SECTION 2.0

Groundwater Modeling of Wellfield Alternatives

2.1 Introduction

This chapter summarizes work performed to assess wellfield alternatives with respect to potential water level and water quality impacts. As part of this work, wellfield alternatives were defined based on location of new wellfields, total pumpage, and distribution of pumpage between existing and new wellfields. This work was supported by use of the District's MODFLOW model of the basin. Development of this model is documented in *Livermore Valley Groundwater Model v2.0* (CH2M HILL, 1998). The model was previously used to support the District's *Salt Management Plan*, which is documented in *Phase 4 Groundwater Modeling: Salt Management Plan Simulations* (CH2M HILL, 1999). This chapter reflects work originally presented to Zone 7 in the Draft Technical Memorandum *Groundwater Modeling of Wellfield Alternatives* (CH2M HILL, 2003).

The District's model is supported by "Visual MODFLOW," which is a user-friendly software package that supports the MODFLOW code. The current work effort was performed using "Groundwater Vistas," which serves the same function as Visual MODFLOW but has the added benefit of supporting "MODFLOW-SURFACT." MODFLOW-SURFACT is capable of modeling the unsaturated zone. This allows the program to keep running even when numerous cells go "dry"—a situation that causes MODFLOW to crash. Visual MODFLOW did not support MODFLOW-SURFACT at the time this work was conducted (though it now does). MT3D was used to simulate salt transport.

The study area is centered in the Bernal and Amador Subbasin portions of the LVGB (Figure 2.1-1). Three existing and eight potential new wellfield sites covering the main portion of the local groundwater basin were reviewed as part of the Well Master Plan Project (Figure 2.1-2). The District is also considering construction of shallow desalting wells to help mitigate salt buildup in the basin. Potential effects of these desalting wells were assessed in select simulations (see Appendix A for location of modeled shallow desalting wells). Potential locations for new wellfields were identified based on discussion with District staff and results of previous work tasks.

2.2 Well Master Plan Modeling Approach

Zone 7 supplied CH2M HILL with data sets representing their pumpage at the following times: average yearly groundwater pumpage at buildout (year 2020), 1-year drought pumpage, and 6-year drought pumpage. These data sets were developed based on historical hydrology. Pumpage estimates for Zone 7 wells for each of these data sets are summarized in Figures 2.2-1 and 2.2-2. Simulated water levels under year 2020 buildout are shown in Figures 2.2-3 and 2.2-4. These results represent typical (or "average") future water level conditions based on a steady-state simulation. These water levels appear reasonable given historical water level data (Figure 2.2-5) and given that pumpage from of the westernmost gravel pits will be stopped, that some of the gravel pits will be used for recharge, and that Zone 7 intends to maintain the basin at near-full conditions.

Zone 7 has a policy of meeting 75 percent of peak-day, valley-wide water demand via groundwater. Based on projected future water demands, this translates to a required peak pumping capacity from District wells of about 70 million gallons per day (mgd). Zone 7 groundwater production capacity requirements for 1- and 6-year drought conditions is lower and dependent upon availability of State Water Project water and other source options. Accordingly, pumping capacities were treated as a variable in developing operational alternatives. New wellfields were preferentially located in higher transmissivity areas of the basin, as indicated by the groundwater model (Figure 2.2-6).

The District has an operational goal of not exceeding historical low water levels. To assess this goal, a map of composite low water levels in the basin was prepared and used as a benchmark for simulation results (Figure 2.2-7). Basinwide water level impacts for each of the alternatives were assessed by comparing simulated 1-year drought water level lows in the deep aquifer with historic low water levels. Areas where simulated water levels are below the historic low were noted and potential impacts assessed.

The 1-year drought simulation provided the most severe short-term pumping stress on the basin (Figures 2.2-1 and 2.2-2). Therefore, drawdowns typically will be greater relative to 6-year drought simulations (see, for example, Appendix C). These effects can vary slightly depending upon pumping assumptions and other variables. However, because variable affects are relatively small, and because 1-year simulations were more efficient to conduct, the 1-year simulations were used in this study as the primary measurement of impact with respect to low water levels. Six-year simulations were conducted on select alternatives in later phases of work.

Hydrographs at “Key Wells” used by Zone 7 to assess basin conditions indicate a more subdued response in the shallow aquifer during pumping in the deep aquifer, as illustrated by hydrographs presented in Appendix C. In this appendix, “L1” hydrographs refer to the shallow aquifer response (Layer-1 of the model) and “L3” to the deep aquifer (Layer-3 of the model). This response reflects the presence of an aquitard between the deep aquifer and more shallow zones. Because drawdown response is more acute in the deep aquifer, it was used as the basis of basinwide water level impact analysis.

Potential impacts of wellfield alternatives to individual local municipal wells were evaluated by comparing simulated water level lows to well construction information. Instances where simulated water levels fall below either the pump setting or top of well screen were noted and potential impacts assessed. Potential impacts from individual new wells was assessed by simulating “typical” wells at each wellfield operating at projected peak rates. Time- and distance-drawdown graphs were constructed to assess potential local impacts of these individual wells and determine recommended well spacing in each of the wellfields.

Potential water quality impacts were assessed under a variety of conditions, including: 1) existing wells only (or new wellfields used only on an emergency basis); 2) new deep aquifer wellfields are built and used on an equal basis with existing wells; and 3) shallow desalination wells are built and operated. These scenarios provide an envelope of potential impacts to water quality. Zone 7 plans on conducting more detailed evaluations in the future, including optimizing the location and pumping rates of shallow desalting wells.

2.2.1 Well Master Plan Groundwater Management Scenarios

It is typically desirable to place high-capacity water supply wells in the most productive portions of an aquifer to lessen drawdown impacts, both in the pumping well and surrounding wells. The best estimate of transmissivity distribution within the Livermore Valley is provided by the groundwater model of the area. Accordingly, this information was used to help site potential new wellfields in the most transmissive portions of the deep aquifer (Figure 2.2-6). The reliability of this information, along with local groundwater quality conditions, will need to be assessed as part of test hole drilling during future wellfield investigations.

