Appendix H – TM 10.4

Groundwater Level and Storage

24 April 2012

Task 10.4 Technical Memorandum

San Francisco Public Utilities Commission

Changes in Groundwater Levels and Storage for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project

Prepared For: Greg Bartow and Jeff Gilman, SFPUC

Prepared by: Michael Maley, Dennis Orlowski, Sevim Onsoy, and Matt Baillie, 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 Proposed Regional Groundwater Storage and Recovery (GSR) Project and CUW30102-TO-2.7 of the Proposed San Francisco Groundwater Supply (SFGW) Project. These projects are funded by the SFPUC's Water System Improvement Program (WSIP).

1.1. GSR and SFGW Project Description

The GSR Project is a conjunctive use project that would allow for increased groundwater supplies in the southern portion of the Westside Basin (South Westside Basin) during periods of drought when SFPUC surface water supplies become limited (MWH, 2008). The project would be designed to provide up to 60,500 acre-feet (af) of stored water to meet SFPUC system demands during the last 7.5 years of SFPUC's Design Drought. The SFPUC plans to install 16 new production wells for the GSR Project to recover the stored groundwater. Under the Draft GSR Operating Agreement, the SFPUC would "store" water in the South Westside Groundwater Basin through the mechanism of in-lieu recharge by providing surface water as a substitute for groundwater pumping by the Partner Agencies (PAs). As a result of the in-lieu deliveries, up to 60,500 af of groundwater storage or "put" credits could accrue to the SFPUC Storage Account. During shortages of SFPUC system water due to drought, emergencies, or scheduled maintenance, the PAs would return to pumping from their existing wells, and SFPUC would extract groundwater from their new wells as long as a positive balance exists in the SFPUC Storage Account.

The SFGW Project would provide a reliable, local source of high-quality groundwater in the northern portion of the Westside Basin (North Westside Basin) to supplement the San Francisco municipal water system. The SFGW Project would construct up to six wells and associated facilities in the western part of San Francisco and extract an annual average of up to 4.0 million gallons per day (mgd) of water from the North Westside Basin (SFPUC, 2009b). The extracted groundwater, which would be used both for regular and emergency water supply purposes, would be blended in small quantities with imported surface water before entering the municipal drinking water system for distribution. The SFGW Project includes two phases, In phase one, SFPUC would build four new groundwater wells at the Lake Merced Pump Station, West Sunset Playground, South Sunset Playground, and the Golden Gate Park Central Pump Station. In phase two, SFPUC would modify two existing irrigation wells (South Windmill Replacement and North Lake) in Golden Gate Park, converting them into municipal water supply wells.

The locations of existing and proposed GSR and SFGW wells, existing PA wells, and monitoring wells are shown on Figure 10.4-1. Additional detailed discussion of the GSR and SFGW Projects is provided in the Task 10.1 Technical Memorandum - Groundwater Modeling Analysis for the Regional Groundwater Storage and Recovery Project and San Francisco Groundwater Supply Project (TM-10.1).

1.2. Objective

Implementation of the proposed GSR and SFGW Projects would influence groundwater levels and storage in the Westside Groundwater Basin (Westside Basin or Basin). Depending on the magnitude of these changes to Basin groundwater conditions, various existing and planned beneficial uses of Basin groundwater could be affected. Evaluation of the potential groundwater effects is a key management issue for the long-term sustainability of the groundwater resources and overall Basin management.

The purpose of this TM is to evaluate potential changes in future groundwater levels and regional changes in groundwater storage resulting from the proposed operation of the GSR and SFGW Projects, primarily with respect to long-term water supply and groundwater management of the Westside Basin. This TM presents information on the past, current, and projected future conditions in the subsurface related to the issue of groundwater storage. The scope of work includes a discussion of Basin hydrogeology and the physical processes that could cause long-term declines in groundwater storage that may affect the existing and planned water uses in the Basin.

2. Approach and Conceptual Understanding

Presented within this section is a basic framework for understanding the natural hydrogeologic processes and anthropogenic factors that can affect groundwater levels and storage in the Westside Basin.

2.1. General Approach

The general approach used to evaluate potential changes in groundwater storage resulting from implementation of the GSR and SFGW Projects is based on an analysis of measured groundwater data and evaluation of groundwater modeling results. This combined approach is considered to be a screening-level analysis to be used for regional groundwater management, with a focus on evaluating whether or not the GSR and SFGW projects would be expected to affect the long-term capability of groundwater users to maintain groundwater pumping for existing or planned land uses.

The groundwater model allows evaluation of the complex interactions produced by the GSR and SFGW projects by simulating potential future conditions. The Westside Basin Groundwater-Flow Model, a regional, basin-wide groundwater model developed by HydroFocus (2007, 2009, and 2011) for the City of Daly City (Daly City), was reviewed with assistance from California Water Service Company (Cal Water), the City of San Bruno (San Bruno), and SFPUC, and the model was accepted for use in selected applications by all parties as capable of supporting water resources planning and management in the Westside Basin. For this evaluation, five model scenarios were constructed and simulated to evaluate potential groundwater and related hydrological effects from the GSR and SFGW Projects and from the Cumulative Scenario that involves the GSR and SFGW Projects and other reasonable foreseeable future projects. The development of the model scenarios is documented in TM-10.1.

For this evaluation, existing data and reports were reviewed and summarized to provide a discussion of how the Basin has responded to historical pumping and other hydrogeologic conditions. Evaluating historical conditions (based on an analysis of measured data) provides a context against which to assess the groundwater modeling results.

2.2. Westside Groundwater Basin

This section provides a brief overview of the physical setting and hydrogeology of the Westside Basin More detailed descriptions of the evaluations of the hydrogeology of the Westside Basin are presented LSCE (2010) and TM10.1. Figure 10.4-2 provides a representative cross section from north to south across the Westside Basin. There are three aquifer systems that are commonly referred to in the Westside Basin. These include:

- Shallow Aquifer: this aquifer is present in the northern part of the Basin, in the vicinity of Lake Merced and the southern portion of the Sunset district of San Francisco. The base of the Shallow Aquifer is defined as the top of the “-100 foot clay.”

- Primary Production Aquifer: this aquifer is present throughout the Basin, overlying the “W-clay” where present. Where the W-clay is not present in locations to the south (in the South San Francisco area), the Primary Production Aquifer is divided into shallow and deep units separated by a clay unit at an elevation of approximately -300 feet mean sea level (msl).
- Deep Aquifer: this aquifer underlies the W-clay, and thus its extent is limited to the generally-known extent of that clay unit (LSCE, 2010).

The three aquifer systems are separated by thick, extensive clay units (e.g., the -100 ft clay and W-clay). Because of the discontinuous nature of these clay layers, the basin is considered to be a semi-confined aquifer system where limited flow occurs between the different aquifer systems where local geologic conditions permit (LSCE, 2010).

2.3. Existing Groundwater Monitoring and Reporting Activities

Over the last decades, there has been a substantial increase in data collection efforts and cooperative management of groundwater resources in the Westside Basin among the SFPUC, the City of San Bruno, the City of Daly City, and California Water Service Company (Cal Water, municipal water purveyor to South San Francisco). Annual monitoring reports have been published by the SFPUC since 2006 (LSCE, 2006 and SFPUC, 2007, 2008 and 2009) and summarized in (LSCE (2010) and TM10.1.

2.4. Conceptual Understanding of Groundwater Levels and Storage

Groundwater levels and storage within a basin are affected by changes in the water balance for that basin. A water balance is an accounting of the amount of groundwater entering (inflow) and leaving (outflow) the groundwater basin. Simply stated, based on the law of conservation of mass, a water balance for a groundwater system is expressed as:

Change in Groundwater Storage = Total Groundwater Inflow – Total Groundwater Outflow

Typical inflow components to a groundwater basin include precipitation, groundwater (subsurface) inflow, and return flow from irrigation. Common outflow components include groundwater (subsurface) outflow and pumping. Interactions between the aquifer and lakes, bays and oceans (groundwater-surface water interactions) can either be groundwater inflow or outflows depending upon the relative difference in head between the groundwater and the surface water body. As indicated by the above expression, the difference between total groundwater inflow and total groundwater outflow results in a change to the volume of groundwater stored in the basin, referred to as “groundwater storage” (Fetter, 1988). Changes in groundwater storage are manifested as changes in groundwater levels measured in wells; net positive changes in groundwater storage result in increased water levels, and net negative changes result in lowered water levels.

3. Groundwater Model Analysis

To evaluate groundwater conditions that may result from the operation of the GSR and SFGW Projects, a series of model scenarios was developed using the Westside Basin Groundwater-Flow Model (HydroFocus 2007, 2009, and 2011). The development of the model assumptions and scenarios is documented in TM-10.1. This section provides an evaluation of model-predicted changes in groundwater levels and storage related to implementation of the GSR and SFGW Projects based on the model scenarios.

3.1. Modeling Scenarios

Five model scenarios were constructed and simulated to evaluate potential groundwater and related hydrological effects from the GSR and SFGW Projects and from the Cumulative Scenario that involves the GSR and SFGW Projects and other reasonably foreseeable future projects. The following is a summary of the five scenarios used for the groundwater model analysis:

1. <u>Scenario 1, Existing Conditions</u>: Scenario 1 Existing Conditions, does not include the SFPUC Projects (either the GSR or SFGW Project). Groundwater pumping by the PAs and irrigation pumping are representative of the existing pumping conditions (as of June 2009). As described in TM10.1, the PA pumping was established based on the historical pumping rates, using the median of the 1959-2009 pumping data for individual agencies.
2. <u>Scenario 2, GSR Project Only</u>: Scenario 2 represents implementation of the GSR Project operations including: “Put” periods represent when groundwater pumping by SFPUC and the PAs does not occur and groundwater is placed into the SFPUC Storage Account through in-lieu recharge; “Hold” periods represent when the PAs are pumping and no in-lieu recharge is occurring because the SFPUC Storage Account is full; and “Take” periods represent when both SFPUC and the PAs are pumping from the South Westside Basin.
3. <u>Scenario 3a, SFGW Project Only (3 mgd)</u>: For Scenario 3a, the four new wells constructed for the SFGW Project would pump at an annual average rate of 3.0 mgd; however, the two existing irrigation wells in Golden Gate Park would remain irrigation wells, and their irrigation pumping rates would be the same as in Scenario 1.
4. <u>Scenario 3b, SFGW Project Only (4 mgd)</u>: For Scenario 3b, the four new wells constructed for the SFGW Project and the two modified irrigation wells in Golden Gate Park would pump at an annual average rate of 4.0 mgd. Irrigation in Golden Gate Park is assumed to be replaced by the Westside Recycled Water Project. Total combined pumping for Scenario 3b is slightly less than under Scenario 3a, because the total SFGW Project pumping in Scenario 3b would increase by 1.0 mgd; however, the irrigation pumping that was replaced would be slightly more than 1.0 mgd.
5. <u>Scenario 4, Cumulative Scenario</u>: Scenario 4 represents implementation of both the GSR and SFGW Projects (Scenarios 2 and 3b) along with other reasonably foreseeable

future projects. The other foreseeable projects are discussed in more detail in TM10-1 but primarily include the Daly City Vista Grande Drainage Area Improvements Project, which increases stormwater diversions into Lake Merced, the Daly City A-Street Replacement Well which shifts some of the Daly City pumping outside the South Westside Basin, and a minor increase in irrigation pumping based on the planned build-out of the Holy Cross cemetery.

As discussed in TM-10.1, the strongest predictive ability of the existing model is in relative changes over time, rather than the simulated groundwater levels. Therefore, it is more appropriate to analyze the results of the groundwater model using differences in water levels relative to a base case rather than simulated groundwater elevations. Scenario 1, the Existing Conditions scenario, forms the base case against which the results of the GSR-only, SFGW-only, and Cumulative Scenarios are compared.

To allow for the model scenarios to be directly comparable, all five model scenarios are set up using similar initial conditions and background hydrology. All of the modeled scenarios have the same projected simulation period of 47.25 years and use initial groundwater conditions that represent June 2009 conditions. All five model scenarios use the same hydrologic sequence, which includes an 8.5-year Design Drought period used in the Program Environmental Impact Report (PEIR; SFPUC, 2007; SFPUC, 2009a). The Design Drought repeats the December 1975 to March 1978 drought period following the dry conditions of July 1987 to November 1992. To incorporate the Design Drought, the historical hydrological sequence was rearranged. A more detailed discussion of the development of the background hydrology is presented in TM-10.1.

The GSR-Only Scenario and the Cumulative Scenario (Scenarios 2 and 4) involve the SFPUC Storage Account. The SFPUC Storage Account is a bookkeeping method that tracks the volume of groundwater stored in the Basin from in-lieu recharge during put periods minus the amount of groundwater pumped from the SFPUC Storage Account during take periods. As part of the initial conditions, the accrued volume in the SFPUC Storage Account at the start of the model scenarios is approximately 20,000 acre-feet (af) based on records of in-lieu exchange with the Partner Agencies prior to July 2009. During the Design Drought, the SFPUC Storage Account is taken from a full condition of 60,500 af to an empty condition of no in-lieu storage available at the end of the Design Drought. During a recovery period following the Design Drought, the scenarios include a 3-year put period that adds 20,000 af to the SFPUC Storage Account. Using this condition, the SFPUC Storage Account begins and ends with 20,000 af for both Scenarios 2 and 4. This allows for a more direct comparison in evaluating the long-term changes in groundwater levels and storage without having to factor in differences in the amount of in-lieu storage.

Table 10.4-1 presents a summary of the estimated Basin-wide average pumping rates corresponding to each of the model scenarios. Note that in addition to the anticipated GSR and SFGW Project wells, average pumping rates are also provided for the PA wells and for irrigation wells in Golden Gate Park.

3.2. Evaluation of Model-Predicted Changes in Groundwater Levels

The groundwater model simulates monthly changes in groundwater levels throughout the Westside Basin for each model scenario. The following discussion summarizes the model results for changes in groundwater elevations.

3.2.1. Methodology

The evaluation of groundwater levels proceeds with groups of wells or other analyzed locations from north to south through the Westside Basin. The analyzed locations begin in the North Westside Basin with well locations in the Golden Gate Park and Lake Merced subarea, and end in the South Westside Basin with locations in the San Bruno subarea (Figure 10.4-1). Progressing with the analysis in this manner helps to emphasize the relative geographic extent that each of the evaluated Project Scenarios (SFGW-Only, GSR-Only, and Cumulative) is expected to have on Basin groundwater conditions.

To facilitate this analysis, model-predicted groundwater levels corresponding to Model Layers 1 and 4 were evaluated. Model Layer 1 results provide information related to expected changes in the Shallow Aquifer, whereas Model Layer 4 results give an indication of groundwater level changes anticipated in the heavily-pumped Primary Production Aquifer. For each location analyzed within the Westside Basin, hydrographs are presented on Figures 10.4-3 through 10.4-13. Figure numbers that end in “a” (e.g., Figure 10.4-4a) pertain to Model Layer 1 results, whereas figure numbers that end in “b” (e.g., Figure 10.4-3b) show Model Layer 4 output. The following locations were selected to evaluate model-predicted changes in groundwater levels corresponding to each scenario:

- SWM-GS (Figure 10.4-3)
- Ortega MW (Figure 10.4-4)
- Santiago-S MW (Figure 10.4-5)
- LMMW-4S (Figure 10.4-6)
- Harding Park MW (Figure 10.4-7)
- Olympic MW (Figure 10.4-8)
- DC-3 (Figure 10.4-9)
- DC-A-St (Figure 10.4-10)
- Cypress Lawn 2 (Figure 10.4-11)
- SSF-02 (Figure 10.4-12)
- SB-12 (Figure 10.4-13)

On each figure, the upper hydrograph shows model-simulated groundwater elevation in feet (NGVD 1929), while the lower pane shows the relative difference between the groundwater levels of each Project Scenario and those of Scenario 1. Positive differences indicate that the Project Scenario has a higher groundwater elevation relative to Scenario 1, while negative results indicate that the Project Scenario has a lower groundwater elevation relative to Scenario 1. The groundwater elevation differences are normalized for fluctuations in the Existing Conditions Scenario, and so provide an evaluation of the direct effect on groundwater levels due to the GSR, SFGW and Cumulative scenarios.

3.2.2. North Westside Basin Area (Golden Gate Park to South Lake Merced)

The North Westside Basin extends from Golden Gate Park to Lake Merced (Figure 10.4-1). The locations evaluated in the North Westside Basin include SWM-GS, Ortega MW, Santiago-S MW, LMMW-4S, Harding Park MW, and Olympic-MW. Hydrographs corresponding to these well locations are presented as Figures 10.4-3 through 10.4-8.

Scenario 1 represents groundwater elevation results without either the GSR or SFGW Projects, and defines the background conditions including wet, normal and dry precipitation years. In the North Westside Basin, these climatic variations are clearly shown on the hydrograph, but the variations are more pronounced in Model Layer 1 than in Model Layer 4. After a sharp increase in groundwater levels representing a period of above average precipitation during Scenario Years 1 to 4, the groundwater levels fluctuate within a narrow range in response to climatic conditions. As discussed in TM-10.1, the hydrologic sequence used for all scenarios includes a Design Drought with below normal precipitation from Scenario Years 36 to 44.

In the northern locations (SWM-GS, Ortega MW, and Santiago-S MW; Figures 10.4-3 through 10.4-5) groundwater levels at the end of the 47.25-year Scenario return to approximately the same levels as at the beginning of the Scenario. Groundwater levels show seasonal variations due to irrigation pumping that are more pronounced in Model Layer 1 than in Model Layer 4. The locations near Lake Merced (LMMW-4S, Harding Park MW and Olympic-MW; Figures 10.4-6 through 10.4-8) show fairly distinct responses in Model Layer 1 versus Model Layer 4; in Model Layer 1, the groundwater level trends are similar to those at the more northern locations, showing strong responses to climatic conditions, whereas variations in groundwater levels in Model Layer 4 are more subdued. This is due to the presence of the -100 foot clay in the Lake Merced vicinity, greater depth to Model Layer 4, and the influence of groundwater conditions in the South Westside Basin on these locations. The difference in groundwater elevations between Model Layers 1 and 4 is smallest in the north (near Golden Gate Park) and greatest in the south (near Lake Merced).

Scenario 2 represents the operation of the GSR Project, which is located in the South Westside Basin. The model results show that all the North Westside Basin locations have at least some response to GSR Project operation. From the beginning of the Scenario to the start of the Design Drought, groundwater levels are higher than under Scenario 1. During the Design Drought, groundwater levels drop below Scenario 1 for the more southerly locations, showing the effects of increased pumping during this period. The recovery period following the Design Drought shows that groundwater levels recover to near-Scenario 1 levels after 3 years of in-lieu recharge.

Results for Scenario 2 for the northern locations in Golden Gate Park and north of Lake Merced (SWM-GS, Ortega MW, and Santiago-S MW; Figures 10.4-3 through 10.4-5) show little change relative to Scenario 1. For example, at the Ortega MW location (Figure 10.4-4), groundwater levels are generally about 0.5 to 1.0 foot higher relative to Scenario 1, but drop to less than 0.5 foot below Scenario 1 at the end of the Design Drought. The subdued response of groundwater conditions in these more northerly locations is expected because of the distance to the GSR and PA wells in the South Westside Basin.

The locations near Lake Merced (LMMW-4S, Harding Park MW and Olympic-MW; Figures 10.4-6 through 10.4-8) show more pronounced effects from the GSR Project. Overall, groundwater levels are generally higher relative to Scenario 1 throughout the Scenario in both Model Layers 1 and 4. This is due to the general decrease in pumping in the South Westside Basin and the effects of in-lieu recharge. Groundwater levels near Lake Merced are generally 5 to 10 feet higher relative to Scenario 1; however, groundwater levels in Model Layer 4 at the Olympic-MW location are about 10 to 30 feet higher relative to Scenario 1 until the start of the Design Drought.

The effects of pumping during the take periods are more pronounced in the southern part of the North Westside Basin than the northern part, and are also more pronounced in Model Layer 4 than in Model Layer 1. At the Olympic-MW location, the three take periods have more of an effect on water levels than further north. In general, groundwater levels in both Model Layers 1 and 4 remain higher than under Scenario 1 until the Design Drought, when both the SFPUC and PA wells are pumping. The lowest groundwater levels occur at the conclusion of the Design Drought.

The 3 years from the end of the Design Drought to the end of the scenario are put years. At the end of this period, groundwater levels have recovered to within 1 to 5 feet of those of Scenario 1 in all of the North Westside Basin locations for both Model Layers 1 and 4.

<u>Scenarios 3a and 3b</u> simulate the operation of the SFGW Project, which is located in the North Westside Basin. Scenario 3a assumes 1.142 mgd of irrigation pumping in Golden Gate Park and 3.0 mgd of project pumping for water supply throughout the North Westside Basin, whereas Scenario 3b assumes 4.0 mgd of project pumping for water supply, and that pumping of groundwater for irrigation in Golden Gate Park is replaced by recycled water. In total, Scenario 3b assumes 0.142 mgd less total pumping than Scenario 3a. Pumping is redistributed among the SFGW Project wells so that there is a 0.072 mgd decrease in pumping in the Golden Gate Park area. Because this overall change in pumping is minor, the regional response of groundwater levels to these scenarios is comparable; therefore, the results for Scenarios 3a and 3b will be discussed together.

In general, all locations evaluated in the North Westside Basin area show a similar declining trend relative to Scenario 1 for groundwater levels due to the SFGW Project operations. There is an initial decrease in groundwater levels relative to Scenario 1 in the first 5 to 10 years of the scenario, followed by a leveling out over the rest of the simulation period. In the northern locations, the rate of change relative to Scenario 1 after about Scenario Year 20 is near zero, whereas the locations near Lake Merced show a steady decline in groundwater levels relative to Scenario 1, but at a rate much less than the initial decline.

In the northern locations (SWM-GS, Ortega MW, and Santiago-S MW; Figures 10.4-3 through 10.4-5), groundwater levels decline by about 5 to 10 feet within the first 10 years of Scenarios 3a and 3b. After this initial decline, groundwater level declines relative to Scenario 1 are greatly reduced to near stable for the remainder of the Scenarios, including the period of the Design Drought. In these northern locations, the change in groundwater levels relative to Scenario 1 is similar for both Model Layers 1 and 4.

The locations near Lake Merced (LMMW-4S, Harding Park MW and Olympic-MW; Figures 10.4-6 through 10.4-8) show a slower rate of decline in the first 10 to 15 years than observed further north, but the decline relative to Scenario 1 continues at a reduced rate throughout the scenario instead of leveling off. The largest groundwater level declines occur in Model Layer 4 at the Harding Park MW and Olympic-MW locations, with a maximum decline of approximately 30 feet relative to the Scenario 1 by the end of the simulation period (Figures 10.4-7 and 10.4-8).

Scenario 4 represents the combined effects of the GSR (Scenario 2) and SFGW (Scenario 3b) Projects. As such, the resulting groundwater level responses in the North Westside Basin tend to be intermediate between the responses seen for Scenarios 2 and 3b. Groundwater levels are more similar to Scenario 3b in Golden Gate Park and north of Lake Merced, and more similar to Scenario 2 near and south of Lake Merced. Scenario 4 also includes additional water being diverted into Lake Merced; however, the response in groundwater levels to these changes to Lake Merced is not clearly recognizable, being overshadowed by the pumping changes in Scenario 2.

In the northern locations (SWM-GS, Ortega MW, and Santiago-S MW; Figures 10.4-3 through 10.4-5), groundwater levels follow a similar trend to those of Scenario 3b. This is expected because Scenario 2 has little effect on groundwater levels in this area. Groundwater levels for Scenario 4 are generally 0 to 5 feet higher than those for Scenario 3b, but still 5 to 10 feet below those of Scenario 1. The responses are similar in Model Layers 1 and 4.

The locations near Lake Merced (LMMW-4S, Harding Park MW and Olympic-MW; Figures 10.4-6 through 10.4-8) show trends similar to Scenario 2, but with groundwater levels about 10 to 20 feet lower than under Scenario 2, and 10 to 20 feet higher than under Scenario 3b. Relative to Scenario 1, groundwater levels are similar in Model Layer 1, but about 10 to 20 feet lower in Model Layer 4. As with the Scenario 3b results, the greatest projected water level declines were observed in Model Layer 4 at the Olympic MW location (Figure 10.4-8b). Figures 10.4-6 and 10.4-7 also show that the LMMW-4S and Harding Park locations appear to be equally affected by the operation of the proposed GSR and SFGW Projects. The effects of the additional water being diverted into Lake Merced should be most apparent in these wells in Model Layer 1; however, no clearly recognizable response is seen. It may be that the scale of the effects from the changes to Lake Merced is small and results in only minor variations. Alternatively, it is possible that the interaction of the GSR project (which generally raises water levels in the Lake Merced area) and the SFGW project (which generally lowers water levels) in Scenario 4 partially obscures the effect of the Lake Merced diversions upon groundwater levels.

3.2.3. South Westside Basin Area (Daly City to San Bruno)

The South Westside Basin area extends from Daly City in the north to San Bruno in the south. Locations evaluated in this area include DC-3, DC-A-St, Cypress Lawn No. 02, SSF-02, and SB-12. Hydrographs corresponding to these locations are presented in Figures 10.4-9 through 10.4-13. As discussed previously, historic groundwater pumping in the South Westside Basin has resulted in sustained declines in groundwater levels in the area.

Scenario 1 represents the change in groundwater elevations without either the GSR or SFGW Project and defines the background conditions, including wet, normal and dry precipitation years. In considering these results it should be recalled that the initial conditions include 20,000 af of storage in the SFPUC Storage Account and that the first seven years of the simulation correspond to a very wet period. These factors may contribute to high groundwater levels early in the simulation, with lower levels occurring later under the corresponding average and dry precipitation years.

- For the Daly City locations (DC-3 and DC-A-St; Figures 10.4-9 and 10.4-10), groundwater levels in both Model Layers 1 and 4 show a similar trend of steady decline from the initial conditions of about 40 feet over the 47-year Scenario. Groundwater elevations in Model Layer 1 and 4 are within 10 to 20 feet of each other.
- For the Colma and South San Francisco locations (Cypress Lawn No. 02 and SSF-02; Figures 10.4-11 and 10.4-12), groundwater levels in Model Layers 1 and 4 decline from the initial conditions steadily over the 47-year scenario, by about 10 to 30 feet in Model Layer 1 and 40 to 50 feet in Model Layer 4. Groundwater levels in Model Layer 1 are about 80 to 170 feet higher than those in Model Layer 4.
- In the San Bruno area (SB-12; Figure 10.4-13), groundwater levels in Model Layer 1 show an increasing trend from the initial conditions with a total rise of about 20 feet over the 47-year simulation period, whereas groundwater levels in Model Layer 4 show a decreasing trend from the initial conditions with a total decline of about 50 feet. The difference in groundwater levels between Model Layers 1 and 4 is about 200 to 250 feet.

Climatic variations are subdued on the hydrographs for Model Layer 4, Scenario 1. This is because groundwater levels are relatively deep in the South Westside Basin and tend to be less responsive to annual variations in recharge.

Scenario 2 represents the operation of the GSR Project, which is located in the South Westside Basin. Overall, all South Westside Basin locations show a distinct groundwater level response to the GSR Project. Groundwater levels increase during put periods and decrease during take periods. The greatest increase in groundwater level occurs after the first extended put period from Scenario Years 1 to 7, then groundwater levels slowly decline. Two take periods (from Scenarios Year 9 to 12 and Scenarios Year 25 to 28) show distinct declines in groundwater levels; however, levels recover to near their pre-take-period levels after the subsequent put periods. All locations evaluated in the South Westside Basin area have their lowest groundwater levels just after the Design Drought. During the Design Drought, pumping occurs from both the PA and SFPUC wells; the greatest declines in groundwater levels during the Design Drought correspond to well locations in the Daly City and Colma areas, because most of the GSR Project extraction wells would be located in this area.

After the end of the 8.5-year Design Drought, the South Westside Basin locations show a rise in groundwater levels because the three years from the end of the Design Drought to the end of the Scenario are put years. In Model Layer 4 representing the Primary Production Aquifer, groundwater levels recover 70 to 100 feet from the end of the Design Drought. At this time, the SFPUC Storage Account is at about 20,000 af which is about one-third of the SFPUC Full Storage Account at 60,500 af. Groundwater levels are generally about 20 to 40 feet below the levels for Scenario 1 at the end of the Scenario 2.

For the Daly City locations (DC-3 and DC-A-St; Figures 10.4-9 and 10.4-10), groundwater levels remain above Scenario 1 levels throughout Scenario 2, including two take periods, until the Design Drought. During the Design Drought, groundwater levels drop below Scenario 1 levels by about 40 feet in Model Layer 1 and from 70 to 100 feet in Model Layer 4. After the Design Drought, groundwater levels recover to about 20 to 50 feet in Model Layer 1 and are 2 to 20 feet below Scenario 1 levels at the end of the simulation. For Model Layer 4, groundwater levels recover about 70 to 80 feet and range from 10 feet above to 20 feet below Scenario 1 levels at the end of the simulation period.

For the Colma and South San Francisco locations (Cypress Lawn No. 02 and SSF-02; Figures 10.4-11 and 10.4-12), groundwater levels show a similar pattern to those of the Daly City area. In Model Layer 1, the responses to put and take periods are more subdued, and groundwater levels are about 10 to 15 feet higher than under Scenario 1. During the Design Drought, groundwater levels are from 0 to 20 feet below those of Scenario 1. Groundwater levels in Model Layer 4 respond more strongly to the put/take/hold pattern, but groundwater levels are lower than observed in Daly City. Groundwater levels drop below Scenario 1 during the first two take periods. At the start of the Design Drought, groundwater levels are near those of Scenario 1 and decline by 120 to 140 feet by the end of the Design Drought. During the three year put period at the end of the scenario, groundwater levels recover to 25 to 50 feet below Scenario 1 levels.

In the San Bruno area (SB-12; Figure 10.4-13), groundwater levels in Model Layer 1 show an increasing trend that does not reflect the pattern of put and take periods, with groundwater levels about 5 to 10 feet higher than under Scenario 1. Rising groundwater levels for Model Layer 1 at this location were also experienced in the HydroFocus 2008 No-Project Scenario and are discussed by HydroFocus (2011). Model Layer 4 shows a similar pattern to the Colma and South San Francisco locations, with similar magnitudes.

<u>Scenarios 3a and 3b</u> represent the operation of the SFGW Project, which is located in the North Westside Basin. Therefore, groundwater level changes in the South Westside Basin show little

to no change relative to Scenario 1 in either Model Layer 1 or 4. The effects of the SFGW Project are greatest in the Daly City area and diminish southward. The maximum groundwater level decline relative to Scenario 1 for Scenarios 3a and 3b is approximately 20 feet in Model Layer 4 at the Daly City locations (Figures 10.4-9b and 10.4-10b), whereas in Model Layer 4 at SB-12, in the San Bruno area, there is a barely discernible decline in predicted groundwater levels (Figure 10.4-13b).

Scenario 4 represents the combined effects of pumping in the SFGW and GSR Project wells, and also other reasonably foreseeable future projects. Groundwater levels for Scenario 4 in the South Westside Basin generally match the results for Scenario 2. Although Scenario 4 includes simulated pumping stresses for both the SFGW and GSR Project production wells, the general patterns of groundwater level responses more closely approximate the levels for Scenario 2 due to the proximity of GSR Project wells.

In the Daly City area (Figures 10.4-9 and 10.4-10), groundwater levels in Model Layer 1 closely follow the same trends as observed in Model Layer 4, but are generally about 20 to 40 feet higher. In both Model Layers 1 and 4, groundwater levels for Scenario 4 are generally 1 to 15 feet higher compared to Scenario 2 levels. Since both Scenario 2 and Scenario 4 use the same GSR Project pumping assumptions, the differences are attributed to the other reasonably foreseeable future projects applied in the Cumulative Scenario. Since locations nearer to Lake Merced, such as the Olympic MW location (Figure 10.4-10) on the south side of Lake Merced show Scenario 2 groundwater levels higher relative to Scenario 4, the observed condition in Daly City cannot be attributed to water additions at Lake Merced. Instead, the higher Scenario 4 groundwater levels demonstrate the local effects of the Daly City A-Street Replacement Well. For Scenario 4, the pumping from the Daly City A-Street Well is shifted to the proposed Daly City A-Street Replacement Well, which is located on the west side of the Serra Fault (Figure 10.4-1). This change in location has a substantial effect because about 17 percent of the Daly City groundwater production would be shifted from the main basin to a location east of the Serra Fault. The conceptual understanding is that the Serra Fault is a barrier to groundwater flow; therefore, the change in the pumping location has the net effect of reducing pumping in the main basin east of the Serra Fault by about 475 afy. The result is that Scenario 4 groundwater levels in the Daly City area are higher than Scenario 2 groundwater levels because there is a decrease in pumping in the Daly City area relative to Scenario 2.

South of Daly City, groundwater levels for Scenario 4 are nearly identical to groundwater levels for Scenario 2. In the Colma, South San Francisco and San Bruno areas, the effect of SFGW Project pumping is generally diminished, as is the effects of the proposed Daly City A-Street Replacement Well described above. As with Scenario 2, the effects from the GSR Project pumping are seen primarily in Model Layer 4 with limited effects from GSR Project pumping on groundwater levels in Model Layer 1.

For Scenario 4, the lowest simulated groundwater levels correspond to take periods, with substantial recovery of levels during put periods. For Scenario 4, the greatest predicted declines in groundwater levels occur during the Design Drought at locations in the Daly City and Colma areas, with groundwater levels in Model Layer 4 ranging from approximately 60 to 135 feet below those of Scenario 1 (Figures 10.4-9b through 10.4-13b). During the three-year put period following the Design Drought, groundwater levels in Model Layer 4 recover 60 to 100 feet. At the end of the simulation, groundwater levels in Model Layer 4 range from about 10 feet higher to 50 feet lower relative to Scenario 1 levels in the South Westside Basin.

3.3. Evaluation of Model-Simulated Changes in Groundwater Storage

The groundwater model provides a mechanism to evaluate the changes in groundwater storage predicted for each scenario. The net difference between inflows (e.g. recharge) and outflows (e.g. pumping) in a groundwater system (water balance) results in a change in groundwater storage, which in turn results in a corresponding change in groundwater levels (Section 2.4).

