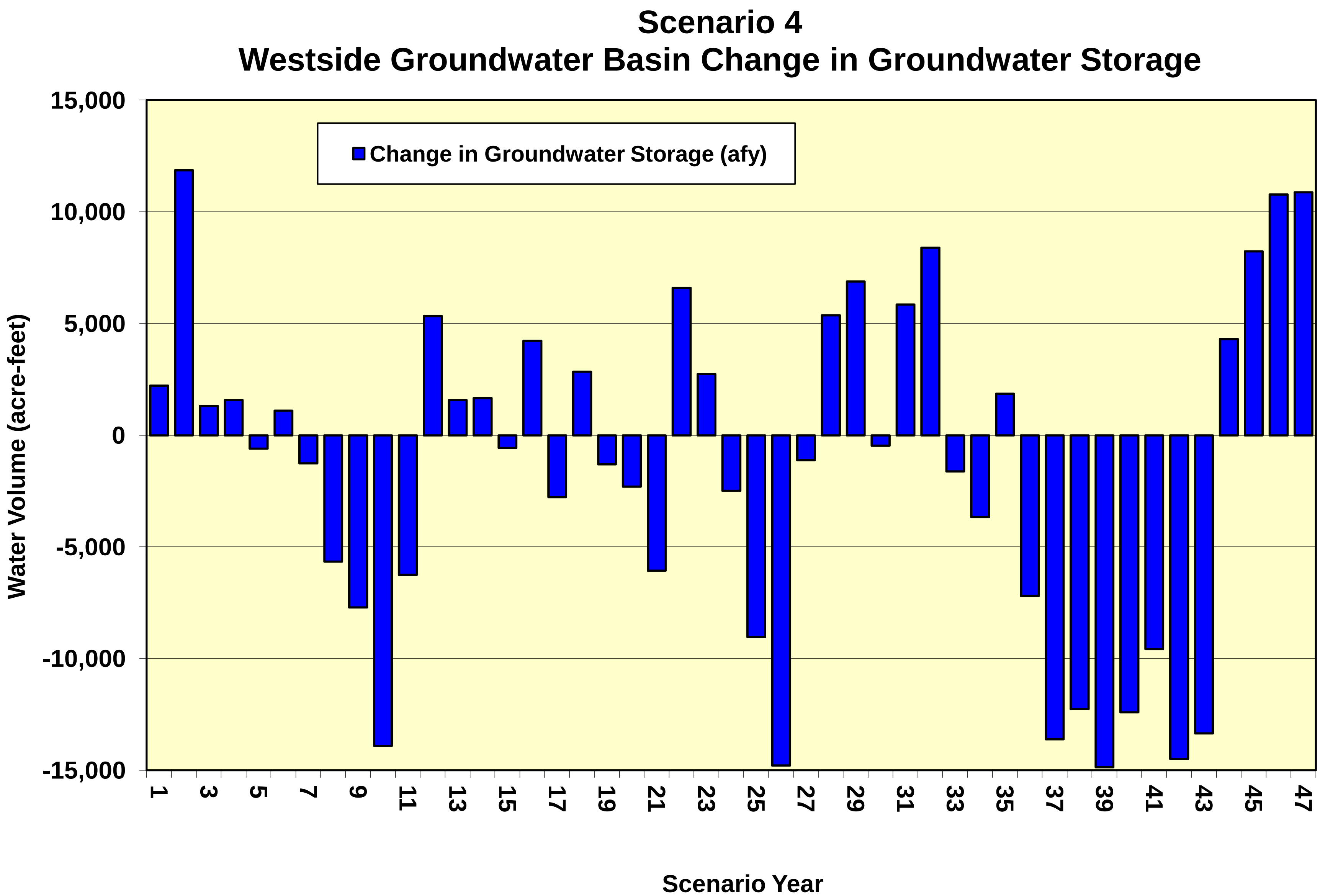
Key:
afy - acre-feet per year
GGP - Golden Gate Park

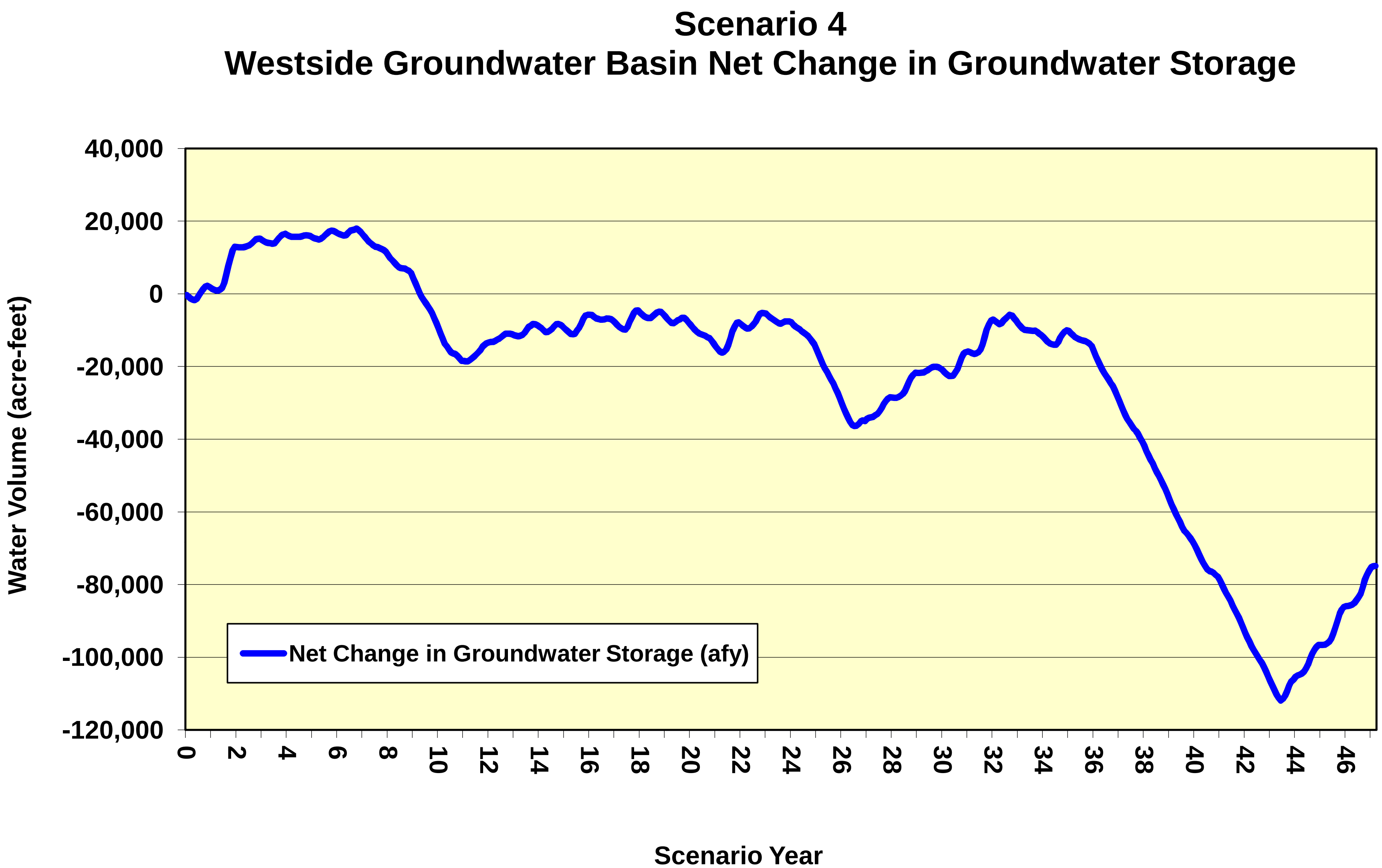
Note: Water balance components represent annual average values on a water year basis. The sign convention is positive for groundwater flowing into the groundwater basin (inflows). The sign convention is negative for groundwater flowing out of the groundwater basin (outflows). This is consistent with 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.

Scenario 4 Westside Groundwater Basin Water Balance



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)
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 4
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)
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
Net Change in Groundwater Storage (afy)

Attachment 10.1-D

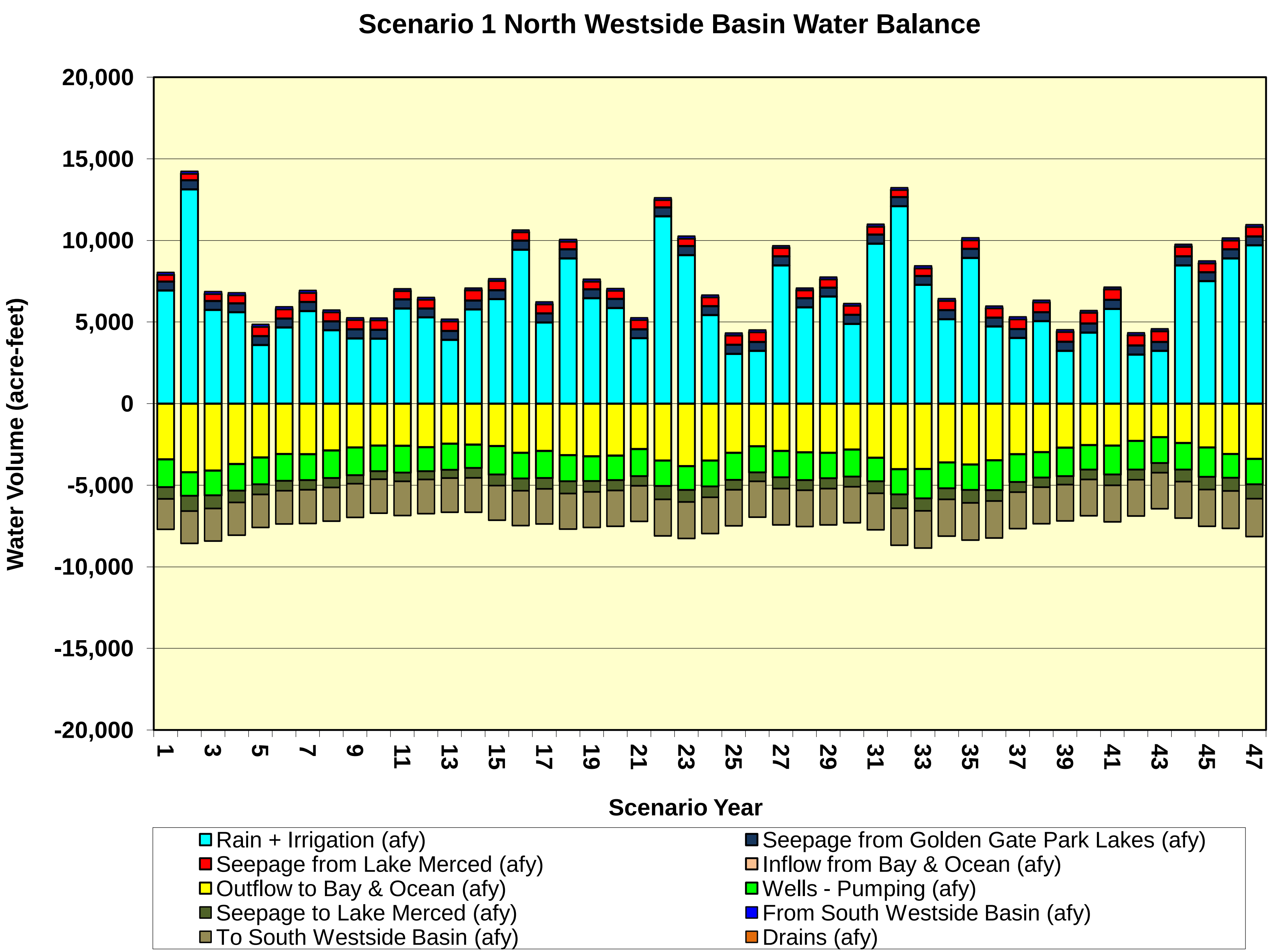
Model Scenario Water Balance Results – North and South Westside Basins

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**

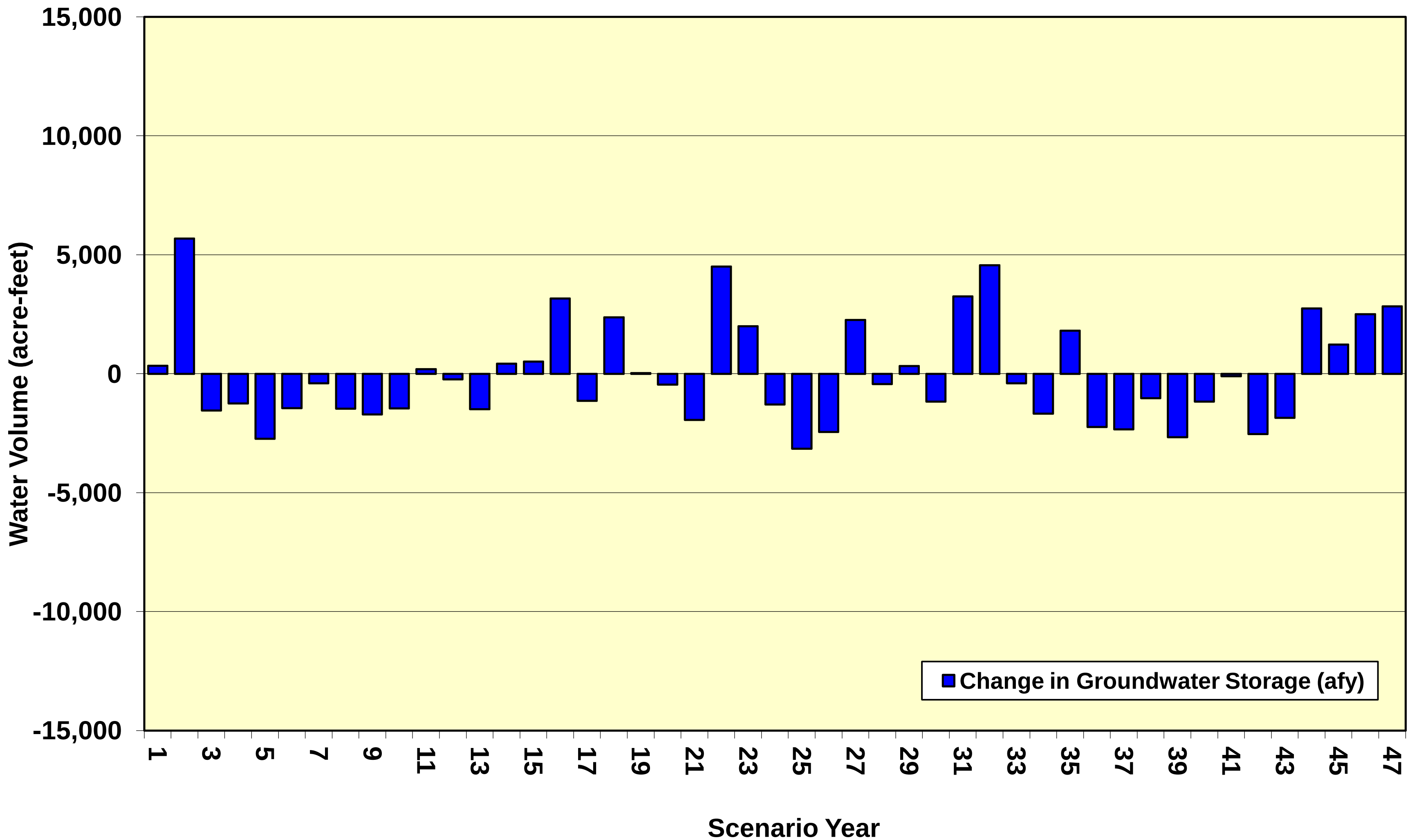
Key:
afy - acre-feet per year
GGP - Golden Gate Park

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



Scenario 1 South Westside Basin Water Balance Summary

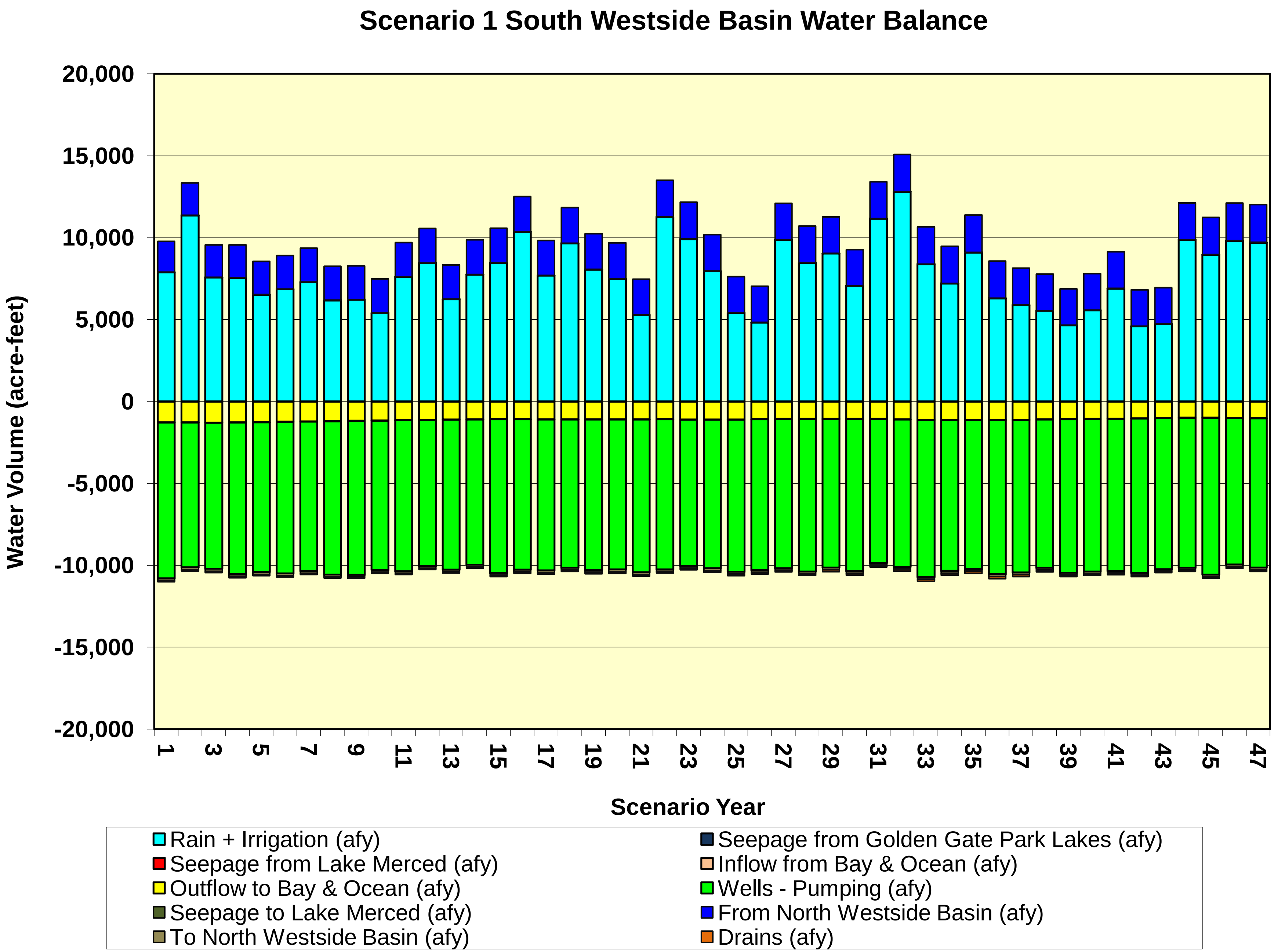
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From North to South Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From South to North Westside Basin (afy)	Drains (afy)	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:

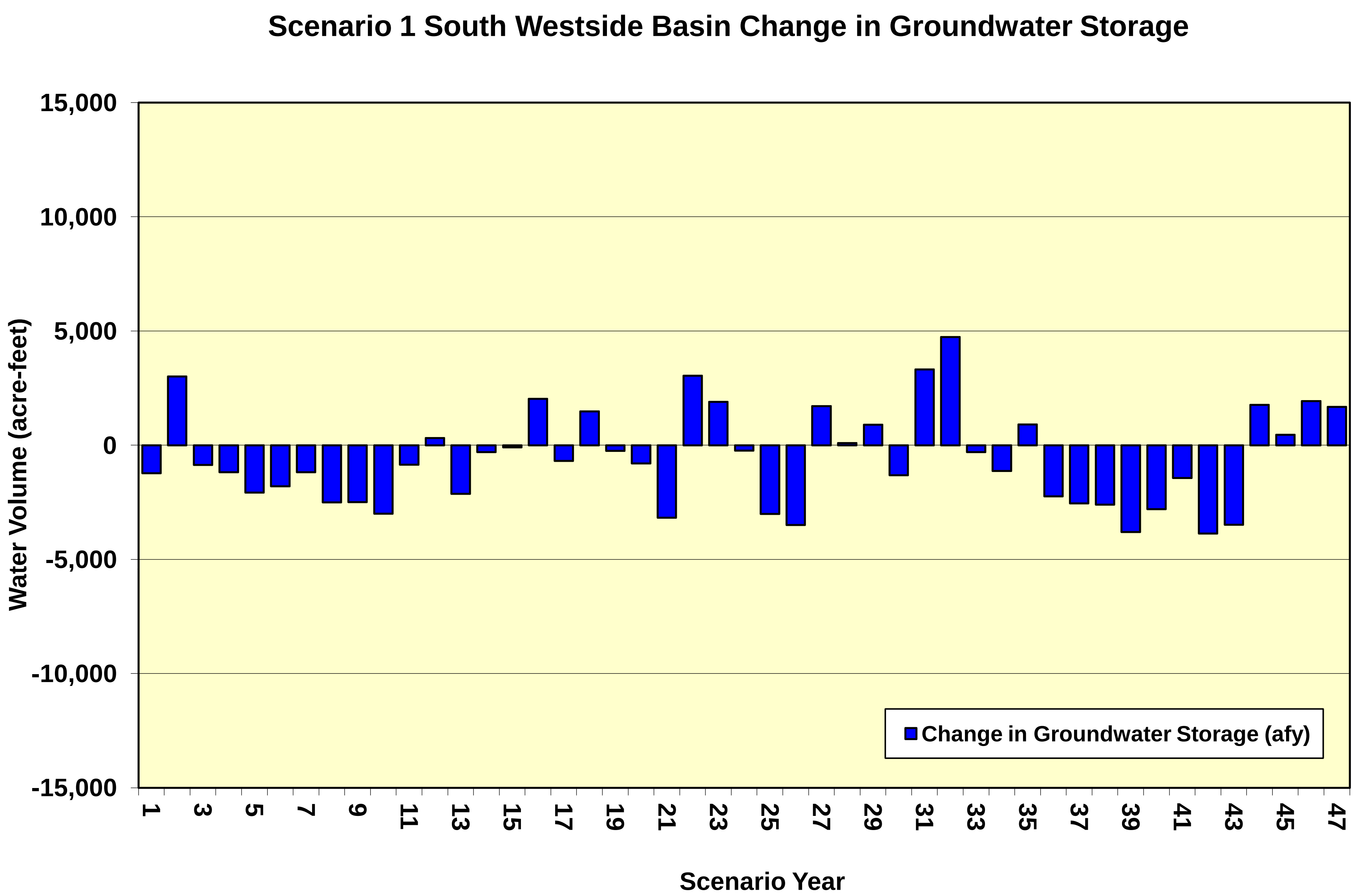
afy - acre-feet per year

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
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)



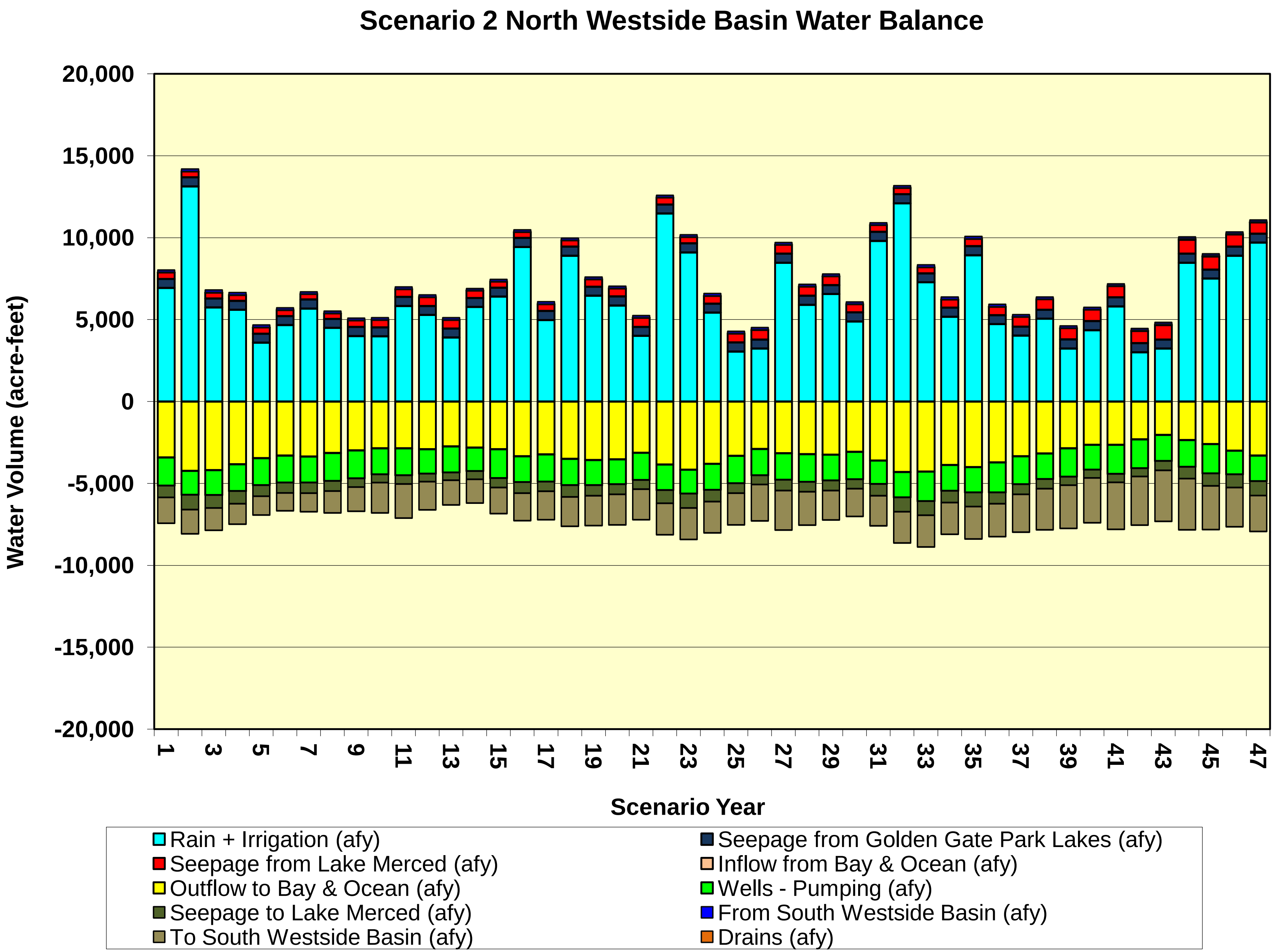
Scenario 1 South Westside Basin Change in Groundwater Storage
Water Volume (acre-feet)
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Change in Groundwater Storage (afy)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year