Assumptions regarding maximum existing and future Zone 7 well production capacities for each of the scenarios modeled are summarized in Table 2.2-1. This table also identifies model run number ("504" etc.) and provides a brief explanation of the purpose of each run. A summary of wellfield pumping rates for select scenarios is provided as Table 2.2-2. Wellfield alternatives are placed into one of the following three scenario categories:

Scenario 1: Existing Wells Only. In this scenario, only existing wells are used to meet future demands. Two variations of this scenario were assessed. One alternative assumes that all existing wells are operational with a resulting production capacity of 32 mgd. A second alternative assumes that two older wells in the Mocho Wellfield (Mocho-1 and Mocho-2) are no longer in operation, reducing total production capacity to 25 mgd. In either case, the District would not be able to reach its goal of meeting 75 percent of valley-wide, peak-day demand via groundwater, which requires District groundwater production capacity of about 70 mgd.

Scenario 2: Existing Wells Plus New Wellfields. This scenario assumes new wellfields are constructed to meet future demands. Sustained Zone 7 pumping capacities between 45 and 70 mgd during droughts and shorter-term emergency demands under varied wellfield options were simulated. Impacts of extended pumping at maximum day demand for select alternatives were also evaluated.

Scenario 3: Existing and New Wellfields Plus Shallow Desalting Wells. This scenario is similar to Scenario 2 but includes installation of shallow desalination wells designed to reduce the salt load of the basin.

Figures 2.2-8 through 2.2-10 present potential monthly Zone 7 groundwater demands during drought under a variety of State Water Project delivery alternatives. These curves were used to help set groundwater development targets. Actual production rates modeled for each well for select scenarios are presented in Table 2.2-1.

2.3 Basinwide Water Level Impacts

This subsection presents an analysis of basinwide water level effects relative to historic lows. This analysis is important because Zone 7 has a goal of not drawing water levels down below historic lows. In addition, drawing water levels down to near or below historic lows can lead to land subsidence.

Figure 2.3-1 illustrates the difference between planned future "average" operating water levels in the basin and historic low water levels. This figure provides an estimate of "available drawdown," or the amount of drawdown that can occur in the future in various portions of the basin without exceeding historical low water levels. This value varies from about 50 feet in the north central portion of the Main Basin to more than 100 feet to the southwest and southeast. This range of water levels provides the bounds for the average available working storage of the basin.

Simulations were conducted using average pumping (pumping assumed constant through the year) and/or peak pumping (pumping varied month-to-month during the year). Although total pumpage over the year is the same in both simulations, drawdowns are marginally larger in the peak pumping case. Although peak monthly data are more representative of actual operating conditions, these data were not used in all simulations because they were generated towards the end of the study to fine-tune potential preferred alternatives.

The relationship between simulated water levels in the deep aquifer at the peak of the 1-year drought and historical lows is the impact of concern addressed in this section. In the discussion that follows, maps showing the *difference* between these water level elevations (i.e., modeled water level minus historic low) are presented and discussed. Water level elevation maps for the deep aquifer for select scenarios are presented in Appendix D.

2.3.1 Scenario 1: Existing Wells Only

Two variations of this scenario were assessed. Scenario 1a assumes all existing wells are fully operational, resulting in a total production capacity of about 32 mgd (Table 2.2-2). Scenario 1b assumes that two older wells in the Mocho Wellfield (Mocho-1 and Mocho-2) are no longer operational, reducing total production capacity to about 25 mgd.

Scenario 1a. Figure 2.3-2 provides a map of peak drawdown for the 1-year drought simulation using average pumpage. This figure indicates peak drawdown of as much as 80 feet in the north-central portion of the basin near the Mocho and Stoneridge Wellfields. Figures 2.3-3 and 2.3-4 show the difference between simulated water levels in the deep aquifer at the peak of the 1-year drought relative to historical lows; Figure 2.3-3 is based on average pumpage; and Figure 2.3-4 is based on peak monthly pumpage. These simulations indicate that maximum drawdowns are generally slightly larger (on the order of 10 feet) using peak monthly data (although areas of lesser drawdown are quite similar). More importantly, these results indicate that existing wells, when pumped at maximum operating rates to attempt to meet 1-year drought demands, will draw the basin down to below historical lows by as much as 20 to 30 feet.

Scenario 1b. Figure 2.3-5 shows water levels with respect to historical lows for the 1-year drought simulation based on peak monthly pumping but with a maximum total capacity for Zone 7 wells of 25 mgd. This would represent the situation if Mocho-1 and Mocho-2 are not used. This is a reasonable scenario since these wells are both fairly old and may soon fail or be retired from service. Results of this simulation indicate that, under this reduced demand, water levels are largely above historic lows except for an area north of the Stoneridge well that is about 10 feet below historic lows. This difference is within the uncertainty range of model results. However, even approaching historic low water levels can lead to subsidence problems and, therefore, this is not an absolute measure of safety. This issue is discussed in Section 2.4.

2.3.2 Scenario 2: Existing Wells Plus New Deep Aquifer Wells

The potential effects of new wells at as many as nine separate wellfield locations were evaluated during Scenario 2 simulations. These wellfields include the three existing wellfields and as many as eight potential new wellfields.

Scenario 2a. The purpose of Scenario 2a was to assess effects of new wellfields constructed to meet drought demands at year 2020 buildout with minimal State Water Project water (about 11 percent; Figure 2.2-10), resulting in groundwater demand of about 71 mgd. It was assumed that six new wellfields were constructed at locations shown in Figure 2.3-6. Existing wells were assumed to pump at their maximum capacities during the height of the drought and, thus, the least number of new wells are constructed. Mocho-1 and Mocho-2 are assumed to be abandoned (zero pumpage). Simulated discharge rates at existing wells and new wellfields for this simulation are presented in Appendix B and summarized in Table 2.2-1 and Table 2.2-2. Simulation results indicate that water levels at the height of the 1-year drought will be drawn down as much as 50 feet below historical lows in the northern portion of the main basin (Figure 2.3-6).