3.3.1. Methodology

For the Basin-wide storage evaluation, the groundwater model was used to determine the changes in groundwater storage for both the whole Basin and for specific subareas for each model scenario, and these results were compared to the storage changes computed for Scenario 1. Based on the model scenario results, volumetric water budget graphs and tables were prepared for the entire simulation period. The water budget includes the major components of inflows to and outflows from the Westside Basin. This water budget analysis was conducted at three different regional scales listed below, with results for each scale for each scenario :

- Westside Basin (Figures 10.4-14 and 10.4-15, and Tables 10.4-2 through 10.4-6).
- Comparison of the SFPUC Storage Account to Scenario 2 aquifer storage (Figure 10.4-16).
- North and South Westside Basins (Figures 10.4-17 through 10.4-20).
- Five subareas that are collectively referred to by HydroFocus (2009 and 2011) as "Developed Subbasin" (Figures 10.4-21 through 10.4-24 and Table 10.4-7).

Separate water balances were established for each of the five model scenarios, and are presented in Attachment C for TM-10.1. Table 10.4-2 presents the annual water balance for the entire Westside Basin for Scenario 1. Tables 10.4-3 through 10.4-6 present the annual water balance for the entire Westside Groundwater Basin for Scenarios 2, 3a, 3b, and 4 relative to Scenario 1. Figure 10.4-14 plots model-simulated total changes in groundwater storage for the entire Westside Basin for all evaluated scenarios, and Figure 10.4-15 shows the simulated storage change for each scenario relative to Scenario 1.

Figure 10.4-16 provides a graphical comparison of the volume of water in the SFPUC Storage Account to the aquifer storage calculated by MODFLOW model for the GSR Project Scenario (Scenario 2) relative to Scenario 1.

Figures 10.4-17 through 10.4-20 present a graphical comparison of water balance components for Scenarios 2, 3a, 3b, and 4 relative to Scenario 1 to demonstrate where the water for the

GSR and SFGW Project pumping is sourced. Graphs are based on the data presented in Attachment 10.1-D in TM-10.1. Since the GSR Project is located in the South Westside Basin and the SFGW Project is located in the North Westside Basin, these graphs are provided to illustrate the relative effects on the North and South Westside Basins from the Project conditions applied for each scenario.

Similar to the approach taken by HydroFocus (2009 and 2011), a water budget was developed for five water budget zones that are collectively referred to as the Developed Subbasin: Lake Merced/Golden Gate Park, Daly City, Colma, Cal Water, and San Bruno. The water balance components were calculated using the U.S. Geological Survey post-processor ZONEBUDGET (Harbaugh, 1990). Table 10.4-7 contains summary tables of the water budgets developed for each of the five model subareas. Results for the five model subareas (both simulated and relative to Scenario 1) are also presented on Figures 10.4-21 through 10.4-24 for the Project Scenarios (Scenarios 2, 3a, 3b, and 4).

The evaluation of Basin-wide changes in groundwater storage provides an overall analysis of the effects related to the various scenarios.

3.3.2. Scenario 1 - Existing Conditions

Scenario 1 represents the change in groundwater elevations without either the GSR or SFGW Projects and defines the background conditions, including wet, normal and dry precipitation years. Groundwater storage for Scenario 1 shows an initial increase in Scenario Years 1 and 2, but that is followed by a general decline over the scenario period except for periods of increase during Scenario Years 21 to 23 and Years 30 to 35. There is a substantial decline during the Design Drought period, followed by an increase in Scenario Years 44 to 47. By the end of Scenario 1, groundwater storage has declined approximately 28,000 af for the entire Westside Basin (Figure 10.4-14).

The 28,000-af decline in groundwater storage in Scenario 1 is due to the assumptions used for the background hydrology as necessitated by the inclusion of the Design Drought for consistency with the PEIR. The Design Drought repeats the 1976-77 drought. The result of repeating the drought is that there is an overall rainfall deficit over the 47-year scenario of nearly 20 inches compared to the 1958-2005 year sequence used in the HydroFocus 2008 No-Project Scenario (HydroFocus, 2011). Over the duration of the HydroFocus 2008 No-Project Scenario there is little to no change in groundwater storage. Recharge from precipitation and irrigation return flow (also dependent on rainfall) is calculated by the Soil Moisture Budget procedure discussed in TM-10.1 and documented in HydroFocus (2007, 2009, and 2011). Comparing the recharge calculated by the Soil Moisture Budget for the SFPUC scenarios with the HydroFocus 2008 No-Project Scenario shows that the 28,000-af decline in groundwater storage in Scenario 1 can be accounted for by the difference in rainfall between the different sets of background hydrology assumptions used. Therefore, the background hydrologic assumptions used in Scenario 1 provide a conservative analysis of the potential changes in groundwater storage. In evaluating groundwater storage, the results will primarily be discussed in terms of relative differences from Scenario 1 (Figure 10.4-15).

3.3.3. Scenario 2 - GSR Project

Scenario 2 represents the operation of the GSR Project, which is located in the South Westside Basin. The key components of the GSR Project are: in-lieu recharge during the put periods when groundwater pumping by SFPUC and the PAs does not occur and groundwater is placed into the SFPUC Storage Account using in-lieu recharge; hold periods when the PAs are pumping and no in-lieu recharge is occurring because the SFPUC Storage Account is full; and take periods which represent periods when both SFPUC and the PAs are pumping from the South Westside Basin. Scenario 2 starts with June 2009 initial groundwater levels that includes 20,000 af already in the SFPUC Storage Account from activities between 2002 and 2009 (LSCE, 2005). .

Scenario 2 begins with a 6.5-year put period that is reflected by an increased groundwater storage of 36,000 af across the whole Basin (not the SFPUC Storage Account) relative to Scenario 1 (Figure 10.4-15). From Scenario Years 7 through 36, there is a general decline in groundwater storage that is interrupted by sharp decreases during the two take periods followed by an equally sharp increase during the put period that returns the groundwater storage to the general declining trend relative to Scenario 1 (Figure 10.4-15). The Design Drought is an extended take period when the entire SPPUC Storage Account of 60,500 af is depleted. Over the duration of the Design Drought, there is an approximately 60,000-af decline in groundwater storage relative to Scenario 1. Following the Design Drought, about 20,000 af of in-lieu recharge is added to the Basin during the subsequent put period, and that is reflected by the 20,000-af increase in groundwater storage in the Basin.

Figure 10.4-15 shows that by the end of the simulation period the model-predicted aggregate reduction in groundwater storage is approximately 20,000 af. This means that at the conclusion of Scenario 2 there is predicted to be approximately 20,000 af less groundwater in storage in the entire Westside Basin than if the GSR Project were not implemented. However, as shown on Figure 10.4-15, Scenario 2 has a surplus of Basin groundwater storage relative to Existing Conditions is anticipated to exist for most of the entire simulation duration. Groundwater storage in the Basin is projected to decline, but still remains above Existing Condition storage levels, in response to the simulated take period around Scenario Year 11 and 27. This is due to increased pumping by GSR production wells during those drought periods, when available surface water supplies would be curtailed. However, it is not until sometime after the start of the Design Drought that Basin-wide groundwater storage is predicted to fall below that under the Existing Conditions Scenario. A relatively rapid recovery in groundwater storage volume is projected after the conclusion of the Design Drought period.

Scenario 2 assumes that there is an initial condition of 20,000 af of groundwater storage in the SFPUC Storage Account at the beginning of the scenario and that the SFPUC Storage Account is returned to a value of 20,000 af as a result of the put periods following the Design Drought. Figure 10.4-16 shows the SFPUC Storage Account and MODFLOW simulated aquifer storage on separate axes to illustrate that the SFPUC Storage Account is tracked separately. The total change in storage over the whole Basin does not represent any surpluses or deficits in the SFPUC Storage Account. Therefore, the groundwater storage deficit of 20,000 af relative to

Scenario 1 at the end of Scenario 2 indicates that the storage efficiency of the whole Basin is less than 100 percent. Averaged over the 47-year simulation period, the average annual loss is 425 afy.

Decline in groundwater storage primarily takes place when the groundwater storage is higher relative to Scenario 1. For example, during the 6.5-year put period at the beginning of the scenario, approximately 40,500 af of in-lieu recharge is added to the Basin; however, the increase in storage in the entire Basin relative to Scenario 1 is only 36,000 af (Figure 10.4-16). This indicates that about 4,500 af of storage is lost during the extended put period. During the following 30-year period, the SFPUC Storage Account is typically at 60,500 af with two short put-take cycles during this time. At the beginning of the Design Drought period, 40,500 af of the net additions of groundwater have been added to the basin through the GSR Project as represented by the SFPUC Storage Account (Figure 10.4-16). However, the MODFLOW model results show a steady decline in aquifer storage such that aquifer storage at the beginning of the Design Drought is only 20,000 af higher relative to Scenario 1.

Conversely, during the Design Drought and the following recovery period, the changes in groundwater storage more closely match the additions and subtractions under the operations of the GSR Project (Figure 10.4-16). Therefore, higher aquifer storage losses occur during periods when groundwater storage is higher relative to Scenario 1 and less aquifer storage losses occur when groundwater storage is lower relative to Scenario 1.

Therefore, a one to one ratio of supplemental surface water deliveries to the PAs does not result in an equal amount of simulated aquifer storage accrual via in-lieu recharge during put periods. During hold periods, when aquifer storage is above recent historic levels, some amount of aquifer storage loss occurs which is not accounted for in the SFPUC Storage Account.

The “efficiency” of the GSR Project is defined as the relative difference between the SFPUC Storage Account and the change in aquifer storage for Scenario 2 relative to Scenario 1. Based on this analysis, the efficiency of the GSR Project with respect to overall groundwater storage varies depending upon Basin conditions. During the initial filling process over the first seven years of put periods, the GSR Project is about 88 percent efficient. During the long period of primarily hold periods after this initial filling to the beginning of the Design Drought, the GSR Project has an efficiency of about 67 percent. During the Design Drought and recovery after the Design Drought, the GSR Project has nearly 100 percent efficiency. The overall average efficiency of the GSR Project over the 47.25 year simulation period is approximately 78 percent. This average efficiency is conservative because Scenario 2 includes a relatively long (30 year) period when the basin is largely full which magnifies the losses. Verification of actual losses can be conducted in the future by comparing modeled and actual groundwater elevations.

For comparison, a 2008 survey (MWH, 2009) found that loss factors used in seven conjunctive use programs in California in “ranged from 0 percent to 15 percent. These loss factors were intended to attain or maintain positive storage balances, account for evaporation/transpiration, account for operational/non-recoverable basin losses, and to minimize political concerns.” These losses factors imply an efficiency of 85 percent to 100 percent in the surveyed programs.

The GSR Project thus has a lower efficiency range of 67 percent to 100 percent (average 78 percent).

In comparing the water balance summary for Scenarios 1 and 2 for the North and South Westside Basins subareas (Figure 10.4-17 and TM10.1 Attachment 10.1-D), the changes in pumping from the GSR Project primarily result in a change in aquifer storage in the South Westside Basin and a shift in groundwater flow between the North and South Westside Basins. Other water balance components show only minor variations as result of GSR Project operations. During put periods, most of the reduced pumping (in-lieu recharge) results in an increase in aquifer storage with a minor amount resulting in a change in groundwater flow from the South to the North Westside Basin. Conversely, during take periods, most of the increased pumping is derived from a decline in aquifer storage with a minor amount resulting in a change in groundwater flow from the North to the South Westside Basin. During hold periods, there are only minor declines in aquifer storage. Overall, the changes in the North Westside Basin are minor relative to those observed in the South Westside Basin. With increasing groundwater levels, the hydraulic gradient in the North Westside Basin shifts to a more westward direction, resulting in slight increases in outflows to Lake Merced and to the Pacific Ocean.

For Scenario 2, the conservation of basin groundwater storage expected for the GSR Project is shown by positive relative storage changes for all five Developed Subbasin model subareas, but is particularly evident in the central South Westside Basin where GSR wells are concentrated (Table 10.4-7 and Figure 10.4-21). For the Daly City and San Bruno subareas, the proposed pumpage rates are smaller than under the Existing Conditions Scenario, which reflects the cessation or reduction of pumping during put periods. The largest relative storage increases, 140 and 141 afy, are shown for the Colma and Cal Water (South San Francisco) subareas, respectively, both located in the central South Westside Basin. In essence, the relative groundwater storage increases in the Colma and Cal Water subareas are provided by groundwater flow from adjacent subareas (Daly City and San Bruno, respectively). The Lake Merced/GGP subarea is shown to be relatively unaffected during GSR Project operation, except for somewhat less groundwater flow to the Daly City subarea to the south.

3.3.4. Scenario 3a and 3b - SFGW Project

Scenarios 3a and 3b represent the operation of the SFGW Project, which includes additional groundwater pumping in the North Westside Basin. The changes in groundwater storage are similar for Scenarios 3a and 3b (Figures 10.4-14 and 10.4-15). Basin-wide groundwater storage shows a steady decline over the duration of the scenario, but the rate of decline decreases over the simulation period. At the end of the simulation period, groundwater storage declines by approximately 32,000 and 30,000 af for Scenarios 3a and 3b, respectively. The slight differences in storage changes between the two scenarios are attributable primarily to the somewhat greater total Basin pumping rate in Scenario 3a (12.75 mgd) compared to Scenario 3b (12.61 mgd; Table 10.4-1).

Figures 10.4-18 and 10.4-19 show the water balance components for Scenario 3a and 3b, respectively, relative to Scenario 1 in the North Westside Basin. The results for Scenario 3a and

3b are similar so they are discussed together. Figures 10.4-18 and 10.4-19 indicate that the majority of the increased pumping would initially come from groundwater storage (i.e. loss of groundwater storage). Loss of groundwater storage is highest in the first five years of the simulation. Over the first 10 to 15 years of the simulation, annual storage loss resulting from SFGW Project pumping would continue to decline, while the interception of groundwater flow to the Pacific Ocean would continue to increase. This represents that after the initial decline in groundwater levels, groundwater pumping by the SFGW Project is primarily sustained by the interception of groundwater flow that would otherwise have discharged to the Pacific Ocean. There are little to no changes in the South Westside Basin due to the increased pumping from the SFGW Project.

For Scenarios 3a and 3b, pumping associated with SFGW Project wells located in the North Westside Basin is shown on Table 10.4-7 and Figures 10.4-22 and 10.4-23 as substantial increases in pumping rates for the Lake Merced/Golden Gate Park subarea relative to Scenario 1. Based on this subarea zone budget analysis, 76 percent of the increased groundwater pumping from the SFGW Project wells in the North Westside Basin is offset the interception of groundwater flow to the Ocean, while the decrease in storage represents only 15 percent of the increased groundwater pumping. As expected, the effects of Scenarios 3a and 3b on the subareas in the South Westside Basin is small compared to the changes seen in the Lake Merced/Golden Gate Park subarea.

3.3.5. Scenario 4 – Cumulative Scenario

Scenario 4 represents the combined effects of operations of the GSR (Scenario 2) and SFGW (Scenario 3b) Projects. Scenario 4 also includes additional water being diverted into Lake Merced.

For Scenario 4, Figure 10.4-15 shows that groundwater storage increases to about 22,000 af above that of Scenario 1 after the initial 7-year put period. Groundwater storage steadily declines over following 30 years closely following the trend of Scenario 2 but about 15,000 to 20,000 af lower relative to Scenario 2 reflecting the influence of the SFGW Project. At the beginning of the Design Drought, the groundwater in storage is about 4,000 af lower than under Scenario 1. During the Design Drought, the combined pumping of the GSR and SFGW Projects lowers the groundwater storage to about 65,000 af lower than under Scenario 1. After the put period at the end of the simulation period, groundwater storage for the entire Westside Basin is approximately 45,000 af less than under Scenario 1. Because of the similar trends in groundwater storage between Scenario 2 and 4, the storage efficiency for Scenario 4 is considered to be similar to Scenario 2. Because Scenario 4 includes assumptions not included in Scenario 1, a direct comparison to estimate efficiency is not appropriate.

The overall trend in groundwater storage changes for Scenario 4 follows that of Scenario 2, but the volume of groundwater storage for Scenario 4 is lower, reflecting the increased pumping by the SFGW Project (Figure 10.4-15). However, the difference in storage between Scenarios 2 and 4 is less than the decrease of storage under Scenarios 3a and 3b. This discrepancy is the primarily the result of additional recharge under Scenario 4 due to the stormwater additions to Lake Merced under the Daly City Vista Grande Basin Improvements Project.

Figure 10.4-20 shows the net change in the water balance for the North and South Westside Basins. In general, the graphs look like a composite of Scenarios 2 and 3b, as would be expected. The influence of the other foreseeable projects under the Cumulative Scenario is relatively small with respect to groundwater storage. A portion of the increase in groundwater storage in Scenario 4 compared to Scenario 1 is a result of additional seepage from Lake Merced, amounting to about 4,000 af by the end of Scenario 4. This can be seen on Figure 10.4-20 and Table 10.4-6 (also see TM 10.1 Attachment 10.1-D) where Lake Merced has an overall net discharge to groundwater due to the stormwater additions from the Daly City Vista Grande Basin Improvements Project.

For the Developed Subbasin subareas, storage changes related to pumping of the SFGW Project in the North Westside Basin and pumping of the GSR Project in the South Westside Basin are shown on Table 10.4-7 and Figure 10.4-24. By combining the Design Drought pumping conditions of Scenario 2 with the year-round pumping of the SFGW Project wells in the North Westside Basin, Scenario 4 has the maximum Basin storage declines during the Design Drought among the Project Scenarios relative to the Existing Conditions.

4. Historical Data Evaluation and Qualitative Assessment

The results of significant groundwater modeling efforts, such as the Westside Basin Groundwater-Flow Model, are often substantiated by other independent means. While the model development process involves internal calibration and validation (using comparisons to observed groundwater levels), additional efforts are often undertaken to evaluate the “reasonableness” of model results as they relate to observable measurements or practical expectations. The process of comparing model results to observed data, or evaluating the results from the perspective of what might be reasonable based on scientific principles, is termed “empirical analysis.” The purpose of conducting an empirical analysis of groundwater modeling results is to provide an additional, independent confirmation of the model results.

4.1. Groundwater Level Analysis

The empirical analysis conducted for this TM involved comparing groundwater level changes predicted by the model to historic groundwater levels measured within the Westside Basin. To facilitate the comparisons, the ranges of groundwater levels (low to high) simulated by the model for each scenario were compared to the ranges of recorded historic groundwater levels.

The historic groundwater levels were measured in wells that are included in the Westside Basin Groundwater Monitoring Network. Most of the continuous water level data available from these wells were collected from the early 2000s through 2009 (SFPUC, 2010). However, some of the well measurement data extend back to the mid-1990s, a period during which extreme drought conditions (and thus very low local groundwater levels) were experienced in the Westside Basin. Actual groundwater level measurements from that recent drought period are particularly useful for comparing to model results because both sets of measurements, actual and simulated, reflect groundwater levels under particularly stressed Basin conditions.

Table 10.4-8 provides a summary of the comparison between historic and model-predicted groundwater levels corresponding to each of the evaluated scenarios (refer to Figure 10.4-1 for the locations of wells listed on the table). The selected well locations provided in Table 10.4-8 encompass representative portions of the Basin, from Golden Gate Park in the north to Burlingame in the south. The monitoring wells are grouped according to whether they are completed in the Shallow Aquifer or the Primary Production Aquifer and the period when measured data are available for each location is shown.

This comparison of the range of observed groundwater levels to the range of simulated groundwater levels for each scenario provides context for evaluating the simulation results for the GSR and SFGW Projects to the range of groundwater levels that have been observed in the Basin. A direct comparison is limited because the historical conditions represent a different set of conditions than those included in the scenarios. Rather the intent is to compare whether the GSR and SFGW Project scenario results show groundwater levels that are substantially higher or lower than was has been experienced historically.

From Table 10.4-8, the results of the comparisons show the following:

- For Scenario 1, the simulated groundwater levels are generally within the range of historical groundwater levels measured in the Basin over the past 5 to 15 years.
- For Scenario 2, groundwater levels in the North Westside Basin and the Shallow Aquifer are generally within the historical range whereas groundwater levels in the South Westside Basin and the Primary Production Aquifer show a range wider than the historical range representing the effects of the put-take-hold conditions of the GSR Project operations.
- For Scenarios 3a and 3b, groundwater levels in the North Westside Basin are typically below the historical range showing the effects of the SFGW Project operations. In the South Westside Basin, groundwater levels are generally within the historical range.
- For Scenario 4, groundwater levels in the North Westside Basin are generally below the historical range, representing the effects of the SFGW Project. In the South Westside Basin and the Primary Production Aquifer show a range wider than the historical range representing the effects of the put-take-hold conditions of the GSR Project operations.

Overall, this empirical analysis demonstrates that the ranges of model-predicted changes in groundwater levels for each of the scenarios fall reasonably within the ranges measured in the Basin over the past 15 years or so.

4.2. In-Lieu Recharge Demonstration Study

From fall 2002 to spring 2005, SFPUC, in coordination with the PAs, conducted an In-Lieu Recharge Demonstration Study (Demonstration Study; also known as the Westside Basin Conjunctive Use Pilot Project) in the Westside Basin. The primary purpose of the Demonstration Study was to evaluate the response of Basin groundwater conditions to reduced pumping by the PAs (i.e. implementation of “in-lieu” recharge). The manner in which the Demonstration Study was conducted is closely representative of planned operations for the proposed GSR Project. Therefore, the response of Basin groundwater conditions observed during the Demonstration Study is an important indicator for forecasting the potential Basin response to future implementation of the GSR Project.

4.2.1. Project Overview

The In-Lieu Recharge Demonstration Study involved the cessation of municipal pumping in the South Westside Basin by Daly City, Cal Water, and San Bruno. Supplemental surface water provided by SFPUC to each of the PAs was used to replace the water supply normally obtained by pumping in the Basin.

The Demonstration Study occurred mostly from October 2002 through March 2005, when it was discontinued in the San Bruno area (LSCE, 2005b and 2010). Between January 2003 to March 2005, SFPUC delivered approximately 3,900 af of water to San Bruno, 6,200 af to Daly City, and 1,820 af to Cal Water. After the completion of the Demonstration Study in 2005, SFPUC continued to deliver supplemental surface water to Cal Water through January 2007 and to Daly City through April 2007, resulting in reduced groundwater pumping in these areas. With the continued surface water delivery of SFPUC to Cal Water and Daly City, the total surface water delivery to the PAs from October 2002 through April 2007 reached approximately 20,000 afy. No supplemental deliveries were conducted from May 2007 to May 2009.

After cessation of the Demonstration Study in March 2005, San Bruno pumping resumed at about 1,800 to 2,300 afy (LSCE, 2010). Groundwater pumping for municipal supply by Cal Water in the South San Francisco area resumed on a limited basis in March 2008 and totaled 206 af during 2008 (LSCE, 2010). Daly City pumping was about 3,600 af for 2008.

4.2.2. Results

Results from the Demonstration Study indicated that in-lieu recharge in the Westside Basin can be successfully accomplished by reducing pumping, resulting in increases in groundwater storage. During the Demonstration Study, groundwater levels were measured in select wells located throughout the Basin to document the recovery, or rise, in groundwater levels resulting from reduced pumping. From these data, the amount of groundwater storage increase associated with the rising water levels was estimated for the three areas of the Basin encompassed by each of the PAs. Groundwater levels rose by about 20 feet in the Daly City area, 13 feet in the South San Francisco area, and 12 feet in the San Bruno area during the period of the Demonstration Study (LSCE, 2005b). Details of the changes in groundwater levels are discussed in more detail in reports by LSCE (2005b, 2010).

For the entire area within the three PA service areas, the total increase in groundwater storage in the South Westside Basin during the Demonstration Study was estimated to be approximately 13,000 af (LSCE, 2005b). At the start of the Demonstration Study, Daly City reduced groundwater production by 2.9 mgd from October 2002 to March 2005. In other words, the aquifer in the Daly City area was being recharged, by in-lieu means, at the rate of approximately 2.9 mgd for approximately 2 years and 5 months. By the end of that period, it was estimated that approximately 6,300 af of in-lieu recharge had occurred in Daly City. Cal Water reduced groundwater pumping by 1.2 mgd for approximately 2 years and 4 months (from November 2002 to March 2005), which resulted in an estimated resultant groundwater storage increase of approximately 3,600 af. The storage increase for San Bruno was estimated to be 3,000 af (LSCE, 2005b).

For Scenarios 2 and 4, 13,000 af of groundwater recharge occurred during the major put periods of the simulation including the first three years of the simulation, the recovery after two take periods during the simulation, and after the Design Drought. In these cases, the simulated groundwater levels rose by about 50 feet in the Daly City area, 50 feet in the South San Francisco area, and 40 feet in the San Bruno area. The model results show some differences because the drawdown during the preceding take period included the operation of both the GSR Project and PA municipal wells which is different than the conditions of the Demonstration Study. Therefore, a portion of the rise in groundwater levels includes an aquifer recovery from the decreased pumping. Therefore, it is considered that the model results are comparable to the observed conditions from the Demonstration Study.

The results of the Demonstration Study show the responsiveness of the Westside Basin aquifers to in-lieu recharge, the increase in Basin groundwater storage related to cessation of large-scale municipal pumping. The Demonstration Study results are likely not directly applicable to full-scale implementation of the proposed GSR Project due to the variable subsurface conditions present throughout the entire Basin, and due to the Basin storage inefficiencies discussed previously. However, the approximate relationship of reduced large-scale pumping to increases in groundwater storage demonstrated by the Demonstration Study gives an indication of the magnitude of storage increases that could be reasonably expected in the Basin with GSR Project implementation.

4.3. Westside Groundwater Basin Water Budget

A groundwater budget for the entire Westside Basin was produced as part of the calibration of the Westside Basin Groundwater-Flow Model (HydroFocus, 2007, 2009, and 2011). Groundwater budgets have been developed for Golden Gate Park, the Golden Gate Park and Lake Merced area, and the Daly City area, and are presented in LSCE (2010).

Under existing conditions the predominant inflow component is percolating rain and irrigation water, which together are the primary recharge mechanisms in the Westside Basin system (HydroFocus, 2007). Inflow from Lake Merced and the GGP lakes is relatively minor, with modeled inflow from the Ocean and Bay even smaller and limited to the coastal fringe areas. The primary outflow component is large-scale pumping from municipal and irrigation wells in the Basin. Outflows to the Ocean and Bay are relatively modest (although substantially greater than simulated inflow rates from the same), and outflow seepage to Lake Merced is lower still (but greater on average than simulated inflows to the lake).

The average annual recharge for the Westside Basin from the period 1959 through 2009 was estimated by the groundwater model to be 14,740 afy (HydroFocus, 2011). Of that, 7,006 afy were apportioned to the North Westside Basin and 7,734 afy to the South Westside Basin. For the North Westside Basin, recharge was estimated by LSCE (2007) to be 6,800 afy, while Phillips et al. (1993) estimated 4,850 afy of recharge for 1988 and 1989, the first two years of an extended drought period. The estimate by Phillips et al. (1993) was developed for a drought period, and is not considered representative of long-term average conditions. No other estimates of total recharge for the South Westside Basin have been documented.

In discussing the water balance, the HydroFocus (2011) report focuses on the Developed Basin. The results of the 2008 No-Project Scenario (HydroFocus, 2011) are compared to the results of Scenario 1 (Table 10.4-7) for the Developed Basin. Key observations are that the recharge from precipitation and return flows are higher in the 2008 No-Project Scenario (11,532 afy compared to 10,310 afy annual average) as expected because Scenario 1 uses a more conservative hydrologic sequence that incorporates the Design Drought (TM 10.1). Pumpage rates are comparable with an annual average of 10,551 afy for the 2008 No-Project Scenario and

10,227 afy for Scenario 1. The differences are due to minor changes to the pumping assumptions as discussed in TM 10.1. Similarly, outflow to the Pacific Ocean is comparable with an annual average of 3,258 afy for the 2008 No-Project Scenario and 3,139 afy for Scenario 1. There is a difference in the net change in groundwater storage due primarily to the differences in recharge. The annual average change in aquifer storage is an increase of 3 afy for the 2008 No-Project Scenario and a decrease of 613 afy for Scenario 1.

This comparison of the 2008 No-Project Scenario to Scenario 1 shows that the overall model assumptions are similar. The use of the new hydrologic sequence makes Scenario 1 more conservative with respect to aquifer storage due to the overall decrease in groundwater recharge with the addition of the Design Drought to Scenario 1.

4.4. Total Groundwater Volume in Westside Basin

A volumetric calculation was made to evaluate a reasonable estimate for the total volume of groundwater currently present in the Westside Basin. The volumetric estimate is based the volume of the aquifer from the Westside Basin Groundwater Model and an estimate of the available pore space, or porosity, within the aquifer to store water. This is a static calculation of the total groundwater present in the Basin and does not consider recharge or the long-term effects of pumping. This volumetric estimate provides additional context for evaluating the scale of aquifer storage changes from the GSR and SFGW Project scenarios. This analysis compares the total groundwater storage changes from each model scenario and compares that to the total groundwater in the basin. The purpose of this comparison is only to provide a sense of the scale of the potential aquifer storage changes relative to the size of the groundwater basin. This analysis is not intended to provide an assessment of the sustainable yield or operational storage of the Westside Basin.

The method used to estimate the total groundwater in the Basin was based on results from the Westside Basin Groundwater-Flow Model (HydroFocus, 2011). Because the spatial distributions of the five Model Layers are different, the total groundwater volume was estimated separately for each layer. The upper surface of each Model Layer cell was defined as the lower of either the top aquifer elevation or, for Model Layer 1, the June 2009 groundwater elevation. The lower surface of each layer was the bottom aquifer elevation. The aquifer thickness is the difference between the upper and lower surface elevations. This process was repeated to determine the volume of each of the five Model Layers individually, and these volumes were then summed to determine the total aquifer volume.

To define the groundwater volume, the aquifer volume of each Model Layer was multiplied by the specific yield values used in the Westside Basin Groundwater-Flow Model (HydroFocus, 2011). The specific yield provides a representative estimate of the effective porosity of the aquifer. The specific yield used in the calibrated Westside Basin Groundwater-Flow Model (HydroFocus, 2011) was 0.14 for Model Layers 1 through 4 and 0.05 for Model Layer 5.

Using the above method results in a total saturated storage capacity, a reasonable maximum storage based on June 2009 groundwater levels calculated by the model. To facilitate this analysis, the Westside Basin is defined as three onshore subareas. The two offshore subareas included in the MODFLOW model underlying the Pacific Ocean and San Francisco Bay are not included in this analysis. The results of the volumetric calculations for the three onshore subareas are summarized below:

- The North Westside Basin subarea was defined as the portion of the Basin north of the San Mateo-San Francisco County Line and east of either Ocean Beach or the Serra Fault (where it is located onshore). The total estimated groundwater volume in this subarea is 223,000 af.
- The South Westside Basin subarea was defined as the portion of the Basin east of the Serra Fault, south of the San Mateo-San Francisco County Line, and west of the San Francisco International Airport. The total estimated groundwater volume in this subarea is 513,000 af.
- The Serra Block subarea was defined as the portion of the Basin east of the Pacific coast and west of the Serra Fault (where it is located onshore). The total estimated groundwater volume in this subarea is 340,000 af.

The total groundwater volume in the onshore Westside Basin estimated using this method was 1,078,000 af.

For the GSR-Only Scenario (2), the change in groundwater storage relative to the Existing Conditions Scenario (1) was a decrease of approximately 420 afy for a total change in storage over the 47-year simulation period of about -19,530 af. This volume represents about 1.8 percent of the total groundwater volume in the entire Westside Basin and 3.8 percent of the total groundwater volume of the South Westside Basin subarea.

For the SFGW-Only Scenario 3a, the change in groundwater storage relative to the Existing Conditions Scenario (1) was a decrease of approximately 680 afy for a total change in storage over the 47-year simulation period of about -32,170 af, representing about 3.0 percent of the total groundwater volume in the entire Westside Basin at the end of the simulation period and 14.4 percent of the total groundwater volume of the North Westside Basin subarea. For Scenario 3b, the change in groundwater storage relative to the Existing Conditions Scenario (1) was a decrease of about 640 afy, for a total change in storage over the 47-year simulation period of about -30,080 af, representing about 2.8 percent of the total groundwater volume in the entire Westside Basin and 13.5 percent of the total groundwater volume of the North Westside Basin subarea.

For the Cumulative Scenario (4), the change in groundwater storage relative to the Existing Conditions Scenario (1) was a decrease of approximately 970 afy for a total change in storage over the 47-year simulation period of about -45,480 af, representing about 4.2 percent of the total groundwater volume in the entire Westside Basin.

5. Summary

This section summarizes the results of the numerical modeling and analytical approaches with respect to changes in groundwater levels and storage in the Westside Basin.

5.1. Existing Conditions (Scenario 1)

Scenario 1 simulates Basin conditions without either the GSR or SFGW Projects and defines the background conditions against which the other model scenarios are compared, including wet, normal and dry precipitation years. By the end of Scenario 1, groundwater storage would decline approximately 28,000 af for the entire Westside Basin (Figure 10.4-14). The 28,000-af decline in groundwater storage in Scenario 1 is due to the assumptions used for the background hydrology, which include a Design Drought as necessitated by the need for consistency with the PEIR. The Design Drought repeats the historical 1976-77 drought, resulting in an overall rainfall deficit of nearly 20 inches over the 47-year simulation period. This rainfall deficit is nearly equivalent to losing a full year of precipitation and its associated recharge for the entire basin. Comparing the recharge calculated by the Soil Moisture Budget for the SFPUC scenarios with the HydroFocus 2008 No-Project Scenario shows that the decline in groundwater storage in Scenario 1 can be accounted for by the difference in rainfall between the different sets of background hydrology assumptions used. The background hydrology assumptions used for all of the scenarios therefore provide a conservative analysis with respect to the potential changes in groundwater levels and storage.

In the North Westside Basin, groundwater levels generally fluctuate within a narrow range in response to climatic conditions. Both groundwater levels and storage for Scenario 1 show an initial increase in Scenario Years 1 and 2, followed by a general decline over the scenario period except for periods of increase during Scenario Years 21 to 23 and Years 30 to 35. There is a substantial decline during the Design Drought period followed by an increase in Scenario Years 45 to 47.