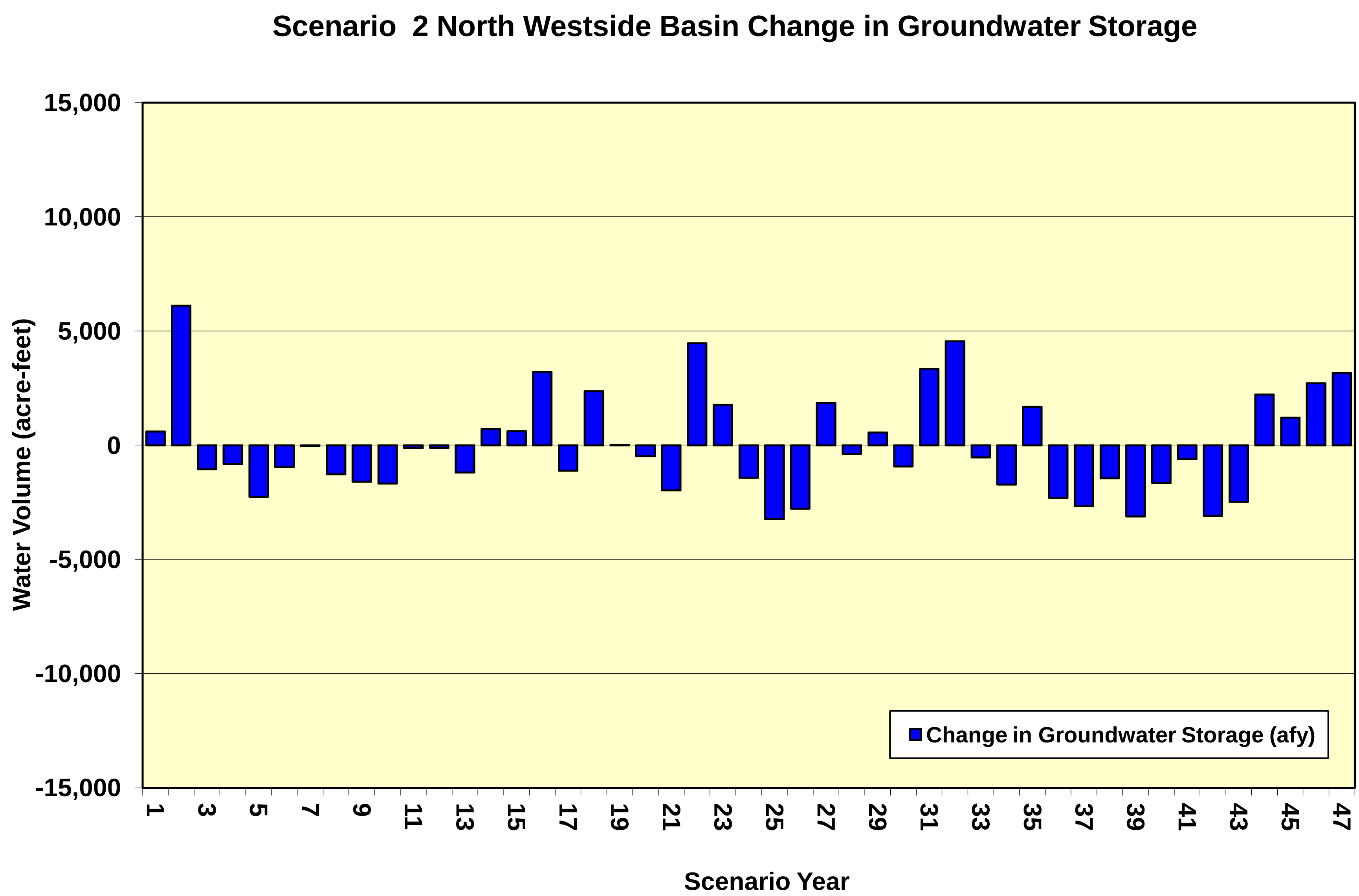
Scenario 2 North Westside Basin Water Balance Summary

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
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 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)
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 2 South Westside Basin Water Balance Summary

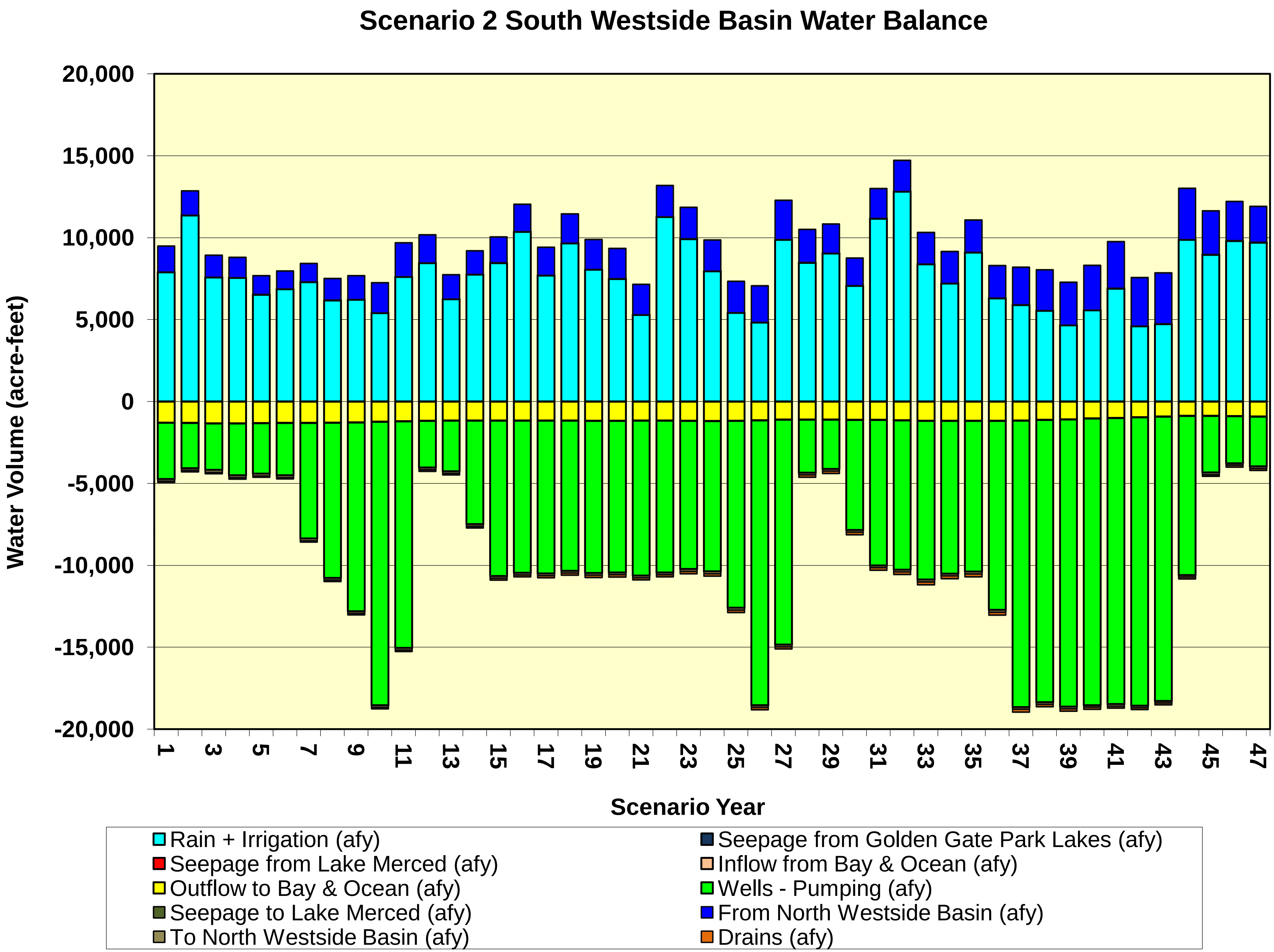
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From North to South Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From South to North Westside Basin (afy)	Drains (afy)	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
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
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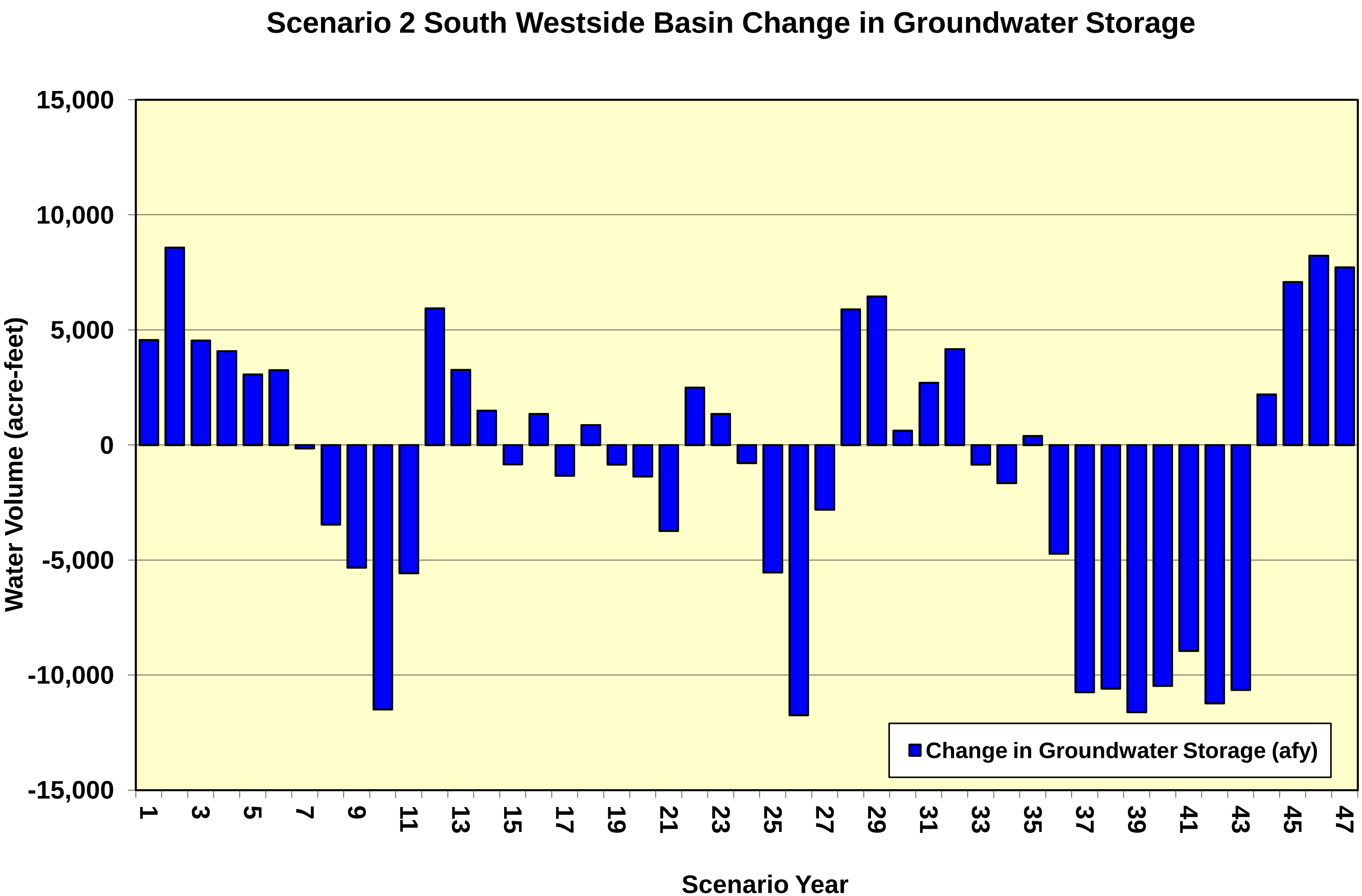
Scenario Year
Rain + Irrigation (afy)
Seepage from Golden Gate Park Lakes (afy)
Seepage from Lake Merced (afy)
Inflow from Bay & Ocean (afy)
Outflow to Bay & Ocean (afy)
Wells - Pumping (afy)
Seepage to Lake Merced (afy)
From North Westside Basin (afy)
To North Westside Basin (afy)
Drains (afy)


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
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33
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39
41
43
45
47
Scenario Year
Change in Groundwater Storage (afy)

Scenario 3a North Westside Basin Water Balance Summary

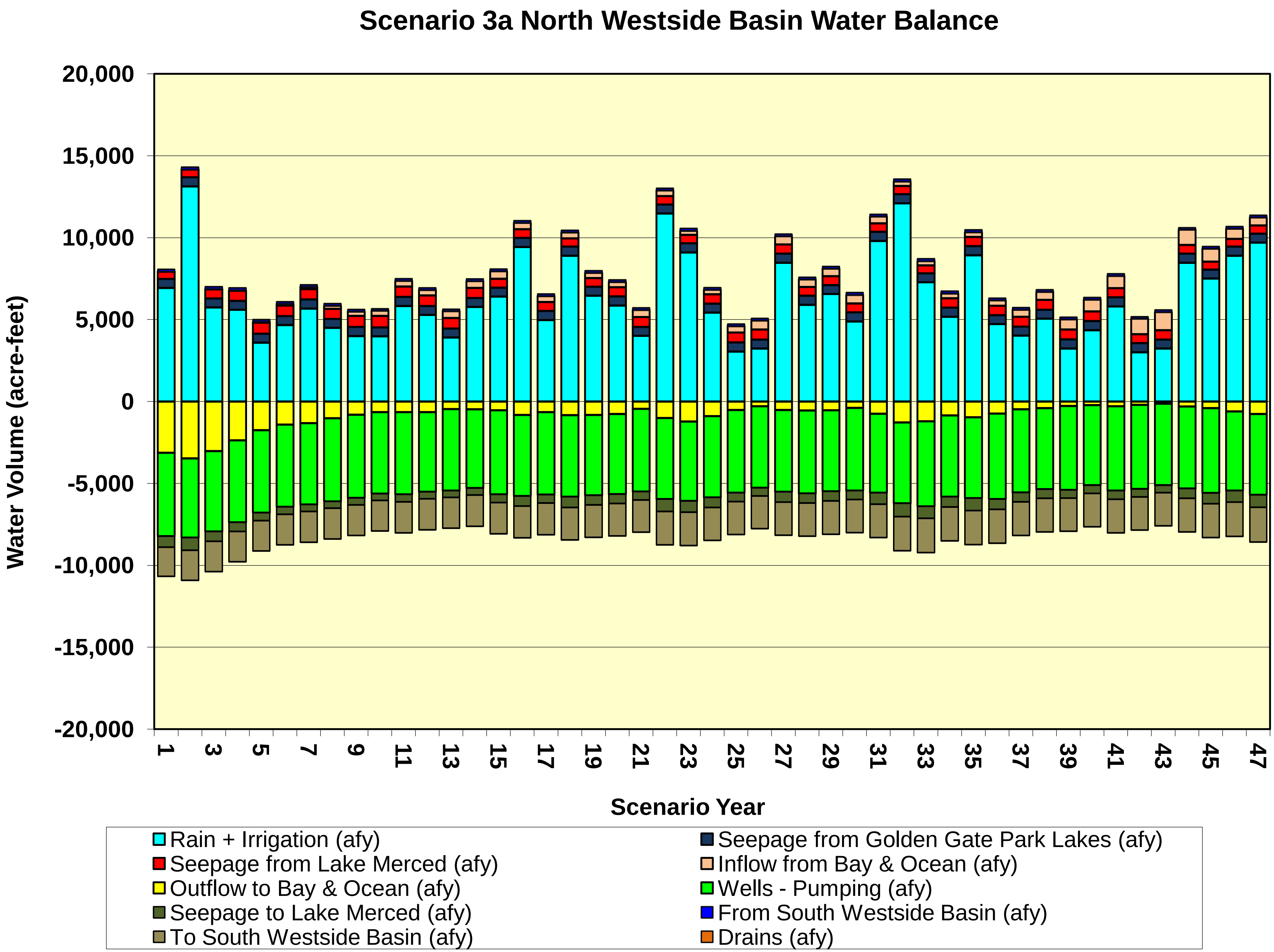
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From South to North Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From North to South Westside Basin (afy)	Drains (afy)	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:

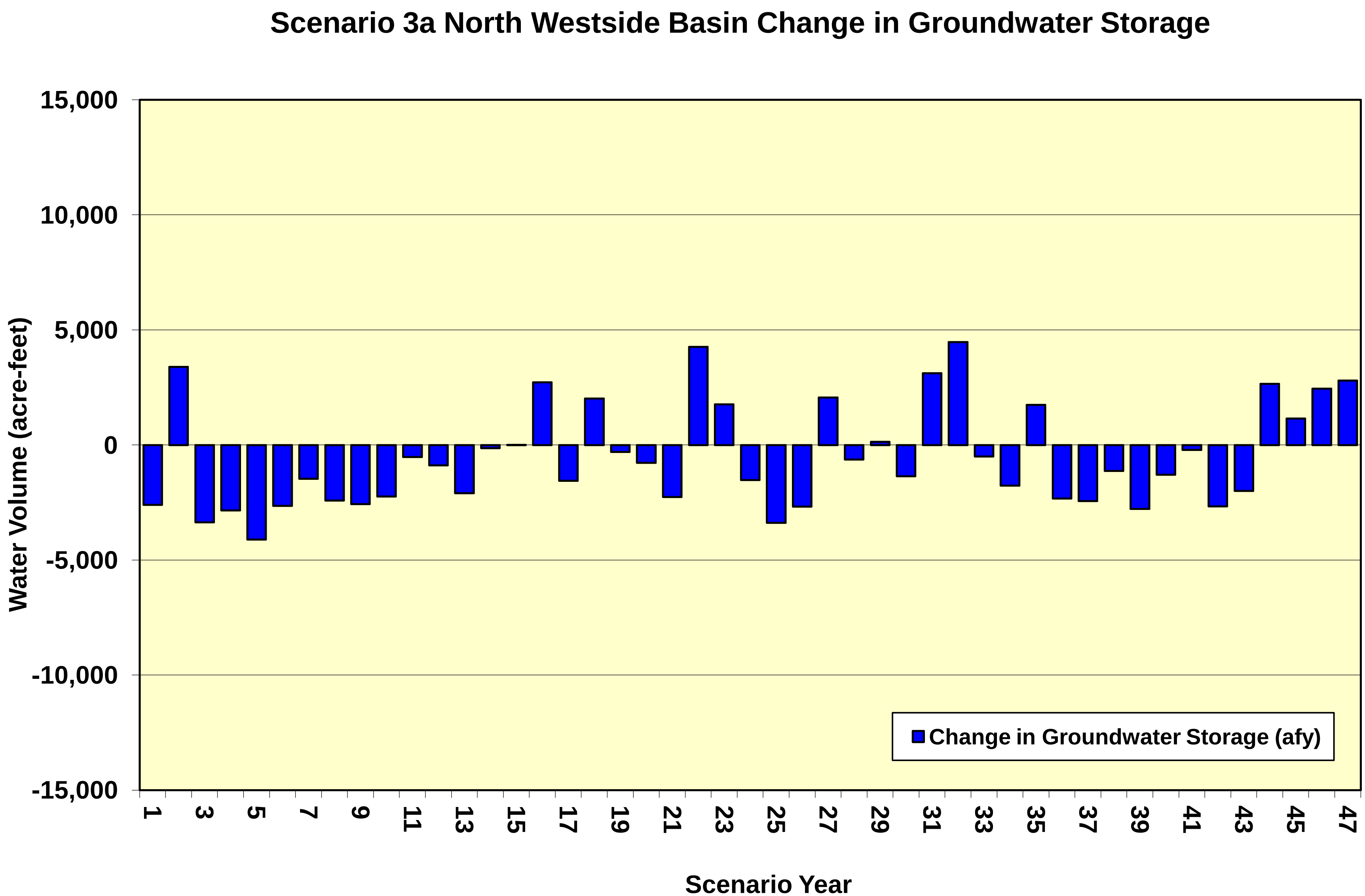
afy - acre-feet per year

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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45
47
Scenario Year
Change in Groundwater Storage (afy)

Scenario 3a South Westside Basin Water Balance Summary

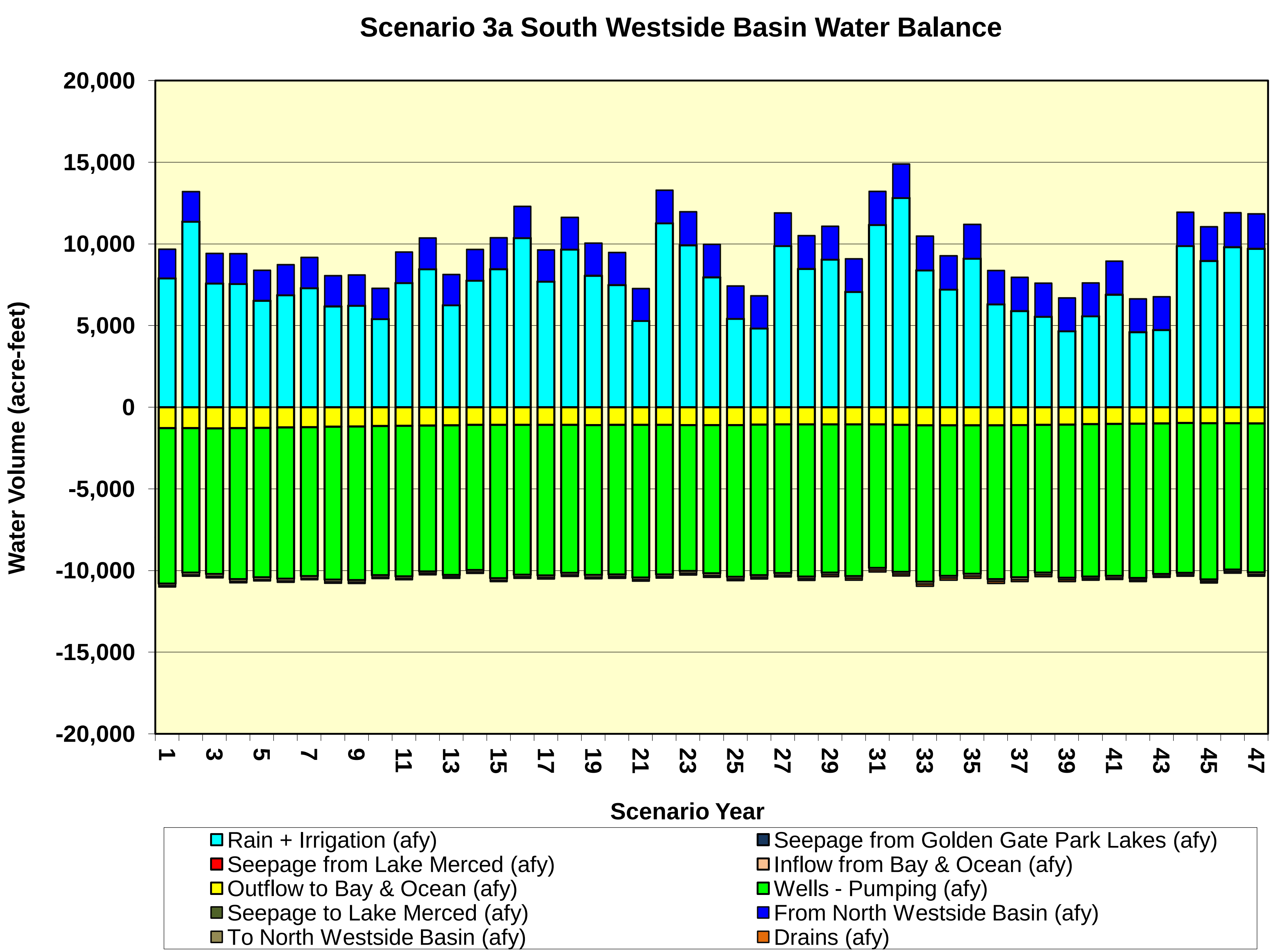
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From North to South Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From South to North Westside Basin (afy)	Drains (afy)	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**