Scenario 2b. Because Scenario 2a drawdowns exceeded historical low water levels over relatively large areas, another scenario was developed and simulated to spread Zone 7 pumpage out more to try and avoid concentrated drawdown near the north-central portion of the basin. In this scenario, pumpage is reduced in existing wellfields and preferentially placed into outer wellfields (Tables 2.2-1 and 2.2-2). Three new "outer" well fields were simulated and one previous "inner" wellfield taken out of the simulation (Figure 2.3-7). Mocho-1 and Mocho-2 are assumed to be abandoned (zero pumpage).

Simulation results indicate that water levels at the height of the one year drought may be 10 to 20 feet below historical lows in the northern portion of the main basin during the peak of this 1-year drought (Figure 2.3-7). Although this simulation did not completely eliminate exceedance of historical lows, it does demonstrate that by increasing the number of outer wellfields and preferentially using these wellfields, water level impacts related to exceedance of historical low water levels can be mitigated.

Scenario 2c. This scenario was developed and simulated to assess basinwide water level impacts assuming lower production rates (55 mgd total) and a lesser number of wellfields to be constructed in the most favorable areas. Pumpage was distributed in a more even fashion than in the previous scenario although most pumpage is still from the new wellfields (Table 2.2-1 and Table 2.2-2). Mocho-1 and Mocho-2 are assumed to be abandoned (zero pumpage). Results of this simulation indicate that historical low water levels are still exceeded in the northern portion of the basin by as much as 20 to 30 feet during the peak of the 1-year drought (Figure 2.3-8).

Scenario 2d. This scenario focused on assessing how much water Zone 7 could pump while maintaining water levels above historical lows and assuming relatively few new wells are built (see Tables 2.2-1 and 2.2-2; model run number "Scen506c"). Results of this simulation indicate relatively minimal exceedance of historical low water levels at the height of the 1-year drought (see Figure 2.3-9). Results of modeling of the 6-year drought are presented as Figure 2.3-10. Based on these results, it appears that the basin can sustain about 45 mgd of groundwater production from Zone 7 wells during a 1-year drought with only minimal exceedance of historical low water levels. This assumes that pumpage at existing wellfields is maintained at about 18 mgd or less during these times.

A simulation was conducted to assess how this configuration of wells would work to meet maximum day demands if only enough new wells were constructed to meet drought demands of 45 mgd (run number "Scen805"). In this alternative, Zone 7's total instantaneous well capacity is about 52 mgd—25 mgd from existing Zone 7 wells and 27 mgd from new Zone 7 wells. The 25 mgd from existing Zone 7 wells represents the case if Mocho-1 and Mocho-2 are no longer in service, which is not unreasonable given their age. Modeling conducted as part of this study indicates that 52 mgd of production from these wells can be sustained for at least 4 days while maintaining water levels above historical lows (Figure 2.3-11). After 30 days of operation, water levels are significantly below historical lows in the northern portion of the basin (Figure 2.3-12)

Additional simulations were conducted using the basic Scenario 2d well configuration to assess potential wellfield configurations might be used to meet maximum day demands of about 70 mgd while avoiding drawdowns below historical lows (run numbers Scen801 through Scen806). Results of these simulations indicate that the system is most sensitive to the amount of pumpage from existing wellfields, and that if existing wells are pumped at about 15 mgd, then about 53 mgd can be pumped from new wellfields for prolonged periods of time (as much as 60 days) before historical lows are exceeded. Scen806 is the most successful in this respect, but would require a total of about 10-15 new wells to meet the 70 mgd target. Results of this simulation are presented in Figure 2.3-13.

Scenario 2e. Two additional simulations were conducted at the same total pumping rate as Scenario 2d to evaluate potential impacts under different wellfield configurations. The first simulation introduced a minimal number of new wells in all outer wellfields and is herein termed Scenario 2e (Tables 2.2-1 and 2.2-2). Results of this simulation for the 1-year drought are similar to Scenario2 d (Figure 2.3-14).

Scenario 2f. The third simulation conducted at the same total pumping rate as Scenario 2d introduced additional new wells in outer wellfields and is herein termed Scenario 2f (Tables 2.2-1 and 2.2-2). Results of this simulation for the 1-year drought are similar to Scenarios 2d and 2e, but with slightly more exceedance of drawdown below historical lows (Figure 2.3-15). This appears to be because more water is developed from the western portion of the basin, as opposed to eastern wellfields.

2.3.2.1 Summary of Scenario 2 Simulation Findings

Based on results discussed above, development of 45 mgd to meet drought demands could be achieved under a number of wellfield configurations, three of which were examined in this study. Implementation of this alternative will require installation of about five to 15 new wells. The fewest new wells are needed if the Chain of Lakes and Gravel Pit Wellfields can be heavily developed. Results of model run "Scen506c" are considered representative of these conditions and are used for impact analysis purposes; this model run is herein referred to as the "preferred alternative."

If Zone 7 decides to develop only enough water to meet drought demands (45 mgd), then its total instantaneous well capacity will be about 52 mgd—25 mgd from existing wells and 27 mgd from new wells. Modeling indicates that 52 mgd of groundwater production from these wells can be sustained for at least 4 days with water levels remaining above historical lows, but that after 30 days of operations, water levels are significantly below historical lows in northern portion of the basin (Section 2.3.2).

If maximum day demands of 70 mgd are to met for extended periods of time (30 days or more) then additional wells will need to be constructed in the eastern portions of the basin. The Chain of Lakes and Gravel Pit Wellfields are very favorable in this respect. Expanded use of these wellfields under the preferred alternative could allow Zone 7 to pump about 70 mgd from the basin for extended periods of time (about 60 days) without water level declines below historical lows. This would require installation of a total of about 10 to 15 new wells.

Further modeling would likely be successful in optimizing Scenario 2d well locations and pumpage distributions to reduce all exceedances to less than historical maximums. However, this implies a level of accuracy relative to actual future response of the system that is unreasonable given assumptions made during modeling. In addition, simply keeping water levels above observed historical lows will not necessarily prevent subsidence. This is discussed below. Therefore, results of this evaluation need to be viewed as a general guide as to how much groundwater might be produced from the basin, not an absolute answer. As new wells and wellfields are installed, they will need to be tested and their effects monitored to assess actual impacts. Wellfield construction activities and well operations can then be adjusted as needed.