In the South Westside Basin, groundwater levels in Model Layer 4 show a similar trend of steady decline over the 47-year simulation period. In Model Layer 1, groundwater levels show an increasing trend, with about a 20-foot rise over 47 years. The difference in groundwater elevations in the Shallow and Primary Production Aquifers (Model Layers 1 and 4) ranges from 10 to 20 feet in the Daly City area to 200 to 250 feet in the San Bruno area.

5.2. GSR Project Only (Scenario 2)

Scenario 2 represents the operation of the GSR Project, which is located in the South Westside Basin. Groundwater levels and storage show increases during put periods and decrease during take periods (see Section 3 for a definition of put/take/hold periods). Because of the Project location, the largest changes in groundwater levels and storage are primarily in the South Westside Basin. The general response to the GSR operations is greatest in the Primary

Production Aquifer (Model Layer 4) and more subdued to absent in the Shallow Aquifer (Model Layer 1), especially in the South San Francisco and San Bruno areas.

In general, groundwater levels and storage increase during put/hold periods and decrease during take periods. The greatest increase occurs during the first extended put period from Scenario Years 1 to 7, which is followed by a slow decline. Two take periods from Scenario Years 9 to 12 and Scenario Years 25 to 28 show up distinctly with declines in groundwater levels and storage. All locations have their lowest groundwater levels and storage at the end of the Design Drought when pumping from both the SFPUC and PA wells occurs. The greatest declines occur in the Daly City, South San Francisco and Colma areas because most of the GSR Project wells are located in this area. At the start of the Design Drought, groundwater levels and storage are well above Scenario 1 levels, but decline to well below Scenario 1 levels by the end of the Design Drought. During the 3-year put period from the end of the Design Drought to the end of the scenario, groundwater levels generally recover to near or above Scenario 1 levels.

In the North Westside Basin, the greatest effects of the GSR Project occur in locations near the southern end of Lake Merced primarily in the Primary Production Aquifer (Model Layer 4). Locations north of Lake Merced and in Golden Gate Park show little to no change in groundwater levels or storage due to the GSR Project.

Scenario 2 assumes that there is 20,000 af of groundwater in the SFPUC Storage Account at the beginning of the scenario (represented in the initial conditions) and 20,000 af in the SFPUC Storage Account at the end of the scenario due to the put period immediately following the Design Drought. Therefore, the reduction in groundwater storage of about 20,000 af relative to Scenario 1 is not due to any change in the SFPUC Storage Account, but rather to the fact that the storage efficiency of the Basin is less than 100 percent. Most of this decline occurs when groundwater levels are higher than under Scenario 1 during Scenario Years 7 through 36. Most of this loss in storage is attributed to declines in groundwater inflows from the North to the South Westside Basin. With the increased groundwater levels simulated under Scenario 2, the hydraulic gradient in the North Westside Basin shifts to a more westward direction, resulting in increased outflows to Lake Merced and to the Pacific Ocean. Based on this analysis, the overall average efficiency of the GSR Project of the 47.25 year simulation period is approximately 78 percent.

Based on this analysis, groundwater levels and storage during Scenario Years 1 through 36 are generally higher than Scenario 1. During the Design Drought, groundwater levels and storage decline below Scenario 1 levels, but show a strong recovery after the Design Drought. Therefore, from a groundwater Basin management perspective, the operation of the GSR Project is not expected to deplete or interfere with Basin groundwater supplies in a manner that would result in a substantial regional deficit in aquifer storage.

5.3. SFGW Project Only (Scenarios 3a and 3b)

The SFGW Project would construct up to six wells and associated facilities in the western part of San Francisco and pump either 3.0 mgd (Scenario 3a) or 4.0 mgd (Scenario 3b) of groundwater from the North Westside Basin (SFPUC, 2009). Scenario 3a assumes 3.0 mgd of pumping for water supply and 1.142 mgd irrigation pumping in Golden Gate Park, whereas Scenario 3b assumes 4.0 mgd of pumping for water supply, with pumping of groundwater for irrigation in Golden Gate Park replaced by recycled water. Because this overall change in pumping is minor, the regional response of groundwater levels to these scenarios is comparable, and the results for Scenarios 3a and 3b are discussed together.

In general, all well locations evaluated in the North Westside Basin area show a similar declining trend in groundwater levels relative to Scenario 1 due to the SFGW Project operations. There is an initial decrease in groundwater levels in the first 5 to 10 years of the scenarios. Following this, the rate of change in groundwater levels relative to Scenario 1 is much less. In the northern locations, the rate of change relative to Scenario 1 after about Scenario Year 20 is near zero, whereas the locations near Lake Merced show a steady decline in groundwater levels relative to Scenario 1, but at a rate much lower than during the initial decline.

In the South Westside Basin, modest groundwater level and storage declines occur in the Daly City area, but these effects diminish to the south and are barely discernible in the San Bruno area.

At the end of the scenarios, the reductions in Basin groundwater storage are approximately 30,000 af for both Scenarios 3a and 3b. For locations in the North Westside Basin, the results show that groundwater levels and storage tend to stabilize after an initial period of steeper declines. During the early simulation period, the majority of the increased pumping initially comes from groundwater storage. Over time, storage provides less of the SFGW Project pumping, and groundwater pumping is instead primarily sustained by the interception of groundwater flow to the Pacific Ocean. Therefore, from a long-term regional groundwater basin management perspective, the operation of the SFGW Project is not expected to deplete or interfere with Basin groundwater supplies in a manner that would result in a substantial regional deficit in aquifer storage or produce continuing long-term declines in groundwater levels.

5.4. Cumulative Project Scenario (Scenario 4)

Scenario 4 represents the combined effects of operations of the GSR (Scenario 2) and SFGW (Scenario 3b) Projects. The resulting groundwater level responses in the North Westside Basin tend to be intermediate between the responses seen for Scenarios 2 and 3b. Scenario 4 also includes additional stormwater being diverted into Lake Merced. The effect of these stormwater additions substantially improves lake levels in Lake Merced. Also, increases in groundwater levels resulting from the additional seepage due to these lake additions are primarily concentrated in the Shallow Aquifer in the vicinity of Lake Merced. Another change for Scenario 4 is the planned replacement of the Daly City A-Street Well with a production well located west of the Serra Fault, which is away from the main part of the Westside Basin. This change has the effect of reducing pumping in the Daly City area east of the Serra Fault due to the low groundwater flow across the fault.

In general, Scenario 4 responses in the North Westside Basin closely resemble those of Scenario 3b, whereas in the South Westside Basin the responses closely resemble those of Scenario 2. The Lake Merced and Daly City areas represent the transition zone, where a combined effect is seen. In these areas, the responses vary by aquifer; Shallow Aquifer (Model Layer 1) responses more closely resemble those of Scenario 3b, whereas Primary Production Aquifer (Model Layer 4) responses more closely resemble those of Scenario 2. The Daly City area also shows a slight increase in groundwater levels and storage relative to Scenario 1 due to the change in the location of the Daly City A-Street Well.

The overall trend in groundwater storage changes for Scenario 4 follows that of Scenario 2, but the volume of groundwater storage in Scenario 4 is lower, reflecting the increased pumping by the SFGW Project. However, the difference in storage between Scenarios 2 and 4 is less than the decrease in storage seen under Scenarios 3a and 3b. There is a slight increase in groundwater storage in Scenario 4 relative to Scenario 1 resulting from the additional seepage from Lake Merced, amounting to about 4,000 af by the end of Scenario 4. The storage efficiency is similar in Scenario 4 to Scenario 2 as the trends are very close to parallel.

With respect to regional groundwater management issues, the cumulative operation of the SFGW and GSR Projects, along with other reasonably foreseeable future projects, is not expected to deplete or interfere with Basin groundwater supplies in a manner that would result in a substantial regional deficit in aquifer storage.

References

California Department of Water Resources (DWR), 2003, California's Groundwater, Bulletin No. 118, DWR, Sacramento, CA, 265p.

City of San Bruno (San Bruno), 2007, *Urban Water Management Plan*, 321p. Dated January 2007.

Fetter, C.W., 1988. Applied Hydrogeology, 2nd Edition. Mcmillan Publishing Company, New York. 592 pp.

Harbaugh, A. W., 1990, *A Computer Program for Calculating Subregional Water Budgets Using Results from the U.S. Geological Survey Modular three-dimensional Finite-difference Ground-water Flow Model,* U.S. Geological Survey Open-File Report 90-392.

HydroFocus, 2007, *Westside Basin Groundwater-Flow Model (version 2.0), Historical Calibration Run (1959-2005) Results and Sensitivity Analysis*, 76p.

HydroFocus, 2009. Westside Basin Groundwater-Flow Model: Revised Historical Simulation and No-Project Simulation Results (Technical Memorandum). Dated 05/20/2009.

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

Kennedy/Jenks Consultants. 2009. San Francisco Water System Improvement Program (WSIP) Lake Merced Water Levels Restoration (CUW30101) Draft 100% Conceptual Engineering Report (prepared for SFPUC). January 2009.

Luhdorff & Scalmanini Consulting Engineers (LSCE), 2002. Conceptualization of the Lake-Aquifer System, Westside Ground-Water Basin, San Francisco and San Mateo Counties. Dated March 2002, Re-released July 2002.

Luhdorff & Scalmanini Consulting Engineers (LSCE). 2005a. North Westside Groundwater Basin Management Plan, City and County of San Francisco. Final Draft. April 2005.

Luhdorff & Scalmanini Consulting Engineers (LSCE). 2005b. Results of In-Lieu Recharge Demonstration, Fall 2002 Through Spring 2005, Westside Basin Conjunctive Use Pilot Project. October 2005.

Luhdorff & Scalmanini Consulting Engineers (LSCE). 2006. Hydrogeologic Conditions in the Westside Basin – 2005 (prepared for SFPUC). November 2006.

Luhdorff & Scalmanini Consulting Engineers (LSCE). 2007. Assessment of Groundwater Recharge and Potential Groundwater Development for Maintenance of Lake Merced North Westside Groundwater Basin. Technical Memorandum. August 2007.

Luhdorff & Scalmanini Consulting Engineers (LSCE), 2010. Task 8B Technical Memorandum No. 1, Hydrogeologic Setting of the Westside Basin. Dated 02/26/2010.

MWH, 2009, 2008 Groundwater Banking Programs Survey, Groundwater Resources Association Annual Meeting Presentation, October 2009.

MWH, 2008, *San Francisco Public Utilities Commission Water System Improvement Program, Groundwater Conjunctive Use Project, WSIP Project CUW30103, Conceptual Engineering Report*, 299p.

Phillips, S.P., S.N. Hamlin, and E.B. Yates, 1993, Geohydrology, water quality, and estimation of ground-water recharge in San Francisco, California, 1987-92, U.S. Geological Survey Water-Resources Investigations Report 93-4019, U.S. Geological Survey, Sacramento, CA, 73p.

San Francisco Public Utilities Commission (SFPUC), 2007, *SFPUC Water System Improvement Program Programmatic Environmental Impact Report.*

San Francisco Public Utilities Commission (SFPUC) 2007. 2006 Annual Groundwater Monitoring Report, Westside Basin, San Francisco and San Mateo Counties, California. Dated April 2007.

San Francisco Public Utilities Commission (SFPUC) 2008. 2007 Annual Groundwater Monitoring Report, Westside Basin, San Francisco and San Mateo Counties, California. Dated April 2008.

San Francisco Public Utilities Commission (SFPUC) 2009. 2008 Annual Groundwater Monitoring Report, Westside Basin, San Francisco and San Mateo Counties, California. Dated April 2009.

San Francisco Public Utilities Commission (SFPUC) 2010. Final 2009 Annual Groundwater Monitoring Report, Westside Basin, San Francisco and San Mateo Counties, California. Dated May 2010.

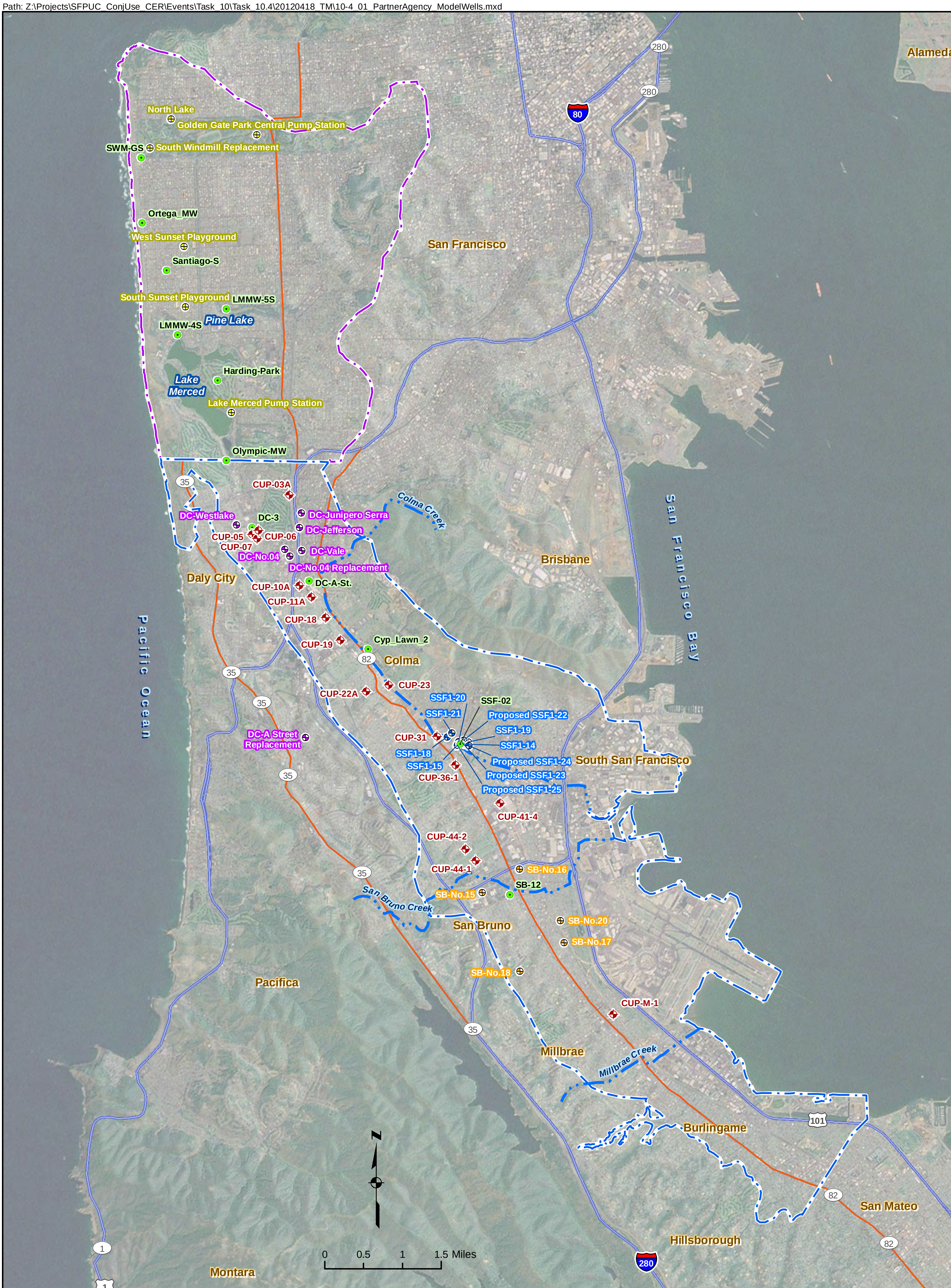
Yates, E.B, S.N. Hamlin, and L.H. McCann, 1990. Geohydrology, Water Quality, and Water Budgets of Golden Gate Park, and the Lake Merced Area in the Western Part

Figure List

Table List

Figures

Path: Z:\Projects\SFPUC_ConjUse_CER\Events\Task_10\Task_10.4\20120418_TM\10-4_01_PartnerAgency_ModelWells.mxd



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

Note:
The Santiago-S Location and the Harding Park Location are locations used by the Westside Basin Groundwater-Flow Model to track the model-simulated water levels. They represent historical well locations, but are not the current locations of active monitoring wells

Legend

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

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

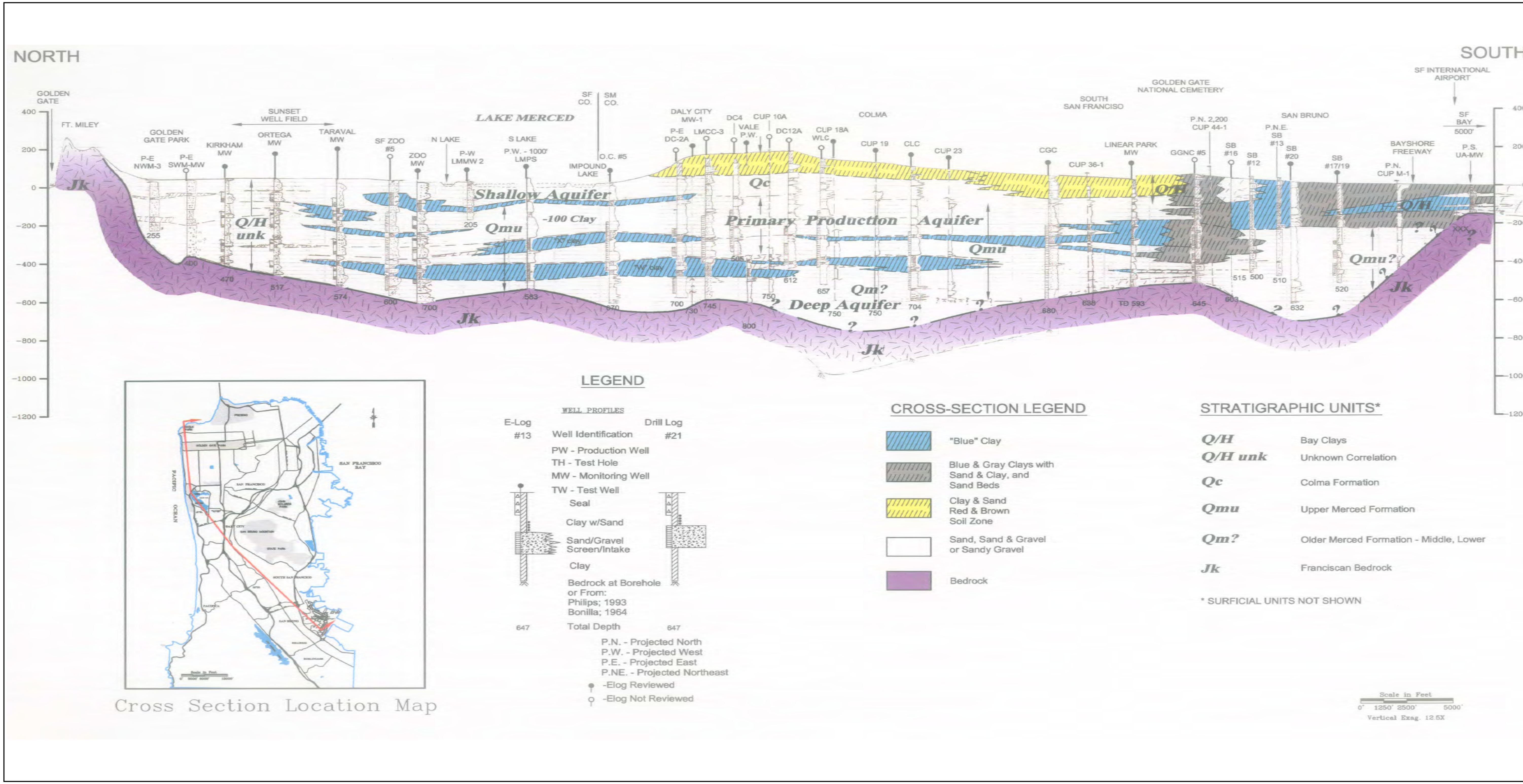
LOCATIONS OF PARTNER AGENCY WELLS, PROPOSED GSR AND SFGW PROJECT MUNICIPAL WELLS, AND SELECTED REPRESENTATIVE MONITORING WELLS WITH MODEL RESULTS

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

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

Figure **10.4-1**

Date April 2012



Source: Final Task 8B Technical Memorandum No.1, Hydrologic Setting of the Westside Basin, LSCE, May 2010.

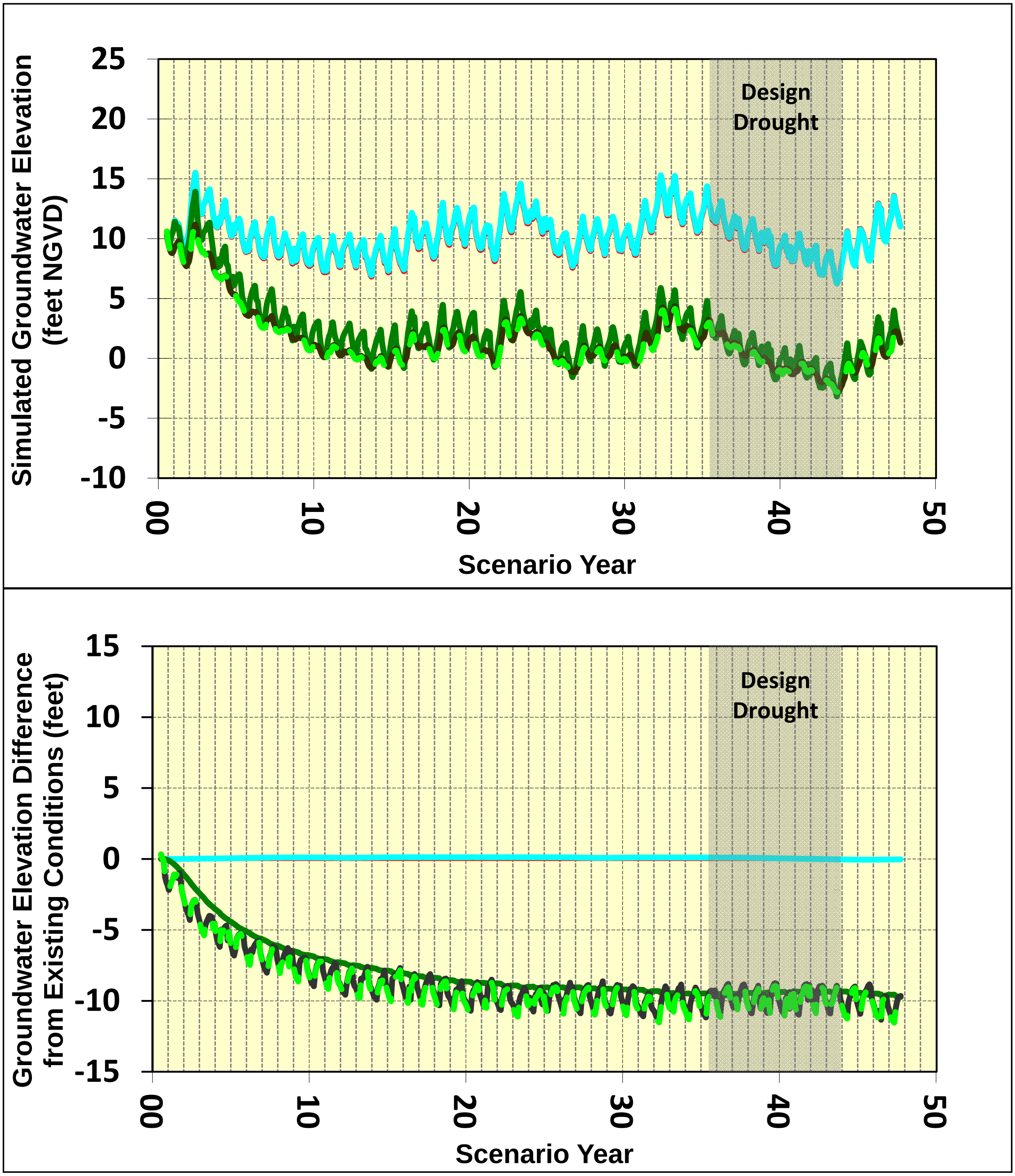
Kennedy/Jenks Consultants

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

Westside Basin Regional Subsurface Hydrogeology

K/J 0864001
April 2012

Figure 10.4-2



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

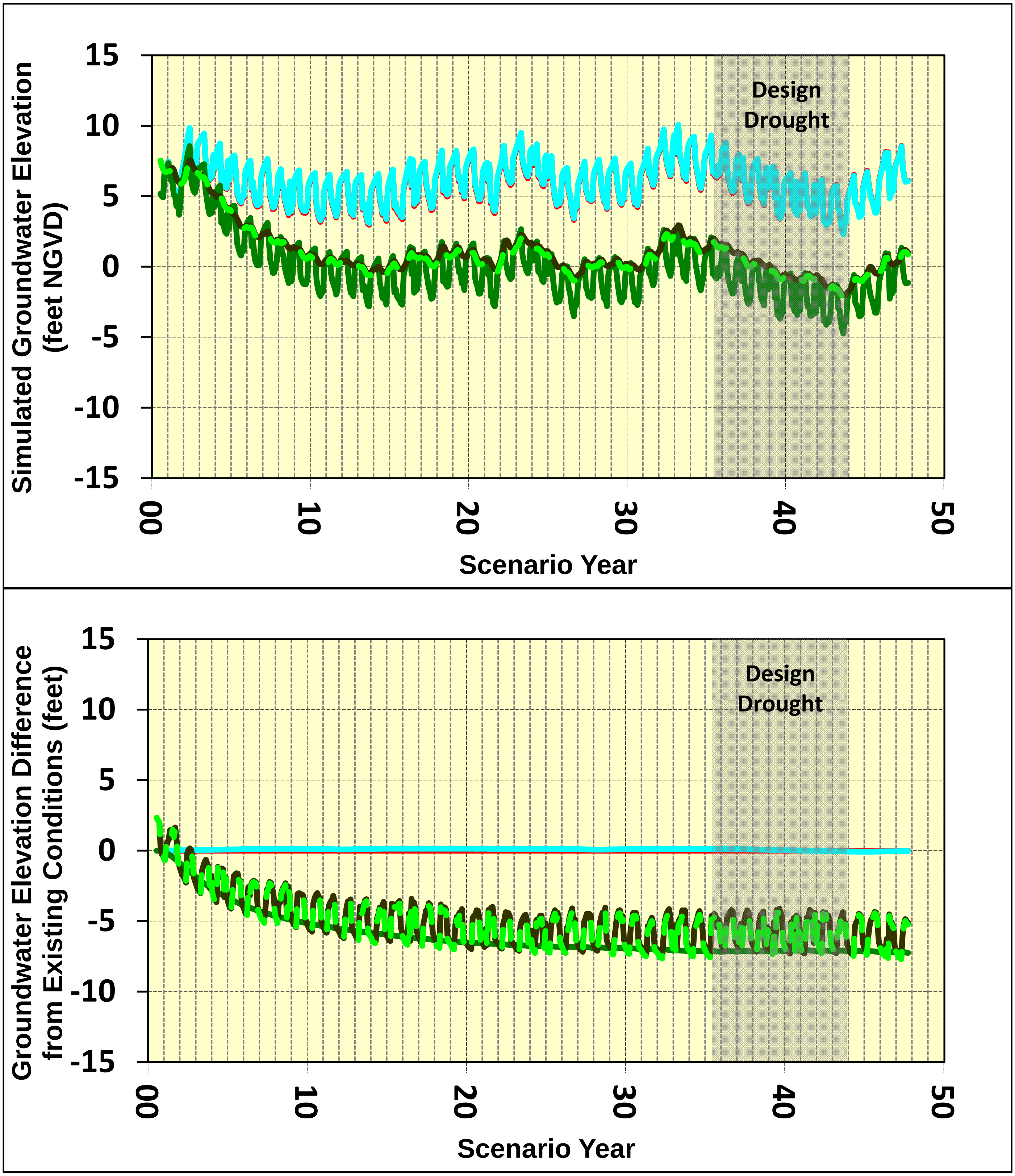
Kennedy/Jenks Consultants

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

Model Layer 1 Hydrographs for SWM-GS

K/J 0864001
April 2012

Figure 10.4-3a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

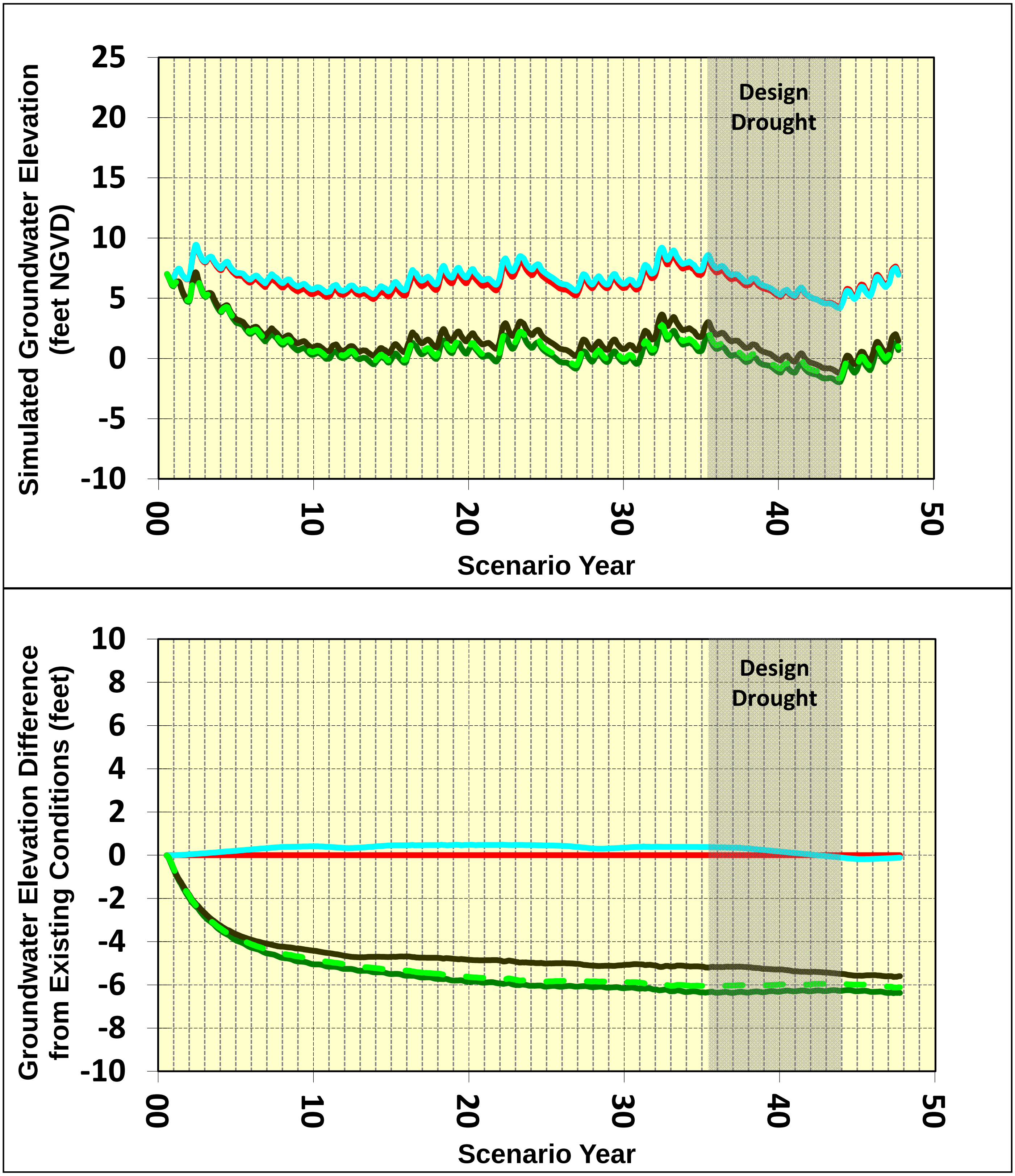
Kennedy/Jenks Consultants

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

Model Layer 4 Hydrographs for SWM-GS

K/J 0864001
April 2012

Figure 10.4-3b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

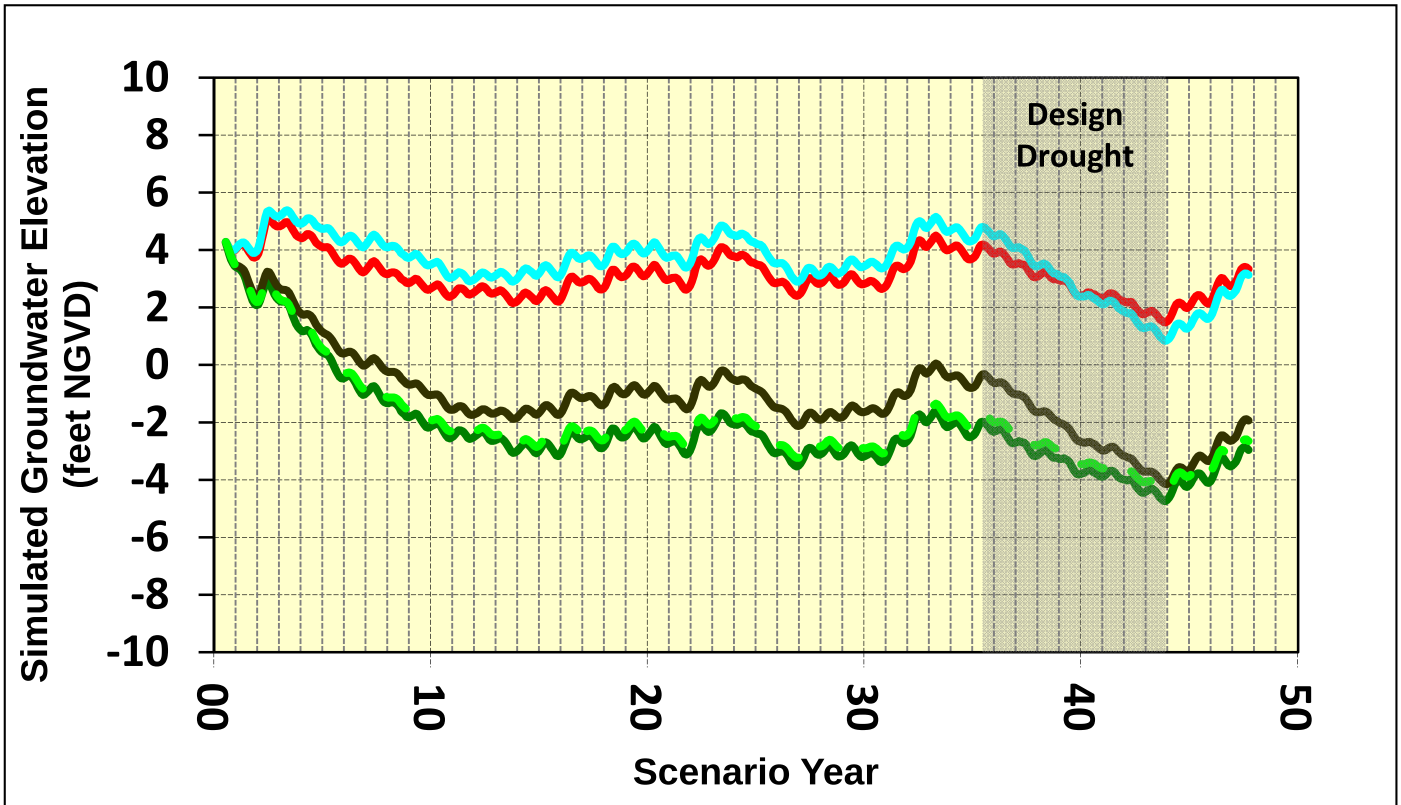
Kennedy/Jenks Consultants

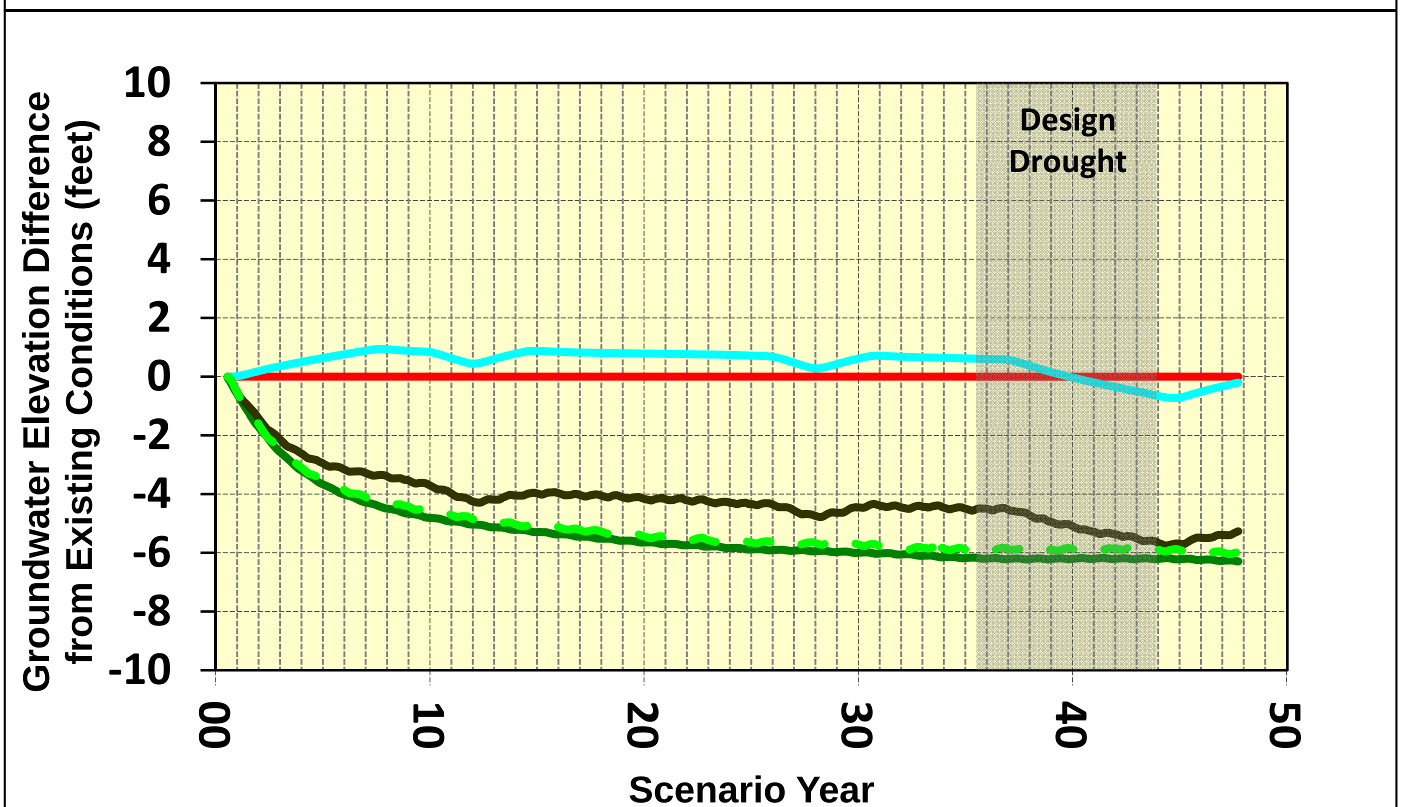
Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Model Layer 1 Hydrographs for Ortega MW