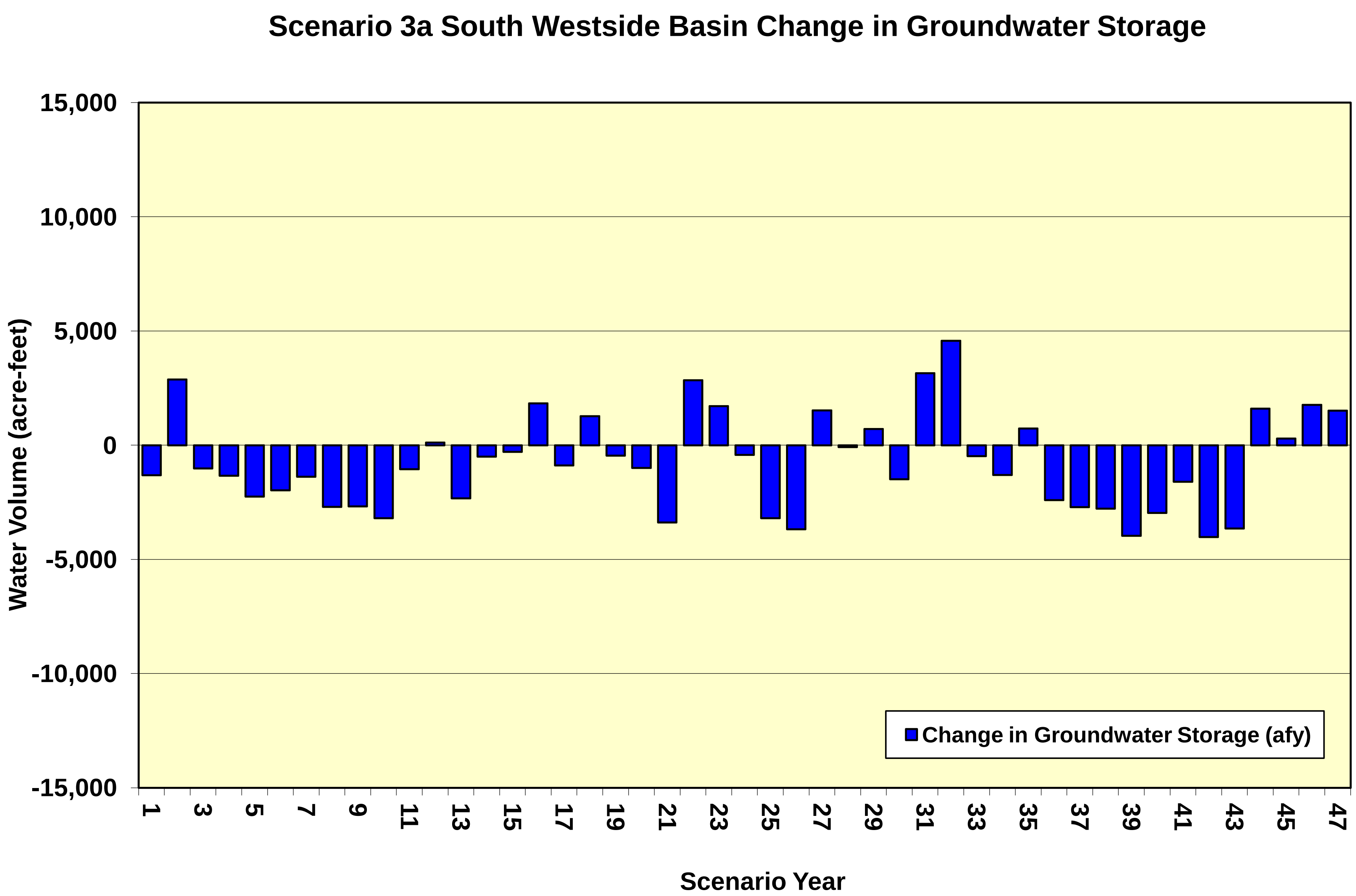
Key:

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
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 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

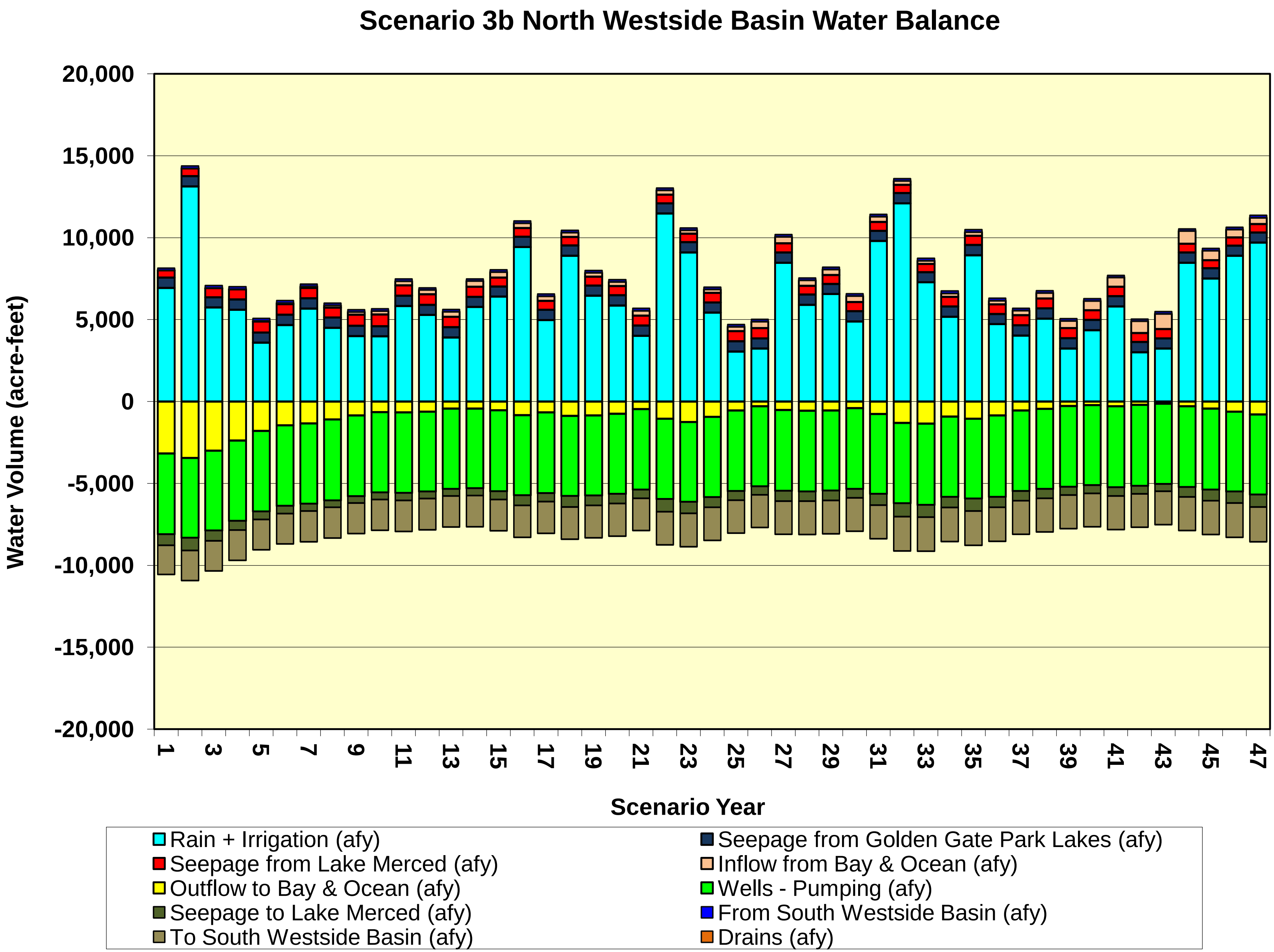
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From South to North Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From North to South Westside Basin (afy)	Drains (afy)	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
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
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33
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41
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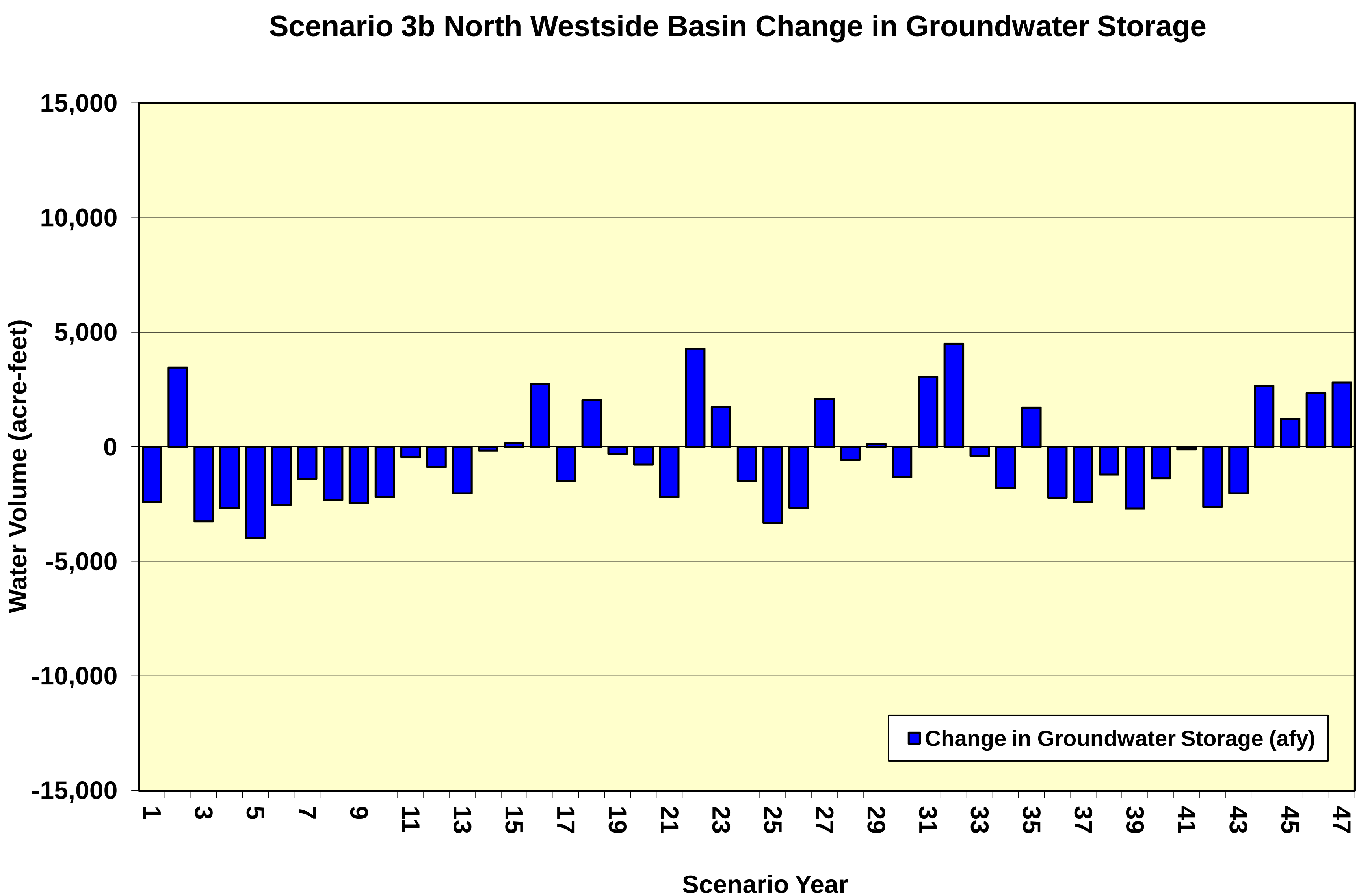
45
47
Scenario Year
Rain + Irrigation (afy)
Seepage from Golden Gate Park Lakes (afy)
Seepage from Lake Merced (afy)
Inflow from Bay & Ocean (afy)
Outflow to Bay & Ocean (afy)
Wells - Pumping (afy)
Seepage to Lake Merced (afy)
From South Westside Basin (afy)
To South Westside Basin (afy)
Drains (afy)



Scenario 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)
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 South Westside Basin Water Balance Summary

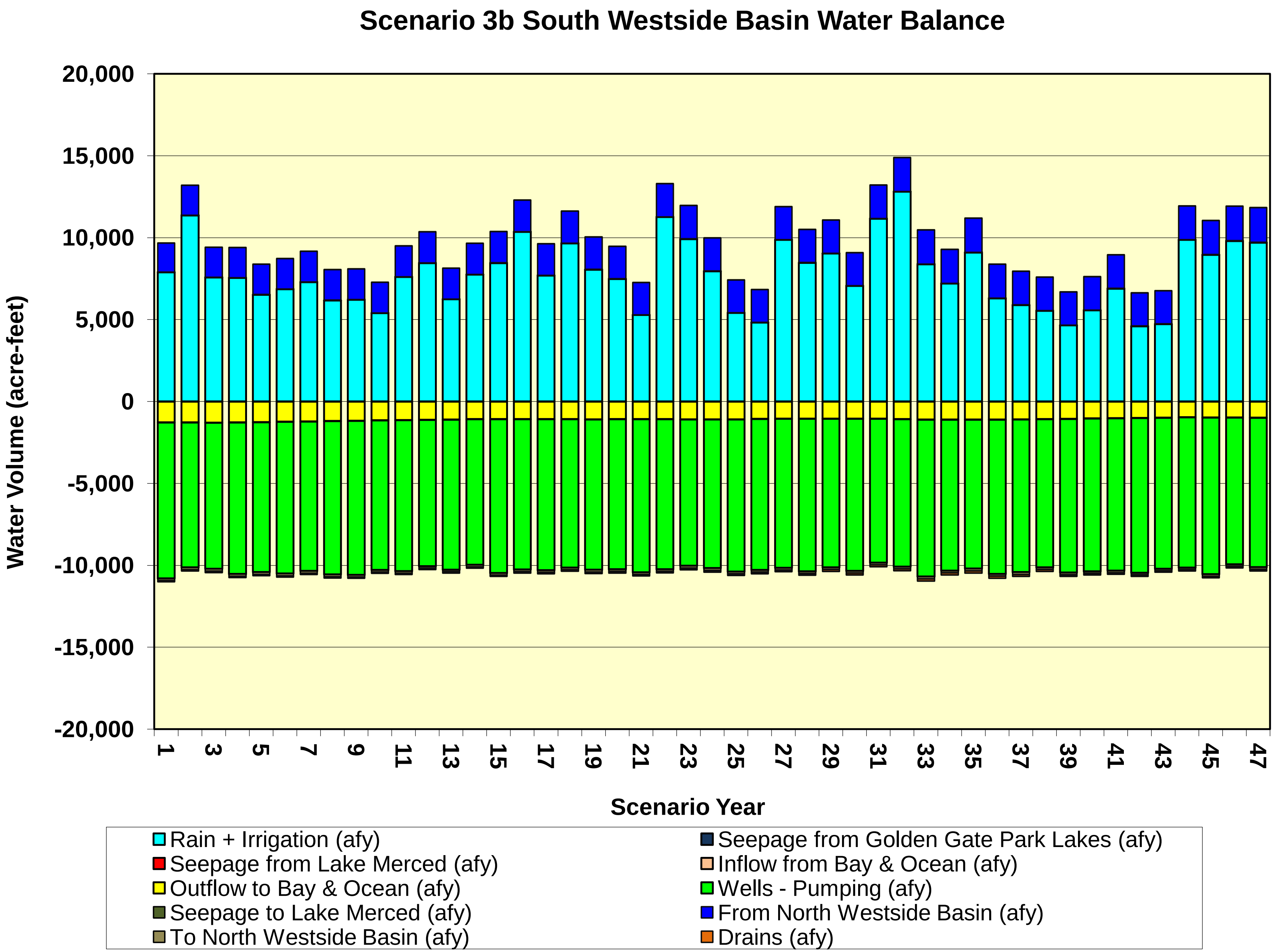
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From North to South Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From South to North Westside Basin (afy)	Drains (afy)	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**

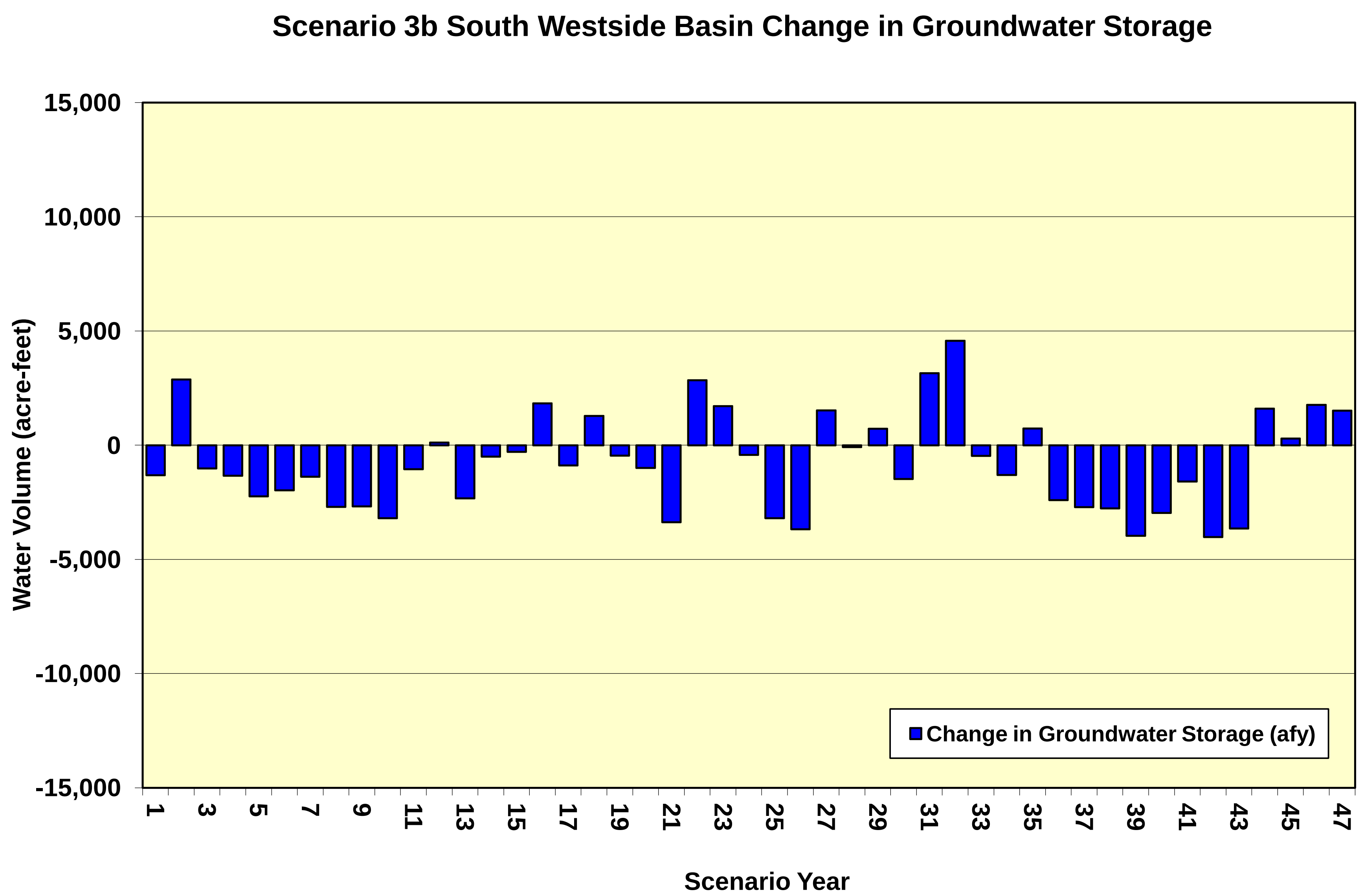
Key:

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
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 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

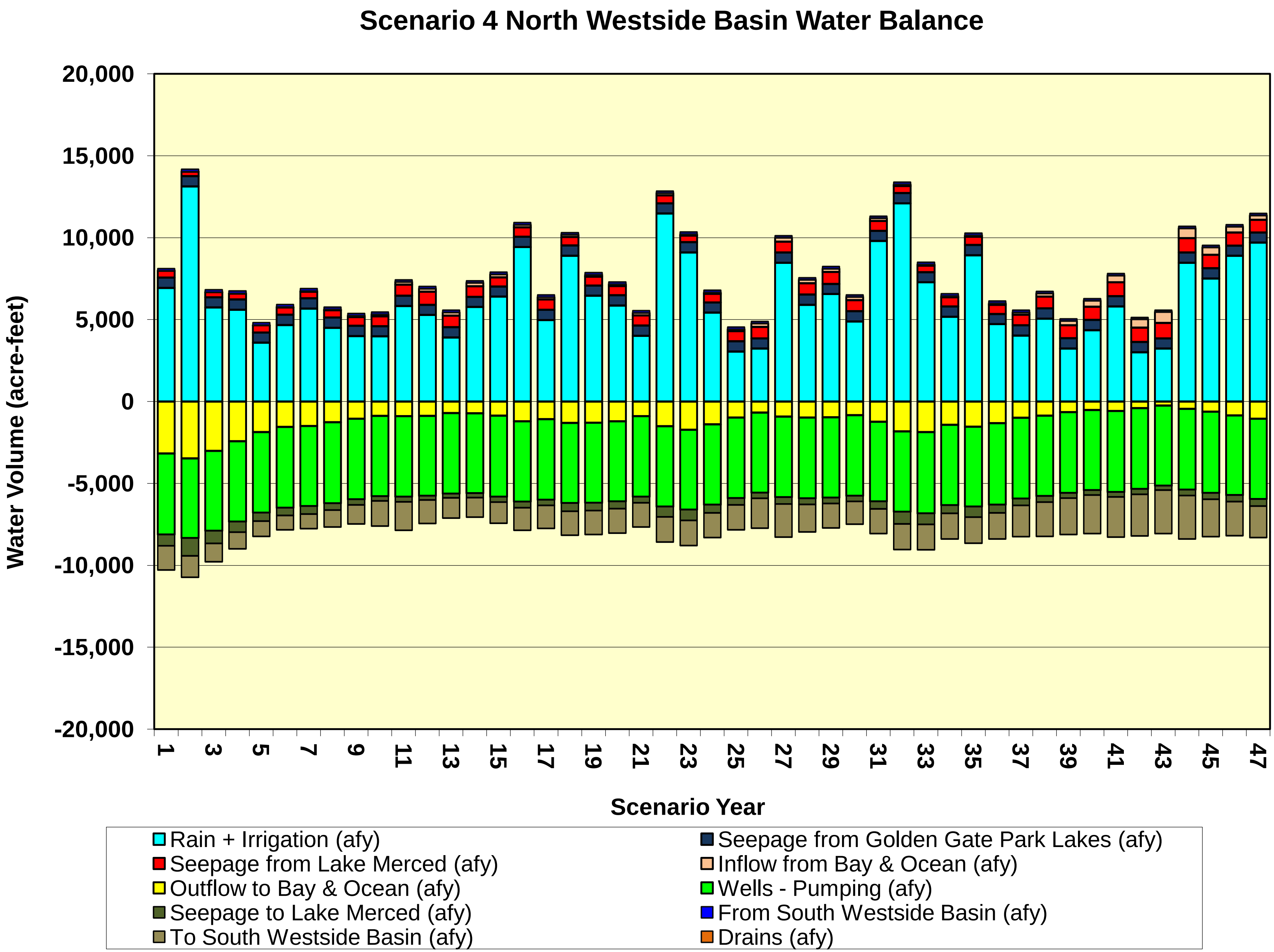
Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	From South to North Westside Basin (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	From North to South Westside Basin (afy)	Drains (afy)	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**

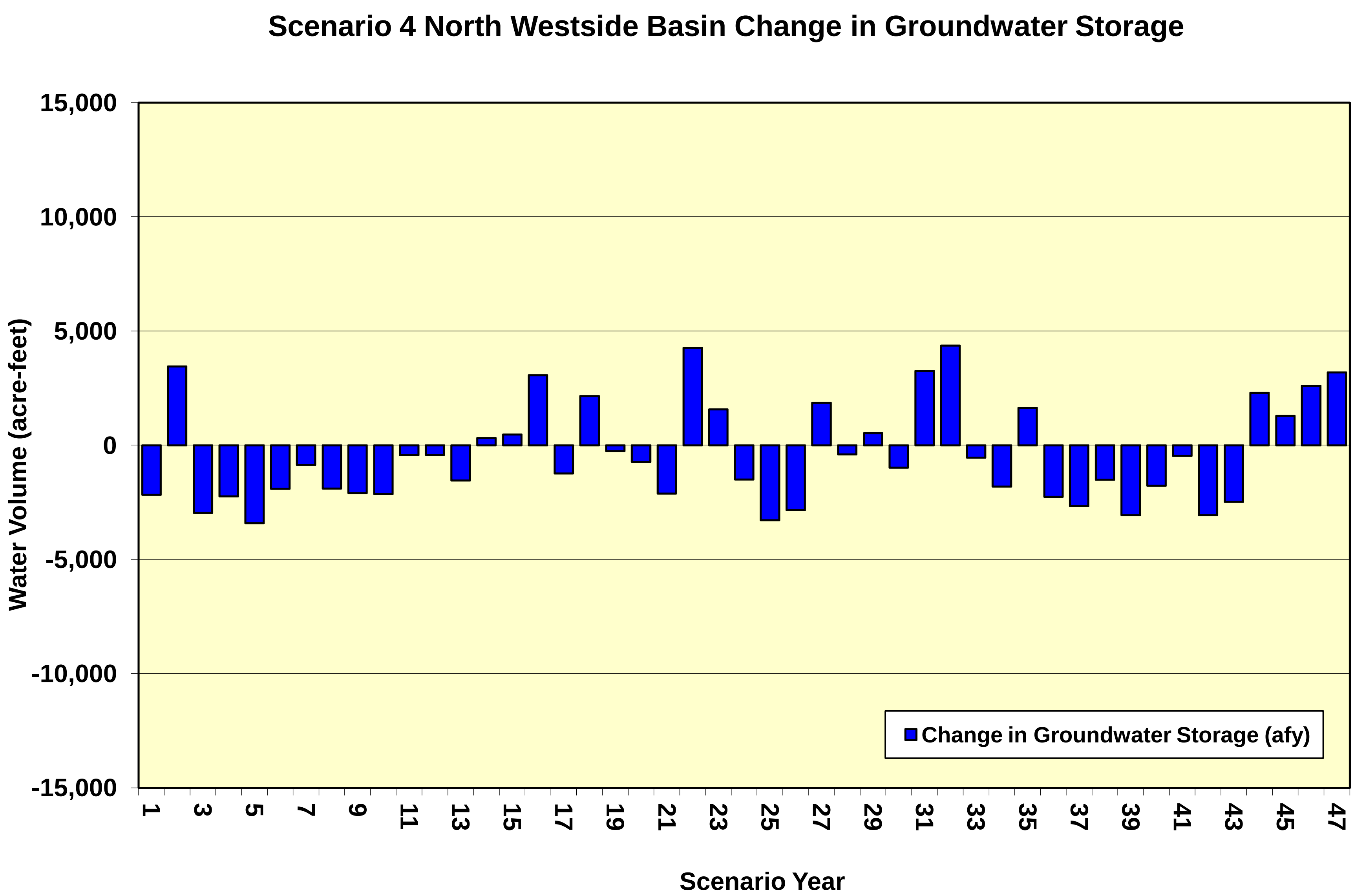
Key:

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 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)