2.3.3 Scenario 3: Existing Plus New Deep Wells Plus Shallow Desalination Wells

In Scenario 3, shallow desalting wells were included to meet a part of the groundwater demand. This scenario assumes about 51 mgd pumping from the deep aquifer and 4.5 mgd from the shallow. This run is analogous to Scenario 2c, except that a portion of the pumpage is shifted to the shallow aquifer. Simulation results indicate that water levels at the height of the 1-year drought are still as much as 50 feet below historical lows in the northern portion of the main basin during the peak of the one year drought (Figure 2.3-16).

2.4 Subsidence Potential

Results of groundwater modeling indicate that water levels in portions of the basin might be drawn down below historical low water levels under a number of operational scenarios. Drawdown to or near historical lows can lead to land subsidence. Zone 7 is currently conducting subsidence investigations that will better define these issues. The following subsections discuss the mechanics of land subsidence, land subsidence issues in the LVGB, and techniques for monitoring and managing subsidence.

2.4.1 Subsidence Theory

When a well is pumped in a confined aquifer the water levels in the surrounding aquifer/aquitard system are lowered with a resultant decrease in hydrostatic pressures and increase in grain-to-grain effective stresses. This increase in stress compresses the soil structure and results in ground subsidence. The rate and total amount of subsidence are dependent on a number of factors, including the amount and duration of drawdown, local geologic structures, and local changes in stratigraphy.

Of particular interest is the value of drawdown at which an aquifer/aquitard system changes from "elastic" to "inelastic" deformation. After the first cycle of historical drawdown, the change from elastic to inelastic deformation is typically coincident with the minimum historical heads (pore pressures) in aquitards interbedded and contiguous with pumped aquifers. When aquitard pore pressures in these zones decline below previous minima, the aquifer system releases a relatively large amount of water from "inelastic" aquitard storage but at the cost of relatively large amounts of land subsidence. When aquitard pore pressures are maintained above historic low pressures, a confined aquifer/aquitard system gains and releases water largely from elastic storage accompanied by relatively small movements of the land surface.

Historical low water levels (as measured in major aquifers) are often used as a guide of allowable pressure minima in the system; this is largely due to the fact that these are the only zones where abundant data are available. However, this approach assumes that the entire aquifer/aquitard system has fully equilibrated to these lower pressures, which is rarely the case. Aquitards generally drain slowly toward equilibrium with adjacent aquifers due to their relatively low permeability. Although some subsidence is expressed as soon as water levels begin to decline, full expression of subsidence within thicker aquitards can take a fairly long time, sometimes on the order of tens to hundreds of years or longer. This lag time in pore pressure equilibration is a function of the thickness of the aquitards and their degree of isolation from pumped aquifer zones. Because this equilibrium takes a long time to reach, as water levels approach historic lows, the possibility of inelastic subsidence increases. Historic low water elevations can therefore be used as a guide to the limit of elastic response but not as an absolute reference.

As discussed above, land subsidence is much greater during inelastic deformation. In the Santa Clara Valley, reducing groundwater pressures to inelastic regions (as defined by declines below historical low water levels) resulted in subsidence on the order of 5 percent of the associated decline below historic lows. Much of this subsidence was inelastic (i.e., permanent). When pressures within this aquifer/aquitard systems were maintained above historical lows, the subsidence was much less, typically on the order of about 0.5 percent of the associated drawdown and was largely elastic (i.e., temporary).

2.4.2 Subsidence Potential in the LVGB

Groundwater modeling conducted as part of this study indicates that the area near and north of the Mocho and Stoneridge wellfields is the most prone to drawdowns below historical low water levels. This is largely due to the presence of the Camps Park Fault north of these wells, which appears to form a groundwater flow barrier. Such a flow barrier could also lead to differential subsidence, which is of particular concern because it can cause localized deformation that can stress overlying structures. Current subsidence investigations will provide a better understanding of local relationships between pumpage, water levels, and subsidence.

2.4.3 Subsidence Monitoring

Because water levels within portions of the LVGB are prone to declining below historical lows even when pumping existing Zone 7 wells, it is recommended that subsidence monitoring be implemented using some combination of survey points, satellite imagery (InSAR), and/or extensometers. Extensometers are especially useful since they provide extremely precise and near-real-time data that are very useful in managing wellfields prone to subsidence. The most favorable location for an extensometer in the LVGB would be near the Mocho and Stoneridge Wellfields, since available information indicates this area has the greatest potential to reach historical low water levels.

Survey points can provide high-quality data at select locations though typically only at periodic intervals on the order of months due to cost constraints. This technique would be useful in accurate definition of subsidence at and near key wells and other important structures. These points would need to be surveyed regularly during both pumping and non-pumping seasons to assess the amount of subsidence and rebound. InSAR is used to cover broad swaths of an area to evaluate potential subsidence and, in some cases, can be used to evaluate historical subsidence as far back as the early 1990s. Thus, InSAR may be able to be used to assess patterns of subsidence on a broader scale and through time. Final recommendations will be made upon completion of ongoing subsidence investigations.

Mitigating subsidence is relatively straightforward—simply raise groundwater levels. This can be accomplished by reducing groundwater pumpage and/or recharging the aquifer. Subsidence observations from a properly implemented monitoring program can be used to identify water level conditions under which subsidence becomes problematic. At this point, pumping rates could be adjusted to limit subsidence to safe and acceptable levels. As stated above, extensometers are particularly useful in this regard since they provide near-real-time information.

2.5 Water Level Impacts at Individual Wells

MODFLOW calculates the "average" water level over the area of a model cell, not the water level within a well in the cell. Actual water levels within a pumping well are lower than modeled values for two main reasons: cell size effects and well efficiency effects. Cell size effects arise from the difference between well diameters (on the order of 18 inches) and the size of the model cell over which the pumping is averaged (500 feet in the case of the LVGB model). Well efficiency effects stem from the fact that the model assumes that the well is 100-percent efficient, whereas actual well efficiencies are lower due to damage that occurs near the well bore during well construction. Due to these effects, water levels in an actual well during pumping are lower than estimates provided by analytical or numeric models.