K/J 0864001
April 2012

Figure 10.4-4a





Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

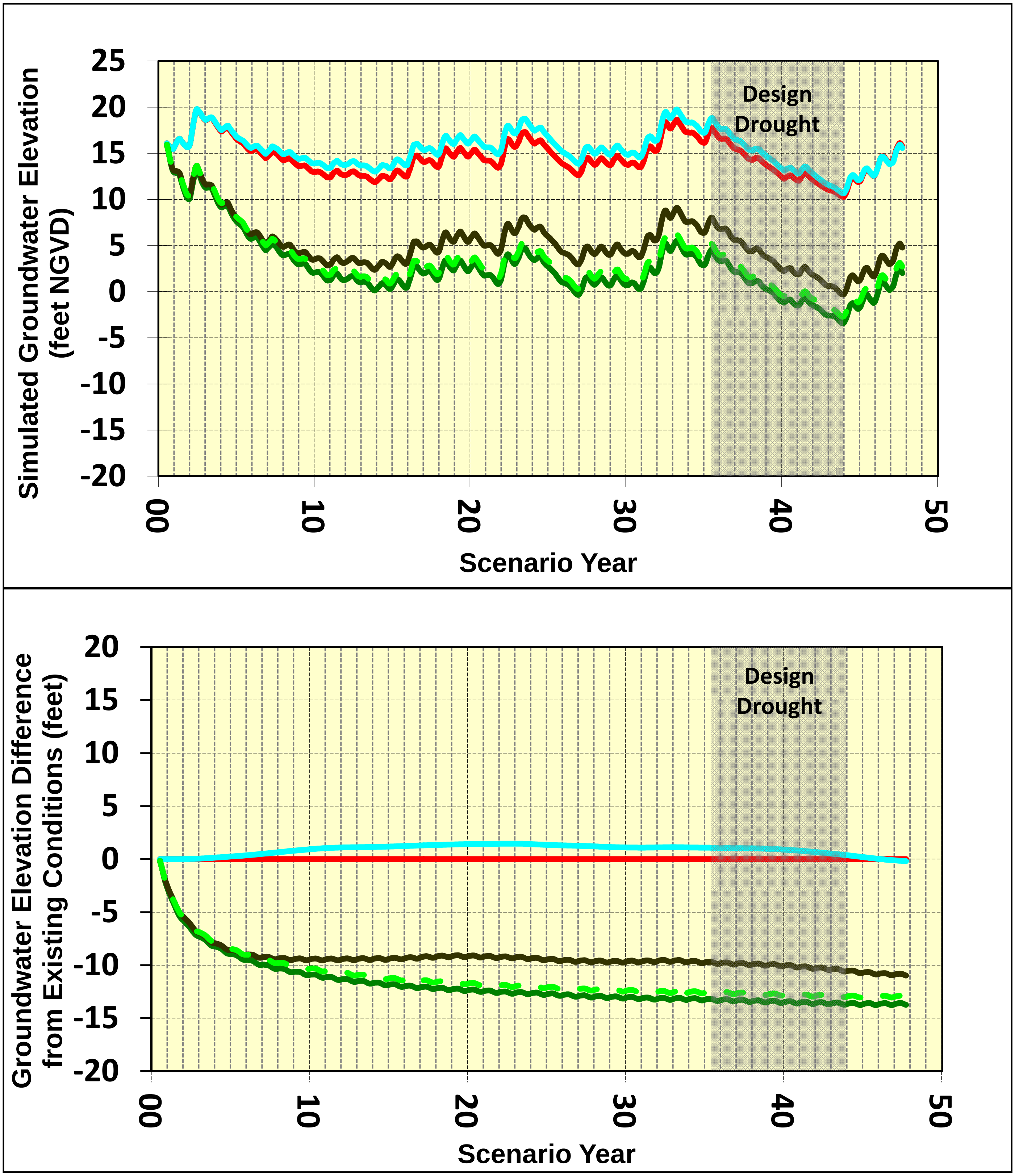
Kennedy/Jenks Consultants

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

Model Layer 4 Hydrographs for Ortega MW

K/J 0864001
April 2012

Figure 10.4-4b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

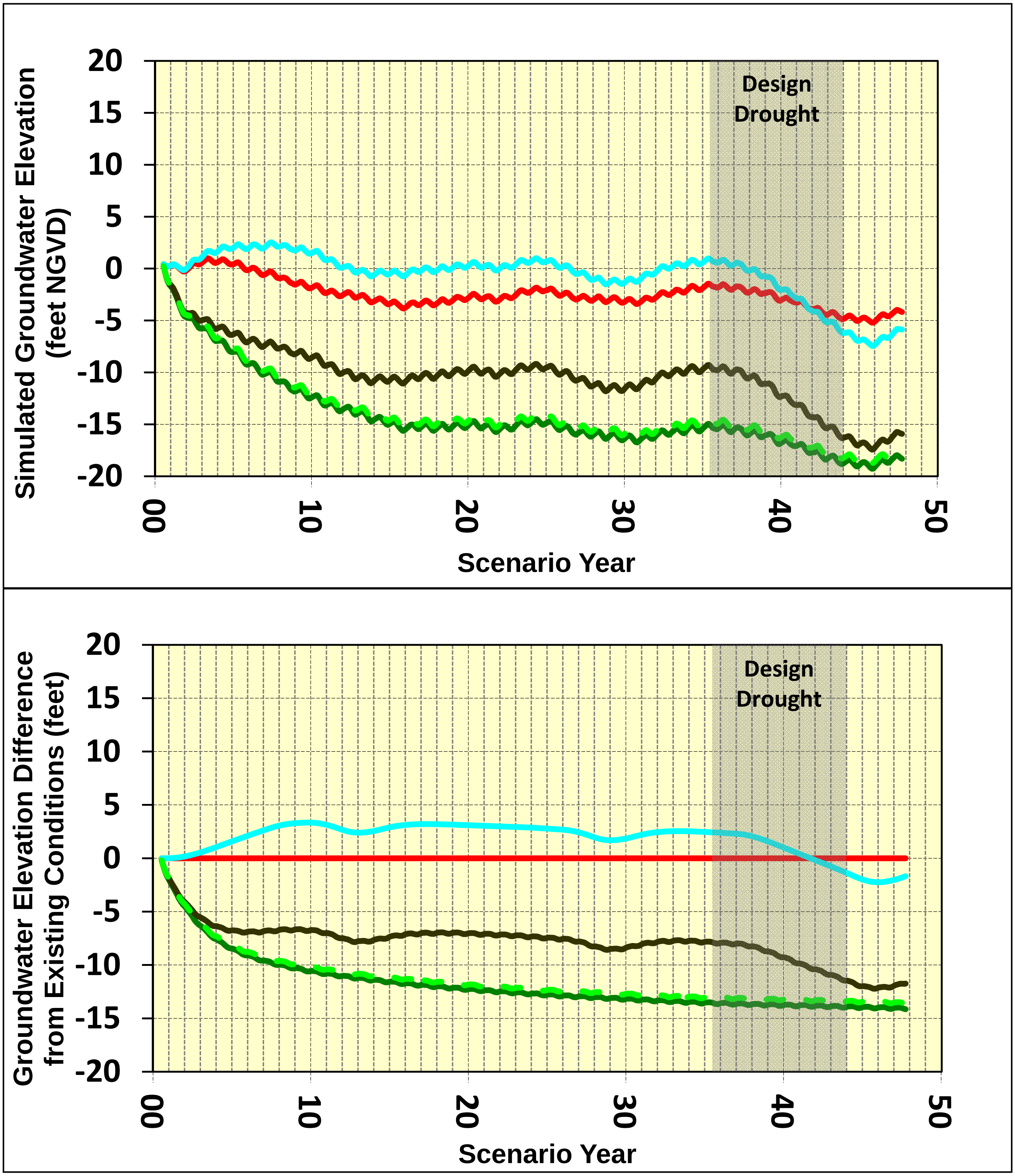
Kennedy/Jenks Consultants

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

Model Layer 1 Hydrographs for Santiago-S MW

K/J 0864001
April 2012

Figure 10.4-5a



Note: Mean sea level is equivalent to zero feet NGVD.

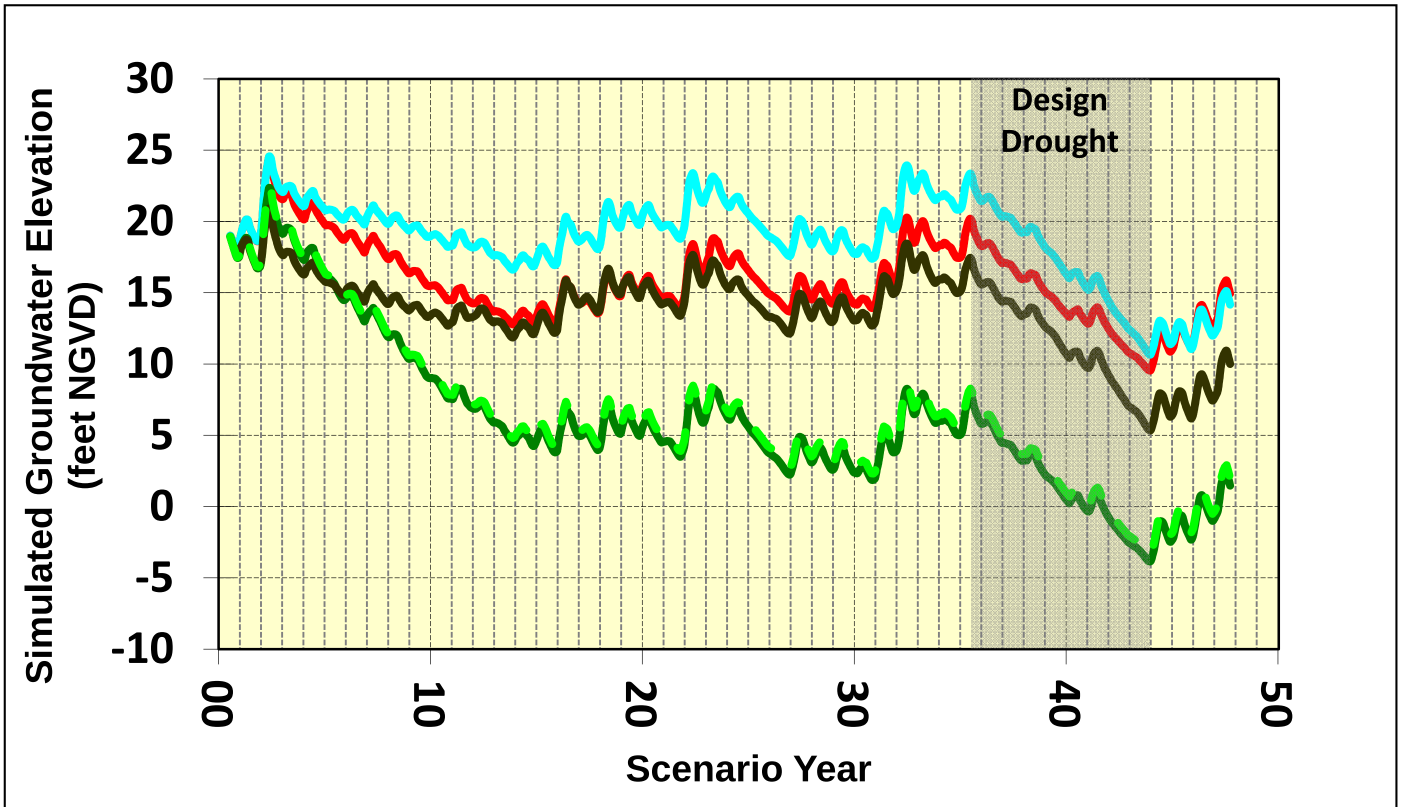
Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

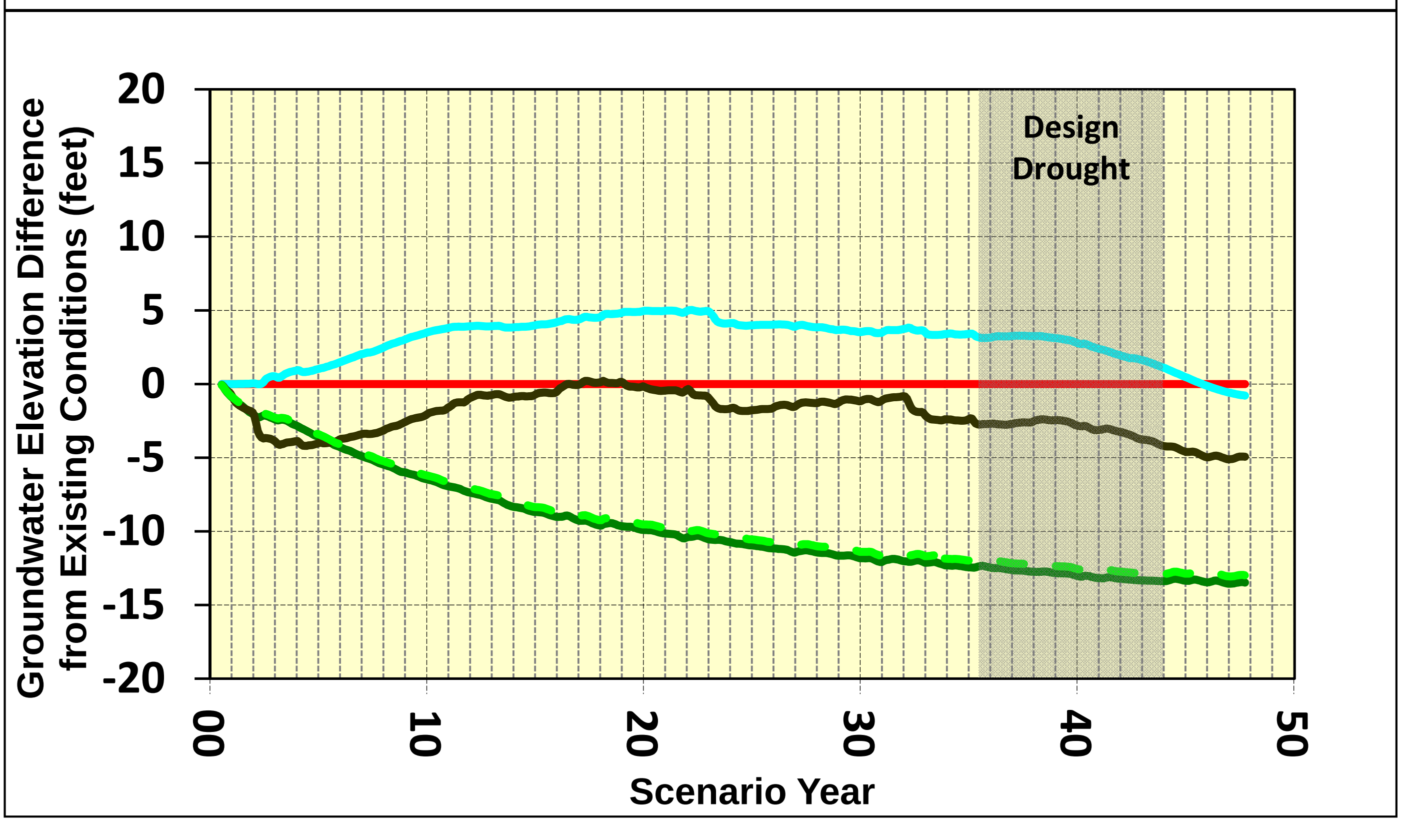
Kennedy/Jenks Consultants

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

Model Layer 4 Hydrographs for Santiago-S MW

K/J 0864001
April 2012
Figure 10.4-5b





Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

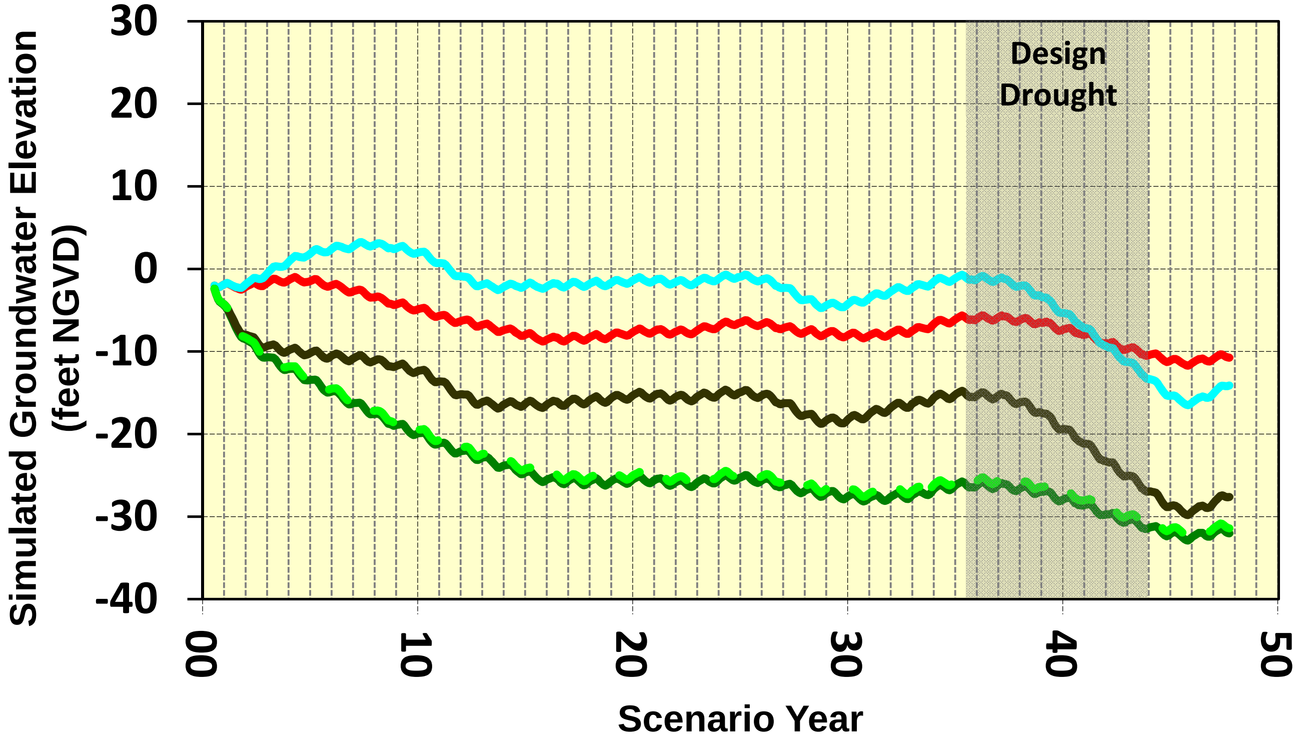
Kennedy/Jenks Consultants

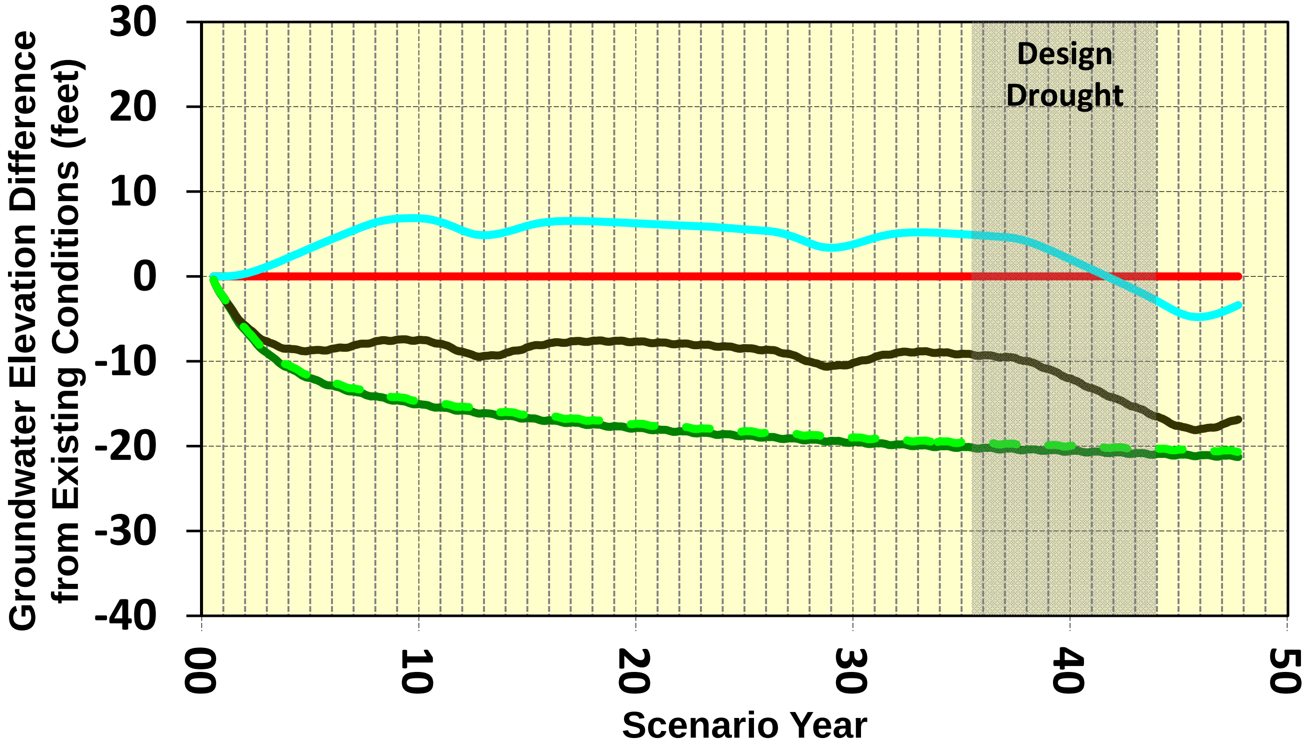
Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Model Layer 1 Hydrographs for LMMW-4S

K/J 0864001
April 2012

Figure 10.4-6a





Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

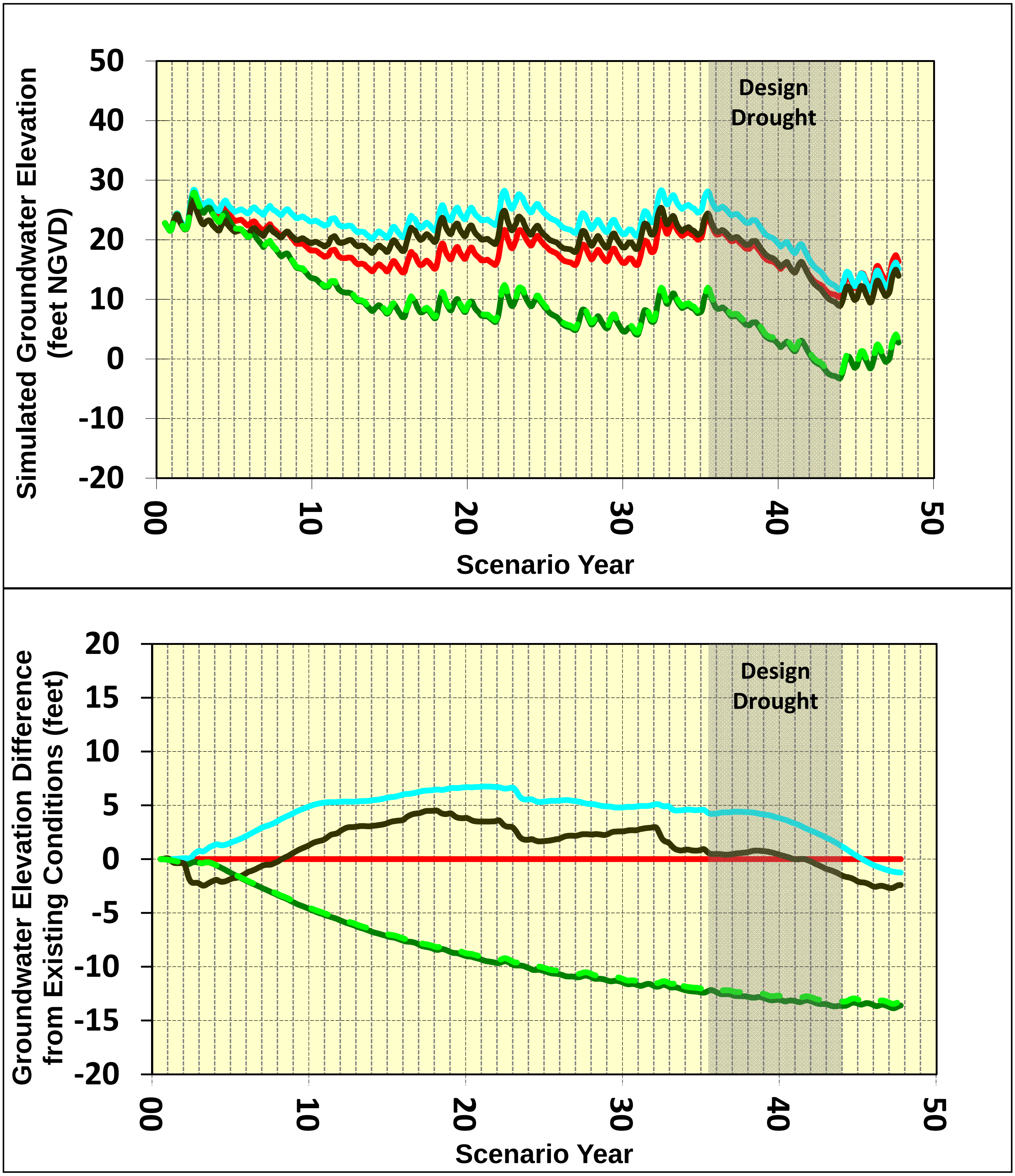
Kennedy/Jenks Consultants

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

Model Layer 4 Hydrographs for LMMW-4S

K/J 0864001
April 2012

Figure 10.4-6b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

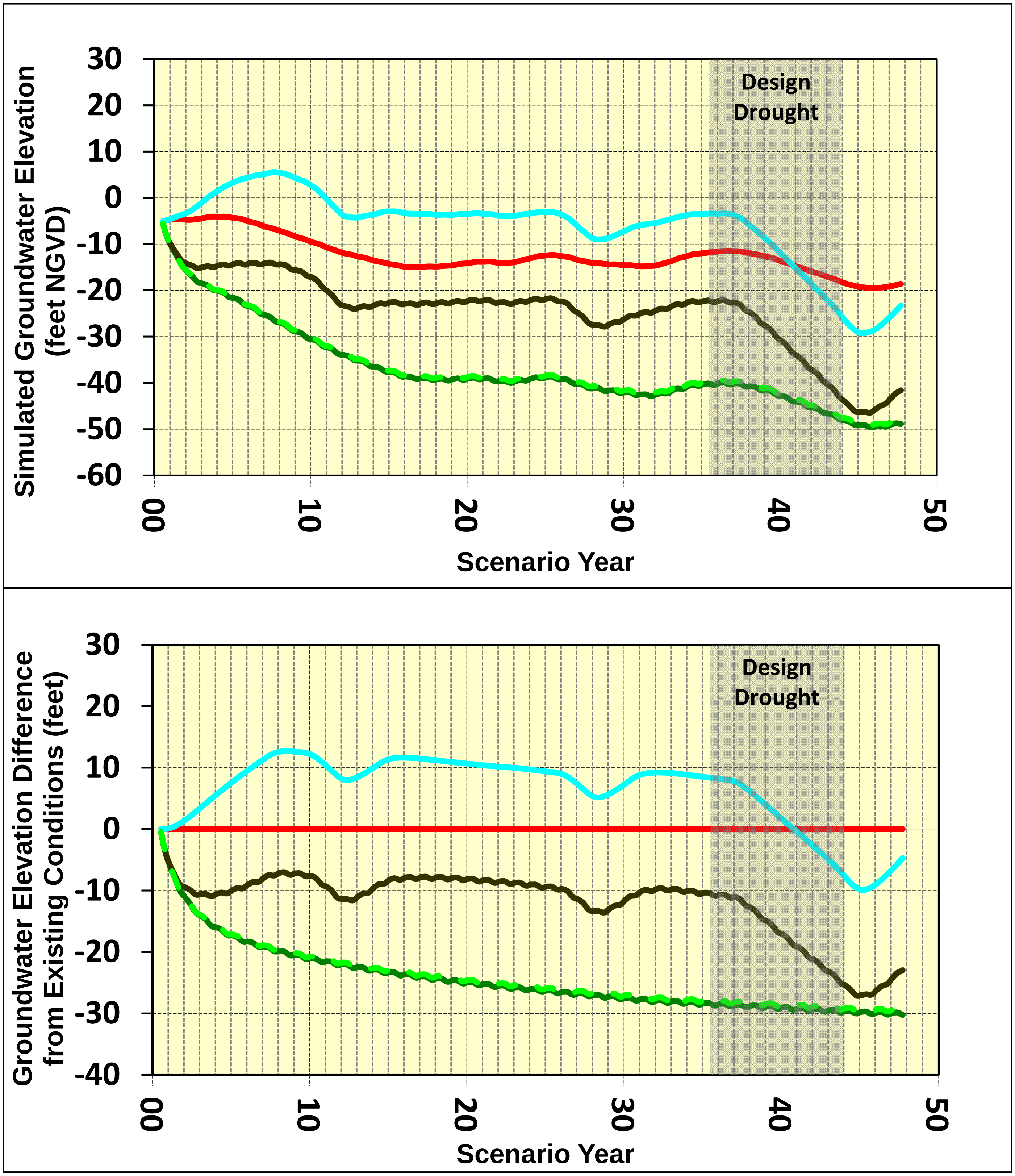
Kennedy/Jenks Consultants

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

Model Layer 1 Hydrographs for Harding Park MW

K/J 0864001
April 2012

Figure 10.4-7a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

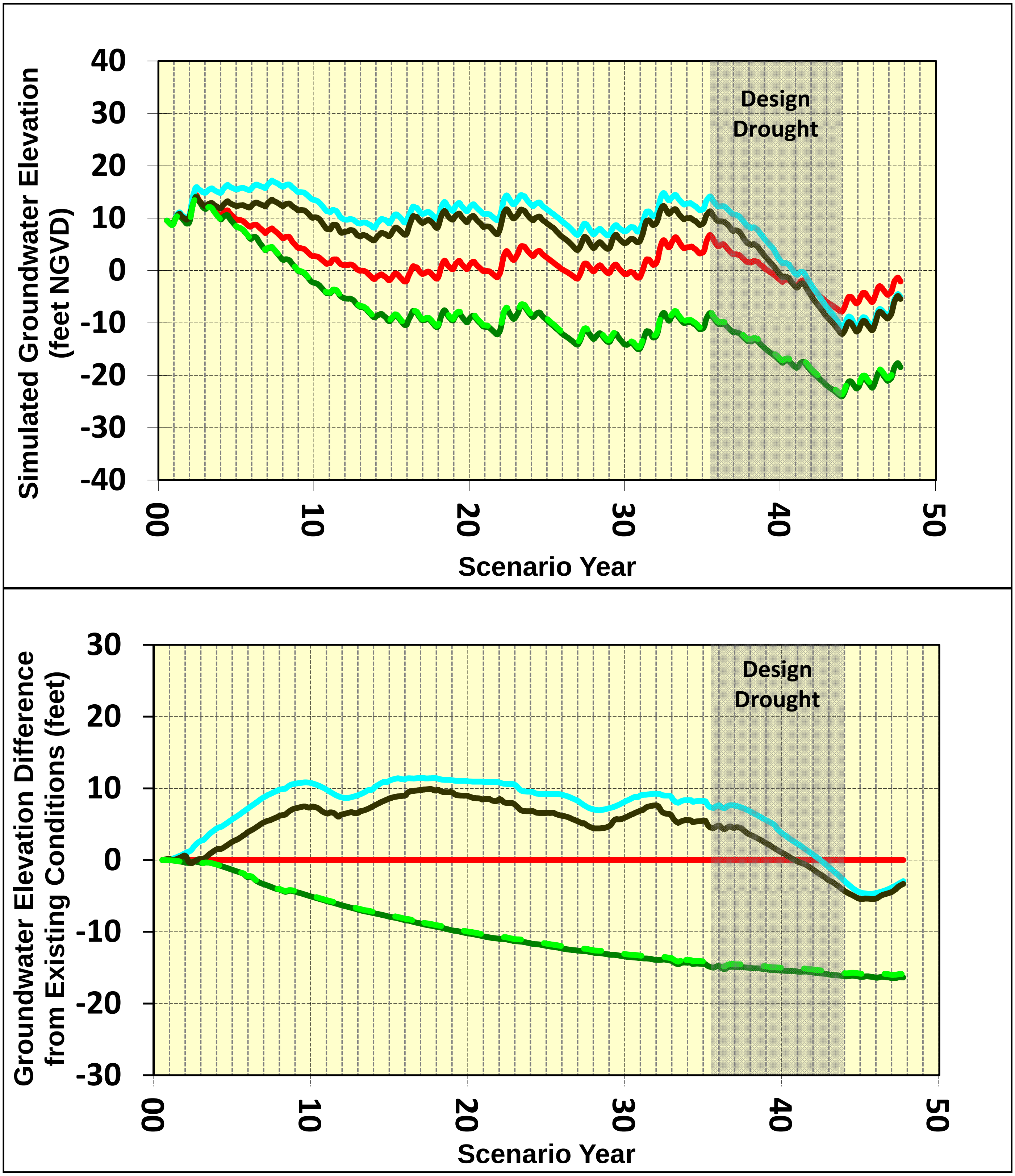
Scenario 1 **Scenario 2**
Scenario 3a **Scenario 3b** **Scenario 4**