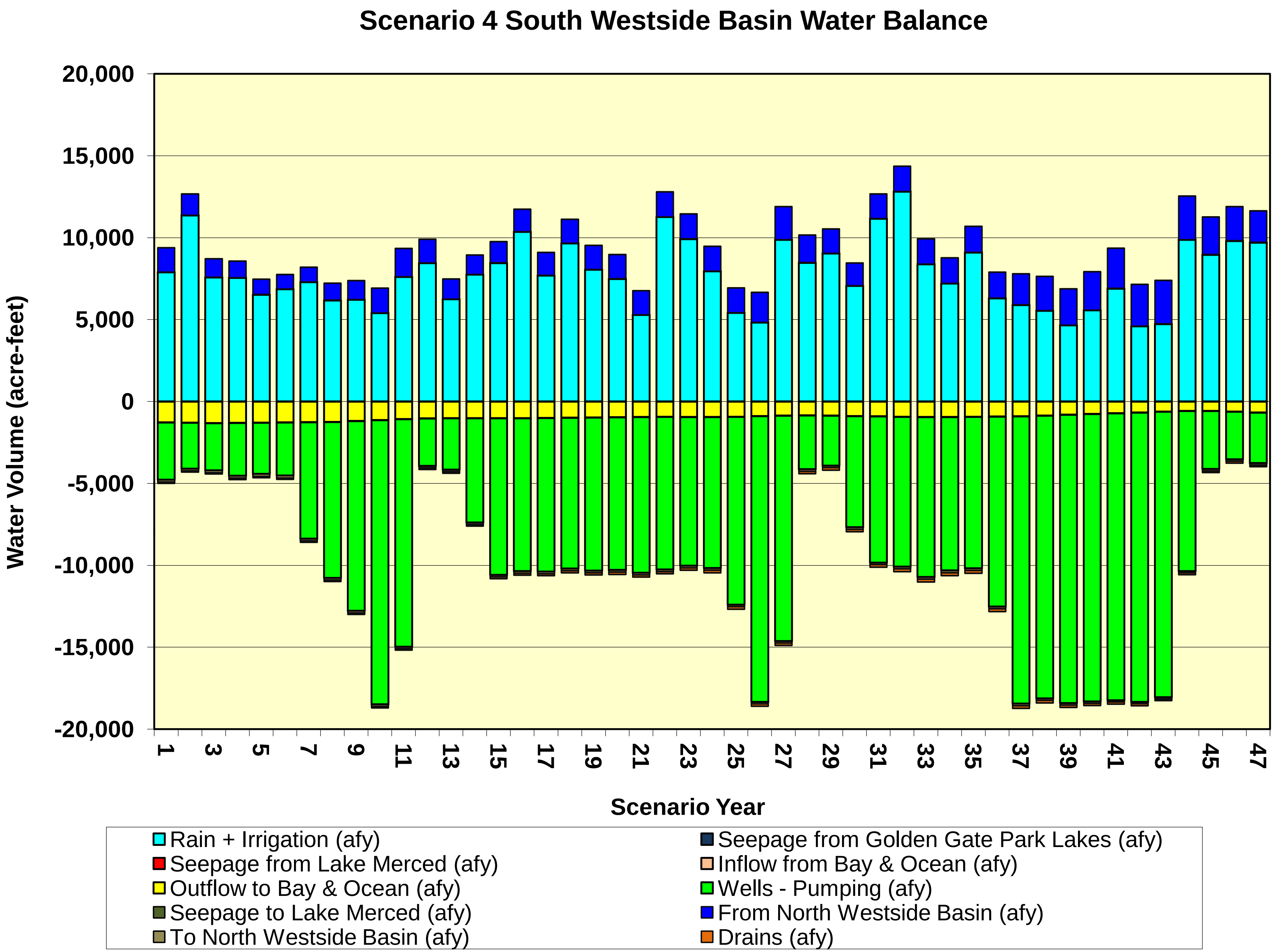
Scenario 4 North Westside Basin Change in Groundwater Storage
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
Water Volume (acre-feet)
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43
45
47
Scenario Year
Change in Groundwater Storage (afy)

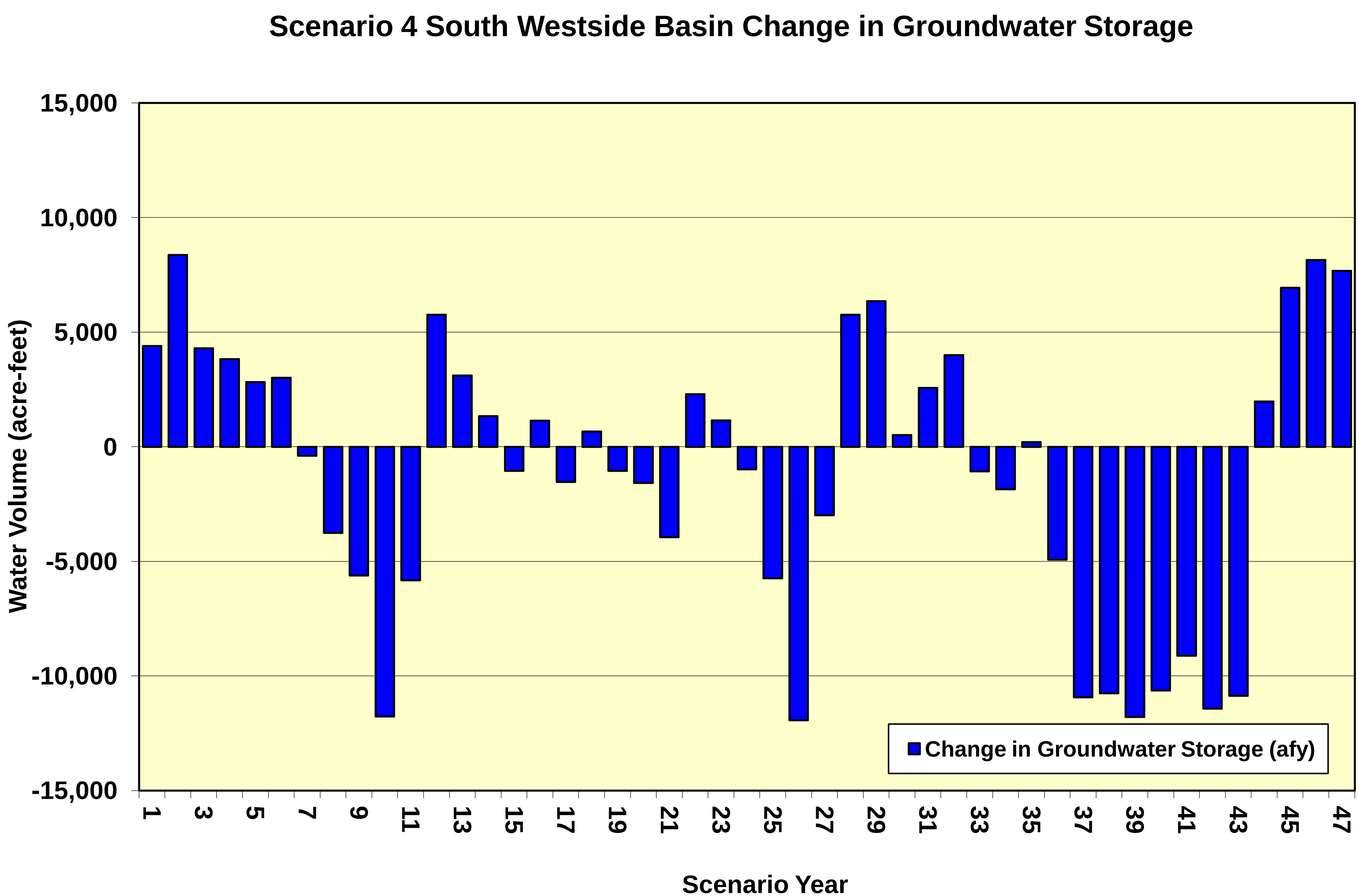
Scenario 4 South Westside Basin Water Balance Summary

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

	Colma	Zone 2
IN (acre-feet/year)	Storage	436
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	917
	Lake Seepage	0
	From Zone 1	82
	From Zone 3	479
	From Zone 11	269
OUT (acre-feet/year)	Storage	334
	Constant Head	0
	Pumpage	716
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 1	659
	To Zone 3	468
	To Zone 11	0
NET (acre-feet/year)	Storage	-103
	Constant Head	0
	Pumpage	-716
	Drains	0
	Recharge	917
	Lake Seepage	0
	Zone 1	-577
	Zone 3	11
	Zone 11	269

	Cal Water	Zone 3
IN (acre-feet/year)	Storage	393
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	1453
	Lake Seepage	0
	From Zone 2	467
	From Zone 4	376
	From Zone 5	180
	From Zone 11	562
OUT (acre-feet/year)	Storage	253
	Constant Head	0
	Pumpage	1535
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 2	478
	To Zone 4	1023
	To Zone 5	139
	To Zone 11	0
NET (acre-feet/year)	Storage	-140
	Constant Head	0
	Pumpage	-1535
	Drains	0
	Recharge	1453
	Lake Seepage	0
	Zone 2	-12
	Zone 4	-647
	Zone 5	41
	Zone 11	562

	San Bruno	Zone 4
IN (acre-feet/year)	Storage	213
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	796
	Lake Seepage	0
	From Zone 3	1023
	From Zone 5	498
	From Zone 6	870
	From Zone 11	3
OUT (acre-feet/year)	Storage	229
	Constant Head	0
	Pumpage	2104
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 3	373
	To Zone 5	308
	To Zone 6	387
	To Zone 11	0
NET (acre-feet/year)	Storage	15
	Constant Head	0
	Pumpage	-2104
	Drains	0
	Recharge	796
	Lake Seepage	0
	Zone 3	650
	Zone 5	190
	Zone 6	484
	Zone 11	3

	Bay Plain/Bay	Zone 5
IN (acre-feet/year)	Storage	59
	Constant Head	6
	Pumpage	0
	Drains	0
	Recharge	332
	Lake Seepage	0
	From Zone 3	139
	From Zone 4	308
	From Zone 6	283
	From Zone 7	112
OUT (acre-feet/year)	Storage	68
	Constant Head	110
	Pumpage	0
	Drains	93
	Recharge	0
	Lake Seepage	0
	To Zone 3	179
	To Zone 4	498
	To Zone 6	265
	To Zone 7	26
NET (acre-feet/year)	Storage	9
	Constant Head	-103
	Pumpage	0
	Drains	-93
	Recharge	332
	Lake Seepage	0
	Zone 3	-40
	Zone 4	-190
	Zone 6	18
	Zone 7	86

	Millbrae	Zone 6
IN (acre-feet/year)	Storage	168
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	557
	Lake Seepage	0
	From Zone 4	387
	From Zone 5	265
	From Zone 7	65
OUT (acre-feet/year)	Storage	153
	Constant Head	0
	Pumpage	110
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 4	870
	To Zone 5	283
	To Zone 7	25
NET (acre-feet/year)	Storage	-15
	Constant Head	0
	Pumpage	-110
	Drains	0
	Recharge	557
	Lake Seepage	0
	Zone 4	-484
	Zone 5	-18
	Zone 7	40

	Burlingame	Zone 7
IN (acre-feet/year)	Storage	361
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	537
	Lake Seepage	0
	From Zone 5	26
	From Zone 6	25
OUT (acre-feet/year)	Storage	290
	Constant Head	12
	Pumpage	468
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 5	112
	To Zone 6	65
NET (acre-feet/year)	Storage	-70
	Constant Head	-12
	Pumpage	-468
	Drains	0
	Recharge	537
	Lake Seepage	0
	Zone 5	-86
	Zone 6	-40

	Lake Merced/GGP	Zone 8
IN (acre-feet/year)	Storage	1652
	Constant Head	0
	Pumpage	551
	Drains	0
	Recharge	5979
	Lake Seepage	544
	From Zone 1	71
	From Zone 10	257
	From Zone 11	24
OUT (acre-feet/year)	Storage	1497
	Constant Head	0
	Pumpage	1618
	Drains	0
	Recharge	0
	Lake Seepage	649
	To Zone 1	2175
	To Zone 10	3139
	To Zone 11	1
NET (acre-feet/year)	Storage	-155
	Constant Head	0
	Pumpage	-1067
	Drains	0
	Recharge	5979
	Lake Seepage	-105
	Zone 1	-2104
	Zone 10	-2882
	Zone 11	23

	Ocean	Zone 10
IN (acre-feet/year)	Storage	50
	Constant Head	5
	Pumpage	0
	Drains	0
	Recharge	0
	Lake Seepage	0
	From Zone 8	3139
	From Zone 11	1182
OUT (acre-feet/year)	Storage	44
	Constant Head	4055
	Pumpage	0
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 8	257
	To Zone 11	21
NET (acre-feet/year)	Storage	-7
	Constant Head	-4050
	Pumpage	0
	Drains	0
	Recharge	0
	Lake Seepage	0
	Zone 8	2882
	Zone 11	1161

	Thornton Beach	Zone 11
IN (acre-feet/year)	Storage	594
	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	480
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	0
	Lake Seepage	0
	To Zone 1	199
	To Zone 2	269
	To Zone 3	562
	To Zone 4	3
	To Zone 8	24
	To Zone 10	1180
NET (acre-feet/year)	Storage	-114
	Constant Head	0
	Pumpage	0
	Drains	0
	Recharge	2101
	Lake Seepage	0
	Zone 1	-199
	Zone 2	-269
	Zone 3	-562
	Zone 4	-3
	Zone 8	-23
	Zone 10	-1159

	Subareas 1, 2, 3, 4, and 8	
IN (acre-feet/year)	Storage	3233
	Constant Head	0
	Pumpage	551
	Drains	0
	Recharge	10301
	Lake Seepage	544
	Ocean	257
	Bay Plain/Bay	678
	Millbrae	870
	Thornton Beach	1057
OUT (acre-feet/year)	Storage	2620
	Constant Head	0
	Pumpage	10227
	Drains	0
	Recharge	0
	Lake Seepage	649
	Ocean	3139
	Bay Plain/Bay	447
	Millbrae	387
	Thornton Beach	1
NET (acre-feet/year)	Storage	-613
	Constant Head	0
	Pumpage	-9676
	Drains	0
	Recharge	10301
	Lake Seepage	-105
	Ocean	-2882
	Bay Plain/Bay	231
	Millbrae	484
	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) 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.

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

Colma	Zone 2
IN (acre-feet/year)	
Storage	737
Constant Head	0
Pumpage	0
Drains	0
Recharge	917
Lake Seepage	0
From Zone 1	216
From Zone 3	560
From Zone 11	268
OUT (acre-feet/year)	
Storage	457
Constant Head	0
Pumpage	1198
Drains	0
Recharge	0
Lake Seepage	0
To Zone 1	482
To Zone 3	566
To Zone 11	0
NET (acre-feet/year)	
Storage	-280
Constant Head	0
Pumpage	-1198
Drains	0
Recharge	917
Lake Seepage	0
Zone 1	-266
Zone 3	-7
Zone 11	268

Cal Water	Zone 3
IN (acre-feet/year)	
Storage	926
Constant Head	0
Pumpage	0
Drains	0
Recharge	1453
Lake Seepage	0
From Zone 2	565
From Zone 4	404
From Zone 5	168
From Zone 11	576
OUT (acre-feet/year)	
Storage	552
Constant Head	0
Pumpage	2120
Drains	1
Recharge	0
Lake Seepage	0
To Zone 2	558
To Zone 4	725
To Zone 5	130
To Zone 11	0
NET (acre-feet/year)	
Storage	-374
Constant Head	0
Pumpage	-2120
Drains	-1
Recharge	1453
Lake Seepage	0
Zone 2	8
Zone 4	-322
Zone 5	38
Zone 11	576

San Bruno	Zone 4
IN (acre-feet/year)	
Storage	496
Constant Head	0
Pumpage	0
Drains	0
Recharge	796
Lake Seepage	0
From Zone 3	725
From Zone 5	449
From Zone 6	787
From Zone 11	3
OUT (acre-feet/year)	
Storage	412
Constant Head	0
Pumpage	1836
Drains	0
Recharge	0
Lake Seepage	0
To Zone 3	398
To Zone 5	282
To Zone 6	350
To Zone 11	0
NET (acre-feet/year)	
Storage	-84
Constant Head	0
Pumpage	-1836
Drains	0
Recharge	796
Lake Seepage	0
Zone 3	328
Zone 5	167
Zone 6	437
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	130
From Zone 4	282
From Zone 6	254
From Zone 7	110
OUT (acre-feet/year)	
Storage	121
Constant Head	122
Pumpage	0
Drains	122
Recharge	0
Lake Seepage	0
To Zone 3	166
To Zone 4	449
To Zone 6	243
To Zone 7	20
NET (acre-feet/year)	
Storage	-10
Constant Head	-118
Pumpage	0
Drains	-122
Recharge	332
Lake Seepage	0
Zone 3	-35
Zone 4	-167
Zone 6	11
Zone 7	90

Millbrae	Zone 6
IN (acre-feet/year)	
Storage	225
Constant Head	0
Pumpage	0
Drains	0
Recharge	557
Lake Seepage	0
From Zone 4	350
From Zone 5	243
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	787
To Zone 5	254
To Zone 7	28
NET (acre-feet/year)	
Storage	-37
Constant Head	0
Pumpage	-179
Drains	0
Recharge	557
Lake Seepage	0
Zone 4	-437
Zone 5	-11
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	1704
Constant Head	0
Pumpage	551
Drains	0
Recharge	5979
Lake Seepage	496
From Zone 1	63
From Zone 10	228
From Zone 11	21
OUT (acre-feet/year)	
Storage	1523
Constant Head	0
Pumpage	1618
Drains	0
Recharge	0
Lake Seepage	645
To Zone 1	1923
To Zone 10	3333
To Zone 11	2
NET (acre-feet/year)	
Storage	-181
Constant Head	0
Pumpage	-1067
Drains	0
Recharge	5979
Lake Seepage	-149
Zone 1	-1859
Zone 10	-3104
Zone 11	20

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

Thornton Beach	Zone 11
IN (acre-feet/year)	
Storage	634
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	497
Constant Head	0
Pumpage	0
Drains	0
Recharge	0
Lake Seepage	0
To Zone 1	184
To Zone 2	267
To Zone 3	574
To Zone 4	3
To Zone 8	22
To Zone 10	1211
NET (acre-feet/year)	
Storage	-136
Constant Head	0
Pumpage	0
Drains	0
Recharge	2101
Lake Seepage	0
Zone 1	-184
Zone 2	-267
Zone 3	-574
Zone 4	-3
Zone 8	-20
Zone 10	-1190

Subareas 1, 2, 3, 4, and 8	
IN (acre-feet/year)	
Storage	4979
Constant Head	0
Pumpage	551
Drains	0
Recharge	10301
Lake Seepage	496
Ocean	228
Bay Plain/Bay	617
Millbrae	787
Thornton Beach	1052
OUT (acre-feet/year)	
Storage	3649
Constant Head	0
Pumpage	10692
Drains	1
Recharge	0
Lake Seepage	645
Ocean	3333
Bay Plain/Bay	412
Millbrae	350
Thornton Beach	2
NET (acre-feet/year)	
Storage	-1330
Constant Head	0
Pumpage	-10141
Drains	-1
Recharge	10301
Lake Seepage	-149
Ocean	-3104
Bay Plain/Bay	205
Millbrae	437
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) 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.

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	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	613	Storage	458	Storage	413	Storage	216	Storage	60	Storage	168	Storage	361	Storage	2079	Storage	58	Storage	599	Storage	3779
Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	7	Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	381	Constant Head	0	Constant Head	0
Pumpage	0	Pumpage	0	Pumpage	0	Pumpage	0	Pumpage	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	Drains	0	Drains	0	Drains	0	Drains	0	Drains	0
Recharge	1155	Recharge	917	Recharge	1453	Recharge	796	Recharge	332	Recharge	557	Recharge	537	Recharge	5979	Recharge	0	Recharge	2101	Recharge	10301
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	573	Lake Seepage	0	Lake Seepage	0	Lake Seepage	573
From Zone 2	754	From Zone 1	86	From Zone 2	443	From Zone 3	1016	From Zone 3	137	From Zone 4	388	From Zone 5	26	From Zone 1	67	From Zone 8	904	From Zone 1	0	Ocean	560
From Zone 8	1983	From Zone 3	501	From Zone 4	378	From Zone 5	499	From Zone 4	308	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 11	209	From Zone 11	275	From Zone 5	180	From Zone 6	872	From Zone 6	284	From Zone 7	65			From Zone 11	30			From Zone 3	0	Millbrae	872
				From Zone 11	566	From Zone 11	3	From Zone 7	112									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	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	285	Storage	318	Storage	242	Storage	225	Storage	67	Storage	152	Storage	290	Storage	1407	Storage	40	Storage	477	Storage	2478
Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	110	Constant Head	0	Constant Head	12	Constant Head	0	Constant Head	1885	Constant Head	0	Constant Head	0
Pumpage	4253	Pumpage	716	Pumpage	1535	Pumpage	2104	Pumpage	0	Pumpage	110	Pumpage	468	Pumpage	4990	Pumpage	0	Pumpage	0	Pumpage	13599
Drains	0	Drains	0	Drains	0	Drains	0	Drains	93	Drains	0	Drains	0	Drains	0	Drains	0	Drains	0	Drains	0
Recharge	0	Recharge	0	Recharge	0	Recharge	0	Recharge	0	Recharge	0	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	Lake Seepage	0	Lake Seepage	0	Lake Seepage	566	Lake Seepage	0	Lake Seepage	0	Lake Seepage	566
To Zone 2	86	To Zone 1	749	To Zone 2	499	To Zone 3	375	To Zone 3	179	To Zone 4	872	To Zone 5	112	To Zone 1	1974	To Zone 8	560	To Zone 1	209	Ocean	904
To Zone 8	67	To Zone 3	446	To Zone 4	1016	To Zone 5	308	To Zone 4	499	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 11	0	To Zone 11	0	To Zone 5	137	To Zone 6	388	To Zone 6	266	To Zone 7	25			To Zone 11	0			To Zone 3	566	Millbrae	388
				To Zone 11	0	To Zone 11	0	To Zone 7	26									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	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	-328	Storage	-140	Storage	-170	Storage	9	Storage	6	Storage	-16	Storage	-71	Storage	-672	Storage	-18	Storage	-122	Storage	-1301
Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	0	Constant Head	-103	Constant Head	0	Constant Head	-12	Constant Head	0	Constant Head	-1505	Constant Head	0	Constant Head	0
Pumpage	-4253	Pumpage	-716	Pumpage	-1535	Pumpage	-2104	Pumpage	0	Pumpage	-110	Pumpage	-468	Pumpage	-4439	Pumpage	0	Pumpage	0	Pumpage	-13048
Drains	0	Drains	0	Drains	0	Drains	0	Drains	-93	Drains	0	Drains	0	Drains	0	Drains	0	Drains	0	Drains	0
Recharge	1155	Recharge	917	Recharge	1453	Recharge	796	Recharge	332	Recharge	557	Recharge	537	Recharge	5979	Recharge	0	Recharge	2101	Recharge	10301
Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	0	Lake Seepage	8	Lake Seepage	0	Lake Seepage	0	Lake Seepage	8
Zone 2	668	Zone 1	-663	Zone 2	-57	Zone 3	641	Zone 3	-42	Zone 4	-485	Zone 5	-86	Zone 1	-1907	Zone 8	344	Zone 1	-209	Ocean	-344
Zone 8	1915	Zone 3	56	Zone 4	-638	Zone 5	191	Zone 4	-191	Zone 5	-18	Zone 6	-40	Zone 10	-344	Zone 11	1143	Zone 2	-275	Bay Plain/Bay	234
Zone 11	209	Zone 11	275	Zone 5	43	Zone 6	485	Zone 6	18	Zone 7	40			Zone 11	30			Zone 3	-566	Millbrae	485
				Zone 11	566	Zone 11	3	Zone 7	86									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.

(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.

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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) 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.

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.