For purposes of this study, cell size effects were addressed using the approach described in the text *Applied Groundwater Modeling* (Anderson and Woessner, 1992). This approach provides an estimate of additional drawdown present at a well within a model cell based on pumping rate, transmissivity, well radius, and model cell size. This calculated value is then added to model calculated values of drawdown to increase the accuracy of the estimate of water levels *near* (not in) a well. Well construction information used to support this analysis is provided in Table 2.5-1. Results of adjusted drawdown calculations are presented in Appendix E and summarized in Table 2.5-2.

To estimate water levels *inside* the well, the well efficiency was assumed to be equal to 80 percent. This is a relatively high value but is in line with measurements obtained at the Mocho-3 and Mocho-4 wells following redevelopment (CH2M HILL, 2001b). The amount of additional head loss present inside the well due to this inefficiency was calculated based on operating production rates and specific capacities. For example, Hopyard-6 has an operating capacity of 3,600 gpm and a specific capacity of 100 gpm/ft. This leads to an estimated drawdown of 36 feet during operation. Twenty percent of this 36 feet (7 feet) is assumed to be well loss. This 7 feet was added to model estimates to better approximate water levels inside the well during operation. Measured values of specific capacity were used for existing wells. For future wells, modeled specific capacity data were calculated based on results of single-well simulations (Appendix G). Well efficiency adjustments are summarized in Table 2.5-2.

As a check on the reasonableness of the above corrections, modeled specific capacity data for the Mocho wellfield area were compared to observed values (Appendix E). Mocho-1 through Mocho-4 have increasingly deep tops of well screens, which correlate with decreasing specific capacities (Table 2.5-1; Appendix E). As can be seen in the figure in Appendix E, specific capacity estimates based on adjusted water levels provide a better estimate of specific capacity relative to unadjusted values.

2.5.1 Near-well Impacts Relative to Historical Low Water Levels

Modeled water levels during the peak of the 1-year drought were adjusted for cell size (but not well efficiency) effects described above and results compared to historic lows. This provides an analysis of potential declines to below historical lows very near the well (as opposed to a broader area). Results from this comparison are provided in Table 2.5-2 and indicate that water levels *near* some wells drop below historic lows. In many instances, this simply reflects larger-scale effects discussed above. However, whereas previous results for Scenario 2d indicate water levels will remain above historic lows near the Mocho wells, this analysis indicates that historical lows may be exceeded near the well at times of peak drawdown. This significance of this needs to be evaluated as part of the ongoing subsidence investigations.

2.5.2 Well Impacts Relative to Pump Settings

Enough water must remain above a pumps suction point to maintain an adequate net positive suction head to prevent cavitation and/or breaking suction during operation. This value varies from well to well, but it should generally be in the range of about 10 to 20 feet for local municipal wells. Pumps may need to be lowered if such symptoms appear. This is generally not a problem from a technical perspective unless the casing is telescoped, and the lower casing is too small to accept the pump. Municipal wells in the LVGB generally do not have shallow telescoping diameters and, therefore, the primary potential impact is economic (i.e., costs associated with resetting pumps).

Modeled water level lows for the 1-year drought were adjusted for both cell size effects *and* well efficiency and then compared against pump settings. If adjusted water levels were within 10 feet of pump suction, the result was flagged (Table 2.5-3). Results indicate that adjusted water levels remain above the tops of existing pump settings at all wells for all scenarios, but that Pleasanton-5 has only a minimal amount of water above the pump (Table 2.5-3). Scenario 2d and Scenario 2c have the least impact in this respect.

2.5.3 Well Impacts Relative to Screen Elevations

Municipal water supply production wells are typically designed and constructed so that water levels inside the well will remain above the uppermost well screen during operation. This is done to avoid potential problems with cascading water that can lead to air entrainment, which can adversely affect pump operation and life and can also lead to problems in the distribution system and customer complaints.

Adjusted modeled water levels drop below tops of well screens at a number of wells in select scenarios: Hopyard-6, Mocho-1, Pleasanton-5, and Pleasanton-7. Modeled drawdown at Hopyard-6 is probably over-estimated because the model transmissivity does not accurately reflect aquifer test data at this well. Response at the other wells, especially at the City of Pleasanton wells, is relatively small and certainly within the range of model uncertainty. Based on model results, the above wells might experience cascading water during peak drought periods. Scenario 2d and Scenario 2c have the least impact in this respect.

2.5.4 Well Interference Impacts

Potential water level impacts from individual new wells on surrounding areas (“well interference”) was assessed by simulating “typical” wells at each wellfield operating at estimated peak pumping rates. Time-drawdown and distance-drawdown graphs were then constructed for each of these wells to assess potential local water level impacts. This information is also useful in determining well spacing within new wellfields. The distance-drawdown graphs were constructed at a time representing 10 days of pumping since this is when most of the drawdown has been expressed. Results of this analysis are presented in Appendices E and F and summarized in Figure 2.5-1.

Results of this analysis indicate that new wells will typically cause a 10-foot to 20-foot impact at a distance of about 500 feet from the well. This provides an initial estimate for well spacing in the wellfields. In the Gravel Pit Wellfield, wells might be spaced more closely, perhaps 200 feet or less apart. Aquifer tests need to be conducted after each new well is completed to better define well spacing requirements. In addition, it is important to note that this impact is additive for each well and, therefore, cumulative from a wellfield perspective.

2.6 Groundwater Quality Trends

The District is developing a Salt Management Plan for the local groundwater basin. To assess potential effects of new wellfields on salt movement and quality of pumped groundwater, three transport simulations were conducted to represent the three basic Well Master Plan scenarios:

Scenario 1: Existing Wells Only. Scenario 1 reflects current conditions or conditions if new wellfields are built but operated infrequently.