Kennedy/Jenks Consultants

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

Model Layer 4 Hydrographs for Harding Park MW

K/J 0864001
April 2012
Figure 10.4-7b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
Scenario 1 — Scenario 2
Scenario 3a — Scenario 3b — Scenario 4

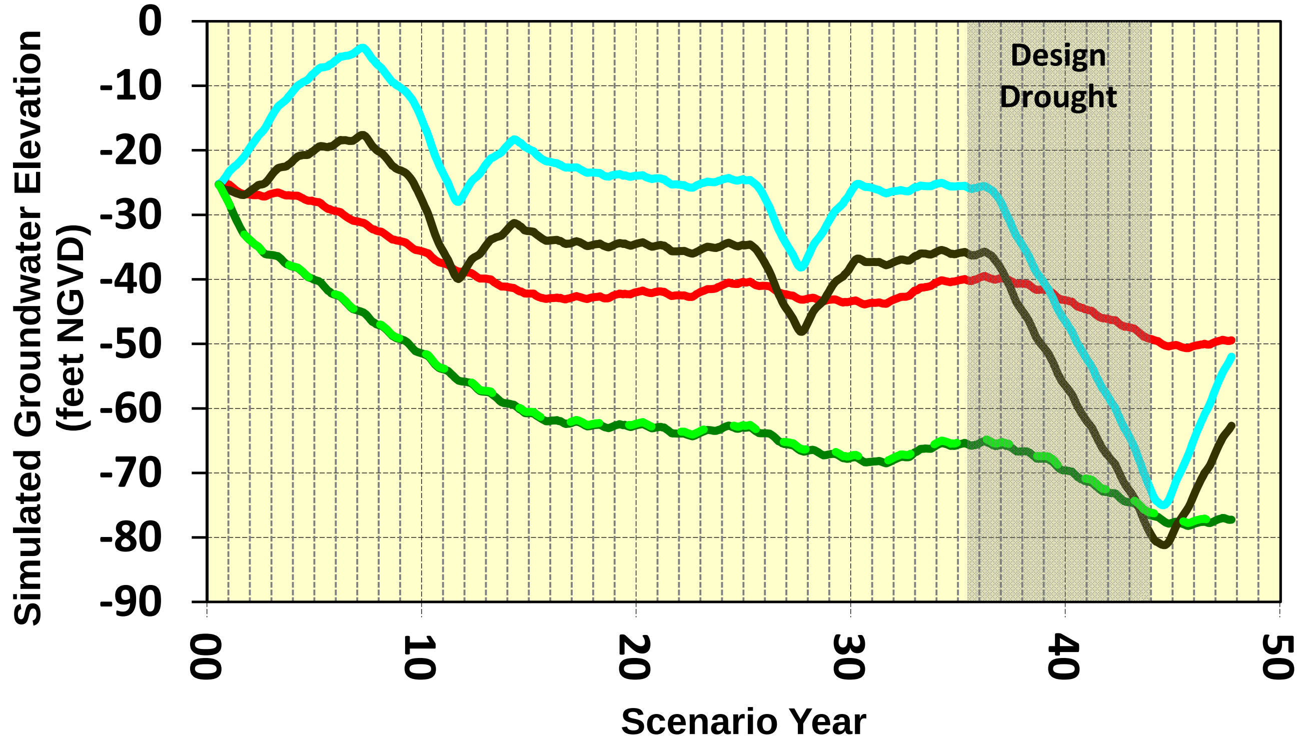
Kennedy/Jenks Consultants

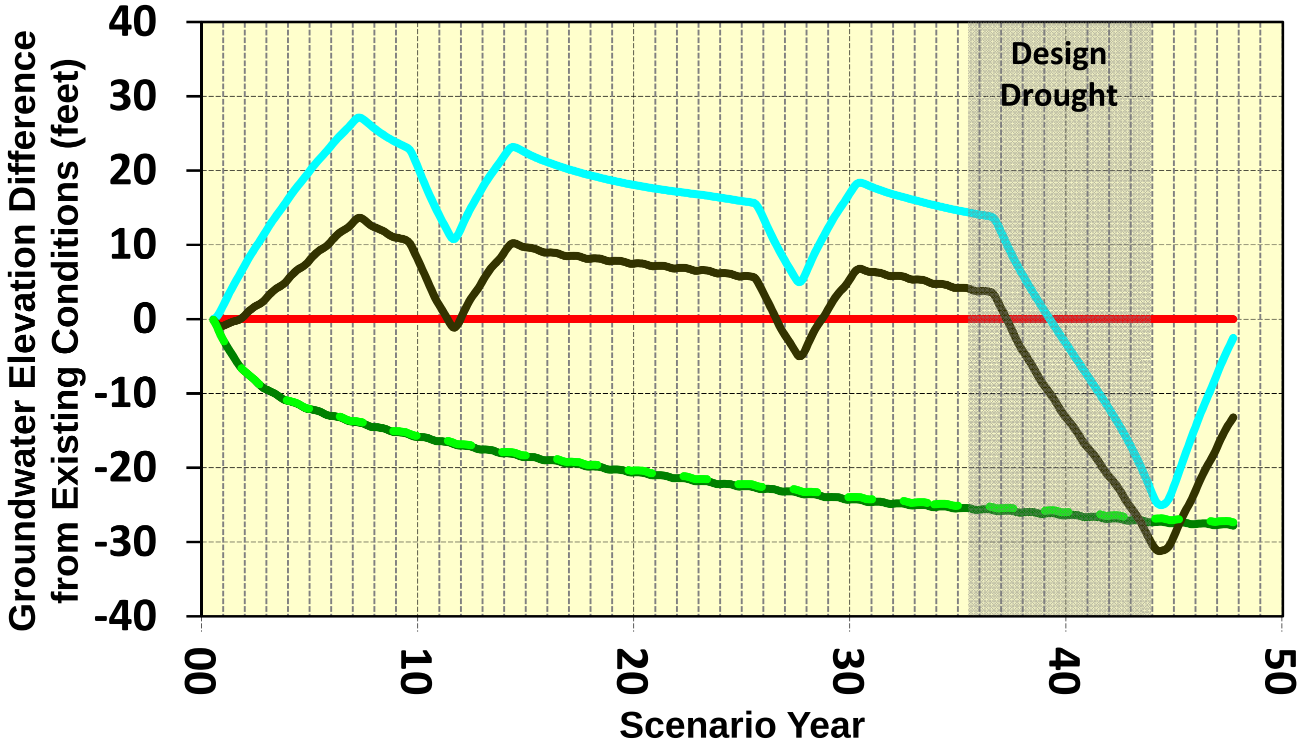
Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Model Layer 1 Hydrographs for Olympic MW

K/J 0864001
April 2012

Figure 10.4-8a





Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

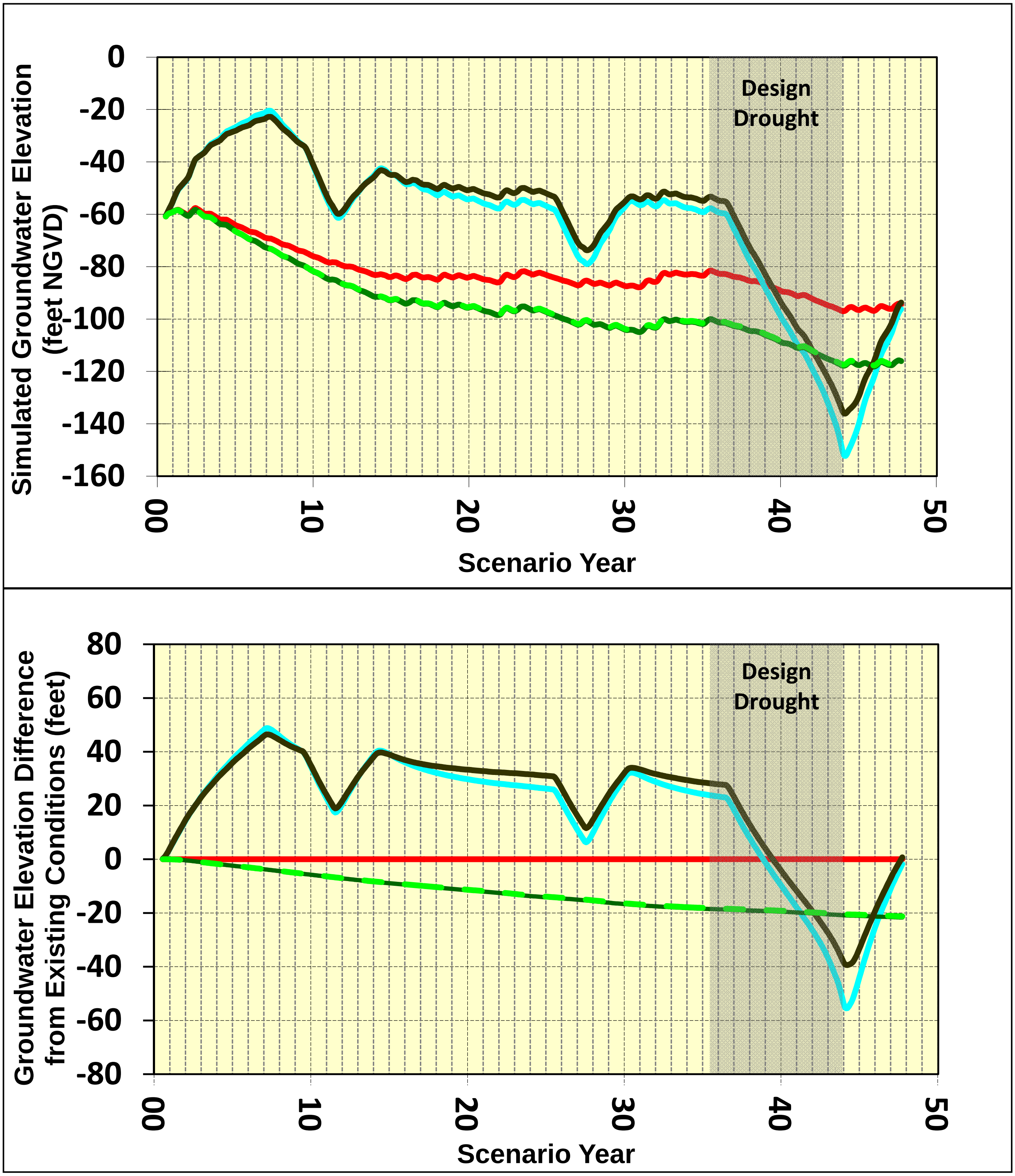
Kennedy/Jenks Consultants

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

Model Layer 4 Hydrographs for Olympic MW

K/J 0864001
April 2012

Figure 10.4-8b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

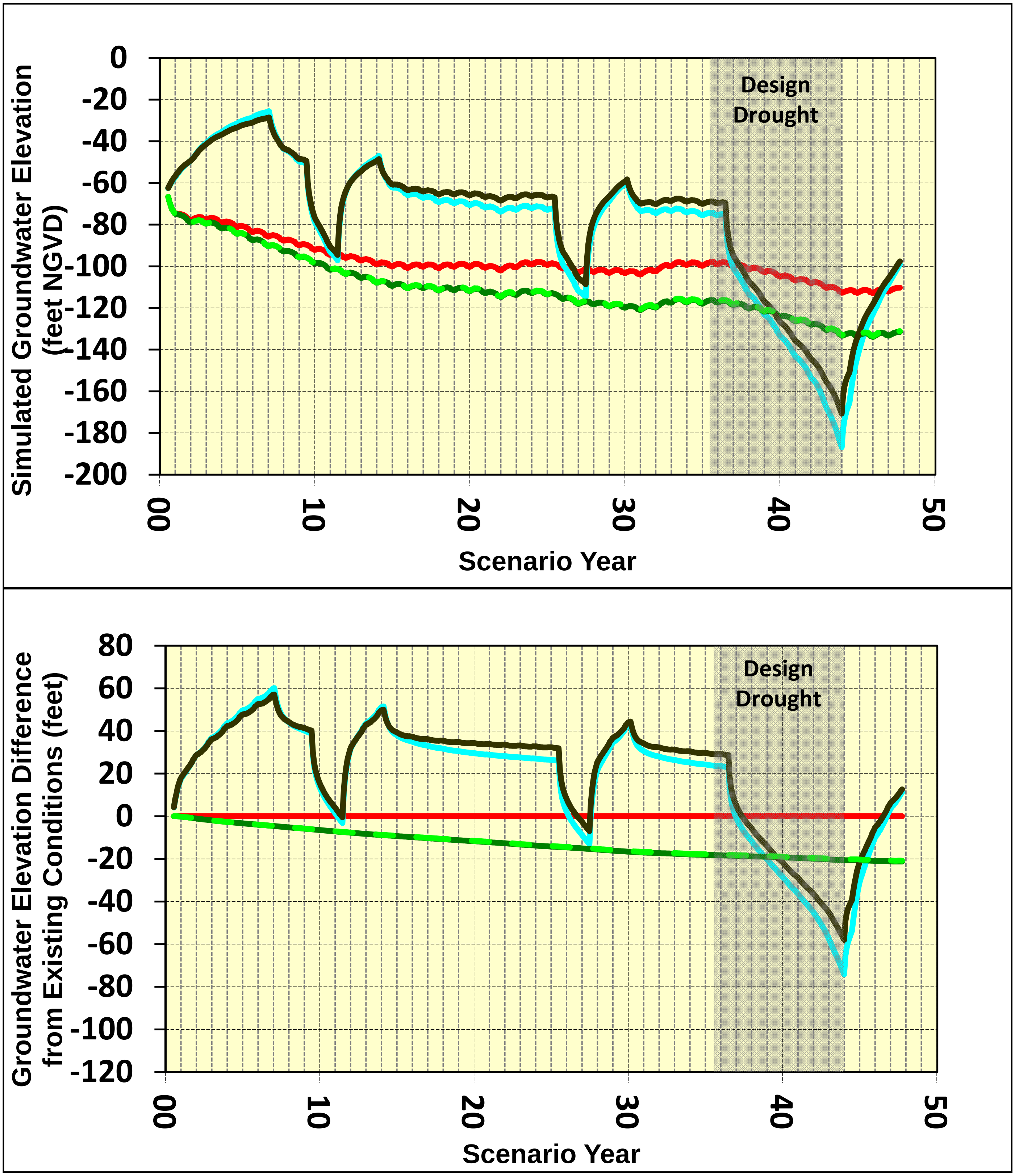
Kennedy/Jenks Consultants

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

Model Layer 1 Hydrographs for DC-3

K/J 0864001
April 2012

Figure 10.4-9a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

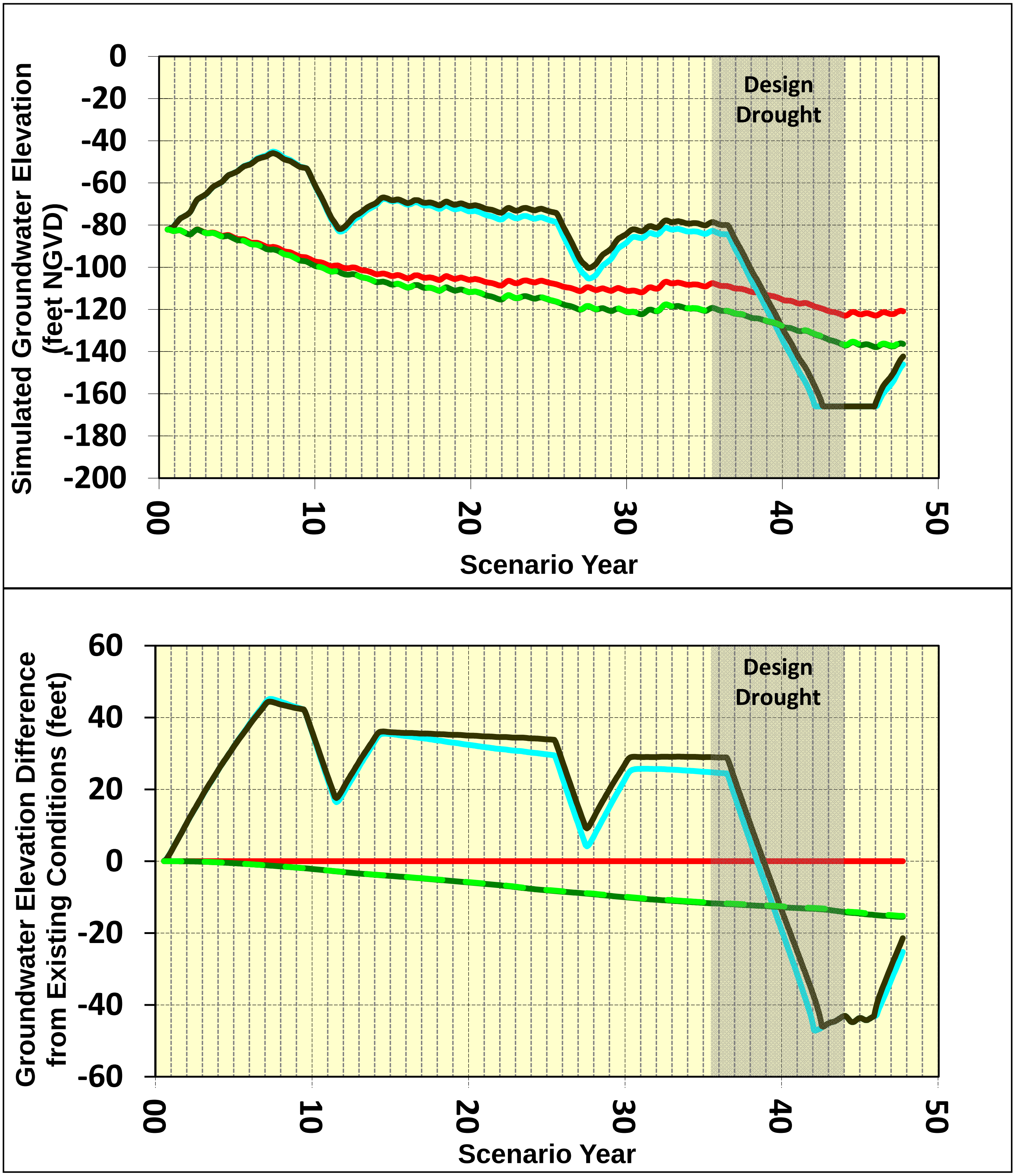
Kennedy/Jenks Consultants

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

Model Layer 4 Hydrographs for DC-3

K/J 0864001
April 2012

Figure 10.4-9b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

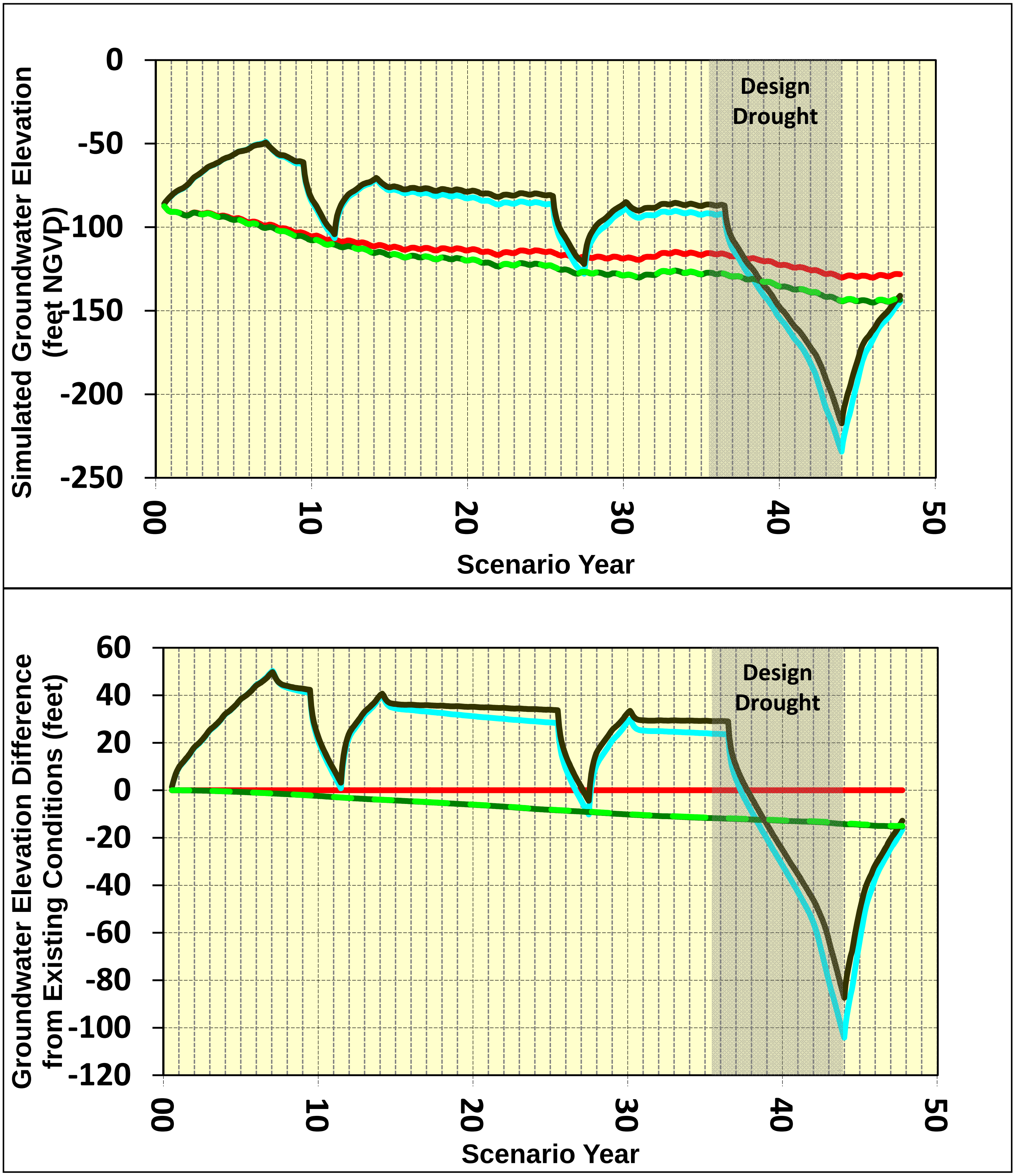
Kennedy/Jenks Consultants

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

Model Layer 1 Hydrographs for DC-A-St

K/J 0864001
April 2012

Figure 10.4-10a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

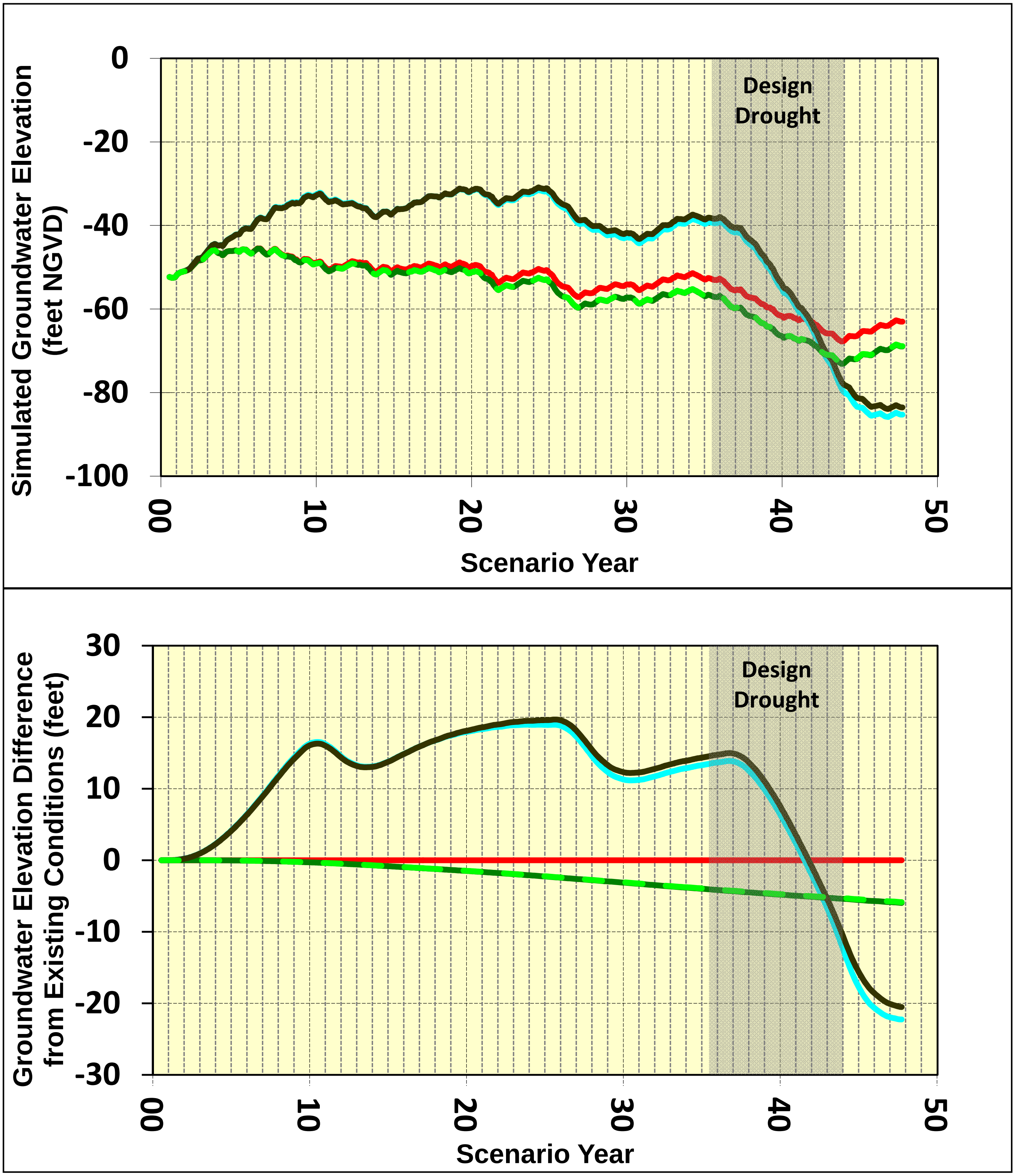
Kennedy/Jenks Consultants

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

Model Layer 4 Hydrographs for DC-A-St

K/J 0864001
April 2012

Figure 10.4-10b



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
Scenario 1
Scenario 2
Scenario 3a
Scenario 3b
Scenario 4