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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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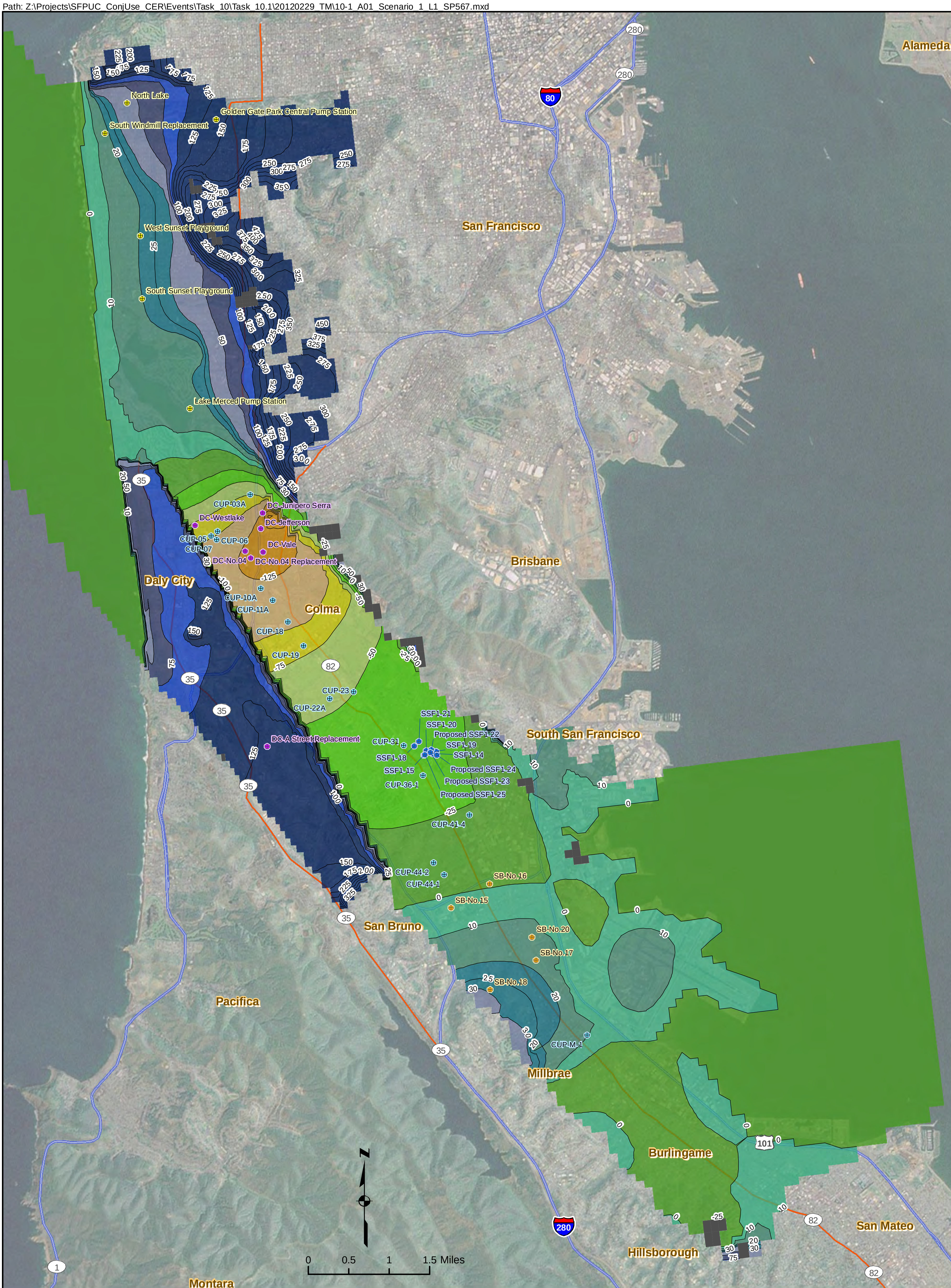

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

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	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 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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San Francisco, CA 94107

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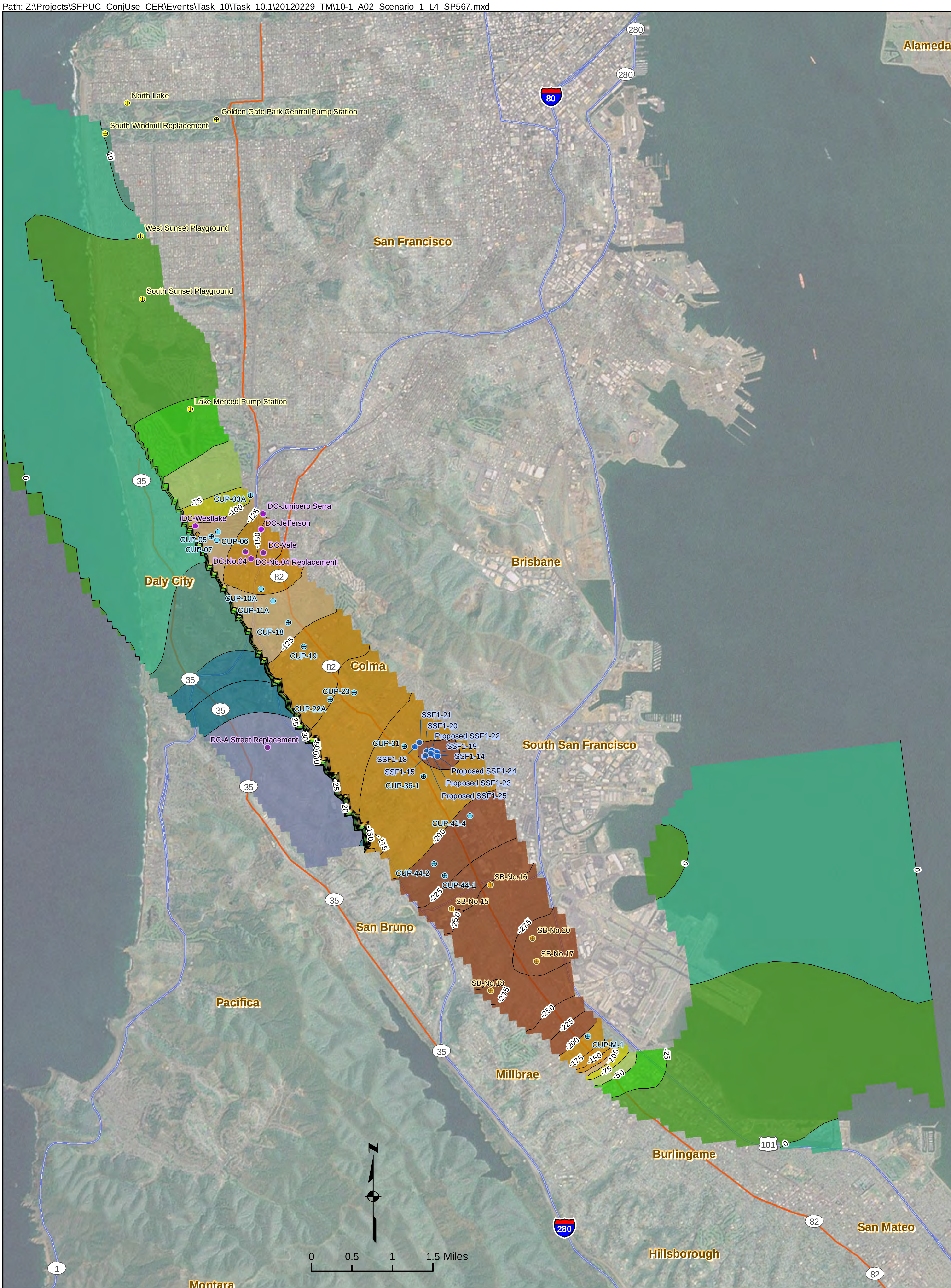

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

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

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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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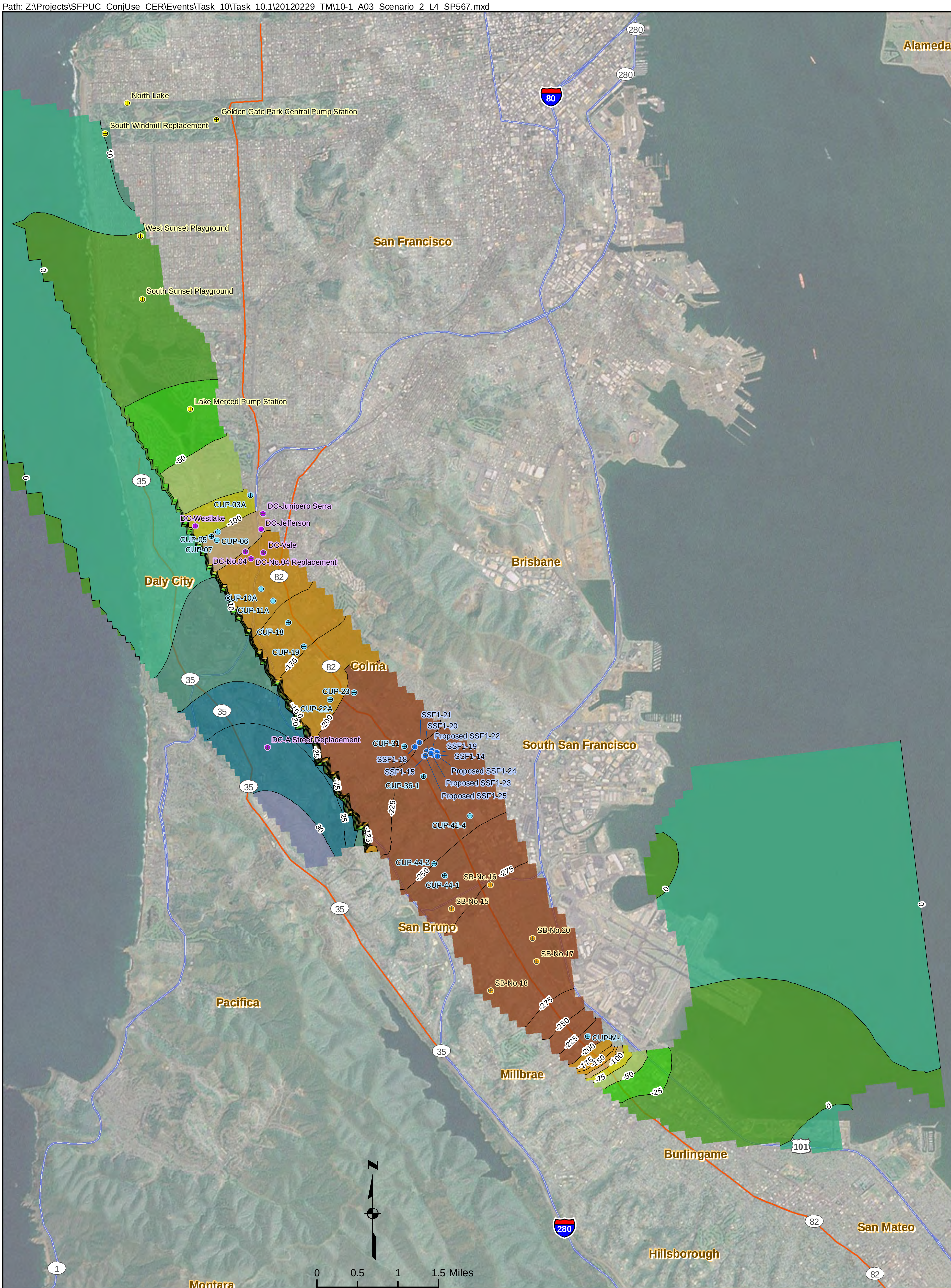

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

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

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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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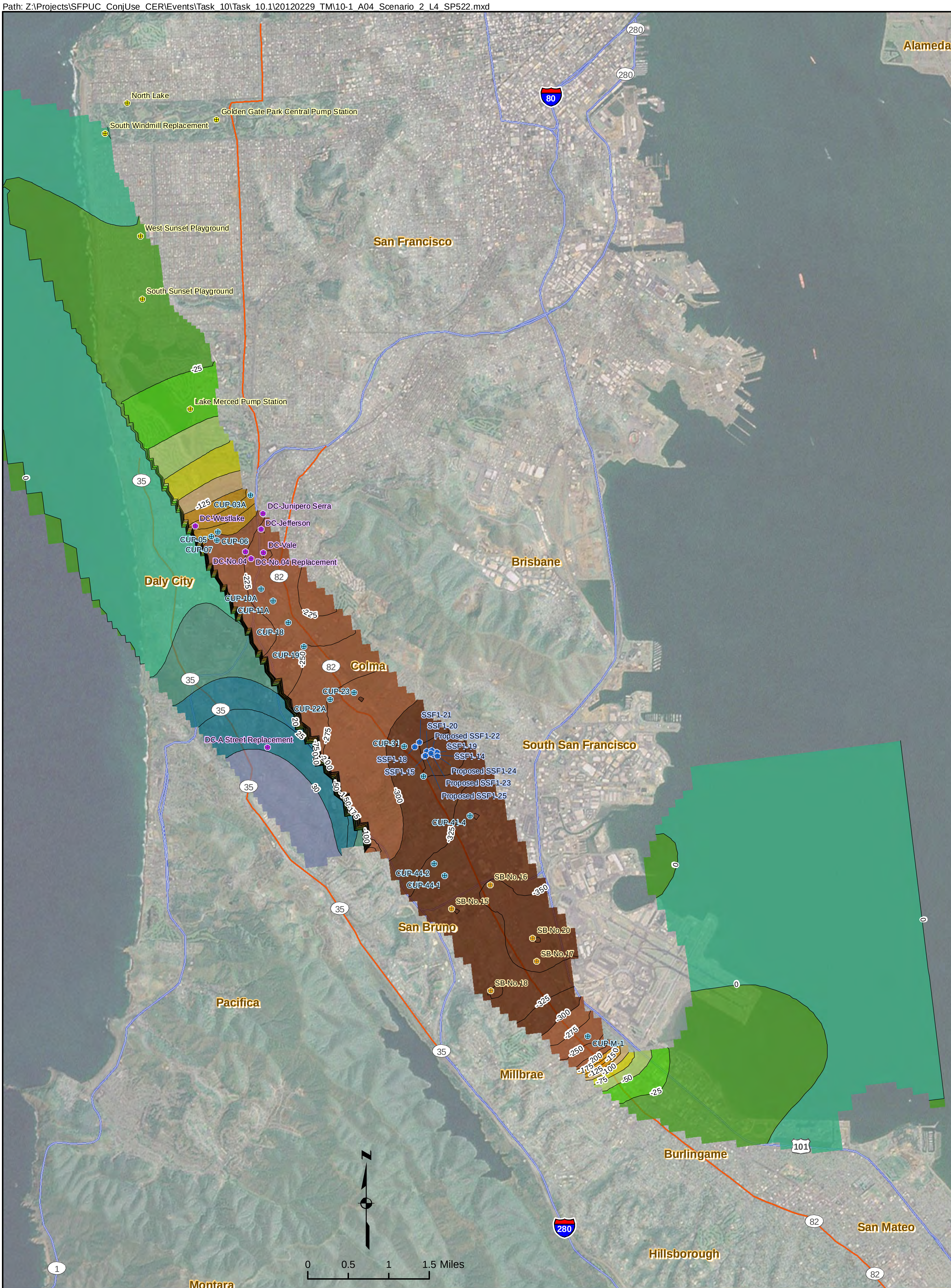

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

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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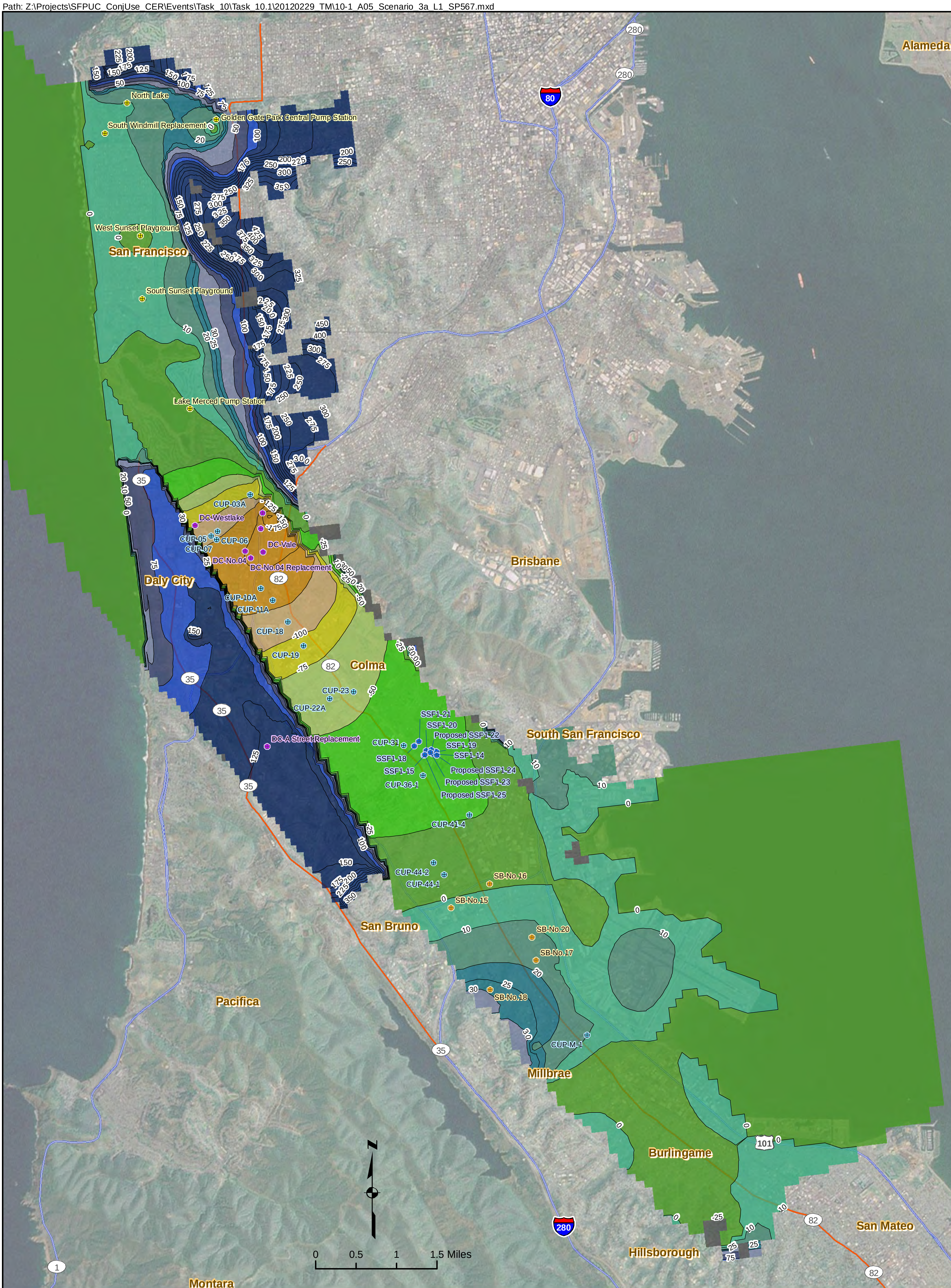

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

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

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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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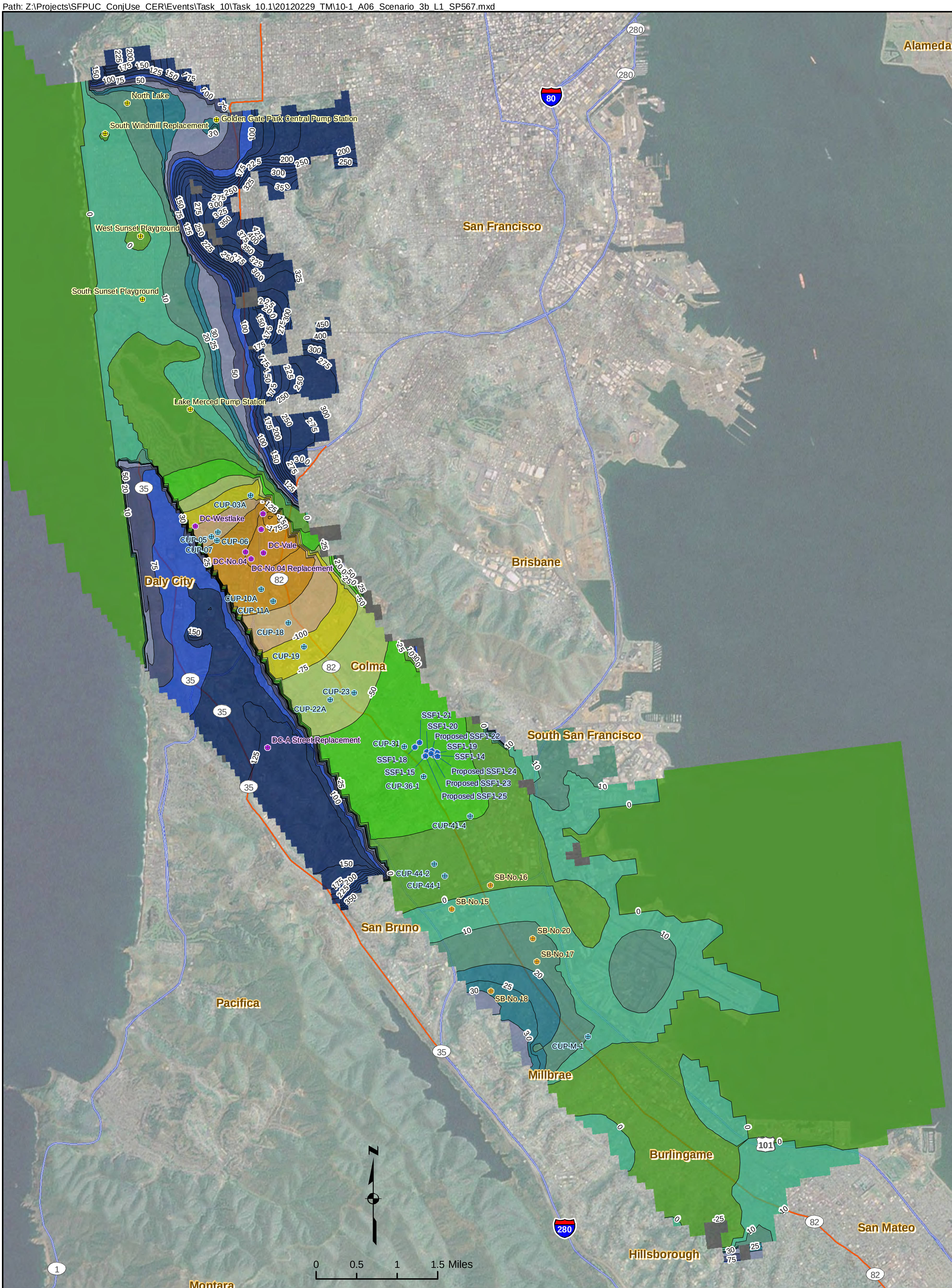

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Note:
Contoured areas shown in the Pacific Ocean and San Francisco Bay Area are part of the Westside Basin Groundwater-Flow Model domain.

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
- 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

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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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April 2012

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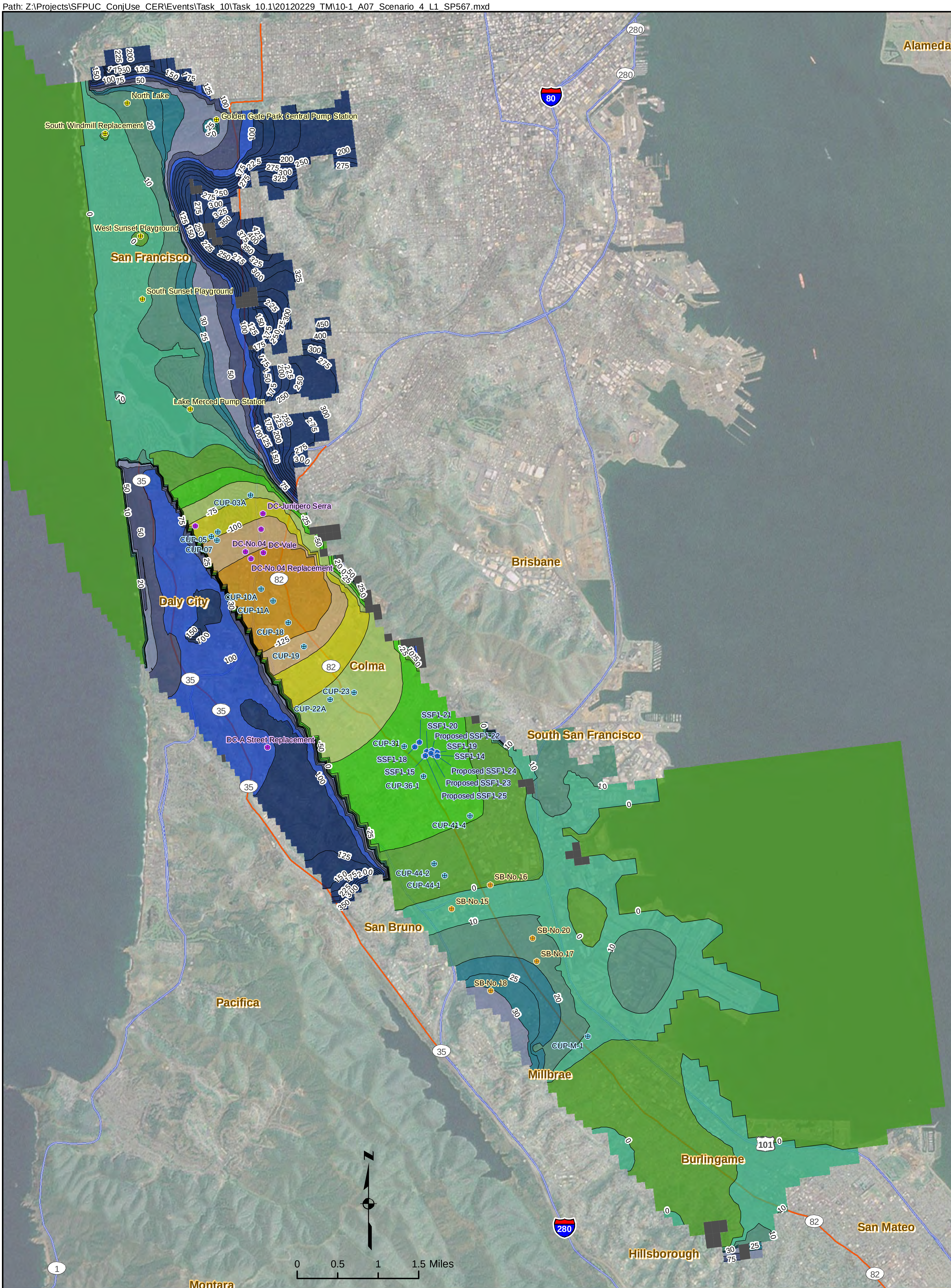

Aerial Photo Source: World Imagery from ESRI. Copyright:© 2009 ESRI, AND, TANA, UNEP-WCMC

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)