Scenario 2: Existing Wells Plus New Deep Aquifer Wellfields. Scenario 2 reflects conditions if new deep aquifer wellfields are constructed and used on an equal basis with existing wells to meet baseload demand. No shallow desalting wells are constructed in this scenario. The Scenario 2 transport simulation assumes that new wells are placed in all potential new wellfields except Isabel and Stanley Avenue.

Scenario 3: Existing Wells Plus Shallow Desalting Wells. Scenario 3 uses Scenario 1 as a basis but adds shallow desalination wells.

Results of transport simulations are presented as chemographs in Figures 2.6-1 through 2.6-7 and maps of TDS distribution in the deep aquifer as Figures 2.6-8 through 2.6-11. Maps for TDS distribution in the shallow aquifer for these same conditions are presented in Appendix G.

Simulation results indicate that installation and use of new deep aquifer wells at potential new wellfields has relatively little effects on TDS distribution. Some wells indicate slight increases in TDS concentrations when new wells are installed and used on a regular basis, but the effect is relatively minor (less than 50 parts per million [ppm] TDS difference; compare Figures 2.6-1 and 2.6-2). Installation of shallow desalting wells has the greatest effect, and leads to a relatively large benefit in terms of reducing overall TDS in the basin, while also lowering TDS of pumped groundwater at some deep aquifer production wells (Figures 2.6-3, 2.6-6, and 2.6-11).

TDS trends at the desalting wells themselves are highly variable and reveal the need to refine locations prior to installation of these wells (Figure 2.6-7). For example, there is little long-term benefit from desalting wells where TDS decreases to less than 500 ppm after several years of operation. In these cases, the groundwater model should be used to optimize well locations to maximize salt removal. In addition, modeling indicated the tendency for the shallow system to “dry out.” Shallow wells in early water quality model simulations tended to “go dry,” and the number of wells, their locations, and associated pumping rates had to be modified to keep the wells saturated. This information should be considered when the shallow aquifer desalting well system is designed.

2.7 Modeling Summary

Results of this modeling conducted in support of the Well Master Plan effort indicate that:

- Zone 7 can produce about 45 mgd of groundwater from the basin during modeled drought periods with only minimal exceedance of historical low water levels and relatively few new wells. This alternative could be achieved under a variety of wellfield configurations. Scenario 2d makes extensive use of the Chain of Lake and Gravel Pit Wellfields and is herein referred to as the “preferred alternative.” This same wellfield could be used to meet peaking needs of 52 mgd for about four days to a week or two, assuming that existing wells are pumped no more than about 18 mgd.

- Additional groundwater yield is possible by expanding preferred alternative wellfields in the Chain of Lakes and Gravel Pit areas and further reducing pumpage at existing wellfields. The local aquifer system is most sensitive to the amount of pumpage from existing wellfields. If existing wells are pumped at about 15 mgd, then about 53 mgd can be pumped from new "outer" wellfields under this configuration for prolonged periods of time (as much as 60 days) before historical lows are exceeded.
- The area in and north of the Mocho and Stoneridge Wellfields is the most susceptible to declines below historical lows under modeled conditions. Accordingly, this area currently appears the most prone to subsidence. Of particular concern in this area is the potential for differential subsidence along the Camp Parks Fault. Accordingly, it is recommended that subsidence monitoring be implemented using a combination of survey points, satellite imagery, and/or extensometers.
- Individual "typical" new wells will cause a maximum of about 10- to 20-foot drawdown at a distance of about 500 feet. This is commonly referred to as "well interference" and can be used as a guide to well spacing. Aquifer tests need to be conducted after each new well is completed to better define these values.
- Installation and use of new deep aquifer wells has relatively little effect on TDS distribution and produced water quality. Installation of shallow desalting wells has the greatest effect and leads to a relatively large benefit in terms of reducing overall TDS in the basin and lowering TDS of pumped groundwater at individual production wells. The benefits of desalting wells appear sensitive to location. Therefore, individual well locations should be optimized using the groundwater model and test wells. Of special concern is ensuring that the shallow wells remain saturated. Shallow wells in early water quality model simulations tended to "go dry," and the number of wells, their locations, and associated pumping rates had to be modified to keep the wells saturated.

Scenario	Scenario-1: Existing Wells Only			Scenario-2: New Wellfields							Scenario-3: New Wellfields + Desalting Wells
	1a	1a	1b	2a	2b	2c	Scenario-2d				3
Run:	504	504a	504b	503a	503c	503f	506c	507	508	806	502a
Hopyard-7											
Hopyard-6	-3,600	-3,600	-3,600	-3,600	-999	-1,998	-3,600	-3,600	-3,600	-2,997	-1,998
Hopyard-9	-1,300	-1,300	-1,300	-1,300	-999	-1,300	-1,300	-1,300	-1,300	-1,499	-1,300
Mocho-1	-2,400	-2,400	-1,998								
Mocho-2	-2,300	-2,300	-1,805								
Mocho-3	-4,100	-4,100	-3,693	-4,100	-999	-1,998	-2,498	-2,498	-2,498	-1,499	-1,998
Mocho-4	-3,700	-3,700	-3,700	-3,700	-999	-1,998	-2,795	-2,795	-2,795	-1,499	-1,998
Stoneridge	-4,700	-4,700	-4,005	-4,700	-999	-1,998	-2,844	-2,844	-2,844	-2,997	-1,998
Bernal-1				-5,995	-5,995	-1,998	-2,498	-1,998	-1,998	-1,998	-1,998
Bernal-2								-999	-999		
Bernal-3									-999		
Busch-Valley				-1,998	-1,998	-3,997	-1,998	-999	-999	-1,998	-3,997
Busch-Valley_2									-999		
Chain of Lakes-1				-7,410	-7,410	-6,994	-2,997	-2,997		-3,997	-5,995
Chain of Lakes-2							-2,997	-2,997		-3,997	
Chain of Lakes-3										-3,997	
Chain of Lakes-4										-4,996	
Gravel Pit-1				-7,993	-7,993	-6,994	-2,997	-999	-999	-3,997	-5,995
Gravel Pit-2							-2,997	-2,997	-2,997	-3,997	
Gravel Pit-3							-2,498	-999		-3,997	
Gravel Pit-4										-3,997	
Gravel Pit-5									-1,998		
Isabel-1								-999	-999		
Isabel-2									-999		
Martin Ave (Lake-I)				-1,998	-1,998	-1,998					-1,998
Stanley Ave-1					-4,135			-999	-999		
Stanley Ave-2					-4,135			-999	-999		
Stanley Ave-3									-999		
Valley/Harvest Park-1					-10,130			-999	-999		-5,995
Valley/Harvest Park-2									-999		
Valley-1				-5,995							
Valley-2						-6,943					
Desalting_1											-155
Desalting_2											-155
Desalting_3											-155
Desalting_4											-155
Desalting_5											-155
Desalting_6											-155
Desalting_7											-155
Desalting_8											-155
Desalting_9											-155
Desalting_10											-155
Desalting_11											-155
Desalting_12											-155
Desalting_13											-155
Desalting_14											-155
Desalting_15											-155
Desalting_16											-155
Desalting_17											-155
Desalting_18											-155
Desalting_19											-155
Desalting_20											-155
TOTAL	**-22,100**	**-22,100**	**-20,102**	**-48,789**	**-48,789**	**-38,217**	**-32,020**	**-32,020**	**-32,020**	**-47,459**	**-38,370**