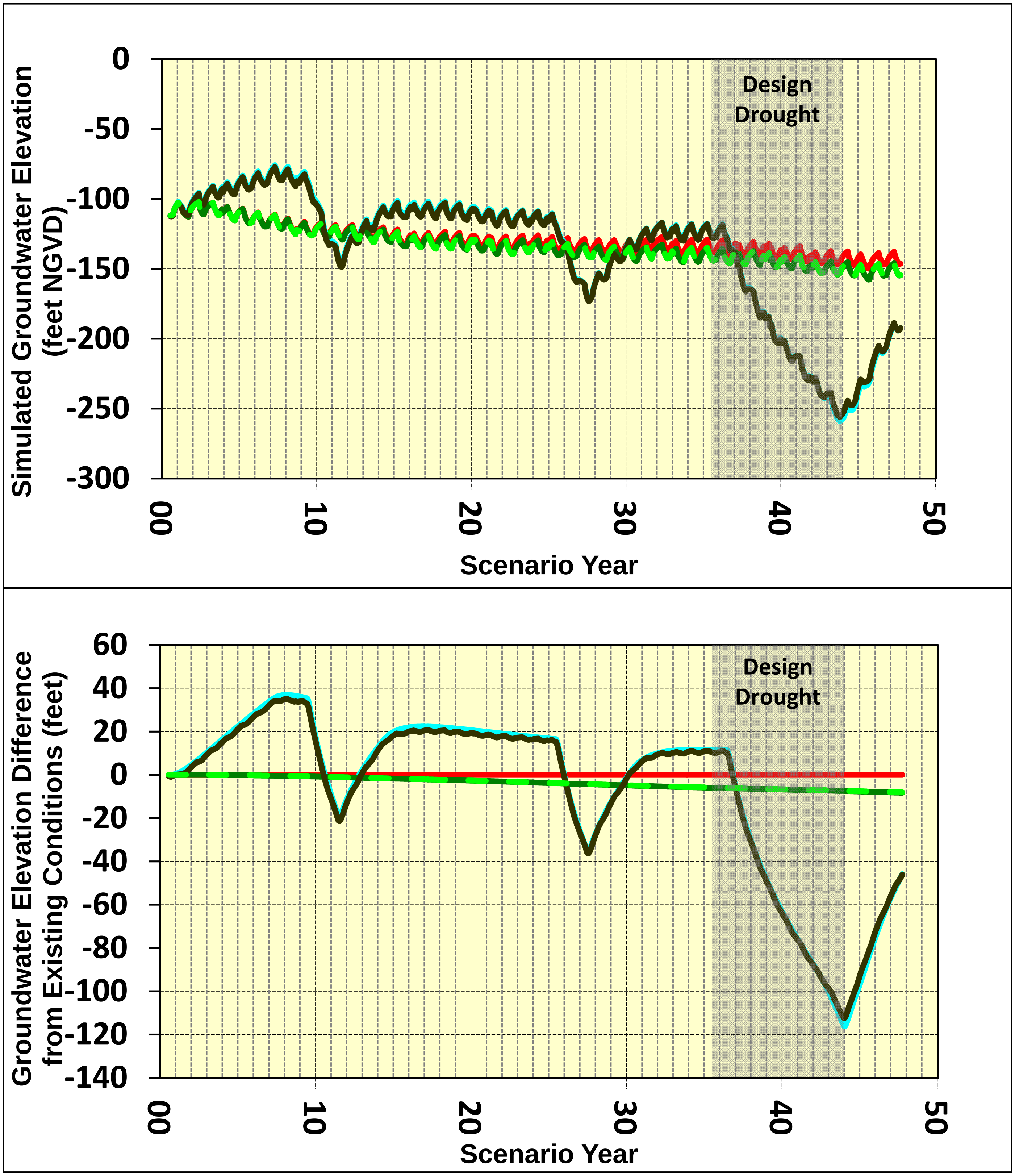
Kennedy/Jenks Consultants

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

Model Layer 1 Hydrographs for Cypress Lawn 2

K/J 0864001
April 2012

Figure 10.4-11a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

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

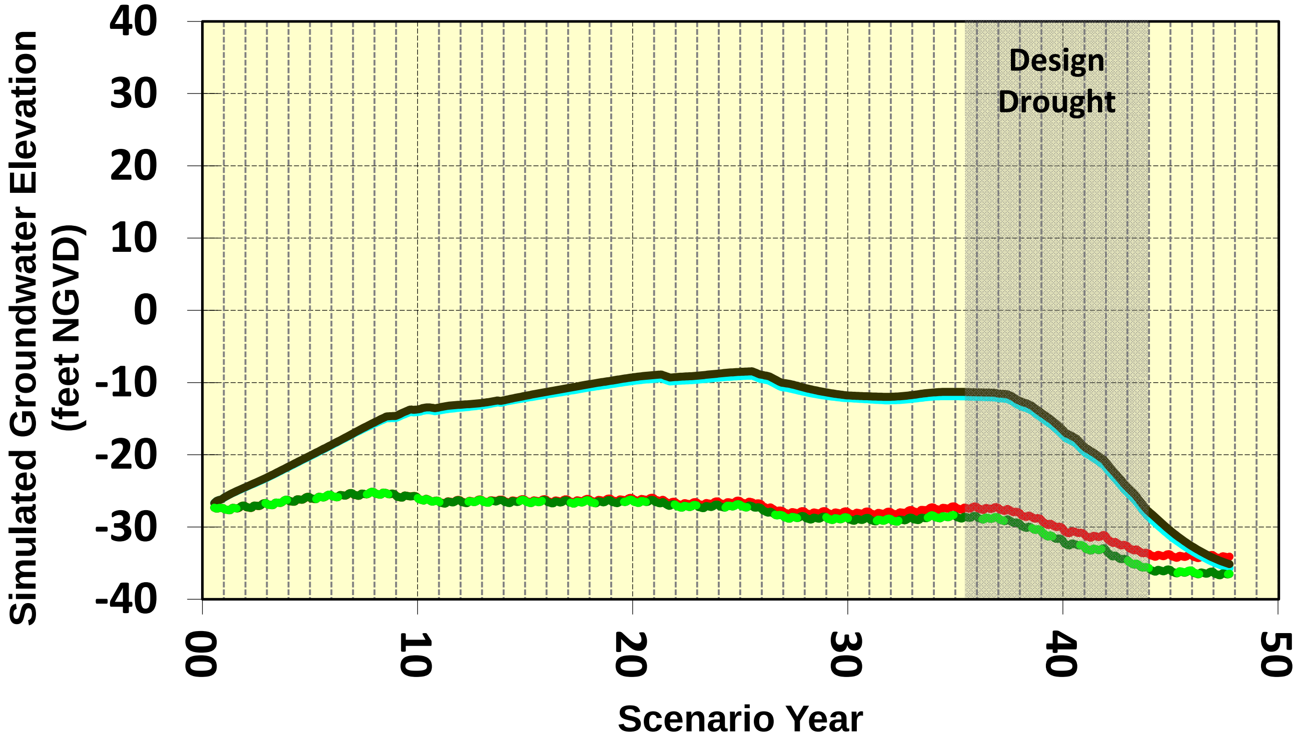
Kennedy/Jenks Consultants

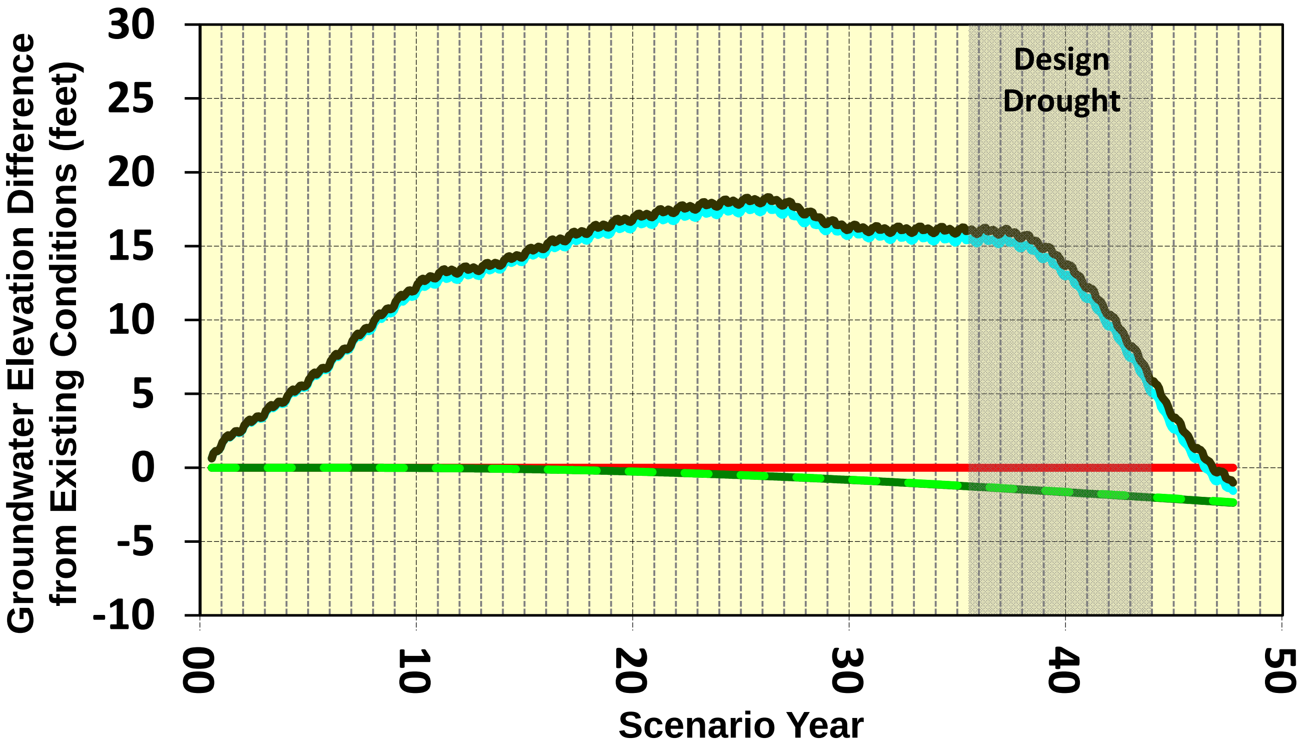
Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Model Layer 4 Hydrographs for Cypress Lawn 2

K/J 0864001
April 2012

Figure 10.4-11b





Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:

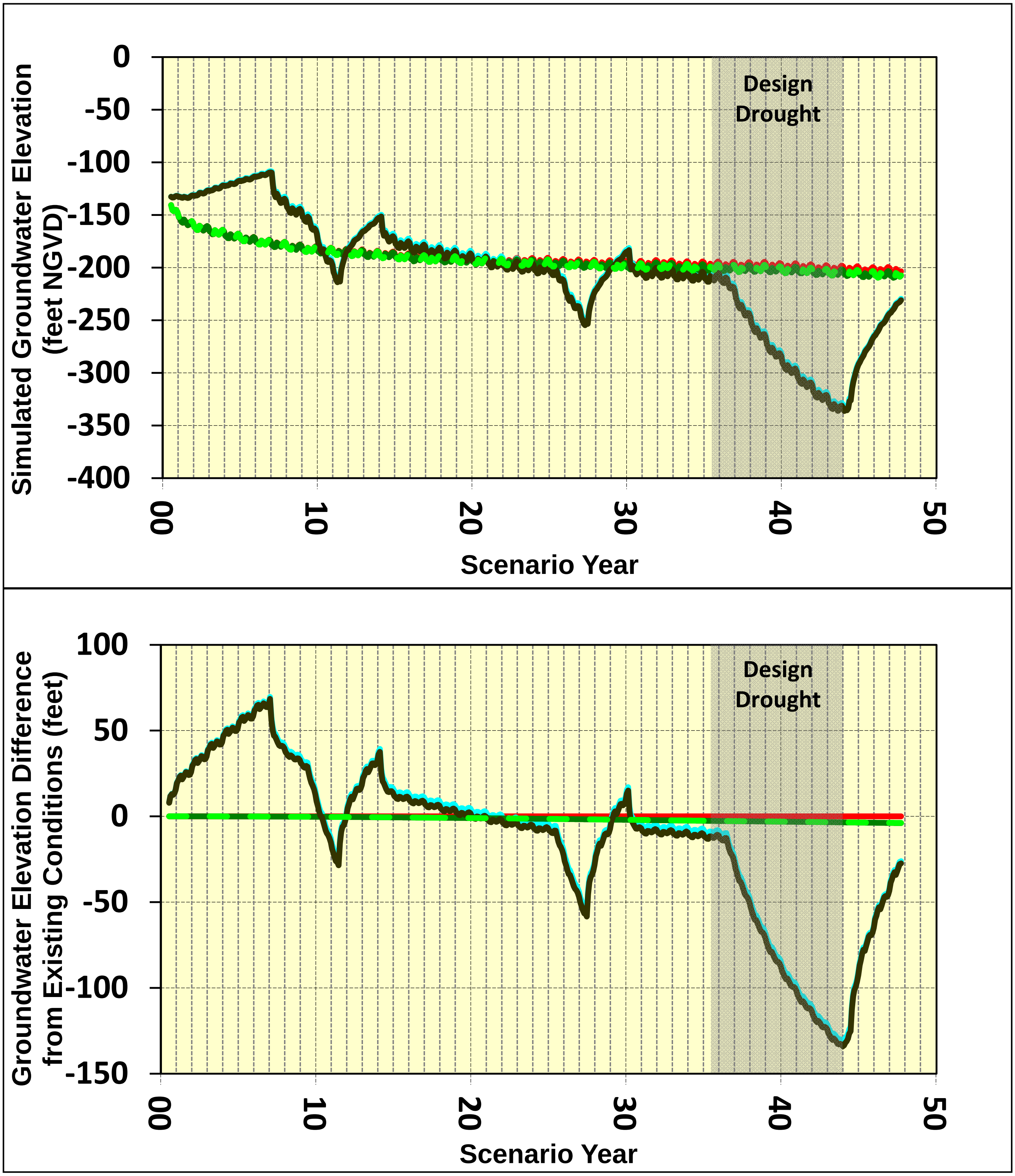
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Kennedy/Jenks Consultants

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

Model Layer 1 Hydrographs for SSF-02

K/J 0864001
April 2012
Figure 10.4-12a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

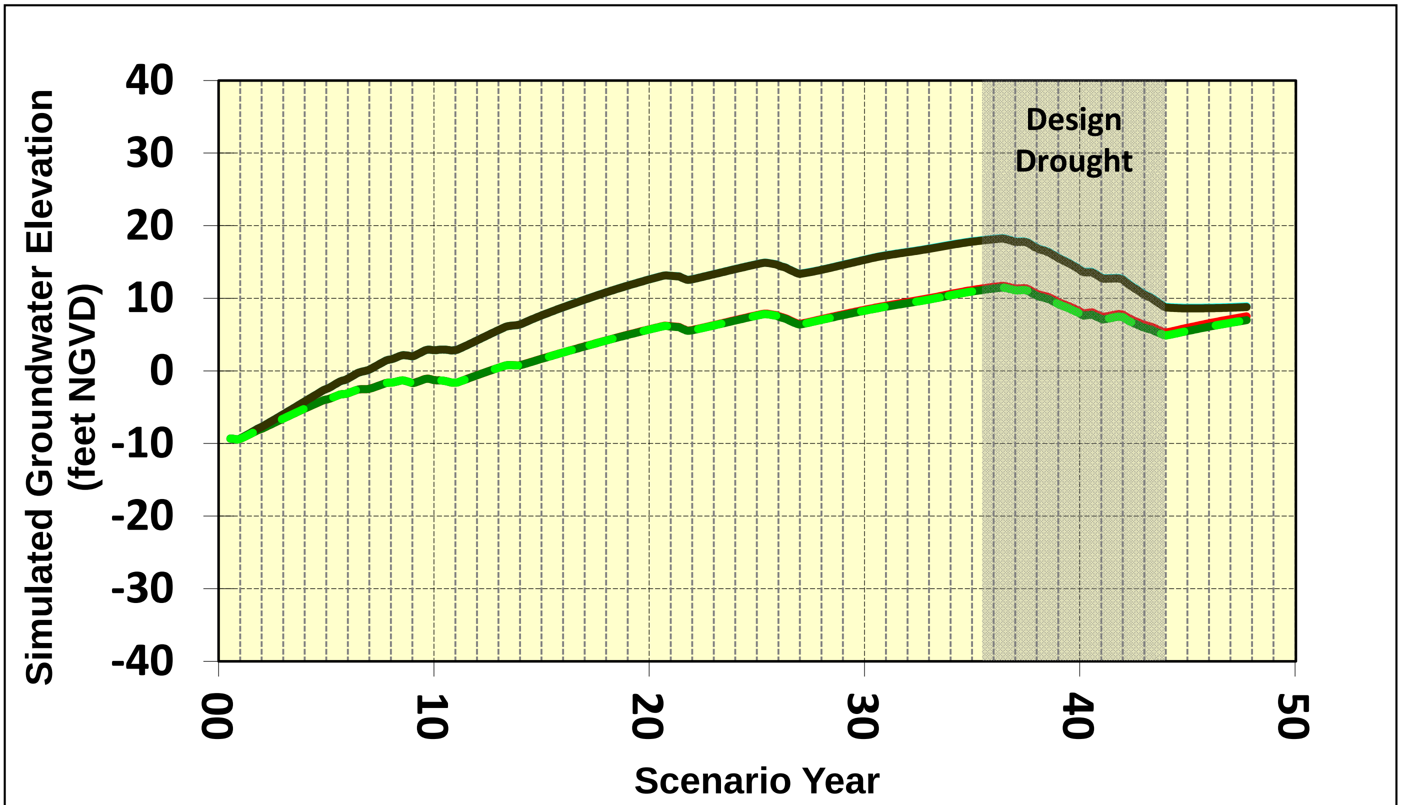
Kennedy/Jenks Consultants

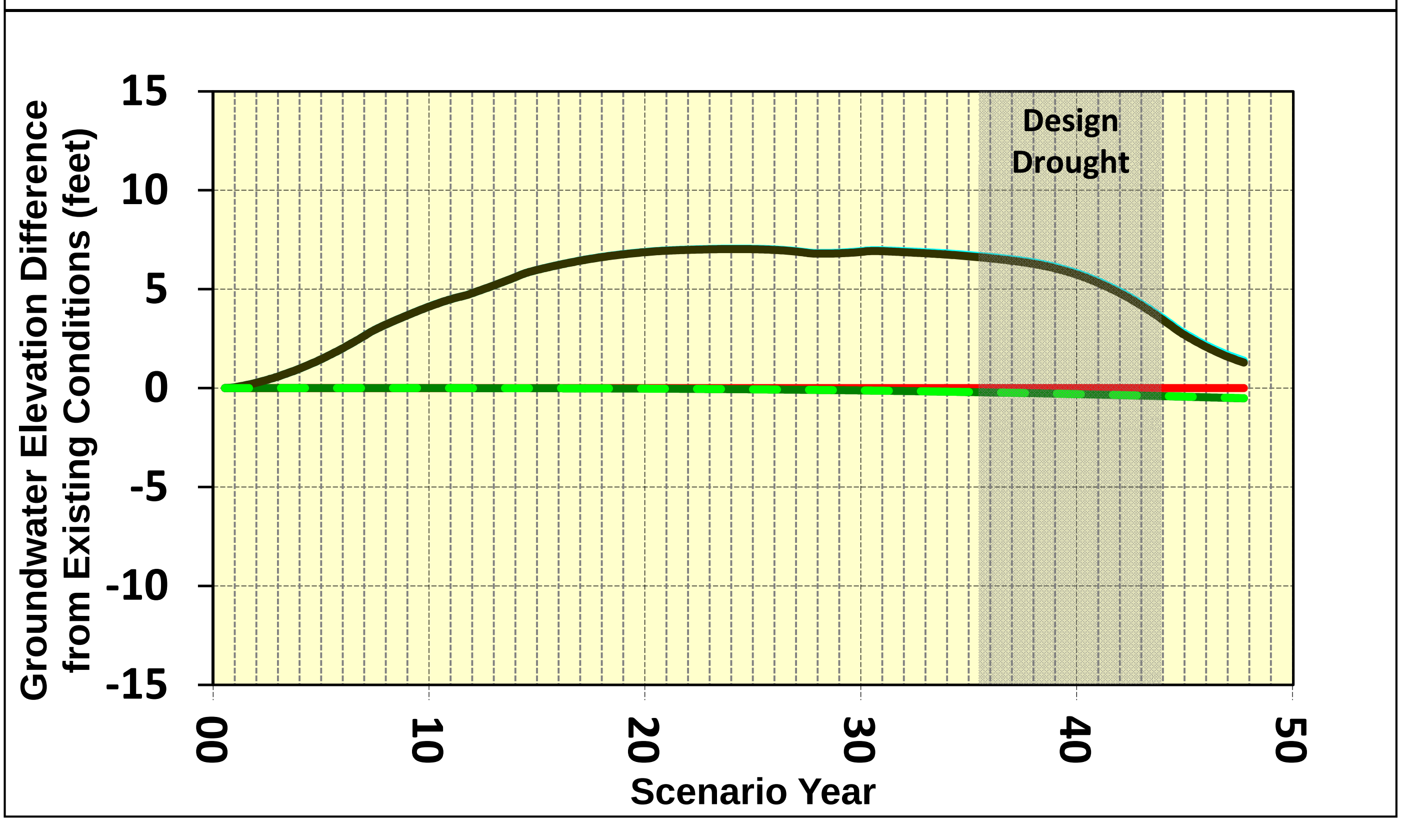
Regional Groundwater Storage and Recovery Project
and San Francisco Groundwater Supply Project
San Francisco Public Utilities Commission

Model Layer 4 Hydrographs for SSF-02

K/J 0864001
April 2012

Figure 10.4-12b





Note: Mean sea level is equivalent to zero feet NGVD.

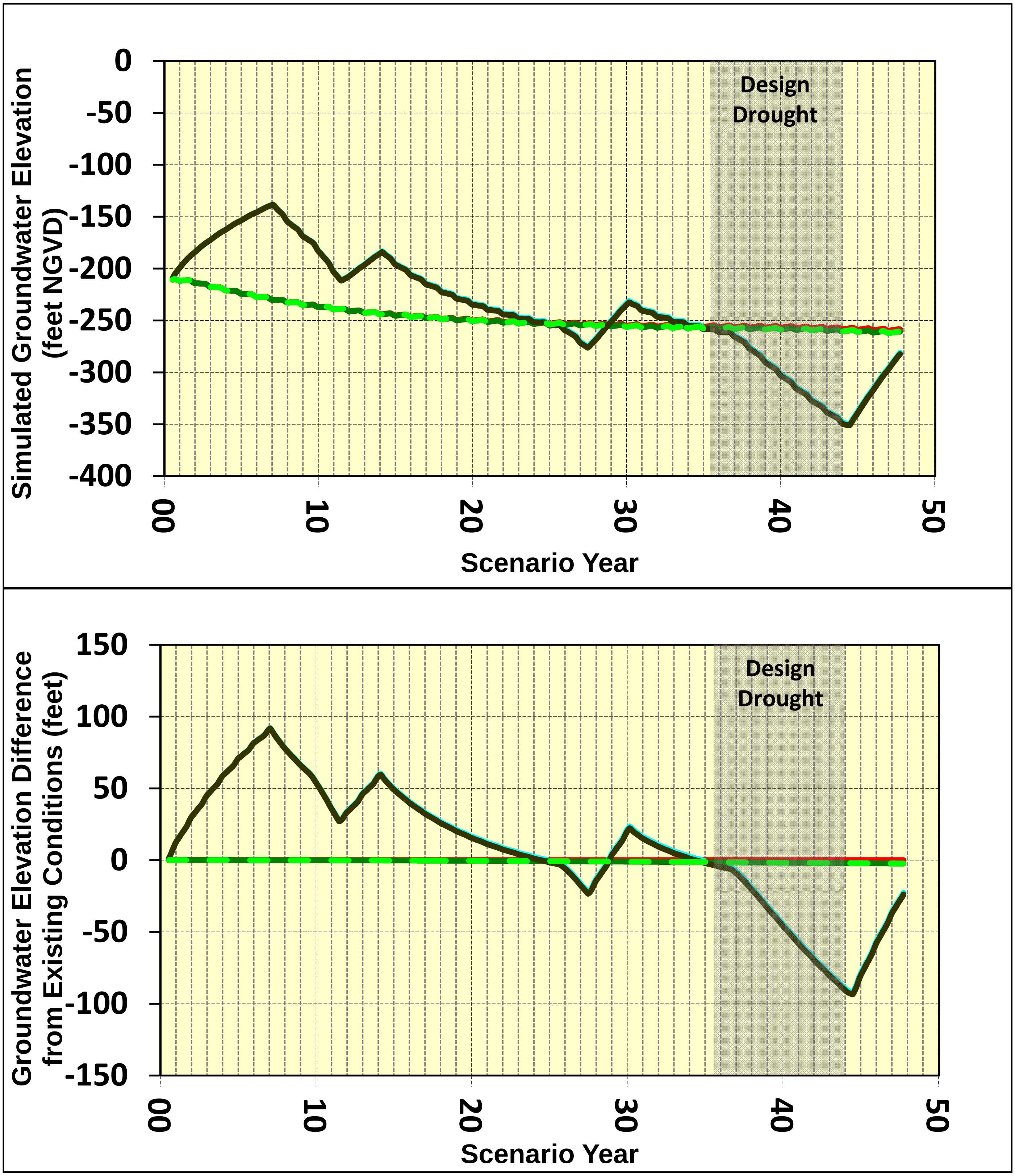
Model Heads:
- Scenario 1
- Scenario 2
- Scenario 3a
- Scenario 3b
- Scenario 4

Kennedy/Jenks Consultants

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

Model Layer 1 Hydrographs for SB-12

K/J 0864001
April 2012
Figure 10.4-13a



Note: Mean sea level is equivalent to zero feet NGVD.

Model Heads:
Scenario 1 | Scenario 2
Scenario 3a | Scenario 3b | Scenario 4

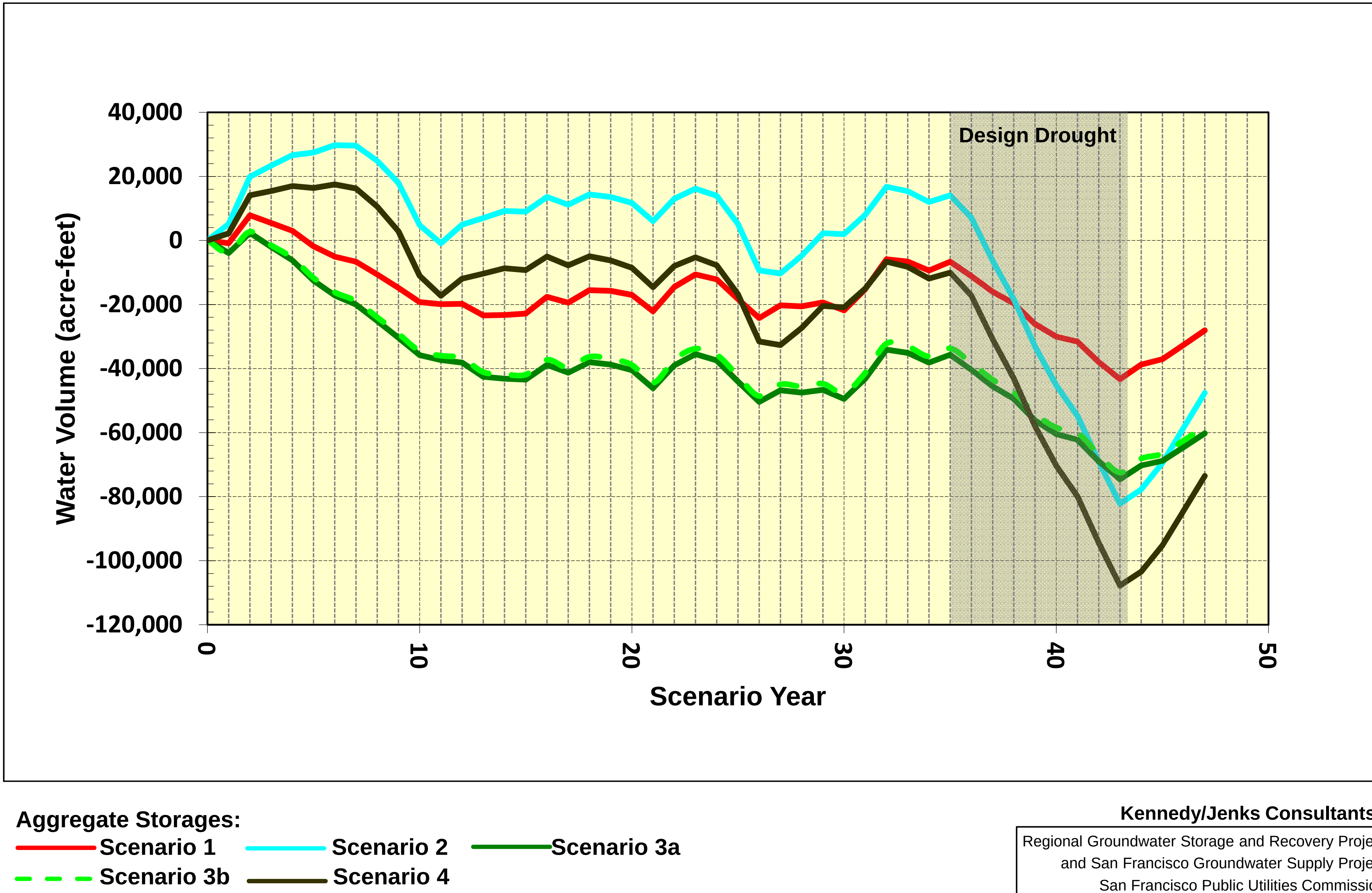
Kennedy/Jenks Consultants

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

Model Layer 4 Hydrographs for SB-12

K/J 0864001
April 2012

Figure 10.4-13b



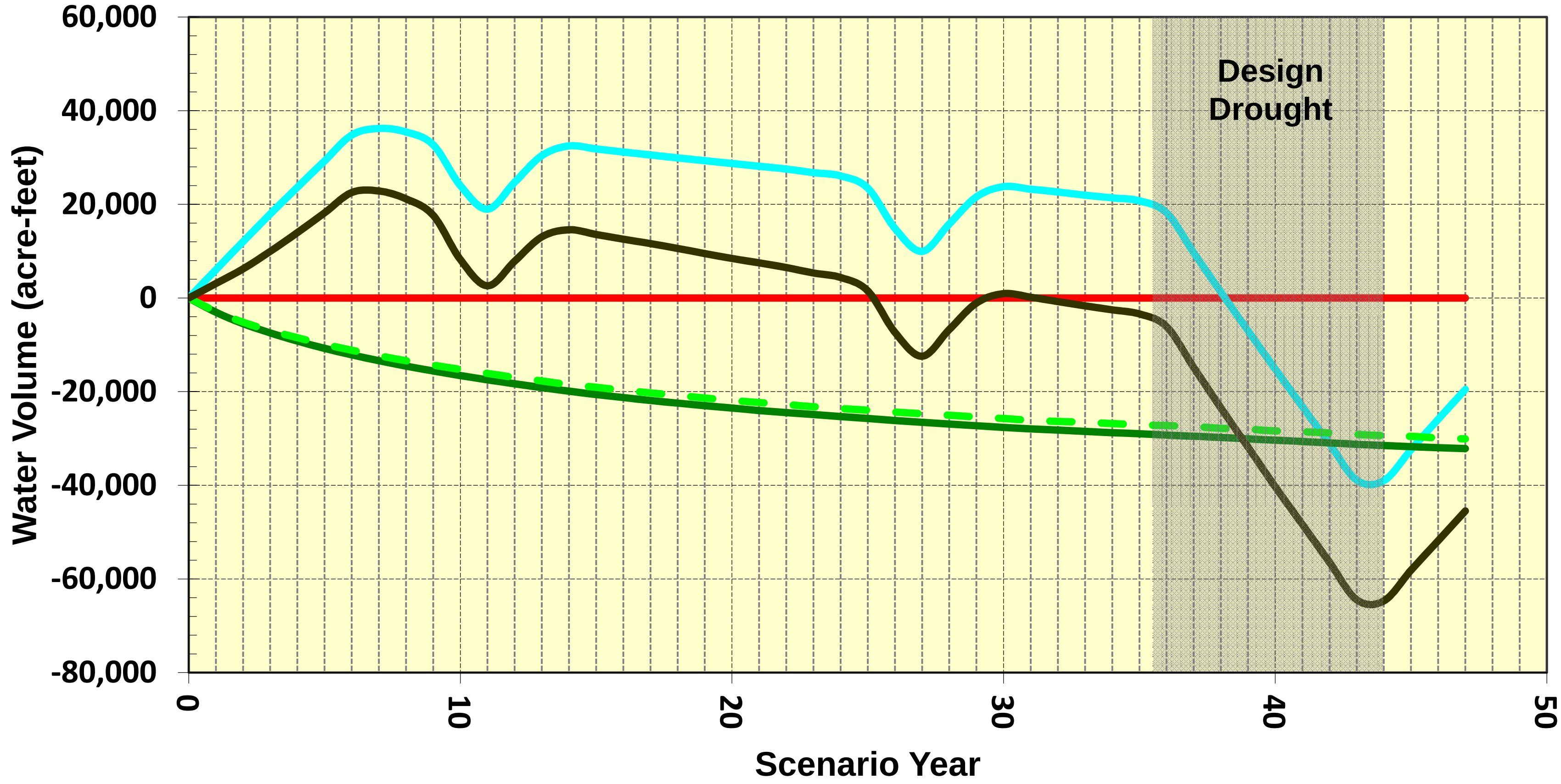
Kennedy/Jenks Consultants

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

Model-Simulated Aggregate Change in Groundwater Storage

K/J 0864001
April 2012

Figure 10.4-14



Aggregate Storages:

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

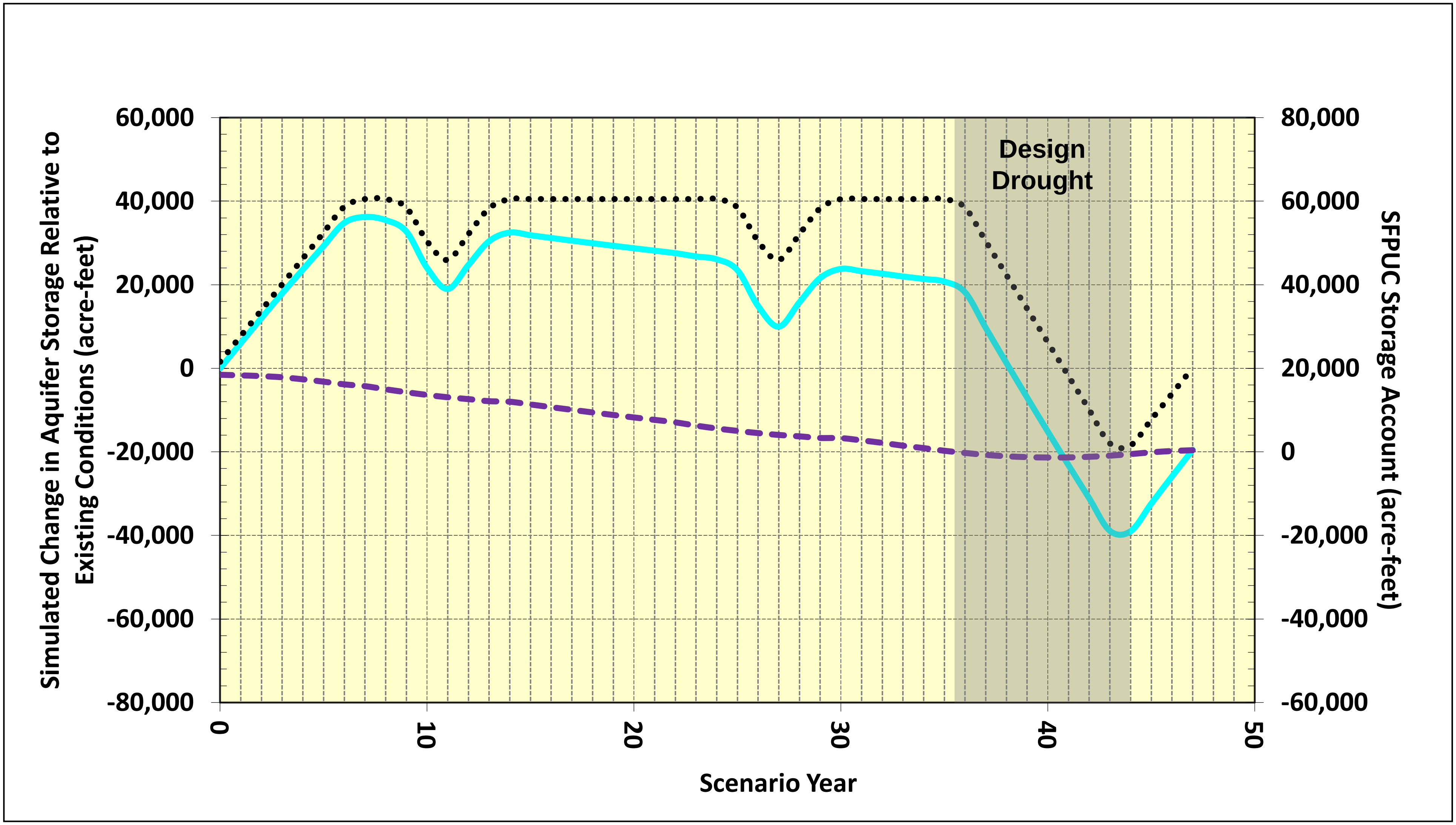
Kennedy/Jenks Consultants

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

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

K/J 0864001
April 2012

Figure 10.4-15



Note: SFPUC Storage Account axis is offset by 20,000 acre-feet relative to the Aquifer Storage axis to account for the 20,000 acre-feet in the SFPUC Storage Account at the start of the Scenario 2 simulation.