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

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

SCENARIO 4, LAYER 1
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

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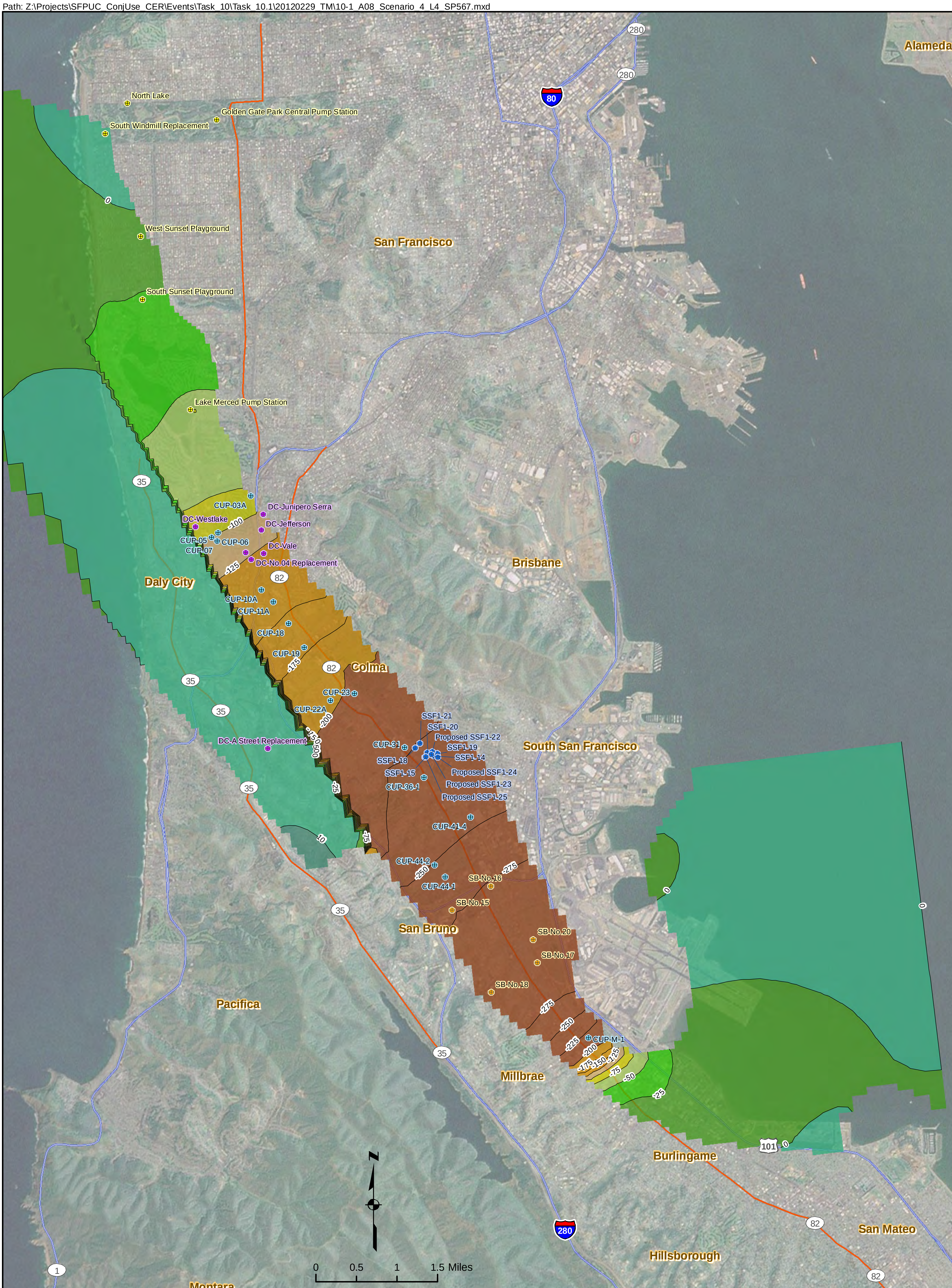

Aerial Photo Source: World Imagery from ESRI. Copyright:© 2009 ESRI, AND, TANA, UNEP-WCMC

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)

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

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

SCENARIO 4, LAYER 4
End of Hydrologic Sequence

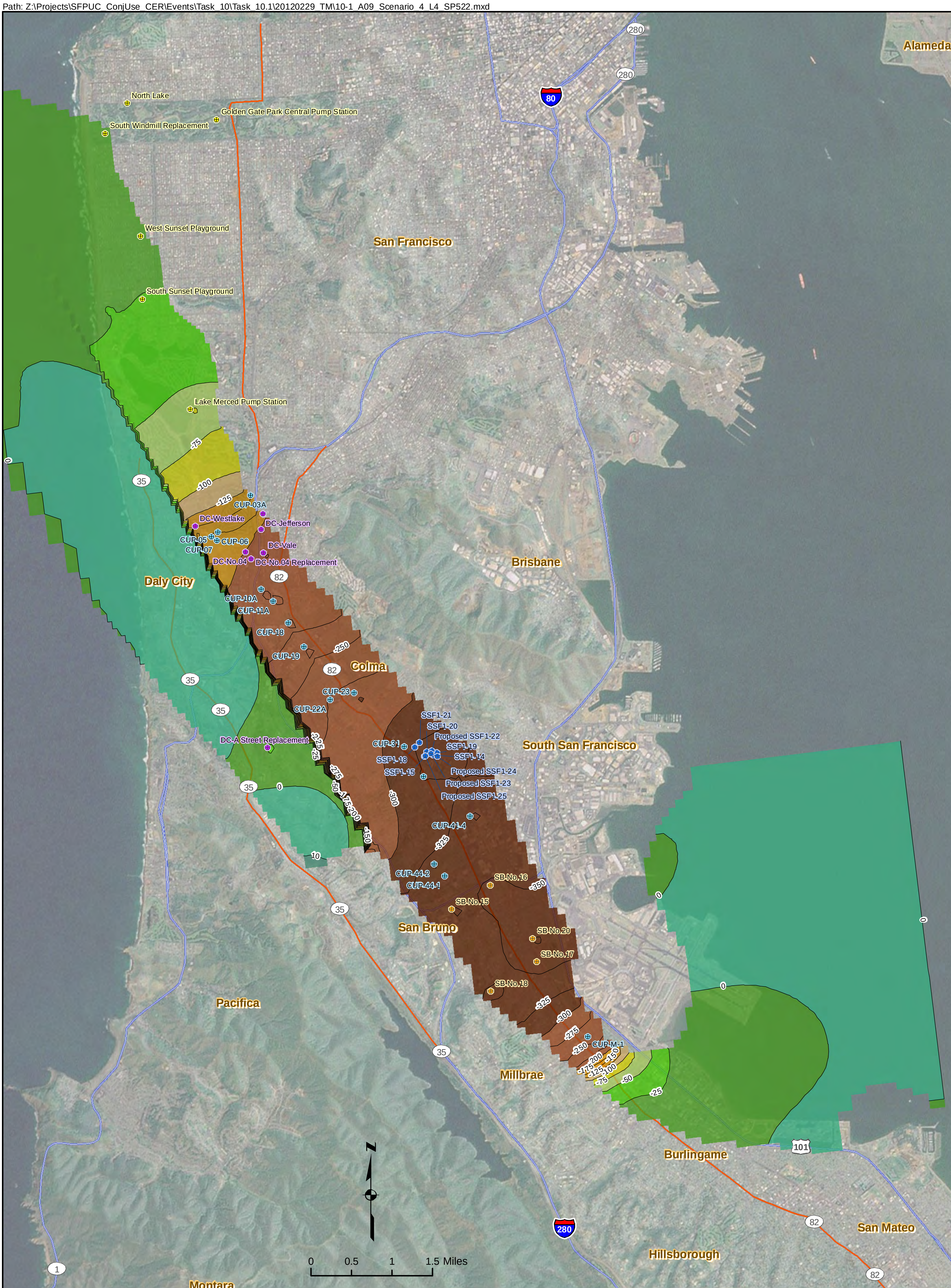
Scenario Year 47

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

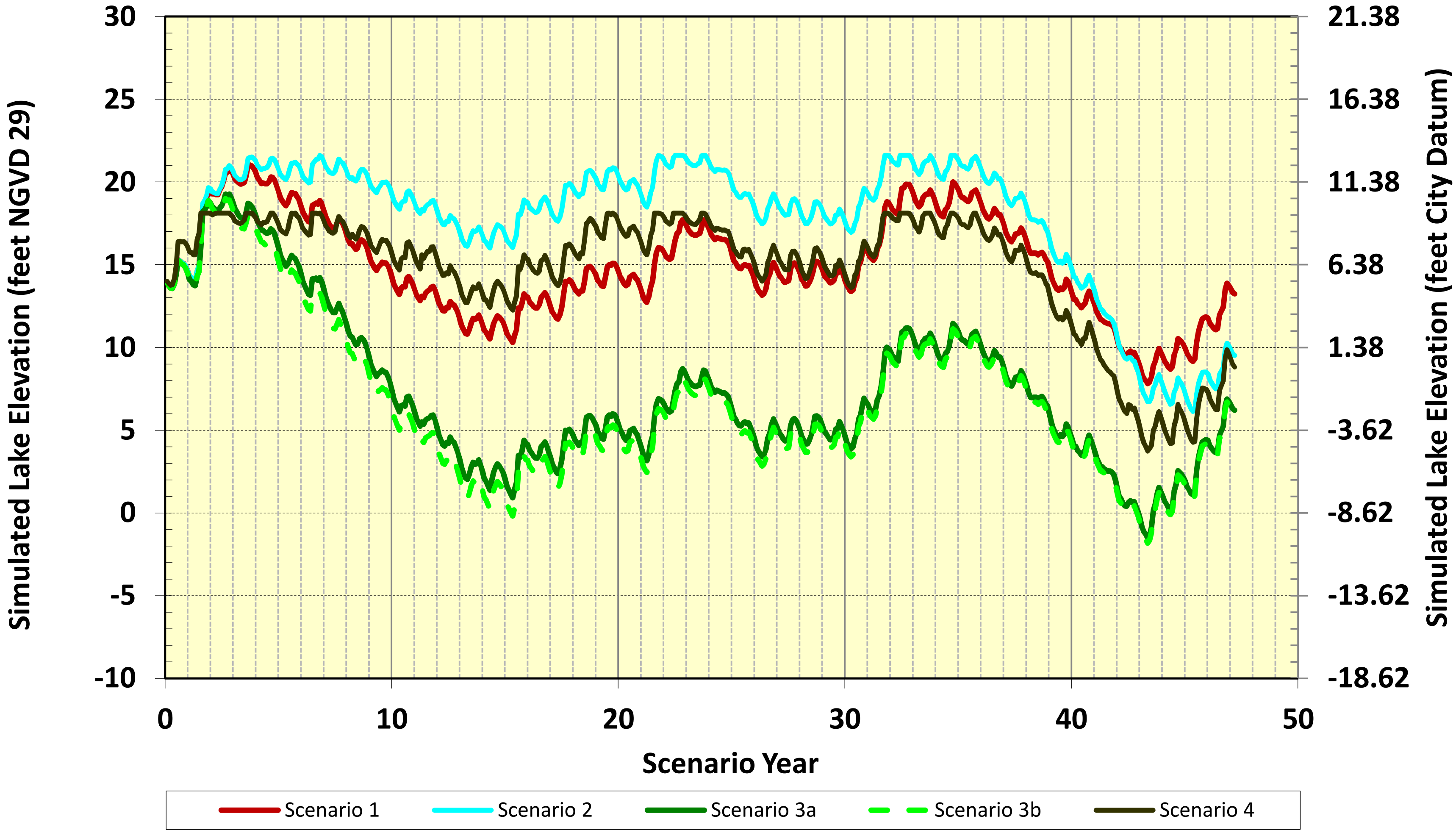
Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Date
April 2012

Attachment 10.1-G

Model Scenario Lake Hydrographs from Lake Merced Lake-Level Model

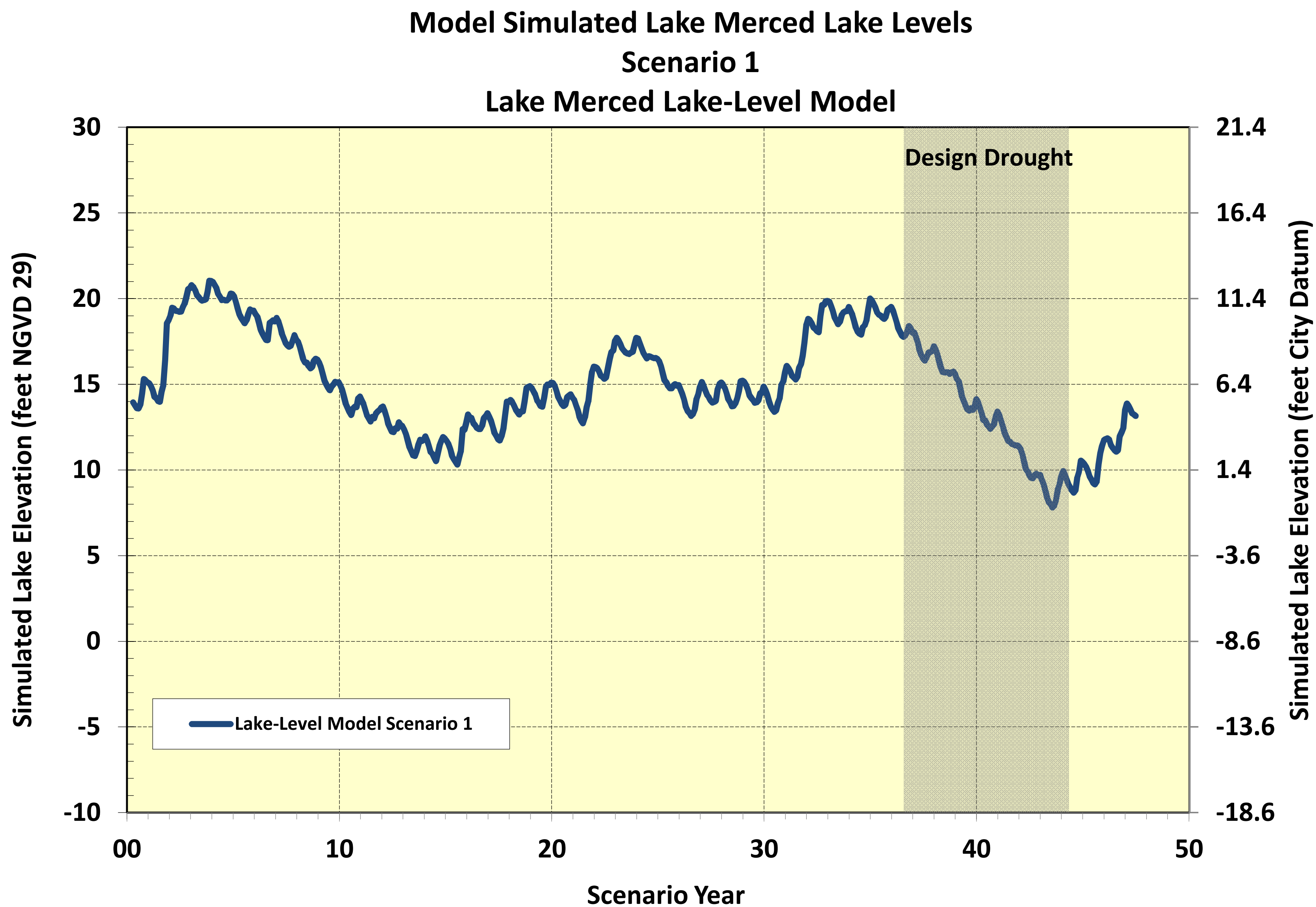
Model Simulated Lake Merced Lake Levels
Comparison of Scenarios 1, 2, 3a, 3b, and 4
Lake Merced Lake-Level Model



Lake Merced Lake-Level Model Water Balance
Scenario 1
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	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**

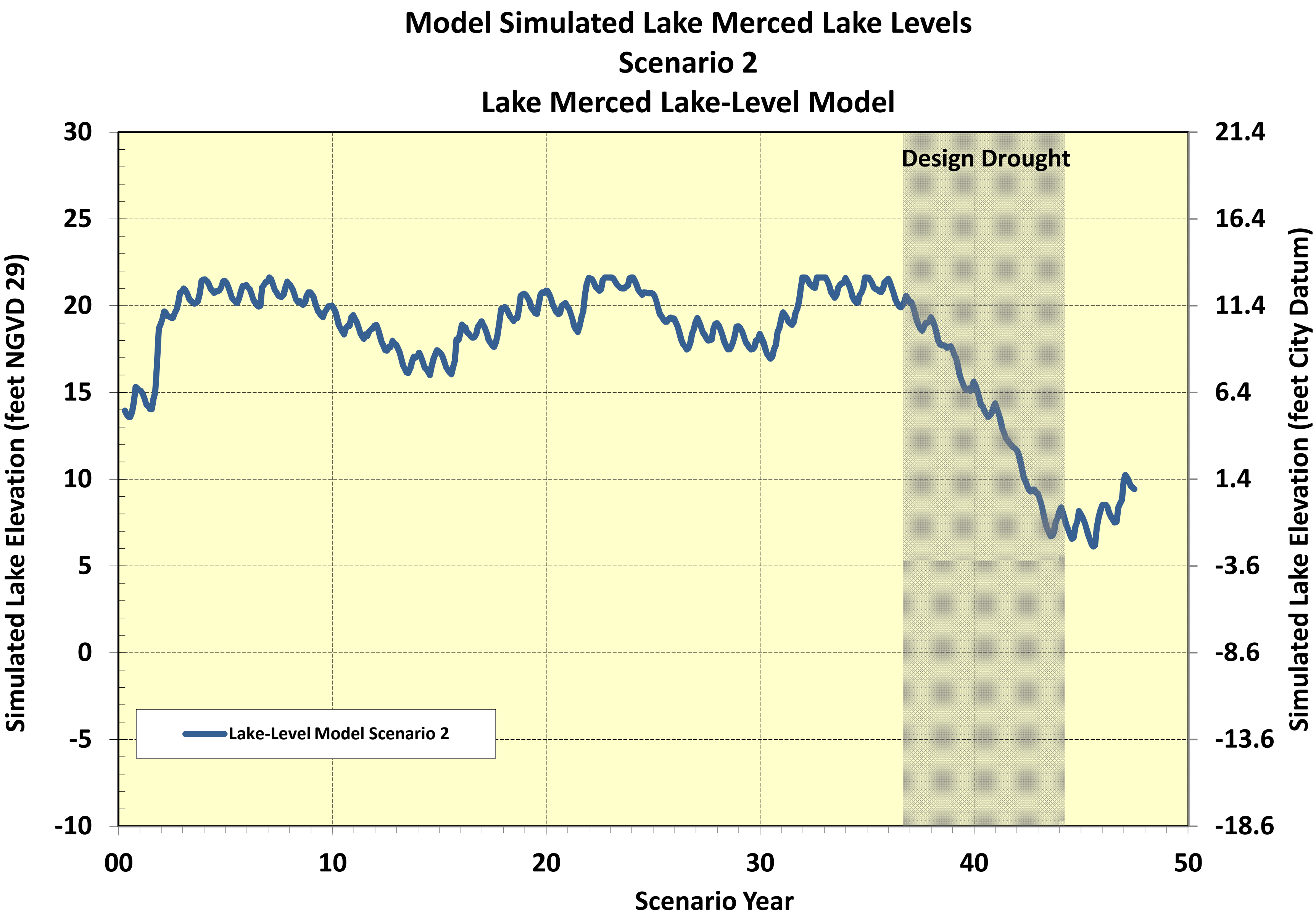
Key:
af - acre-feet
VG - Vista Grande


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

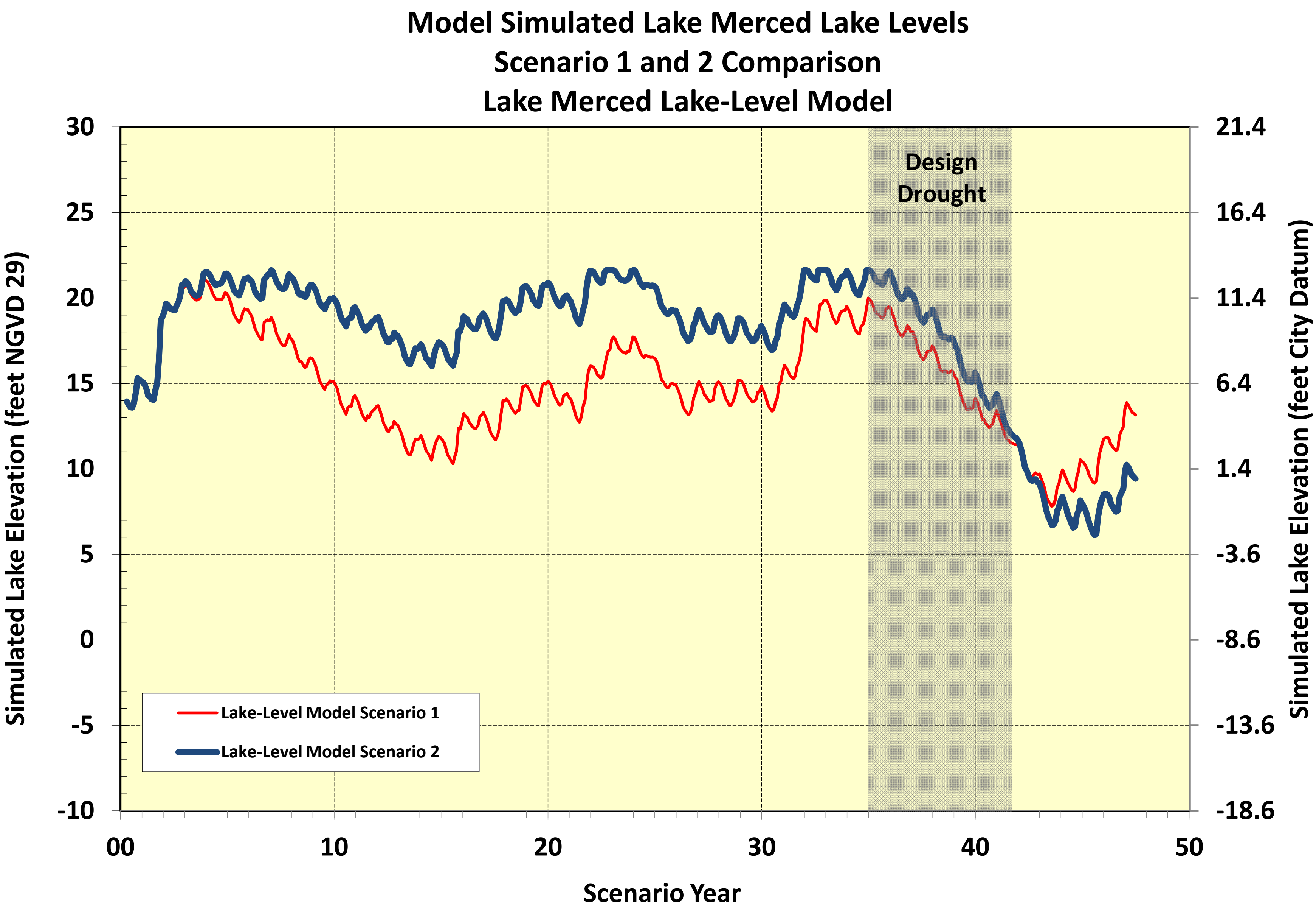
Lake Merced Lake-Level Model Water Balance
Scenario 2
SFPUC GSR and SFGW Projects Technical Analysis

Assumptions:		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	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



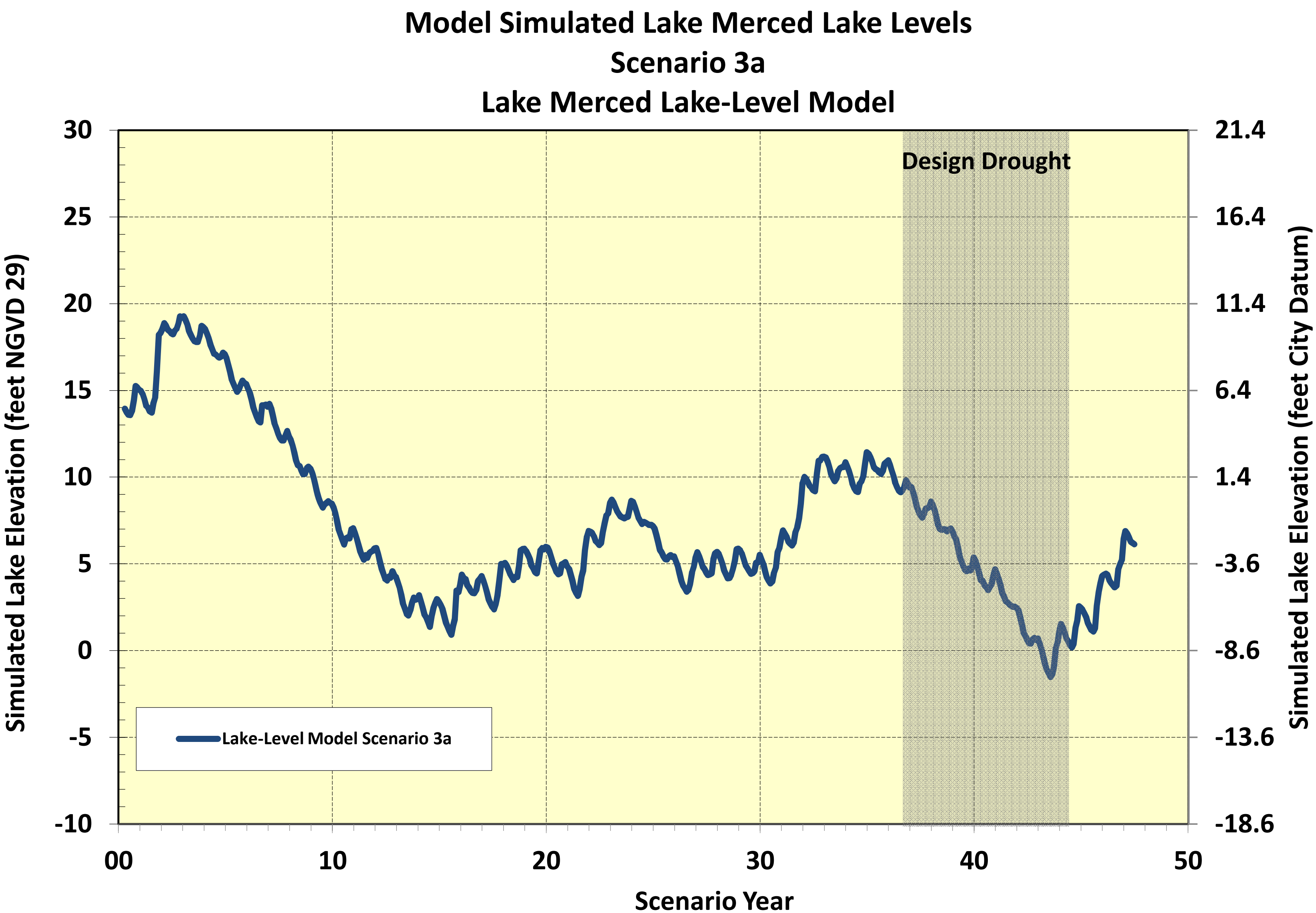
Model Simulated Lake Merced Lake Levels
Scenario 2
Lake Merced Lake-Level Model
Design Drought
Lake-Level Model Scenario 2
Simulated Lake Elevation (feet NGVD 29)
Simulated Lake Elevation (feet City Datum)
Scenario Year
30
25
20
15
10
5
0
-5
-10
21.4
16.4
11.4
6.4
1.4
-3.6
-8.6
-13.6
-18.6
00
10
20
30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