Capacity Summary.xls - - Data-gpm - - 10/13/2003

TABLE 2.2-1
MAXIMUM ZONE 7 WELL/WELLFIELD
PRODUCTION RATES (GPM) FOR SELECT SCENARIOS

ZONE 7 WATER AGENCY
WELL WATER PLAN

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Scenario	Run	Existing Z7 Capacity			Additional New Well Capacity	Total Z7 Capacity			Comments
		Avail	Used	Idle		Avail	Used	Idle	
Scenario-1: Existing Wells									
1a	**504**	31.9	31.9	0.0	0.0	31.9	31.9	0.0	Average monthly pumping. Total max Z7 well Q=32 mgd
1a	**504a**	31.9	31.9	0.0	0.0	31.9	31.9	0.0	Peak monthly pumping. Total max Z7 well Q=32 mgd
1b	**504b**	31.9	25.1	6.8	0.0	31.9	25.1	6.8	Turn off Mocho-1 and Mocho-2. Total max Z7 well Q now is 25 mgd.
Scenario-2: Existing Wells + New Wells									
2a	**503a**	31.9	25.1	6.8	45.2	77.1	70.3	6.8	Turn off Mocho-1 & Mocho-2
2b	**503c**	31.9	7.2	24.7	63.1	95.0	70.3	24.7	Construct more wellfields. Turn off Mocho-1 & Mocbo-2. Reduce Q in other existing wells
2c	**503f**	31.9	13.4	18.5	41.7	73.6	55.1	18.5	Reduce peak Z7 pumpage to 55 mgd w/ "reasonable" wellfields.
2d	**506c**	31.9	17.9	14.0	27.4	59.3	45.3	14.0	Reduce peak Zone 7 pumpage to 45 mgd. Turn off Mocho-1 and Mocho-2. Use minimal new wells.
	805	31.9	25.1	6.8	27.4	59.3	52.5	6.8	*Max day demand simulation:* all wells on at max rates
	806	31.9	15.1	16.8	53.1	85.0	68.2	16.8	*Max day demand simulation:* Cut back existing well Q and drill additional new wells in outer wellfields
2e	**507**	31.9	17.9	14.0	27.1	59.0	45.0	14.0	Put at least one well in all outer wellfields
2f	**508**	31.9	17.9	14.0	27.4	59.3	45.3	14.0	Put at least two wells in all outer wellfields
Scenario-3: Existing Wells + New Wells + Desalting Wells									
3	**502a**	31.9	13.4	18.5	37.2	69.1	50.6	18.5	Add in an additional 5 mgd of shallow desalting pumpage to these values

Capacity Summary.xls - - Data Summary - - 10/13/2003

TABLE 2.2-2
SUMMARY OF SELECT MODEL SIMULATIONS
(ALL VALUES IN MGD)
ZONE 7 WATER AGENCY
WELL WATER PLAN

Well Name	Wellhead Elevation	Total Depth	Casing				Well Screen Intervals								Pump Setting	Operating Q	Specific Capacity	Transmissivity	
			Prod Dia	Tele-scope	Prod Bottom Depth	Lower Dia	upper 1	lower 1	upper 2	lower 2	upper 3	lower 3	upper 4	lower 4	Depth			AQ Test	From Sc
		feet	inch		ft bgs	inch	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	ft bgs	gpm	gpm/ft	gpd/ft	gpd/ft
Hopyard-6	335	500	18				158	164	180	192	215	235	280	490	345	3,600	100	175,000	200,000
Hopyard-9	325	315	18	X	198	12	233	283	293	308					210	1,300	10	100,000	20,000
Mocho-1	345	530	16				150	270	330	510					210	2,400	278	450,000	556,000
Mocho-2	345	575	18				250	330	450	570					210	2,300	165	325,000	330,000
Mocho-3	340	500	20				310	335	355	410	468	493			285	4,100	58	140,000	116,000
Mocho-4	340	745	20				510	530	545	610	620	730			460	3,700	23	60,000	46,000
Stoneridge	345	820	20				250	290	405	425	480	500	515	800	470	4,700	125	200,000	250,000
Pleasanton-5	345	650	18	X	325	12	149	180	201	212	228	265	278	650	160	2,150	116	?	232,000
Pleasanton-6	345	647	18	X	365	14	165	365	371	625	625	647			uncertain	2,150	109	?	218,000
Pleasanton-7	318	480	18				120	440							no pump	0	35	?	70,000
Pleasanton-8	355	500	20				200	230	272	292	320	380	400	495	240	3,700	46	160,000	92,000
CWS-24	420	?					?								?	2,000	*20*	?	
CWS-20	435	?					?								?	2,000	*20*	?	
San Francisco North	320	?					?								?	2,000	*20*	?	
San Francisco Middle	320	?					?								?	2,000	*20*	?	
San Francisco South	320	?					?								?	2,000	*20*	?	
Bernal North	330						200	630							300	3,000	81		
Bernal South	330						200	630							300	2,000	12		
Busch Valley	350						200	650							300	3,000	70		
Chain of Lakes	380						230	780							330	4,000	110		
Gravel Pit	380						230	780							330	3,000	125		
Harvest Park	330						180	630							280	3,000	95		
Martin Avenue	360						260	810							360	2,000	40		
Valley Avenue	330						180	630							280	3,000	95		