Legend:

- **Water in SFPUC Storage Account (right-hand axis)**
- **Scenario 2 Simulated Aquifer Storage Relative to Scenario 1 (Existing Conditions)**
- **Difference between SFPUC Storage Account and Scenario 2 Aquifer Storage**

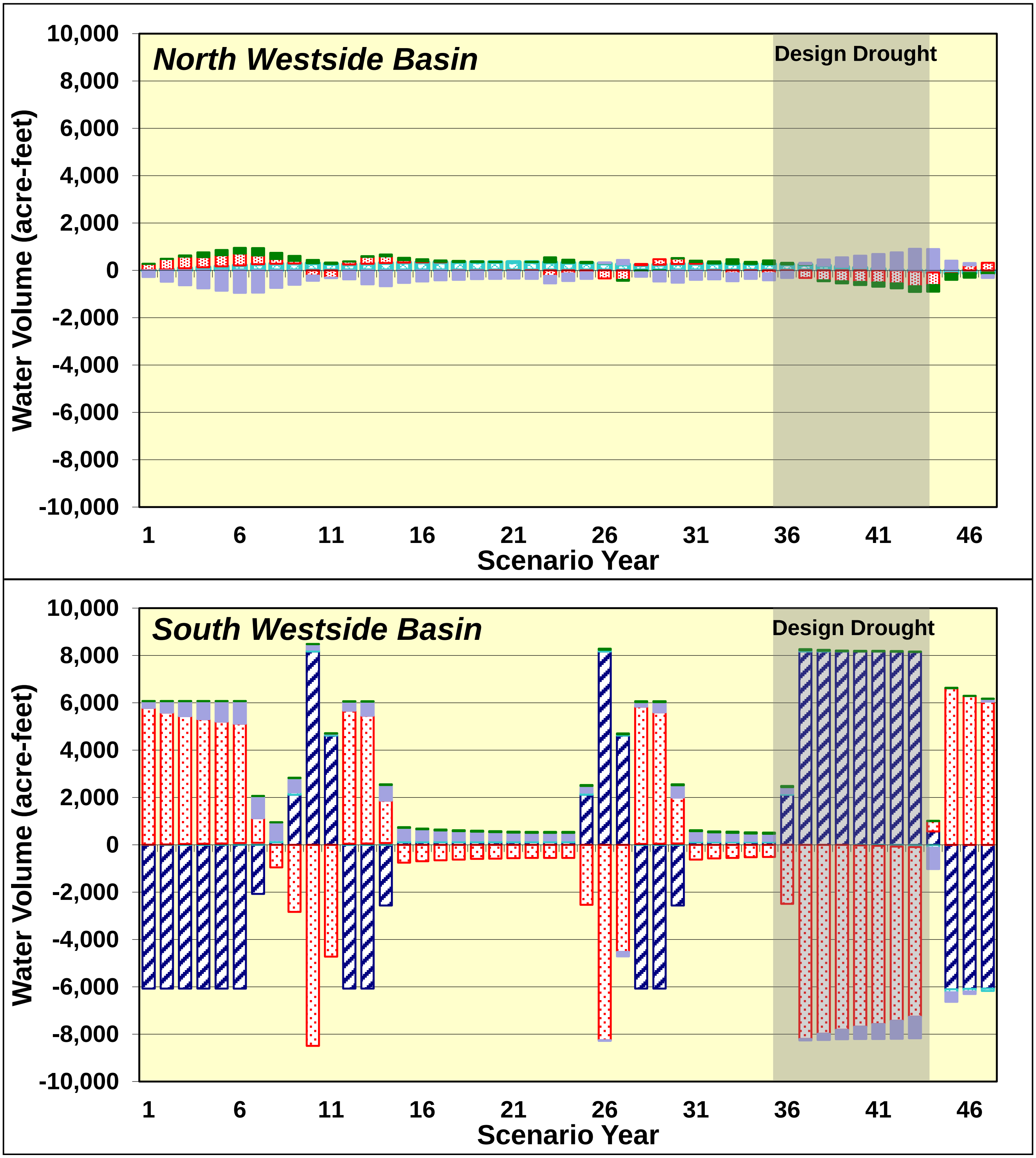
Kennedy/Jenks Consultants

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

Comparison of SFPUC Storage Account to Groundwater Storage Relative to Existing Conditions

K/J 0864001
April 2012

Figure 10.4-16



Note: For pumping, a positive value is an increase in pumping and a negative value is a decrease in pumping relative to Scenario 1.
For groundwater flow, a positive value is outflow from the basin, and a negative value is inflow into the basin.

Components of Analysis of Water Sources to Accommodate Pumping :

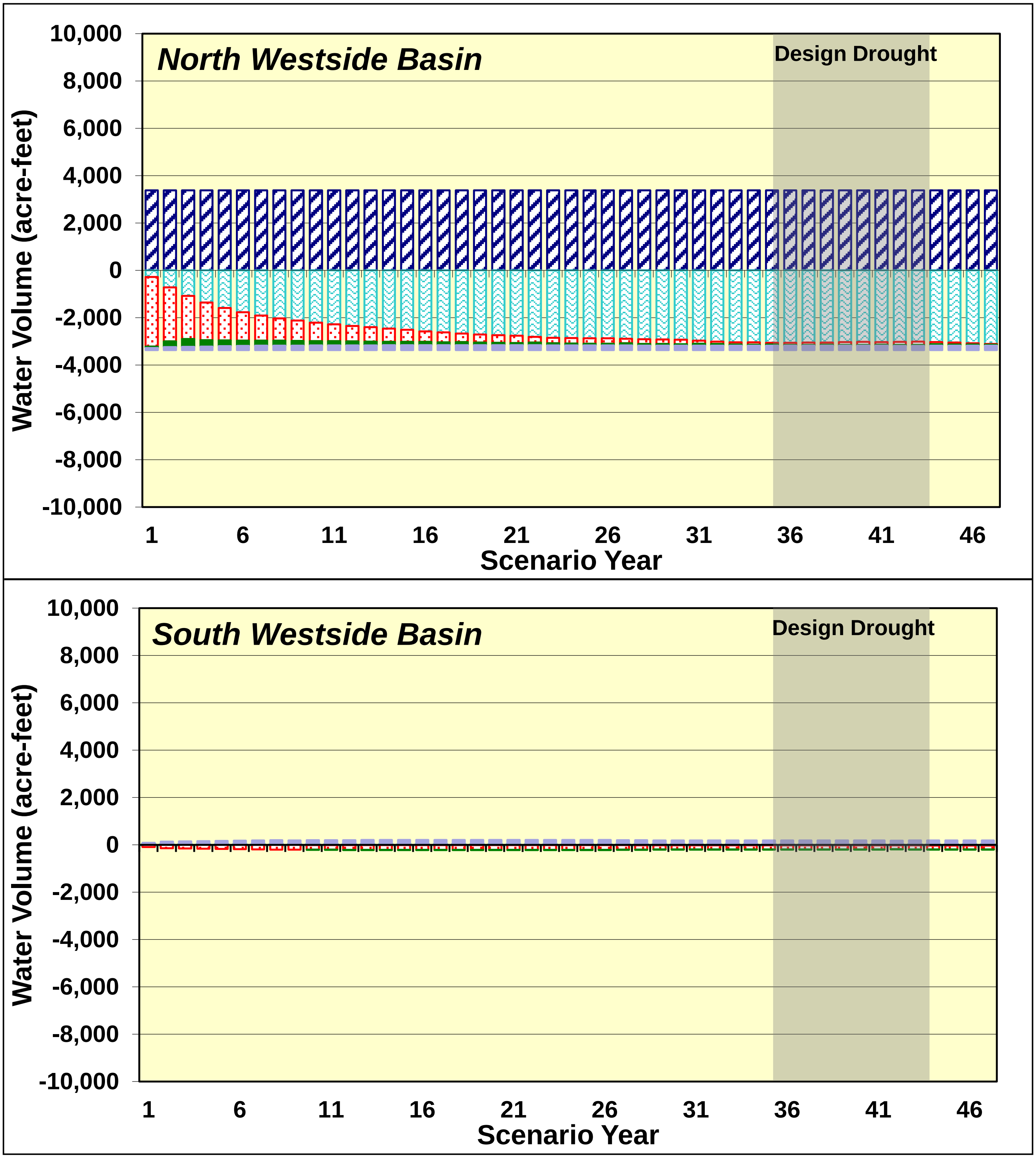
- Pumping – change in pumping relative to Scenario 1
- Ocean – change in outflow to the ocean relative to Scenario 1
- Surface Water – change in outflow to surface water relative to Scenario 1
- Aquifer Storage – change in aquifer storage relative to Scenario 1
- Groundwater flow – relative groundwater flow from adjoining basin

Kennedy/Jenks Consultants

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

Scenario 2 – Analysis of Water Sources to Accommodate Changes in Pumping Relative to Scenario 1

K/J 0864001
April 2012
Figure 10.4-17



Note: For pumping, a positive value is an increase in pumping and a negative value is a decrease in pumping relative to Scenario 1. For groundwater flow, a positive value is outflow from the basin, and a negative value is inflow into the basin.

Components of Analysis of Water Sources to Accommodate Pumping :

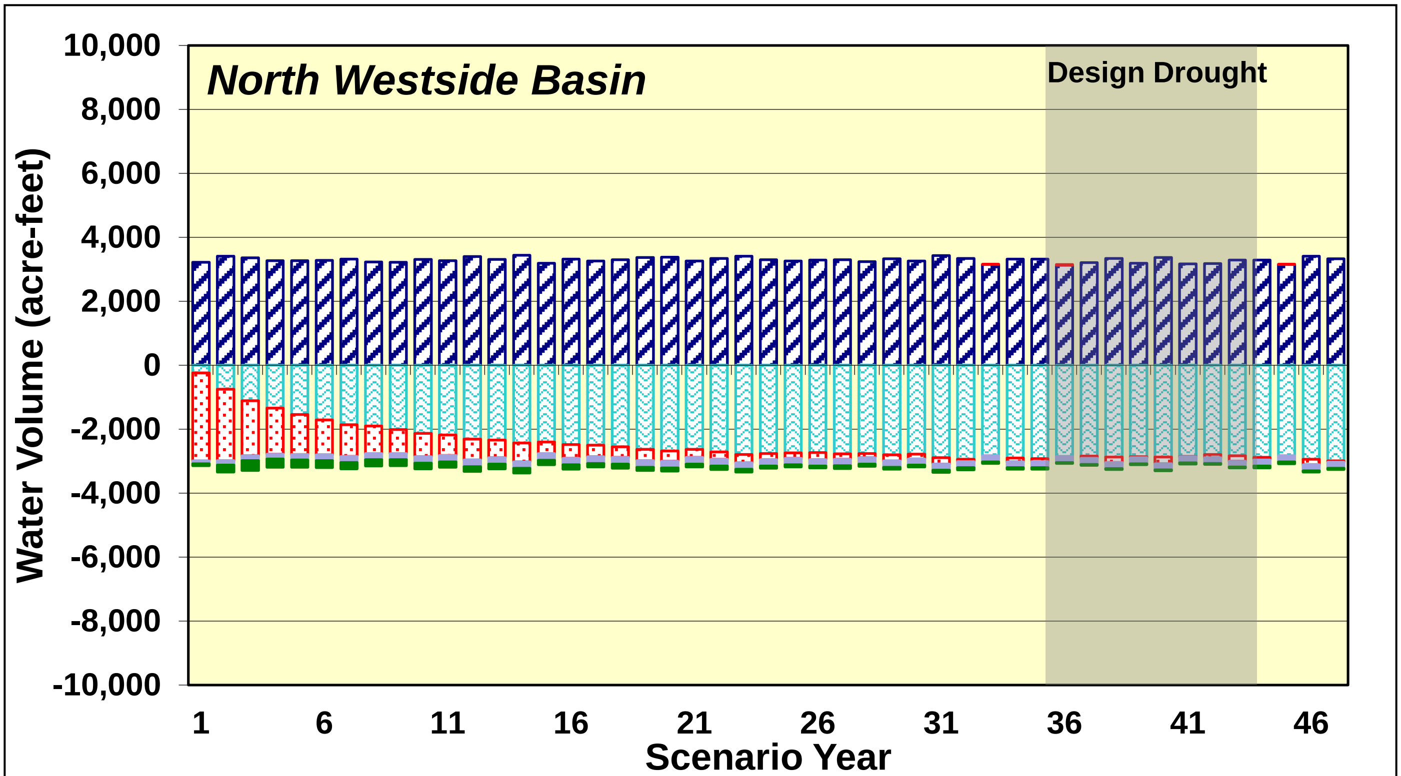
- **Pumping – change in pumping relative to Scenario 1**
- **Ocean – change in outflow to the ocean relative to Scenario 1**
- **Surface Water – change in outflow to surface water relative to Scenario 1**
- **Aquifer Storage – change in aquifer storage relative to Scenario 1**
- **Groundwater flow – relative groundwater flow from adjoining basin**

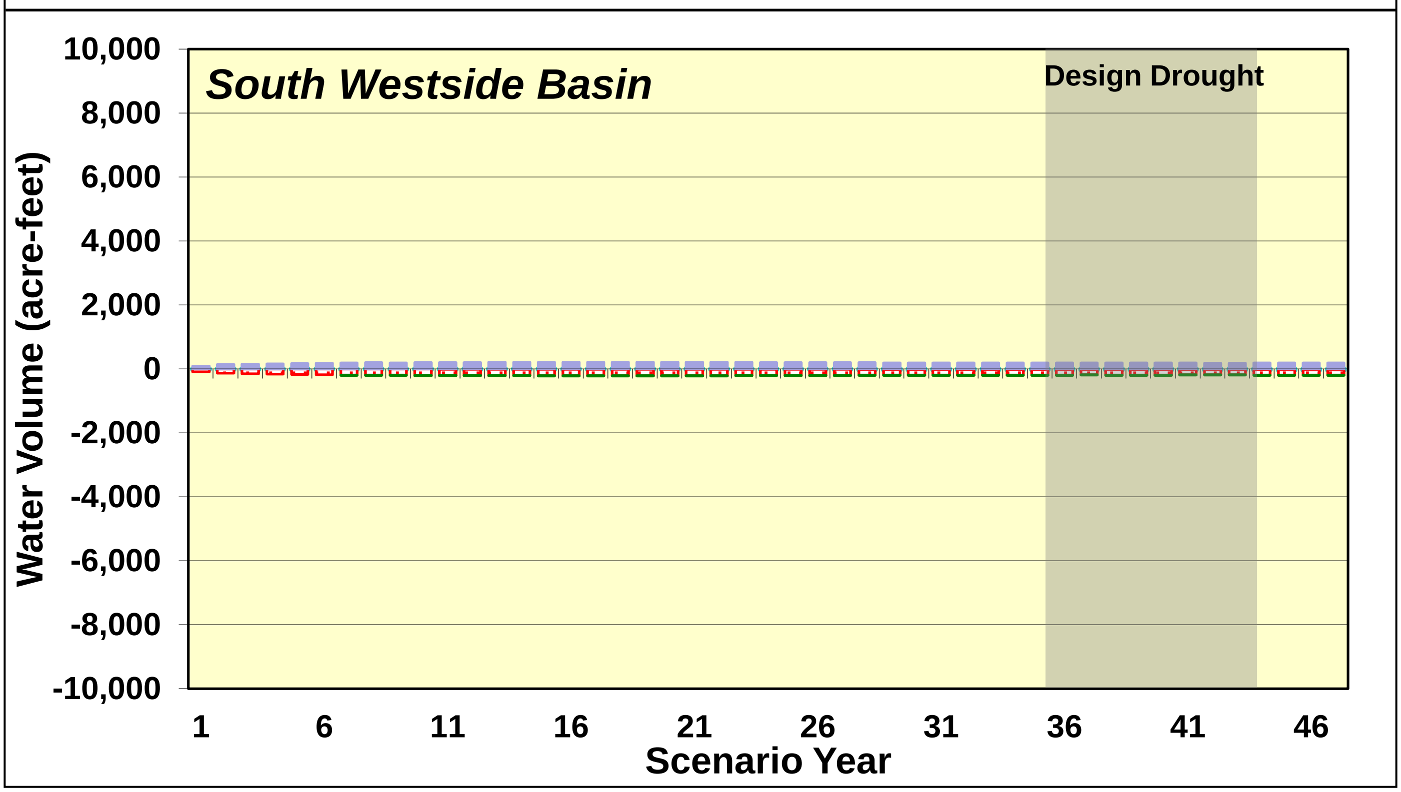
Kennedy/Jenks Consultants

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

Scenario 3a – Analysis of Water Sources to Accommodate Changes in Pumping Relative to Scenario 1

K/J 0864001
April 2012
Figure 10.4-18





Note: For pumping, a positive value is an increase in pumping and a negative value is a decrease in pumping relative to Scenario 1. For groundwater flow, a positive value is outflow from the basin, and a negative value is inflow into the basin.

Components of Analysis of Water Sources to Accommodate Pumping :

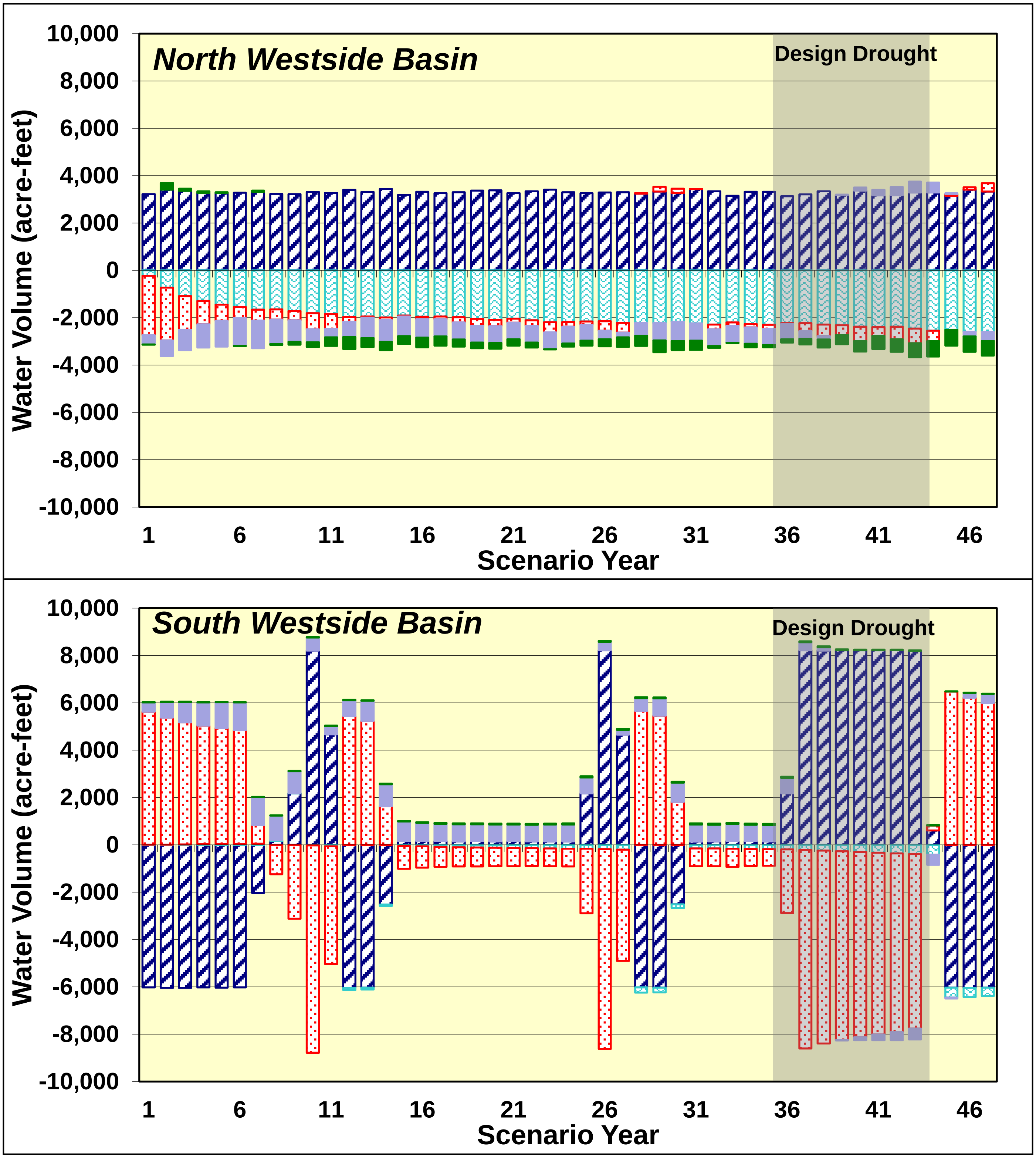
- Pumping – change in pumping relative to Scenario 1
- Ocean – change in outflow to the ocean relative to Scenario 1
- Surface Water – change in outflow to surface water relative to Scenario 1
- Aquifer Storage – change in aquifer storage relative to Scenario 1
- Groundwater flow – relative groundwater flow from adjoining basin

Kennedy/Jenks Consultants

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

Scenario 3b – Analysis of Water Sources to Accommodate Changes in Pumping Relative to Scenario 1

K/J 0864001
April 2012
Figure 10.4-19



Note: For pumping, a positive value is an increase in pumping and a negative value is a decrease in pumping relative to Scenario 1. For groundwater flow, a positive value is outflow from the basin, and a negative value is inflow into the basin.

Components of Analysis of Water Sources to Accommodate Pumping :

- **Pumping – change in pumping relative to Scenario 1**
- **Ocean – change in outflow to the ocean relative to Scenario 1**
- **Surface Water – change in outflow to surface water relative to Scenario 1**
- **Aquifer Storage – change in aquifer storage relative to Scenario 1**
- **Groundwater flow – relative groundwater flow from adjoining basin**

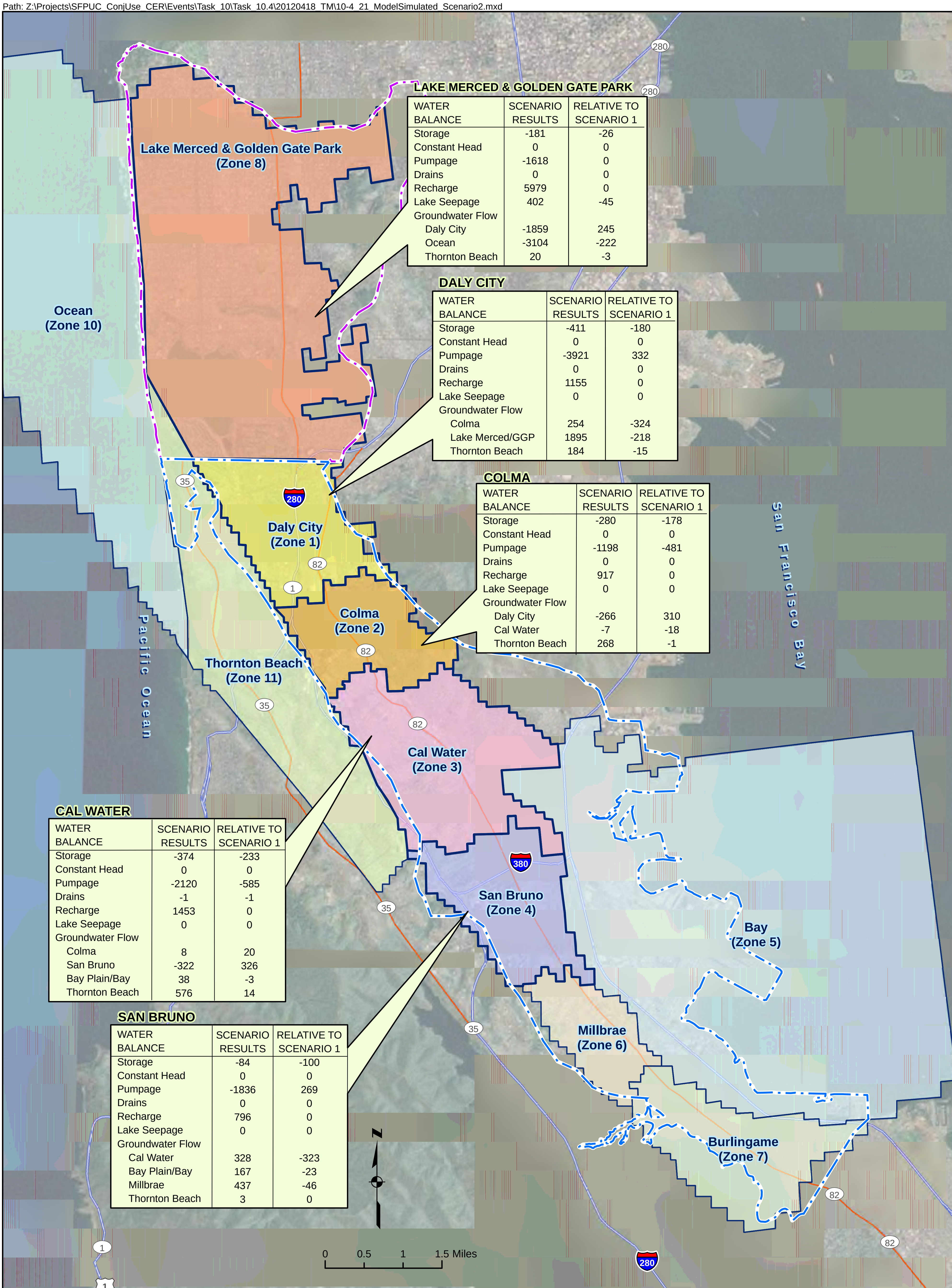
Kennedy/Jenks Consultants

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

Scenario 4 – Analysis of Water Sources to Accommodate Changes in Pumping Relative to Scenario 1

K/J 0864001
April 2012
Figure 10.4-20

Path: Z:\Projects\SFPUC_ConjUse_CER\Events\Task_10\Task_10.4\20120418_TM\10-4_21_ModelSimulated_Scenario2.mxd



LAKE MERCED & GOLDEN GATE PARK

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-181	-26
Constant Head	0	0
Pumpage	-1618	0
Drains	0	0
Recharge	5979	0
Lake Seepage	402	-45
Groundwater Flow		
Daly City	-1859	245
Ocean	-3104	-222
Thornton Beach	20	-3

DALY CITY

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-411	-180
Constant Head	0	0
Pumpage	-3921	332
Drains	0	0
Recharge	1155	0
Lake Seepage	0	0
Groundwater Flow		
Colma	254	-324
Lake Merced/GGP	1895	-218
Thornton Beach	184	-15

COLMA

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-280	-178
Constant Head	0	0
Pumpage	-1198	-481
Drains	0	0
Recharge	917	0
Lake Seepage	0	0
Groundwater Flow		
Daly City	-266	310
Cal Water	-7	-18
Thornton Beach	268	-1

CAL WATER

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-374	-233
Constant Head	0	0
Pumpage	-2120	-585
Drains	-1	-1
Recharge	1453	0
Lake Seepage	0	0
Groundwater Flow		
Colma	8	20
San Bruno	-322	326
Bay Plain/Bay	38	-3
Thornton Beach	576	14

SAN BRUNO

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-84	-100
Constant Head	0	0
Pumpage	-1836	269
Drains	0	0
Recharge	796	0
Lake Seepage	0	0
Groundwater Flow		
Cal Water	328	-323
Bay Plain/Bay	167	-23
Millbrae	437	-46
Thornton Beach	3	0

Legend

South Westside Groundwater Basin

North Westside Groundwater Basin

Model Sub-areas

- Lake Merced and Golden Gate Park
- Daly City
- Colma
- Cal Water
- San Bruno
- Millbrae
- Burlingame
- Ocean
- Thornton Beach
- Bay

Note:
Values are in units of acre-feet per year based on the annual average values over the simulated period.

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

MODEL SIMULATED AVERAGE ANNUAL WATER BALANCE FOR SPECIFIC WESTSIDE BASIN MODEL SUBAREAS SCENARIO 2

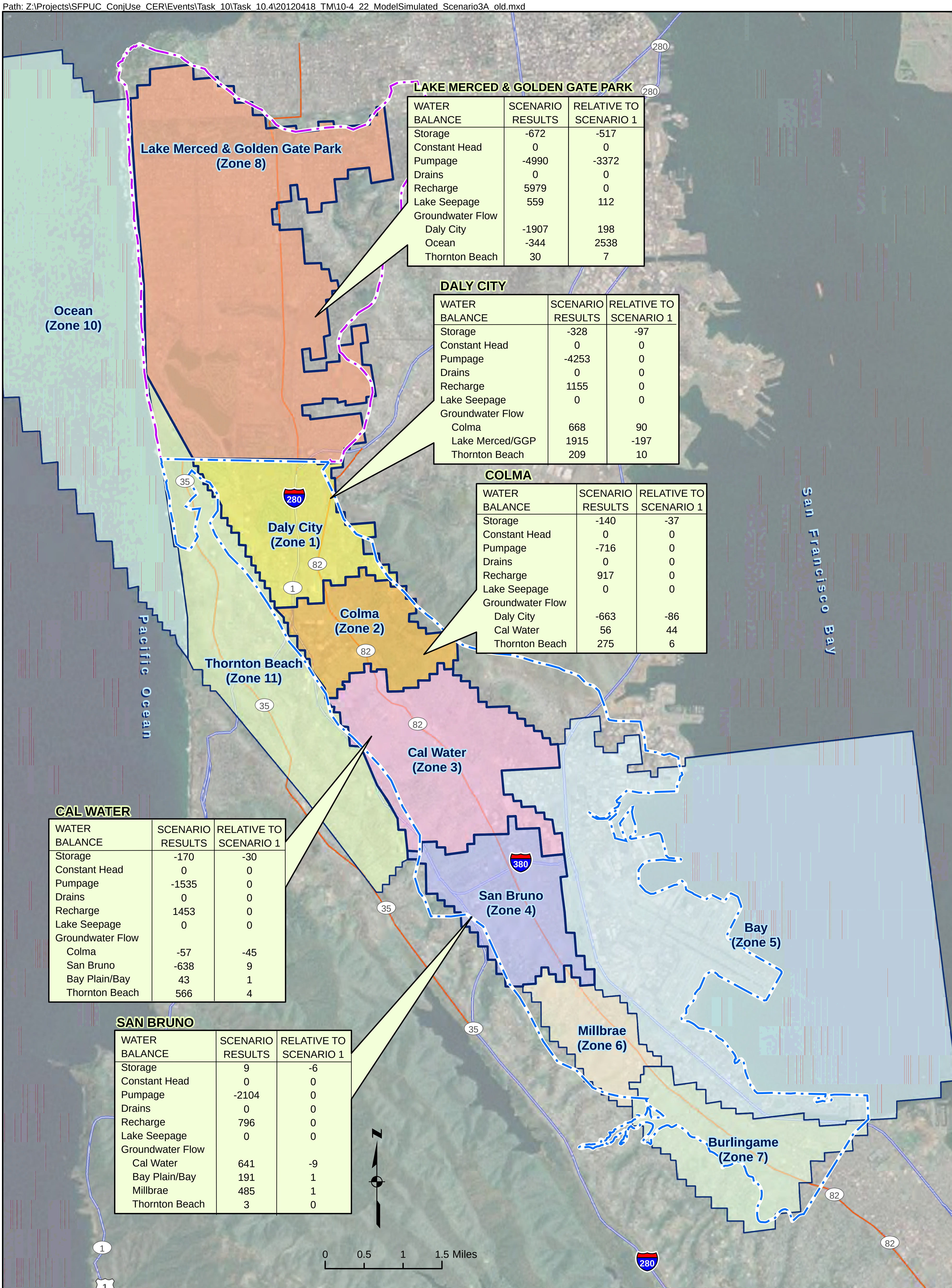
Kennedy/Jenks Consultants
303 Second Street, Suite 300 South
San Francisco, CA 94107

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

Figure
10.4-21

Date
April 2012

Path: Z:\Projects\SFPUC_ConjUse_CER\Events\Task_10\Task_10.4\20120418_TM\10-4_22_ModelSimulated_Scenario3A_old.mxd



LAKE MERCED & GOLDEN GATE PARK

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-672	-517
Constant Head	0	0
Pumpage	-4990	-3372
Drains	0	0
Recharge	5979	0
Lake Seepage	559	112
Groundwater Flow		
Daly City	-1907	198
Ocean	-344	2538
Thornton Beach	30	7

DALY CITY

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-328	-97
Constant Head	0	0
Pumpage	-4253	0
Drains	0	0
Recharge	1155	0
Lake Seepage	0	0
Groundwater Flow		
Colma	668	90
Lake Merced/GGP	1915	-197
Thornton Beach	209	10

COLMA

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-140	-37
Constant Head	0	0
Pumpage	-716	0
Drains	0	0
Recharge	917	0
Lake Seepage	0	0
Groundwater Flow		
Daly City	-663	-86
Cal Water	56	44
Thornton Beach	275	6

CAL WATER

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-170	-30
Constant Head	0	0
Pumpage	-1535	0
Drains	0	0
Recharge	1453	0
Lake Seepage	0	0
Groundwater Flow		
Colma	-57	-45
San Bruno	-638	9
Bay Plain/Bay	43	1
Thornton Beach	566	4

SAN BRUNO

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	9	-6
Constant Head	0	0
Pumpage	-2104	0
Drains	0	0
Recharge	796	0
Lake Seepage	0	0
Groundwater Flow		
Cal Water	641	-9
Bay Plain/Bay	191	1
Millbrae	485	1
Thornton Beach	3	0

Legend

South Westside Groundwater Basin
North Westside Groundwater Basin

Model Sub-areas

Lake Merced and Golden Gate Park
Daly City
Colma
Cal Water
San Bruno
Millbrae
Burlingame
Ocean
Thornton Beach
Bay

Note:
Values are in units of acre-feet per year based on the annual average values over the simulated period.