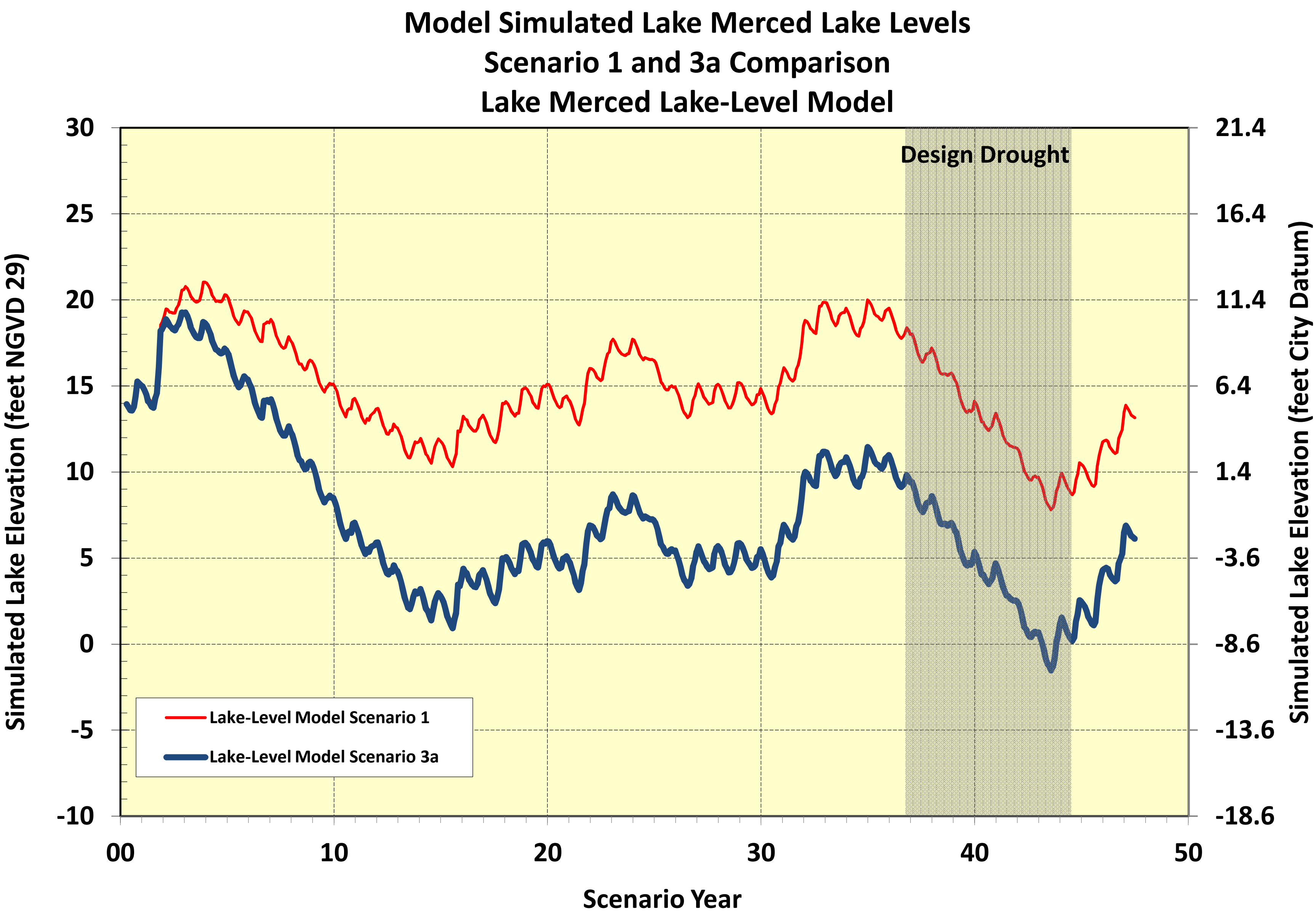
Lake Merced Lake-Level Model Water Balance
Scenario 3a
SFPUC GSR and SFGW Projects Technical Analysis

Assumptions: (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	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

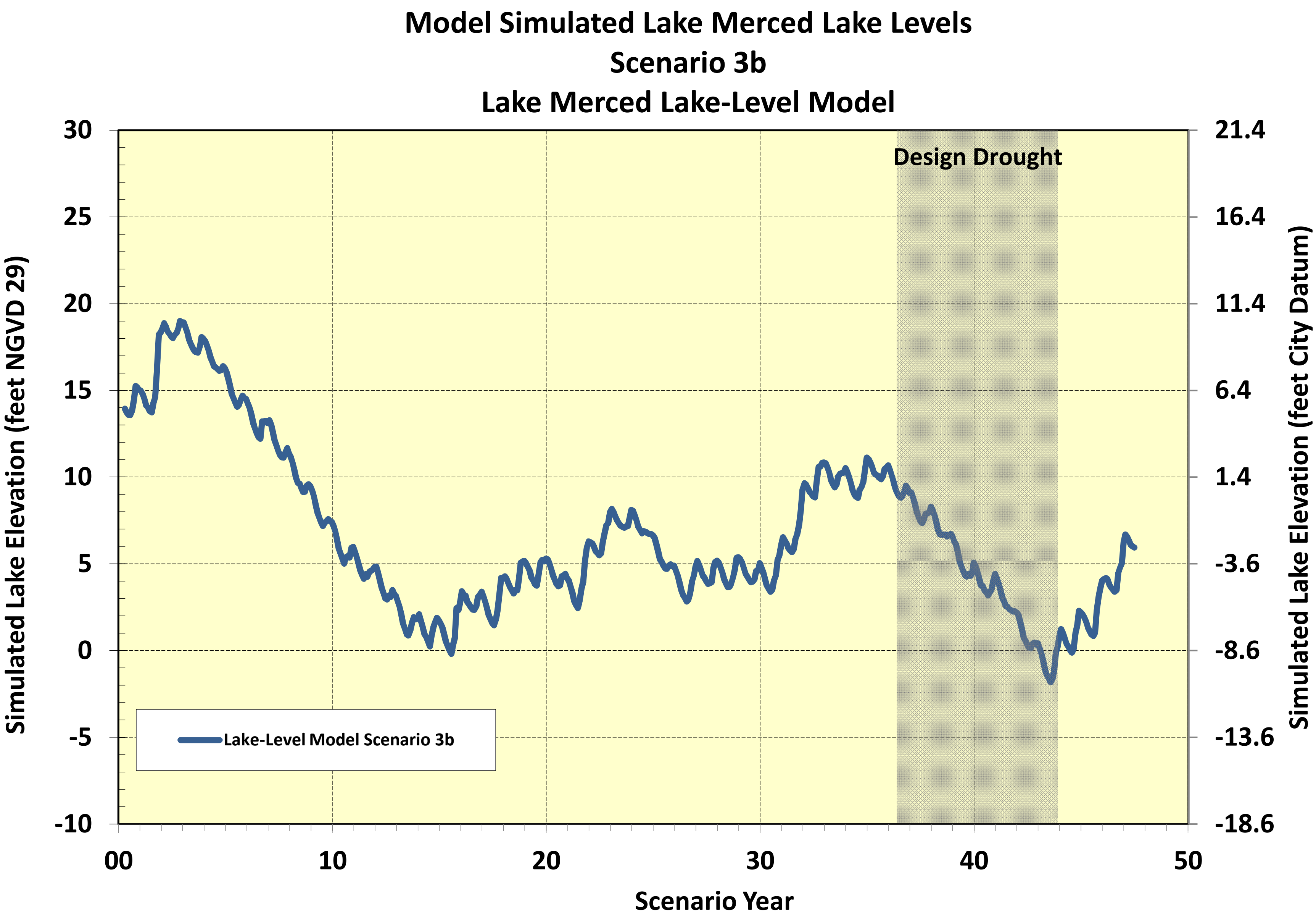


Model Simulated Lake Merced Lake Levels
Scenario 1 and 3a Comparison
Lake Merced Lake-Level Model
Design Drought
Simulated Lake Elevation (feet NGVD 29)
Simulated Lake Elevation (feet City Datum)
Scenario Year
30
25
20
15
10
5
0
-5
-10
21.4
16.4
11.4
6.4
1.4
-3.6
-8.6
-13.6
-18.6
00
10
20
30
40
50
Lake-Level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

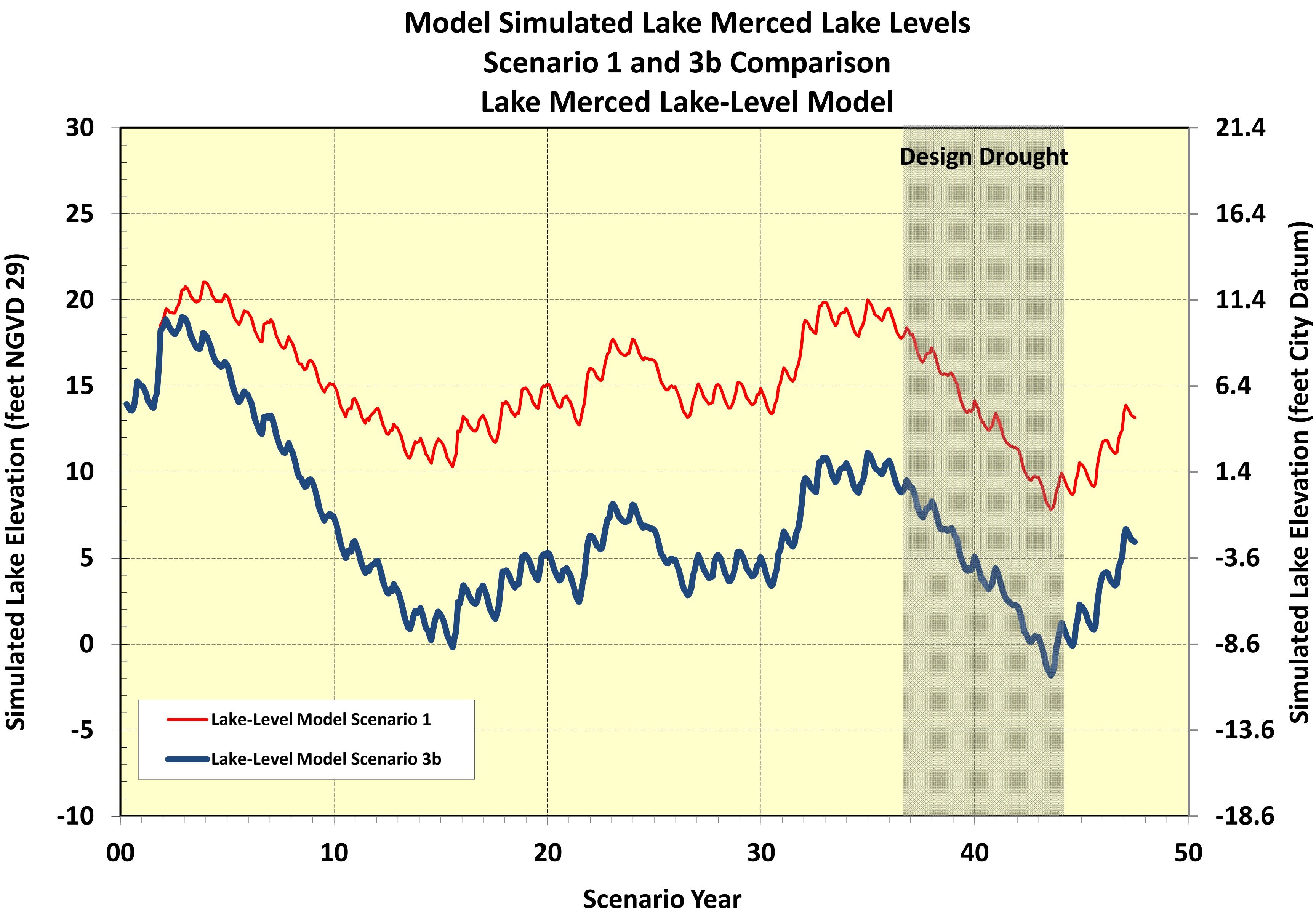
Lake Merced Lake-Level Model Water Balance
Scenario 3b
SFPUC GSR and SFGW Projects Technical Analysis

Assumptions:		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	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
00
10
20
30
40
50

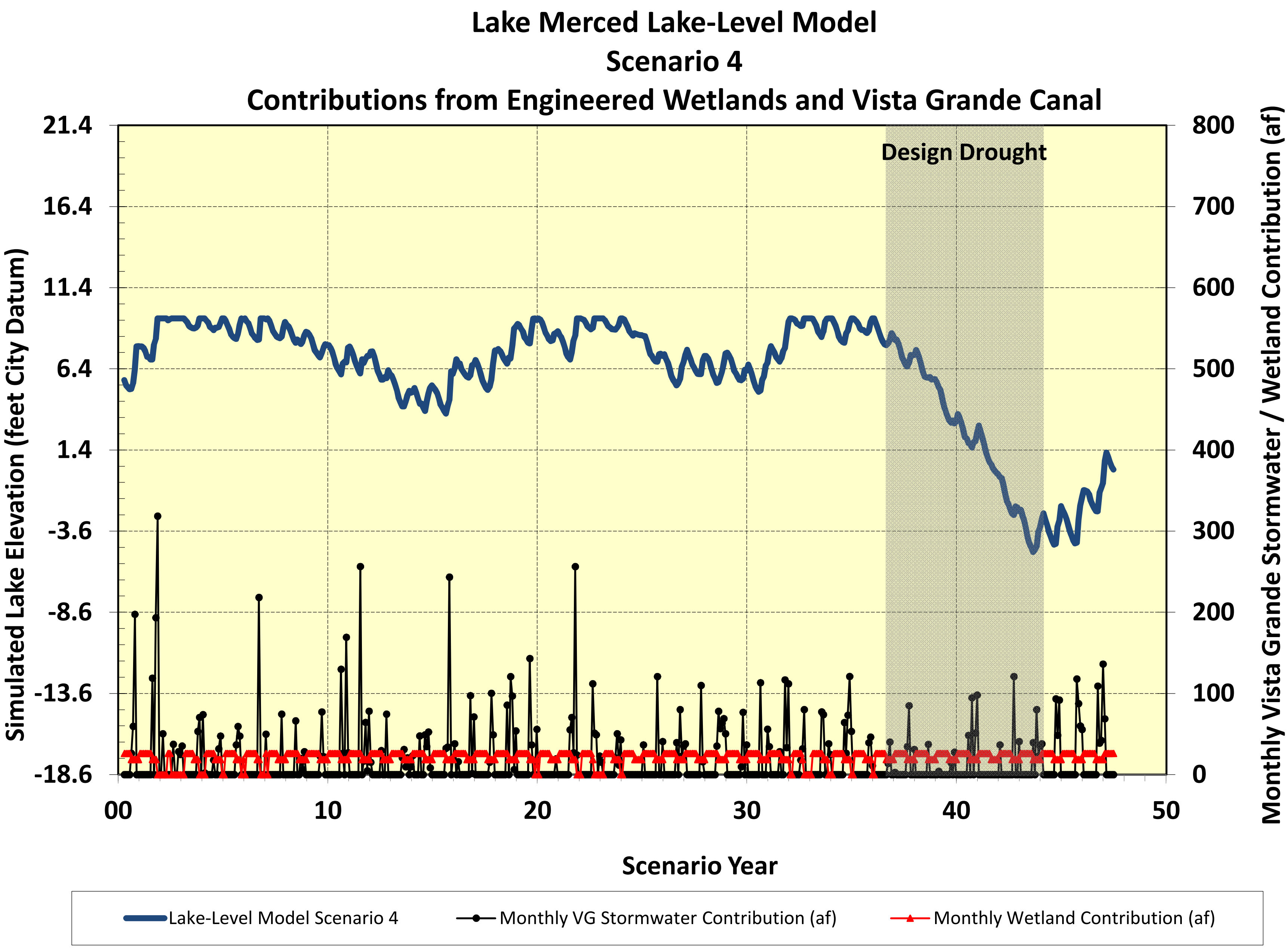


Model Simulated Lake Merced Lake Levels
Scenario 1 and 3b Comparison
Lake Merced Lake-Level Model
Design Drought
Simulated Lake Elevation (feet NGVD 29)
Simulated Lake Elevation (feet City Datum)
Scenario Year
Lake-Level Model Scenario 1
Lake-Level Model Scenario 3b
30
25
20
15
10
5
0
-5
-10
21.4
16.4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

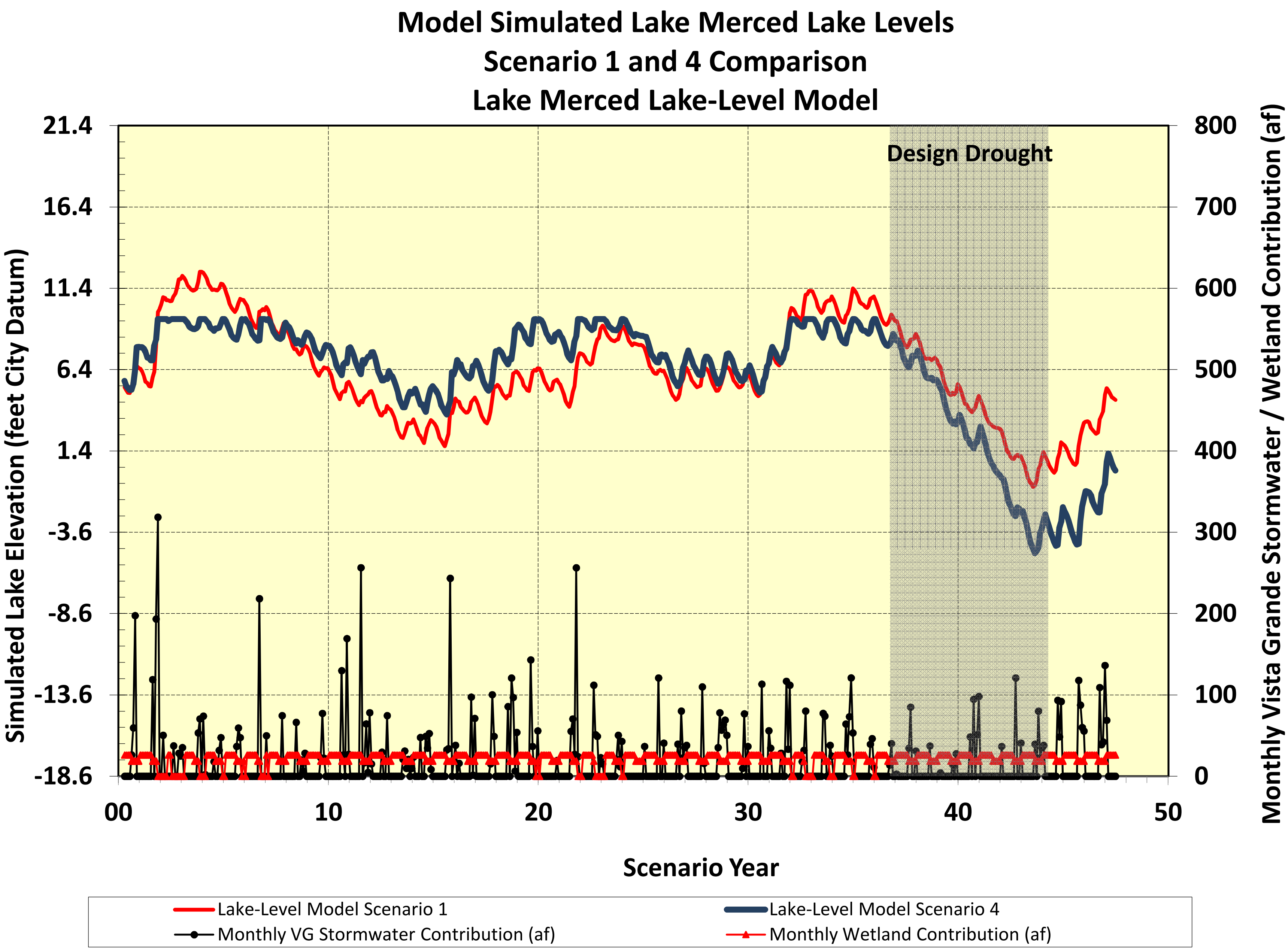
Lake Merced Lake-Level Model Water Balance
Scenario 4
SFPUC GSR and SFGW Projects Technical Analysis

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
21.4
16.4
11.4
6.4
1.4
-3.6
-8.6
-13.6
-18.6
Simulated Lake Elevation (feet City Datum)
800
700
600
500
400
300
200
100
0
Monthly Vista Grande Stormwater / Wetland Contribution (af)
00
10
20
30
40
50
Scenario Year
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

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:

- <u>Change in Lake Storage</u> – 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
- <u>Direct Precipitation</u> – Inflow to Lake Merced resulting from rainfall that falls directly onto Lake Merced surface.
- <u>Stormwater Runoff</u> – 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.
- <u>Evaporation</u> – 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.

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

- <u>Recovering</u> aquifer conditions were defined as periods of high rainfall along with reduced groundwater pumping when lake levels rose significantly.
- <u>Rising</u> aquifer conditions were defined as periods of reduced groundwater pumping or when groundwater levels were generally higher than lake levels.
- <u>Stable</u> aquifer conditions were defined as periods of reduced groundwater pumping or when groundwater levels were generally similar to lake levels.
- <u>Low</u> 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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Source: ESRI Online Aerial Imagery, 2007 (2ft resolution)

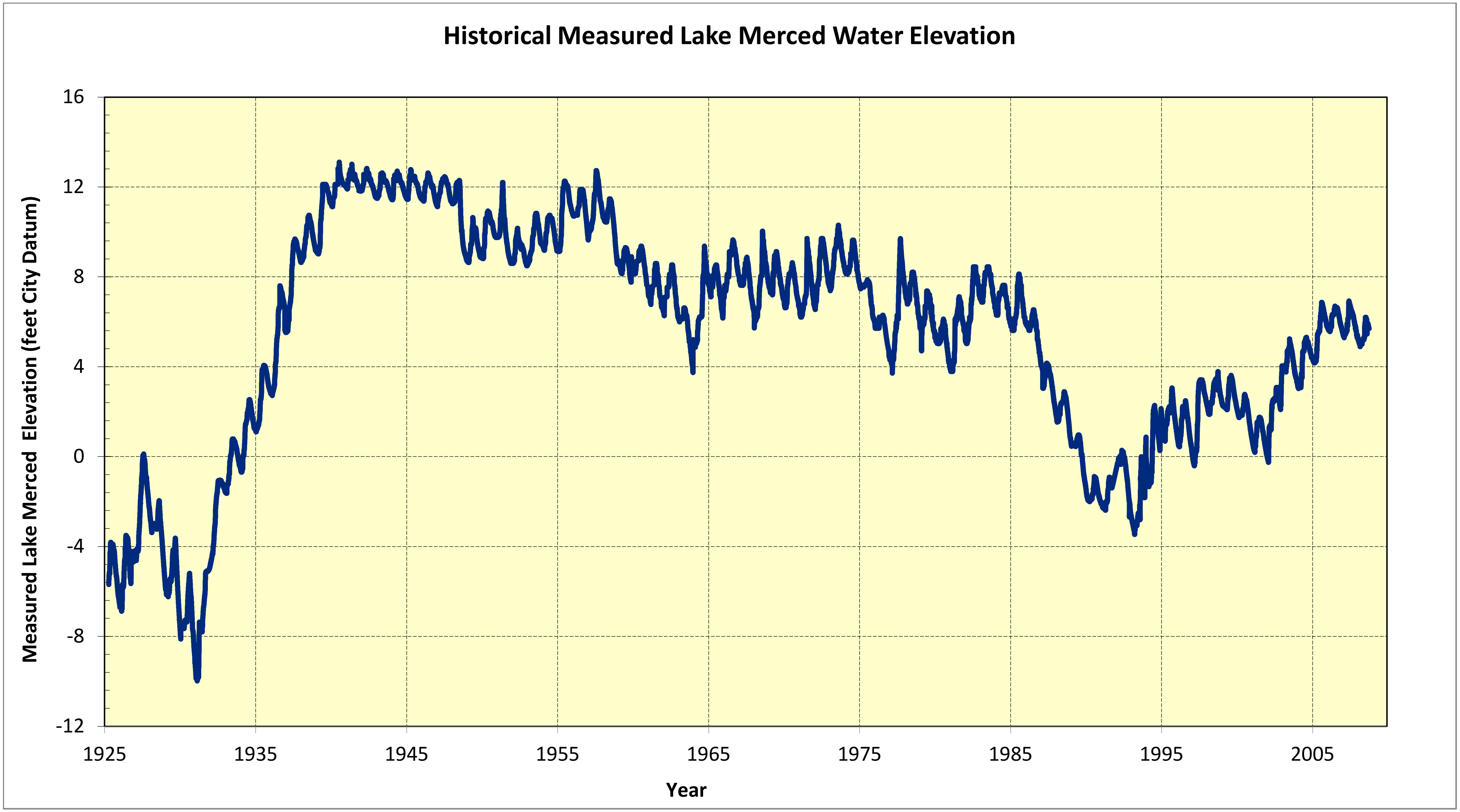
Kennedy/Jenks Consultants

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

Legend

Historical Measured Lake Merced Water Elevation (feet City Datum)