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

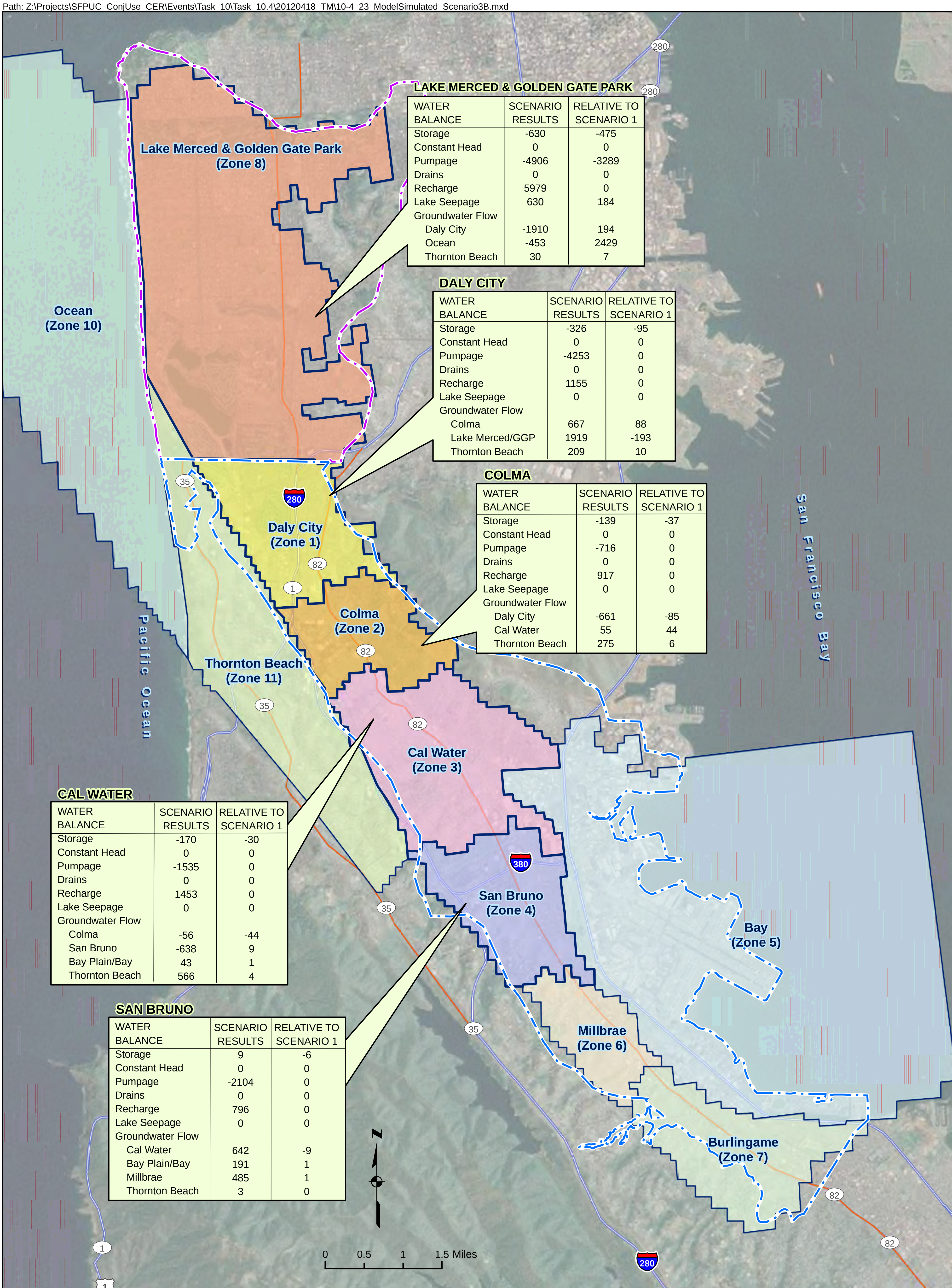
MODEL SIMULATED AVERAGE ANNUAL WATER BALANCE FOR SPECIFIC WESTSIDE BASIN MODEL SUBAREAS SCENARIO 3A

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

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

Figure 10.4-22

Date April 2012



LAKE MERCED & GOLDEN GATE PARK

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-630	-475
Constant Head	0	0
Pumpage	-4906	-3289
Drains	0	0
Recharge	5979	0
Lake Seepage	630	184
Groundwater Flow		
Daly City	-1910	194
Ocean	-453	2429
Thornton Beach	30	7

DALY CITY

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-326	-95
Constant Head	0	0
Pumpage	-4253	0
Drains	0	0
Recharge	1155	0
Lake Seepage	0	0
Groundwater Flow		
Colma	667	88
Lake Merced/GGP	1919	-193
Thornton Beach	209	10

COLMA

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-139	-37
Constant Head	0	0
Pumpage	-716	0
Drains	0	0
Recharge	917	0
Lake Seepage	0	0
Groundwater Flow		
Daly City	-661	-85
Cal Water	55	44
Thornton Beach	275	6

CAL WATER

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-170	-30
Constant Head	0	0
Pumpage	-1535	0
Drains	0	0
Recharge	1453	0
Lake Seepage	0	0
Groundwater Flow		
Colma	-56	-44
San Bruno	-638	9
Bay Plain/Bay	43	1
Thornton Beach	566	4

SAN BRUNO

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	9	-6
Constant Head	0	0
Pumpage	-2104	0
Drains	0	0
Recharge	796	0
Lake Seepage	0	0
Groundwater Flow		
Cal Water	642	-9
Bay Plain/Bay	191	1
Millbrae	485	1
Thornton Beach	3	0

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

Legend

South Westside Groundwater Basin

North Westside Groundwater Basin

Model Sub-areas

- Lake Merced and Golden Gate Park
- Daly City
- Colma
- Cal Water
- San Bruno
- Millbrae
- Burlingame
- Ocean
- Thornton Beach
- Bay

Note:
Values are in units of acre-feet per year based on the annual average values over the simulated period.

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

MODEL SIMULATED AVERAGE ANNUAL WATER BALANCE FOR SPECIFIC WESTSIDE BASIN MODEL SUBAREAS SCENARIO 3B

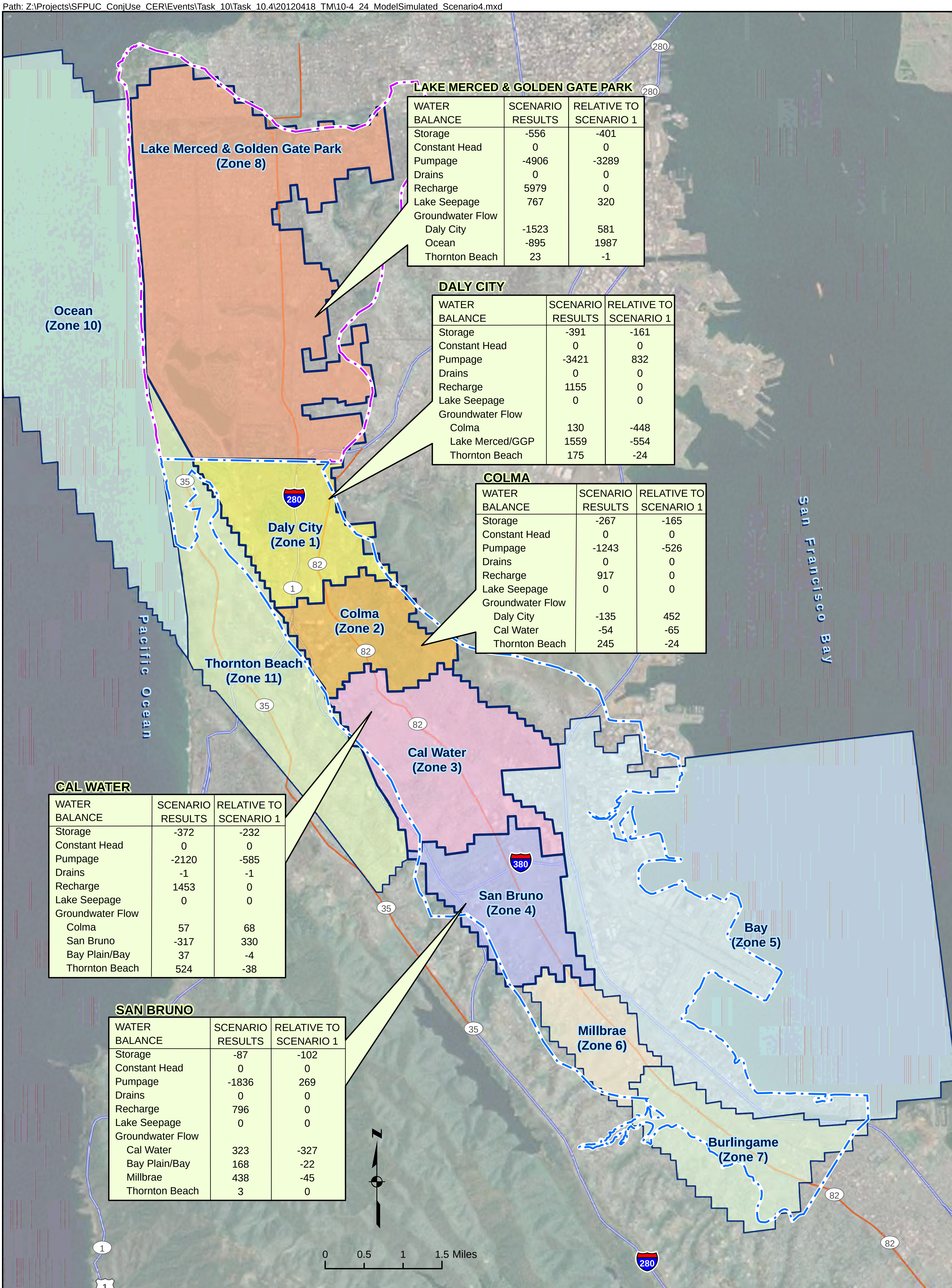
Kennedy/Jenks Consultants
303 Second Street, Suite 300 South
San Francisco, CA 94107

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

Figure 10.4-23

Date April 2012

Path: Z:\Projects\SFPUC_ConjUse_CER\Events\Task_10\Task_10.4\20120418_TM\10-4_24_ModelSimulated_Scenario4.mxd



LAKE MERCED & GOLDEN GATE PARK

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-556	-401
Constant Head	0	0
Pumpage	-4906	-3289
Drains	0	0
Recharge	5979	0
Lake Seepage	767	320
Groundwater Flow		
Daly City	-1523	581
Ocean	-895	1987
Thornton Beach	23	-1

DALY CITY

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-391	-161
Constant Head	0	0
Pumpage	-3421	832
Drains	0	0
Recharge	1155	0
Lake Seepage	0	0
Groundwater Flow		
Colma	130	-448
Lake Merced/GGP	1559	-554
Thornton Beach	175	-24

COLMA

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-267	-165
Constant Head	0	0
Pumpage	-1243	-526
Drains	0	0
Recharge	917	0
Lake Seepage	0	0
Groundwater Flow		
Daly City	-135	452
Cal Water	-54	-65
Thornton Beach	245	-24

CAL WATER

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-372	-232
Constant Head	0	0
Pumpage	-2120	-585
Drains	-1	-1
Recharge	1453	0
Lake Seepage	0	0
Groundwater Flow		
Colma	57	68
San Bruno	-317	330
Bay Plain/Bay	37	-4
Thornton Beach	524	-38

SAN BRUNO

WATER BALANCE	SCENARIO RESULTS	RELATIVE TO SCENARIO 1
Storage	-87	-102
Constant Head	0	0
Pumpage	-1836	269
Drains	0	0
Recharge	796	0
Lake Seepage	0	0
Groundwater Flow		
Cal Water	323	-327
Bay Plain/Bay	168	-22
Millbrae	438	-45
Thornton Beach	3	0

Legend

South Westside Groundwater Basin
North Westside Groundwater Basin

Model Sub-areas

Lake Merced and Golden Gate Park
Daly City
Colma
Cal Water
San Bruno
Millbrae
Burlingame
Ocean
Thornton Beach
Bay

Note:
Values are in units of acre-feet per year based on the annual average values over the simulated period.

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

MODEL SIMULATED AVERAGE ANNUAL WATER BALANCE FOR SPECIFIC WESTSIDE BASIN MODEL SUBAREAS SCENARIO 4

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

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

Figure 10.4-24

Date April 2012

Tables

Tables

Table 10.4-1: Summary of Model Scenario Pumping Assumptions

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

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

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

Table 10.4-2: Scenario 1 (Existing Conditions) Westside Groundwater Basin Water Balance Summary

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

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

Table 10.4-3: Scenario 2 Westside Groundwater Basin Water Balance Summary, Relative to Existing Conditions

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	0	0	0	-13	-13	6,072	-1	0	6,045
2	0	0	0	-51	-59	6,072	44	0	6,005
3	0	0	0	-74	-121	6,072	23	-1	5,900
4	0	0	0	-152	-178	6,072	-40	-1	5,701
5	0	0	0	-204	-228	6,072	-18	-3	5,619
6	-1	0	0	-230	-284	6,072	-14	-4	5,540
7	-1	0	0	-262	-340	2,070	-46	-6	1,414
8	-1	0	0	-306	-371	-108	40	-10	-755
9	-2	0	0	-427	-384	-2,123	219	-14	-2,731
10	-2	0	0	-383	-380	-8,169	238	-17	-8,713
11	-3	0	0	-295	-334	-4,619	233	-19	-5,036
12	-2	0	0	-244	-301	6,072	239	-20	5,743
13	-4	0	0	-348	-332	6,072	319	-22	5,686
14	-7	0	0	-560	-378	2,557	485	-23	2,073
15	-8	0	0	-592	-404	-108	491	-28	-650
16	-8	0	0	-506	-411	-108	414	-33	-652
17	-6	0	0	-534	-417	-108	471	-36	-630
18	-6	0	0	-402	-422	-108	350	-38	-626
19	-5	0	0	-269	-427	-108	242	-40	-606
20	-5	0	0	-261	-429	-108	249	-42	-596
21	-5	0	0	-301	-427	-108	301	-41	-581
22	-6	0	0	-294	-428	-108	285	-41	-592
23	-5	0	0	-303	-418	-108	94	-43	-783
24	-5	0	0	-320	-394	-108	187	-43	-684
25	-5	0	0	-299	-382	-2,123	241	-44	-2,611
26	-6	0	0	-278	-359	-8,169	266	-43	-8,589
27	-6	0	0	-272	-298	-4,618	312	-41	-4,924
28	-5	0	0	-171	-253	6,072	248	-41	5,851
29	-6	0	0	-212	-275	6,072	254	-40	5,792
30	-8	0	0	-337	-313	2,557	322	-41	2,181
31	-8	0	0	-351	-336	-108	299	-42	-546
32	-6	0	0	-293	-339	-108	198	-43	-592
33	-6	0	0	-231	-329	-108	40	-45	-680
34	-6	0	0	-297	-321	-108	198	-47	-580
35	-5	0	0	-208	-316	-108	48	-48	-637
36	-5	0	0	-207	-306	-2,123	134	-47	-2,554
37	-5	0	0	-267	-288	-8,169	248	-42	-8,523
38	-4	0	0	-215	-231	-8,169	256	-39	-8,402
39	-3	0	0	-136	-160	-8,169	233	-35	-8,270
40	0	0	0	-81	-90	-8,169	210	-31	-8,160
41	6	0	0	-108	-23	-8,169	280	-28	-8,041
42	14	0	0	24	44	-8,162	187	-25	-7,918
43	25	0	0	327	109	-8,150	-85	-20	-7,794
44	34	0	0	390	178	-567	-114	-16	-96
45	31	0	0	392	217	6,100	-121	-13	6,606
46	20	0	0	306	205	6,076	-103	-9	6,496
47	11	0	0	186	177	6,073	-70	-6	6,371
Average (afy)	**0**	**0**	**0**	**-206**	**-246**	**-112**	**176**	**-28**	**-416**
Maximum (afy)	**34**	**0**	**0**	**392**	**217**	**6,100**	**491**	**0**	**6,606**
Minimum (afy)	**-8**	**0**	**0**	**-592**	**-429**	**-8,169**	**-121**	**-48**	**-8,713**

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

Table 10.4-4 Scenario 3a Westside Groundwater Basin Water Balance Summary, Relative to Existing Conditions

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	0	0	0	21	270	-3,375	42	0	-3,042
2	2	0	0	61	708	-3,375	168	0	-2,436
3	6	0	0	126	1,067	-3,375	197	0	-1,979
4	21	0	0	113	1,338	-3,375	154	0	-1,748
5	48	0	0	96	1,538	-3,375	145	0	-1,548
6	87	0	0	194	1,678	-3,375	25	0	-1,390
7	122	0	0	267	1,791	-3,375	-58	0	-1,252
8	177	0	0	203	1,852	-3,375	2	0	-1,141
9	238	0	0	182	1,890	-3,375	16	0	-1,049
10	295	0	0	230	1,915	-3,375	-47	0	-981
11	342	0	0	224	1,945	-3,375	-47	0	-911
12	328	0	0	210	2,028	-3,375	-46	0	-855
13	400	0	0	120	2,010	-3,375	32	0	-812
14	420	0	0	-84	2,046	-3,375	232	0	-761
15	451	0	0	-99	2,072	-3,375	243	0	-709
16	385	0	0	-2	2,198	-3,375	144	0	-650
17	360	0	0	-44	2,269	-3,375	165	0	-624
18	351	0	0	99	2,328	-3,375	30	0	-566
19	305	0	0	189	2,417	-3,375	-79	0	-543
20	318	0	0	188	2,437	-3,375	-87	0	-518
21	423	0	0	136	2,348	-3,375	-46	0	-513
22	336	0	0	180	2,485	-3,375	-68	0	-441
23	244	0	0	200	2,615	-3,375	-111	0	-426
24	264	0	0	174	2,614	-3,375	-98	0	-421
25	370	0	0	164	2,514	-3,375	-96	0	-422
26	534	0	0	150	2,351	-3,375	-84	0	-425
27	510	0	0	127	2,396	-3,375	-43	0	-383
28	457	0	0	173	2,468	-3,375	-103	0	-379
29	451	0	0	163	2,491	-3,375	-92	0	-362
30	516	0	0	75	2,436	-3,374	-15	1	-361
31	412	0	0	119	2,574	-3,375	-41	1	-310
32	279	0	0	215	2,752	-3,374	-140	1	-269
33	246	0	0	277	2,810	-3,374	-232	1	-273
34	282	0	0	184	2,784	-3,374	-142	1	-267
35	291	0	0	306	2,792	-3,375	-257	1	-241
36	326	0	0	256	2,756	-3,374	-224	1	-259
37	415	0	0	152	2,658	-3,375	-116	1	-265
38	484	0	0	154	2,585	-3,374	-116	1	-267
39	601	0	0	131	2,456	-3,375	-102	1	-287
40	714	0	0	-82	2,333	-3,374	116	1	-292
41	740	0	0	-155	2,311	-3,375	200	1	-277
42	927	0	0	-173	2,118	-3,375	205	1	-296
43	1,095	0	0	-183	1,941	-3,374	215	1	-305
44	925	0	0	-147	2,128	-3,375	210	1	-257
45	777	0	0	-139	2,301	-3,375	194	2	-241
46	609	0	0	-146	2,497	-3,375	192	2	-221
47	485	0	0	-157	2,651	-3,374	199	2	-194
Average (afy)	**391**	**0**	**0**	**95**	**2,191**	**-3,375**	**13**	**1**	**-684**
Maximum (afy)	**1,095**	**0**	**0**	**306**	**2,810**	**-3,374**	**243**	**2**	**-194**
Minimum (afy)	**0**	**0**	**0**	**-183**	**270**	**-3,375**	**-257**	**0**	**-3,042**

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

Table 10.4-5: Scenario 3b Westside Groundwater Basin Water Balance Summary, Relative to Existing Conditions

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	0	80	0	20	230	-3,223	40	0	-2,852
2	1	70	0	76	736	-3,412	213	0	-2,316
3	4	74	0	189	1,090	-3,364	248	0	-1,759
4	17	77	0	158	1,301	-3,271	167	0	-1,551
5	39	77	0	124	1,479	-3,270	149	0	-1,402
6	69	77	0	133	1,615	-3,274	113	0	-1,268
7	96	73	0	282	1,748	-3,317	-60	0	-1,178
8	127	81	0	219	1,752	-3,233	-4	0	-1,057
9	170	77	0	98	1,828	-3,219	107	0	-938
10	215	74	0	241	1,900	-3,312	-51	0	-934
11	248	77	0	238	1,919	-3,270	-56	0	-844
12	259	70	0	223	2,043	-3,395	-55	0	-855
13	305	73	0	134	2,028	-3,312	22	0	-750
14	346	70	0	-72	2,077	-3,436	222	0	-794
15	330	77	0	-87	2,065	-3,186	233	0	-568
16	297	70	0	9	2,177	-3,321	134	0	-634
17	268	77	0	-31	2,234	-3,261	155	0	-558
18	268	73	0	110	2,285	-3,294	20	0	-538
19	245	73	0	200	2,385	-3,368	-89	0	-554
20	252	70	0	201	2,433	-3,375	-97	0	-518
21	306	77	0	148	2,330	-3,255	-57	0	-450
22	274	73	0	190	2,442	-3,334	-78	0	-433
23	207	70	0	210	2,585	-3,411	-120	0	-459
24	210	77	0	186	2,554	-3,302	-109	0	-384
25	267	77	0	176	2,484	-3,255	-107	0	-357
26	394	77	0	162	2,344	-3,293	-96	0	-410
27	397	74	0	138	2,387	-3,301	-53	0	-359
28	330	77	0	183	2,442	-3,234	-113	0	-315
29	337	73	0	173	2,476	-3,328	-103	0	-372
30	371	77	0	86	2,418	-3,254	-26	0	-327
31	337	70	0	129	2,561	-3,425	-52	1	-380
32	240	70	0	225	2,717	-3,340	-151	1	-238
33	188	81	0	288	2,662	-3,146	-242	1	-168
34	213	73	0	196	2,697	-3,320	-154	1	-293
35	227	73	0	317	2,707	-3,321	-268	1	-264
36	230	81	0	268	2,638	-3,133	-235	1	-150
37	282	80	0	164	2,574	-3,214	-128	1	-241
38	336	74	0	166	2,544	-3,335	-128	1	-342
39	434	77	0	143	2,448	-3,188	-114	1	-198
40	558	70	0	-71	2,335	-3,373	105	1	-375
41	566	77	0	-145	2,310	-3,170	188	1	-172
42	701	77	0	-162	2,115	-3,181	194	1	-254
43	909	77	0	-171	1,943	-3,292	203	1	-330
44	771	74	0	-137	2,132	-3,286	198	1	-247
45	581	81	0	-129	2,279	-3,154	182	2	-158
46	480	70	0	-136	2,482	-3,413	180	2	-334
47	393	74	0	-146	2,620	-3,331	187	2	-202
Average (afy)	**300**	**75**	**0**	**105**	**2,161**	**-3,292**	**11**	**0**	**-640**
Maximum (afy)	**909**	**81**	**0**	**317**	**2,717**	**-3,133**	**248**	**2**	**-150**
Minimum (afy)	**0**	**70**	**0**	**-171**	**230**	**-3,436**	**-268**	**0**	**-2,852**

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

Table 10.4-6 Scenario 4 Westside Groundwater Basin Water Balance Summary, Relative to Existing Conditions

Scenario Year	Inflow from Bay & Ocean (afy)	Seepage from GGP Lakes (afy)	Rain + Irrigation (afy)	Seepage from Lake Merced (afy)	Outflow to Bay & Ocean (afy)	Wells - Pumping (afy)	Seepage to Lake Merced (afy)	Drains (afy)	Change in Groundwater Storage (afy)
1	0	80	0	-4	218	2,793	16	0	3,104
2	0	70	0	-93	704	2,629	-181	0	3,128
3	0	74	0	-139	1,066	2,674	54	-1	3,729
4	4	77	0	-153	1,255	2,754	83	-1	4,019
5	12	77	0	-163	1,395	2,759	136	-3	4,213
6	26	77	0	-153	1,484	2,750	159	-4	4,338
7	36	73	0	-192	1,568	-1,290	142	-6	331
8	52	81	0	-205	1,551	-3,394	241	-10	-1,685
9	79	77	0	-295	1,625	-5,396	414	-14	-3,509
10	116	74	0	-188	1,708	-11,525	383	-17	-9,450
11	163	77	0	-10	1,753	-7,936	374	-19	-5,598
12	183	70	0	50	1,881	2,642	447	-21	5,252
13	196	73	0	6	1,840	2,716	379	-22	5,188
14	203	70	0	-240	1,845	-914	582	-24	1,521
15	178	77	0	-288	1,788	-3,349	622	-29	-1,002
16	154	70	0	-260	1,867	-3,476	674	-34	-1,004
17	129	77	0	-329	1,904	-3,416	720	-37	-951
18	128	73	0	-244	1,947	-3,444	543	-39	-1,037
19	108	73	0	-187	2,047	-3,523	433	-41	-1,090
20	110	70	0	-198	2,106	-3,529	432	-42	-1,052
21	142	77	0	-165	2,033	-3,416	435	-42	-936
22	126	73	0	-219	2,125	-3,488	431	-42	-993
23	82	70	0	-301	2,261	-3,556	311	-44	-1,177
24	81	77	0	-282	2,254	-3,453	412	-44	-956
25	115	77	0	-208	2,215	-5,429	413	-45	-2,862
26	202	77	0	14	2,131	-11,510	286	-44	-8,843
27	235	74	0	30	2,189	-7,962	370	-42	-5,107
28	204	77	0	167	2,238	2,789	265	-42	5,698
29	188	73	0	112	2,242	2,702	378	-41	5,655
30	182	77	0	15	2,151	-747	375	-41	2,013
31	157	70	0	-120	2,235	-3,564	509	-43	-756
32	99	70	0	-243	2,343	-3,488	323	-44	-940
33	68	81	0	-233	2,298	-3,315	239	-46	-908
34	78	73	0	-264	2,367	-3,475	408	-47	-860
35	88	73	0	-171	2,391	-3,472	266	-48	-873
36	89	81	0	-192	2,343	-5,311	335	-47	-2,702
37	126	80	0	-142	2,317	-11,435	378	-43	-8,717
38	186	74	0	84	2,339	-11,546	260	-39	-8,643
39	265	77	0	156	2,332	-11,411	232	-35	-8,385
40	372	70	0	0	2,307	-11,594	430	-31	-8,446
41	398	77	0	61	2,330	-11,389	494	-28	-8,057
42	489	77	0	174	2,247	-11,405	359	-25	-8,083
43	653	77	0	219	2,190	-11,495	369	-20	-8,007
44	598	74	0	243	2,360	-3,898	402	-16	-237
45	450	81	0	246	2,482	2,877	419	-13	6,542
46	357	70	0	178	2,624	2,623	474	-9	6,316
47	277	74	0	95	2,679	2,699	526	-6	6,343
Average (afy)	**174**	**75**	**0**	**-86**	**1,991**	**-3,450**	**356**	**-28**	**-968**
Maximum (afy)	**653**	**81**	**0**	**246**	**2,679**	**2,877**	**720**	**0**	**6,542**
Minimum (afy)	**0**	**70**	**0**	**-329**	**218**	**-11,594**	**-181**	**-48**	**-9,450**

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

Table 10.4-7: Annual Average Water Balances for Selected Subareas, Absolute and Relative to Existing Conditions, All Scenarios

Subarea	Component	Scenario 1 Simulated (afy)	Scenario 2 Simulated (afy)	Scenario 2 Relative (afy)	Scenario 3a Simulated (afy)	Scenario 3a Relative (afy)	Scenario 3b Simulated (afy)	Scenario 3b Relative (afy)	Scenario 4 Simulated (afy)	Scenario 4 Relative (afy)
Daly City	Storage	-230	-411	-180	-328	-97	-326	-95	-391	-161
	Constant Head	0	0	0	0	0	0	0	0	0
	Pumpage	-4,253	-3,921	332	-4,253	0	-4,253	0	-3,421	832
	Drains	0	0	0	0	0	0	0	0	0
	Recharge	1,155	1,155	0	1,155	0	1,155	0	1,155	0
	Lake Seepage	0	0	0	0	0	0	0	0	0
	Groundwater Flow									
	Colma	578	254	-324	668	90	667	88	130	-448
	Lake Merced/GGF	2,112	1,895	-218	1,915	-197	1,919	-193	1,559	-554
	Thornton Beach	199	184	-15	209	10	209	10	175	-24
Colma	Storage	-103	-280	-178	-140	-37	-139	-37	-267	-165
	Constant Head	0	0	0	0	0	0	0	0	0
	Pumpage	-716	-1,198	-481	-716	0	-716	0	-1,243	-526
	Drains	0	0	0	0	0	0	0	0	0
	Recharge	917	917	0	917	0	917	0	917	0
	Lake Seepage	0	0	0	0	0	0	0	0	0
	Groundwater Flow									
	Daly City	-577	-266	310	-663	-86	-661	-85	-135	442
	Cal Water	11	-7	-18	56	44	55	44	-54	-65
	Thornton Beach	269	268	-1	275	6	275	6	245	-24
Cal Water	Storage	-140	-374	-233	-170	-30	-170	-30	-372	-232
	Constant Head	0	0	0	0	0	0	0	0	0
	Pumpage	-1,535	-2,120	-585	-1,535	0	-1,535	0	-2,120	-585
	Drains	0	-1	-1	0	0	0	0	-1	-1
	Recharge	1,453	1,453	0	1,453	0	1,453	0	1,453	0
	Lake Seepage	0	0	0	0	0	0	0	0	0
	Groundwater Flow									
	Colma	-12	8	20	-57	-45	-56	-44	57	68
	San Bruno	-647	-322	326	-638	9	-638	9	-317	330
	Bay Plain/Bay	41	38	-3	43	1	43	1	37	-4
	Thornton Beach	562	576	14	566	4	566	4	524	-38
San Bruno	Storage	15	-84	-100	9	-6	9	-6	-87	-102
	Constant Head	0	0	0	0	0	0	0	0	0
	Pumpage	-2,104	-1,836	269	-2,104	0	-2,104	0	-1,836	269
	Drains	0	0	0	0	0	0	0	0	0
	Recharge	796	796	0	796	0	796	0	796	0
	Lake Seepage	0	0	0	0	0	0	0	0	0
	Groundwater Flow									
	Cal Water	650	328	-323	641	-9	642	-9	323	-327
	Bay Plain/Bay	190	167	-23	191	1	191	1	168	-22
	Millbrae	484	437	-46	485	1	485	1	438	-45
	Thornton Beach	3	3	0	3	0	3	0	3	0
Lake Merced/GGP	Storage	-155	-181	-26	-672	-517	-630	-475	-556	-401
	Constant Head	0	0	0	0	0	0	0	0	0
	Pumpage	-1,618	-1,618	0	-4,990	-3,372	-4,906	-3,289	-4,906	-3,289
	Drains	0	0	0	0	0	0	0	0	0
	Recharge	5,979	5,979	0	5,979	0	5,979	0	5,979	0
	Lake Seepage	446	402	-45	559	112	630	184	767	320
	Groundwater Flow									
	Daly City	-2,104	-1,859	245	-1,907	198	-1,910	194	-1,523	581
	Ocean	-2,882	-3,104	-222	-344	2,538	-453	2,429	-895	1,987
	Thornton Beach	23	20	-3	30	7	30	7	23	-1

Notes: (1) Water balance components represent annual average values on a water year basis, from October to September. The first three months of the simulation period, which represent July through September conditions, are omitted from the annual averages because they represent only a partial water year. The volumes presented represent the 47 complete water years for the simulation period.
(2) Relative values represent average annual net volumetric changes for a given scenario relative to Scenario 1.
(3) Negative storage values represent losses of storage from the aquifer, while positive storage values represent gains in storage in the aquifer.
(4) Recharge is the model-simulated combined recharge from deep percolation of rainfall, irrigation, and leaky pipes and sewers, as well as recharge from lakes and ponds in Golden Gate Park (for Lake Merced/GGP subarea).
(5) Positive Lake Seepage simulated values for the Lake Merced/GGP subarea represent groundwater flow from Lake Merced to the groundwater basin; and negative Lake Merced Seepage simulated values represent groundwater flow out of the groundwater basin into Lake Merced.
(6) Positive simulated values for Groundwater Flow components represent groundwater flow entering the subarea (i.e., inflow); and negative simulated values for Groundwater Flow components represent groundwater flow leaving the subarea (i.e., outflow).

Table 10.4-8: Comparison of Historic and Model-Simulated Groundwater Elevations

Historic Groundwater Level Elevations		Model-Simulated Groundwater Elevations				
Well Location (Period of Record)		**Model Equivalent Location**	**Scenario 1 - Existing Conditions**	**Scenario 2 - GSR Only**	**Scenario 3a - SFGW Only**	**Scenario 4 - Cumulative (GSR & SFGW)**
Shallow Aquifer	**Approx. Elev. Range (ft) (NGVD 29)**	Model Layer 1	**Approx. Elev. Range (ft) (NGVD 29)**			
South Windmill MW-57 (2006-2009)	-4 to 15	SWM-GS-M	6 to 15	6 to 15	-3 to 14	-3 to 11
Taraval MW-145 (2004-2009)	6 to 10	Taraval MW	4 to 9	4 to 9	-1 to 6	0 to 6
LMMW-3S (1996-2009)	2 to 14	LMMW-3S	2 to 20	2 to 21	-13 to 20	1 to 18
LMMW-4S (2003-2009)	11 to 15	LMMW-4S	10 to 25	11 to 25	-4 to 22	5 to 21
Primary Production Aquifer		Model Layer 4				
West Sunset Playground Well (1996-2009)	13 to 24	W-Sunset-PG	-2 to 4	-3 to 4	-14 to 3	-12 to 3
LMMW-2D (1996-2009)	6 to 14	LMMW-2D	-17 to -3	-25 to 6	-44 to -4	-40 to -4
DC-1 Westlake (2002-2009)	-121 to -68	Westlake-DC-1	-120 to -72	-198 to -28	-140 to -72	-181 to -30
MW-CUP-23-515 (08/09-10/09)	-167 to -135	CUP-23	-159 to -111	-289 to -86	-165 to -111	-289 to -87
Cal Water SS1-02 (2002-2009)	-172 to -108	SSF1-02	-206 to -141	-333 to -108	-210 to -141	-336 to -109
MW-CUP-36-1-585 (11/08-10/09)	-175 to -161	CUP-36	-194 to -134	-320 to -107	-198 to -134	-322 to -107
SB-12 Elm Avenue (2004-2009)	-198 to -181	SB-12	-260 to -210	-350 to -138	-262 to -210	-351 to -138