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Regional Groundwater Storage and Recovery Project
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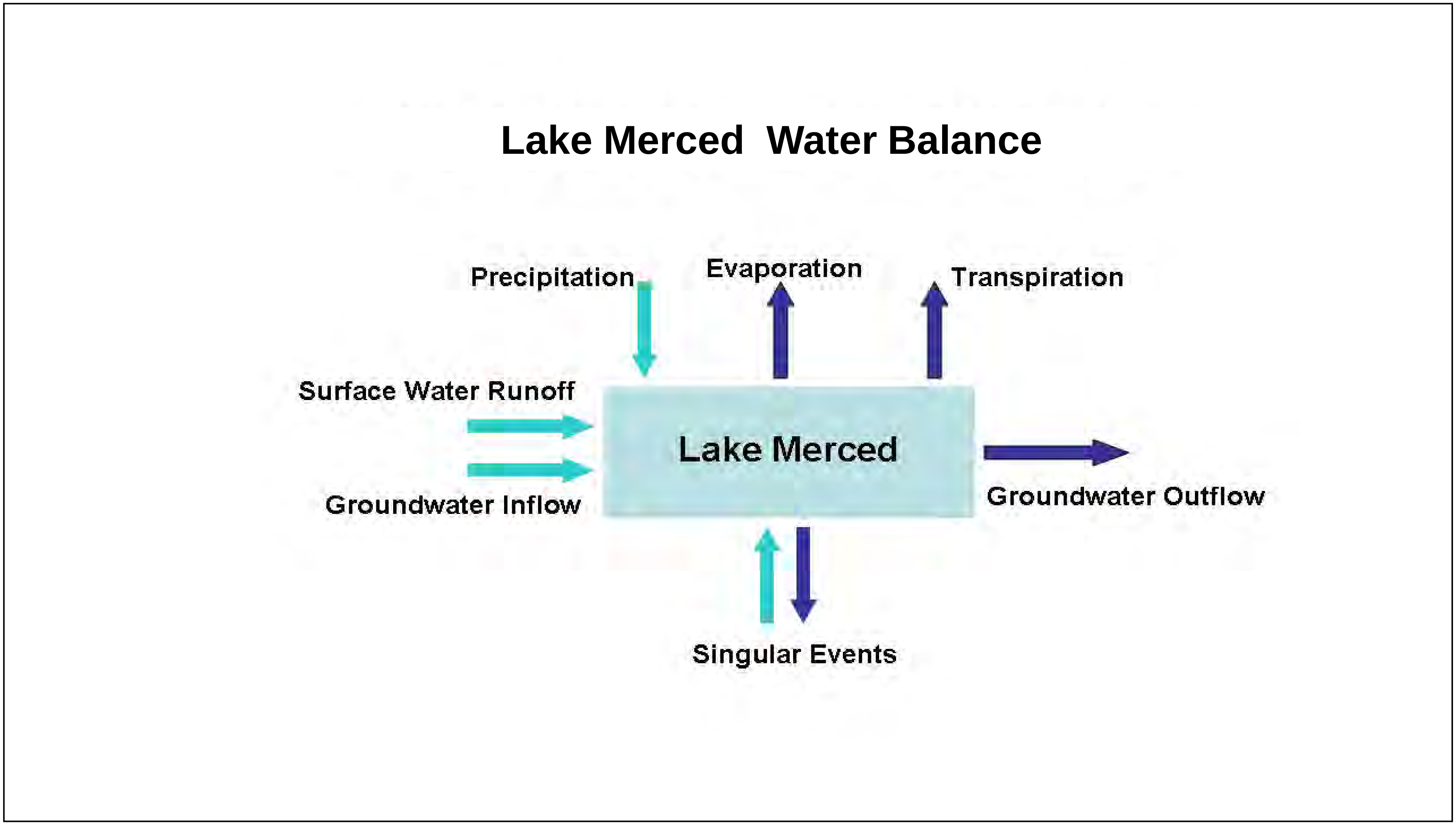
San Francisco Public Utilities Commission

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

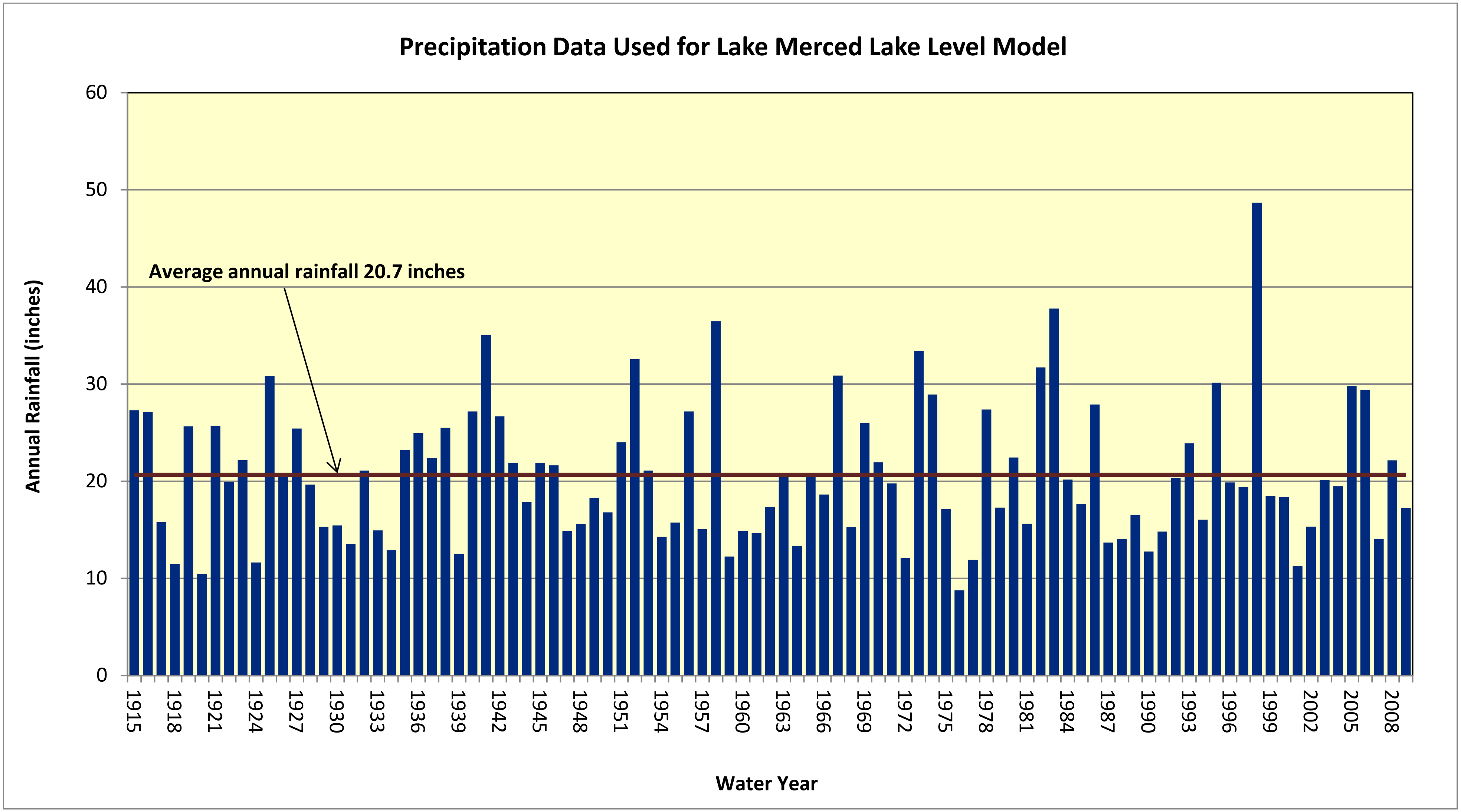
K/J 0864001
April 2012

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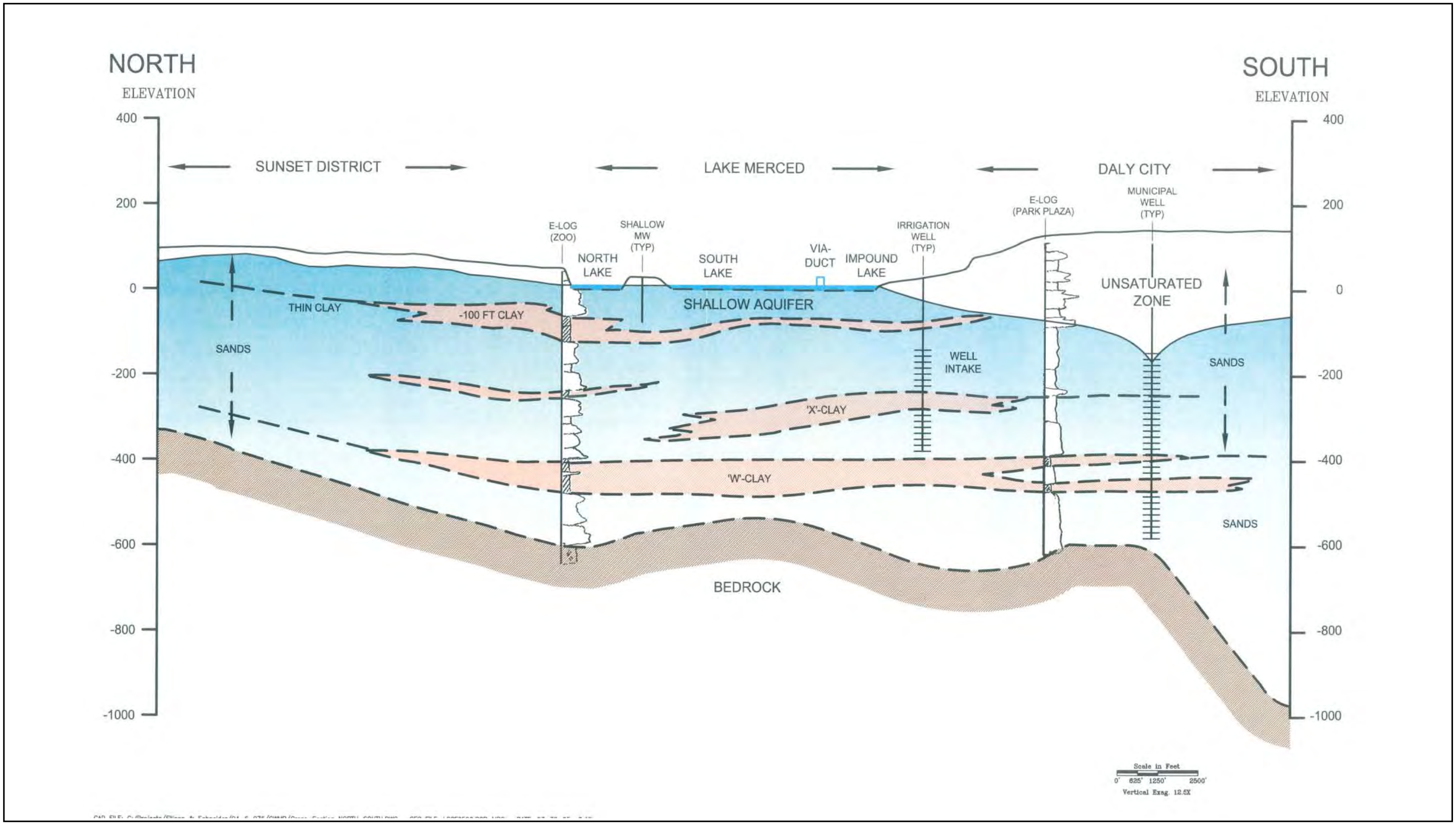
Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Locations of Stormdrain Catch Basins

K/J 0864001
April 2012

Figure 6



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

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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

Path: Z:\Projects\SFPUC_ConjUse\Events\20090804_LakeMercedFigures\Figure8.mxd

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

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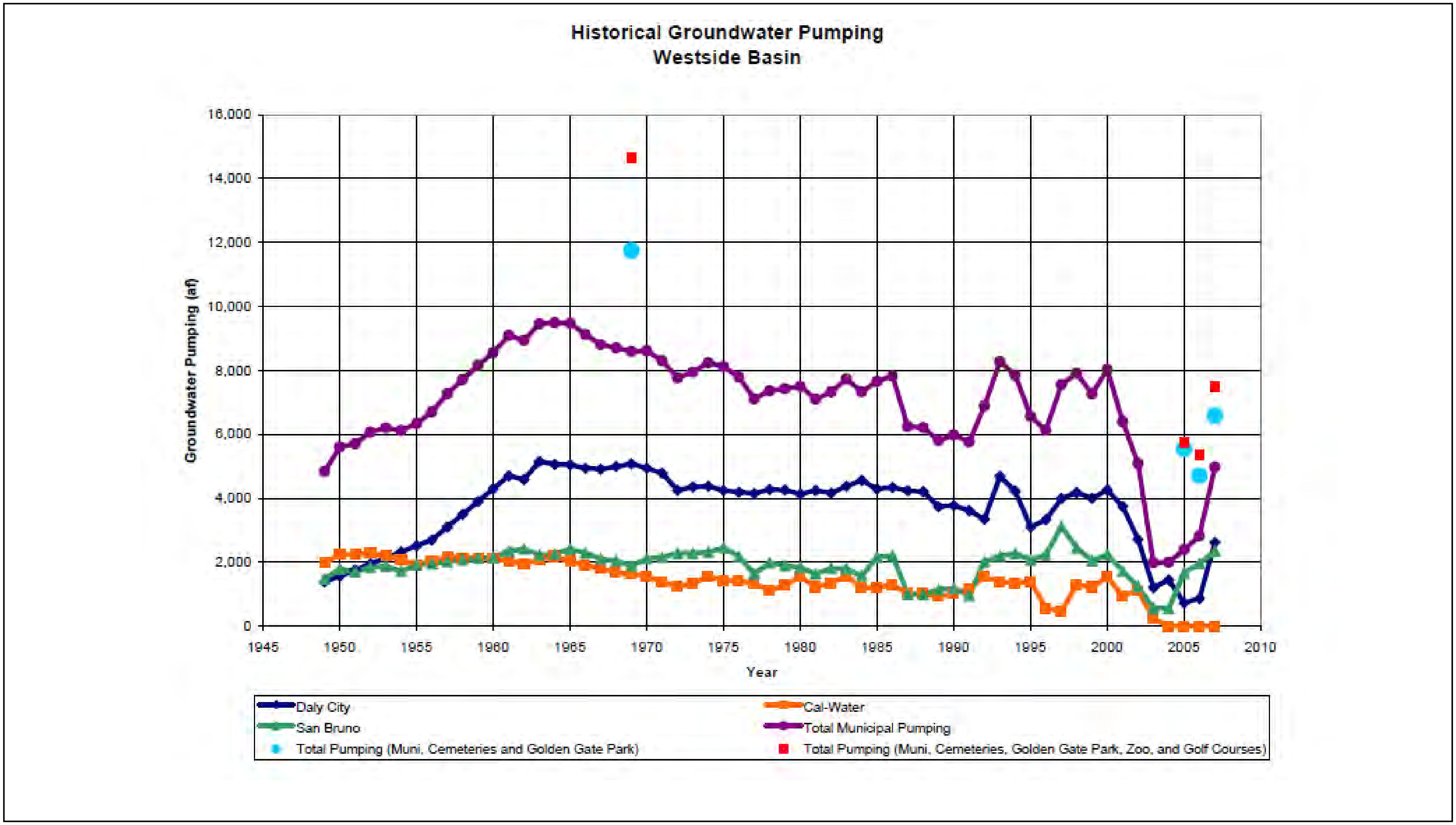
Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

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

Filename: Z:\Projects\SFPUC_ConjUseEvents\20090804_LakeMercedFigures\Figure10.mxd

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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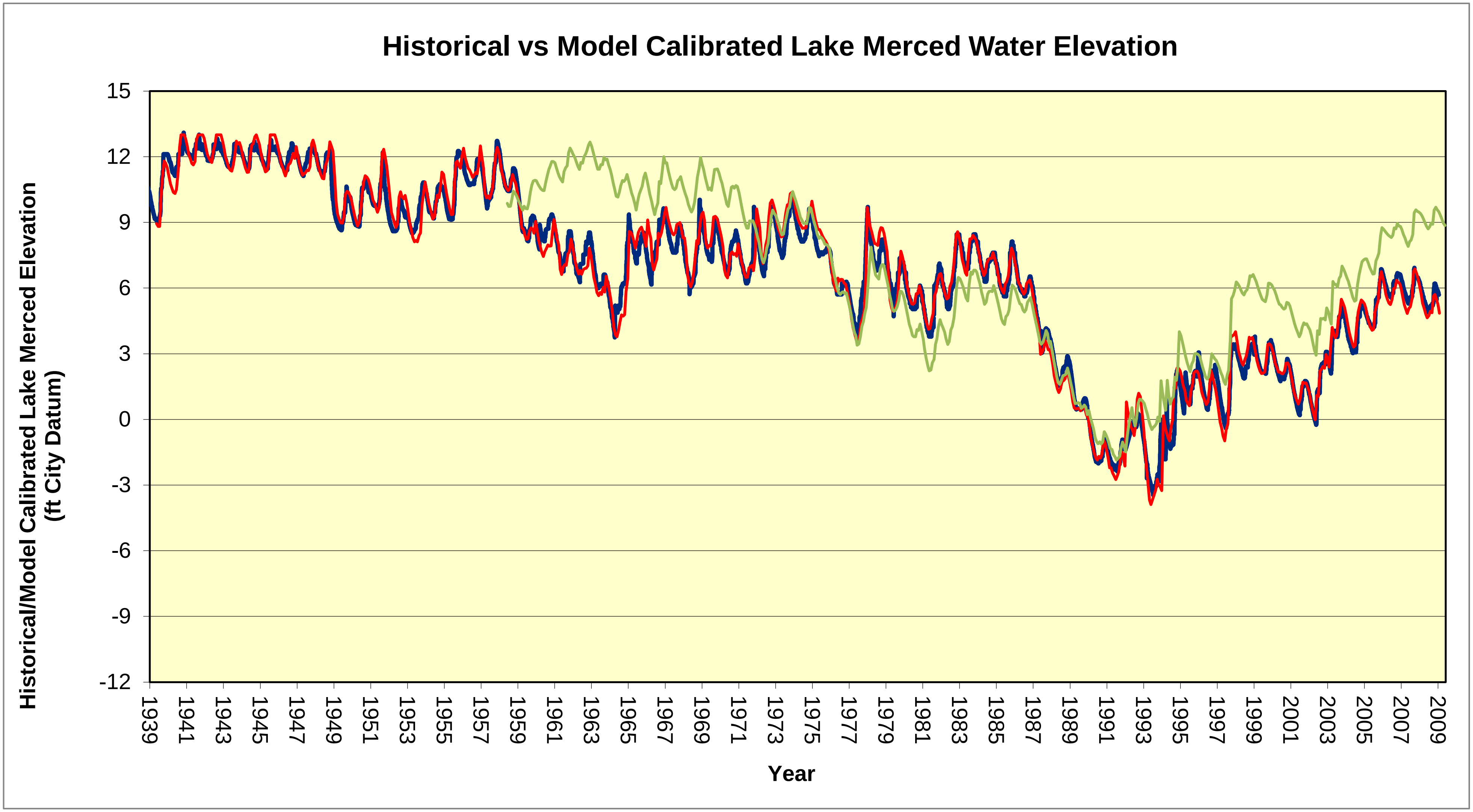
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

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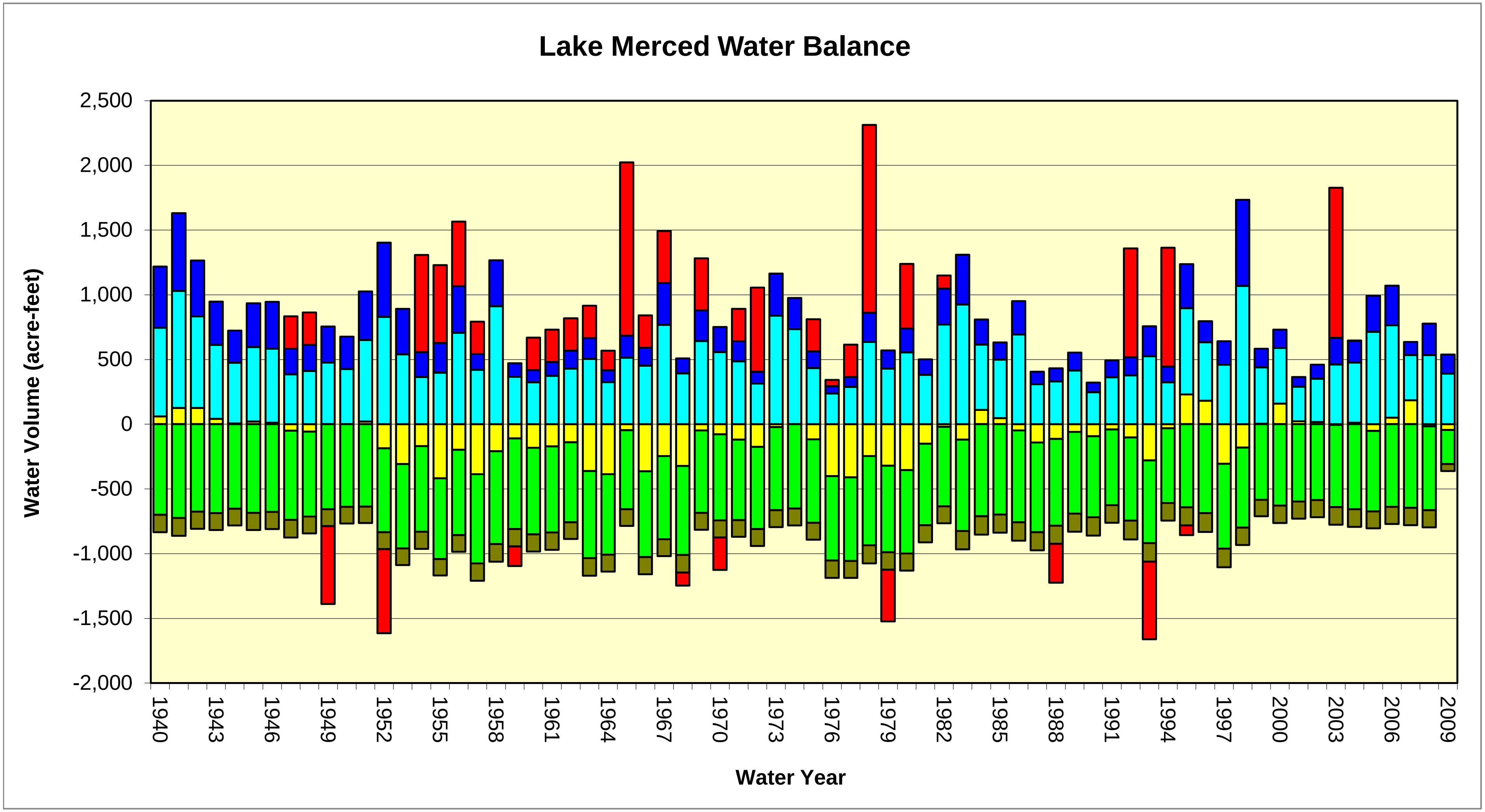
Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

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)

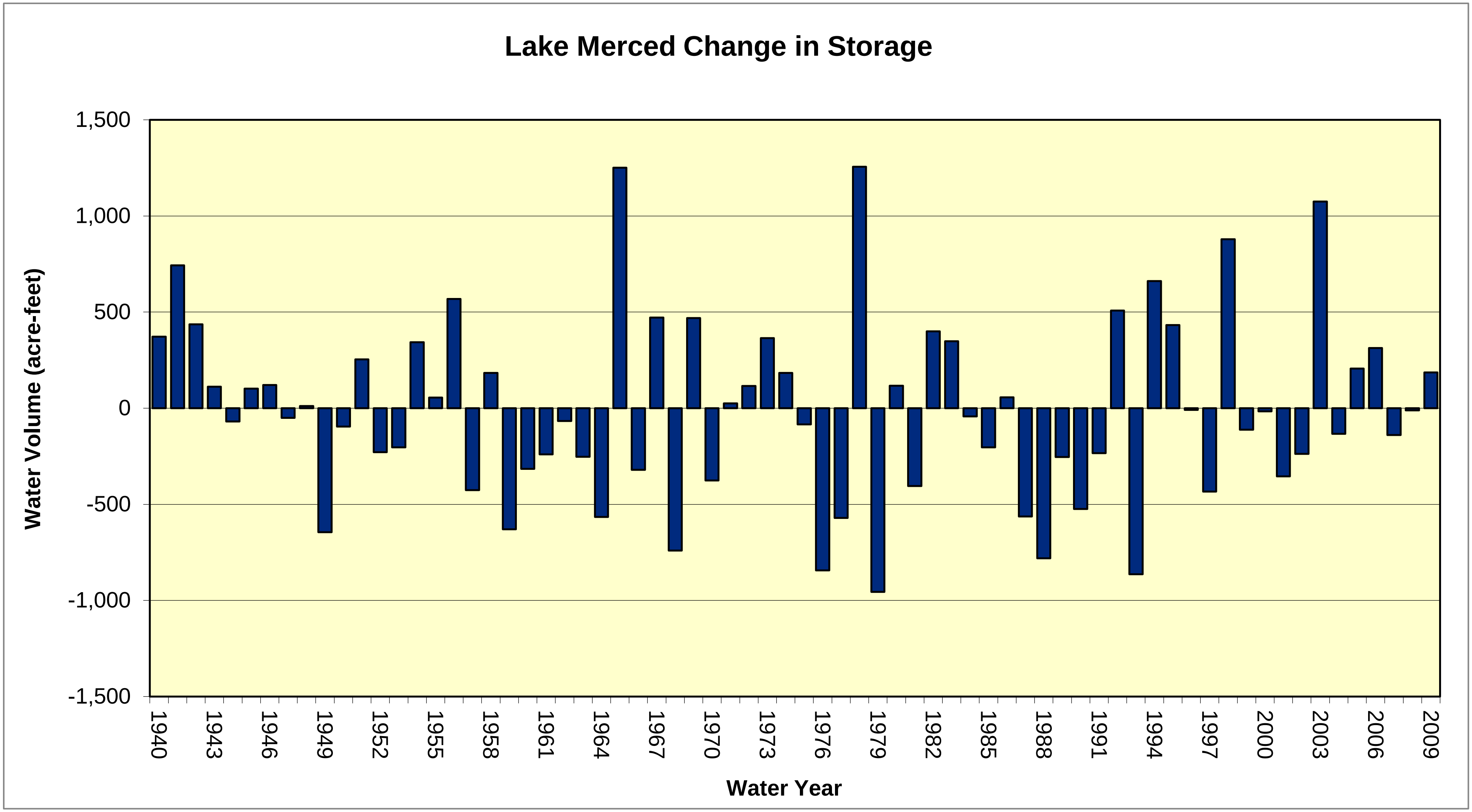
Kennedy/Jenks Consultants

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)

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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

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	60.92a	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	57.17a	55.40	57.29	59.12	61.44	61.95	63.40	60.35	57.28	50.77	57.26
2008	49.85a	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	52.78a	54.11	55.85	58.02	60.39b	59.48h	-----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**