Impact Summary for modeling v3.xls -- Construct data -- 10/13/2003

TABLE 2.5-1
WELL CONSTRUCTION INFORMATION
ZONE 7 WATER AGENCY
WELL WATER PLAN

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Well	Operating Q	Specific Capacity	Calc DD at Operating Q	Cell Size Adjustment	Well Loss (80% eff)	"Typical" Future Operating WLs (610j)	Historic Low WL	Modeled water level lows at peak of drought (ft msl)							Water levels near wells relative to historic low (adjusted for cell size; data in feet)						
															Scenario-1a	Scenario-1b	Scenario-2a	Scenario-2b	Scenario-2c	Scenario-2d	Scenario-3
	gpm	gpm/ft	feet	DD adjustment (feet)		ft msl	ft msl	504a	504b	503a	503c	503f	506c	502a	504a	504b	503a	503c	503f	506c	502a
Hopyard-6	3,600	100	36	**17**	7	266	190	176	200	153	190	185	193	188	**-31**	**-7**	**-54**	**-17**	**-22**	**-14**	**-19**
Hopyard-9	1,300	10	130	**13**	26	276	186	208	228	183	195	200	225	204	9	29	**-15**	**-3**	2	27	5
Mocho-1	2,400	278	9	**9**	2	278	216	197	222	181	210	207	232	211	**-27**	**-2**	**-44**	**-15**	**-17**	8	**-14**
Mocho-2	2,300	165	14	**7**	3	280	210	203	227	185	211	209	235	213	**-14**	10	**-32**	**-7**	**-8**	18	**-4**
Mocho-3	4,100	58	71	**13**	14	276	216	189	214	170	206	201	224	204	**-40**	**-15**	**-59**	**-23**	**-28**	**-5**	**-25**
Mocho-4	3,700	23	161	**12**	32	277	219	191	216	172	207	202	226	206	**-41**	**-16**	**-60**	**-24**	**-30**	**-6**	**-26**
Stoneridge	4,700	125	38	**15**	8	284	225	199	222	174	215	208	232	212	**-42**	**-19**	**-67**	**-26**	**-32**	**-9**	**-29**
Pleasanton-5	2,150	116	19	**6**	4	287	204	227	243	196	209	213	243	217	17	33	**-14**	-1	3	33	7
Pleasanton-6	2,150	109	20	**6**	4	287	204	227	243	196	209	213	243	217	17	34	**-13**	-1	4	33	8
Pleasanton-7	0	35	0	**0**	0	277	180	209	228	184	195	201	225	204	29	48	3	15	20	45	24
Pleasanton-8	3,700	46	80	**12**	16	312	225	268	278	230	237	238	260	243	31	41	**-7**	0	1	23	6
CWS-24	2,000	20	100	**8**	20	353	239	330	333	289	281	294	300	299	83	86	41	33	46	52	51
CWS-20	2,000	20	100	**12**	20	363	204	343	345	309	302	313	319	318	127	130	93	86	97	103	102
San Francisco North	2,000	20	100	**6**	20	287	177	232	247	187	186	209	237	213	49	63	3	2	26	54	29
San Francisco Middle	2,000	20	100	**6**	20	287	178	233	248	194	193	212	241	216	49	63	10	8	28	56	31
San Francisco South	2,000	20	100	**6**	20	287	178	233	248	195	194	213	241	216	49	63	11	9	28	56	31
Bernal North	3,000	81	37	**8**	7	287	177	232	247	185	184	209	237	212	47	62	0	-1	24	52	27
Bernal South	2,000	12	167	**19**	33	294	177	254	263	234	233	242	263	244	57	67	38	37	46	67	48
Busch Valley	3,000	70	43	**8**	9	306	221	255	268	214	226	220	250	224	26	39	**-15**	**-3**	**-9**	21	**-5**
Chain of Lakes	4,000	110	36	**13**	7	343	216	316	320	241	232	250	265	260	87	92	12	3	21	36	31
Gravel Pit	3,000	125	24	**8**	5	337	215	309	314	239	234	250	264	259	86	91	16	10	27	41	36
Harvest Park	3,000	95	32	**9**	6	290	180	228	244	199	182	198	242	204	39	55	10	**-6**	9	53	15
Martin Avenue	2,000	40	50	**13**	10	301	217	239	255	194	215	214	253	218	8	24	**-37**	**-15**	**-16**	22	**-13**
Valley Avenue	3,000	95	32	**9**	6	287	203	223	241	183	210	213	242	217	11	29	**-30**	**-3**	0	30	4

NOTES:

Adjusted T from model (typically increased) based on observed information (aquifer test, Sc, or similar data)

Cell size	500	feet
Well diameter	18	inches
Effective well radius	104	feet

Water levels at wells from Surfer Grid files using resisdual command
original data stored in "Residual file xy.xls"

Impact Summary for modeling v3.xls -- Adjusted WL data -- 10/13/2003

TABLE 2.5-2
ADJUSTED WATER LEVEL ELEVATIONS
ZONE 7 WATER AGENCY
WELL WATER PLAN

Well Name	Pump Setting Elev	Top of Sceen Elev	Water above pump (feet)									Water above top of uppermost well screen (feet)								
			"Typical" Future Operating WLs	Historic Low WL	Scenario-1a	Scenario-1b	Scenario-2a	Scenario-2b	Scenario-2c	Scenario-2d	Scenario-3	"Typical" Future Operating WLs (610j)	Historic Low WL	Scenario-1a	Scenario-1b	Scenario-2a	Scenario-2b	Scenario-2c	Scenario-2d	Scenario-3
	ft msl	ft msl	**0**		504a	504b	503a	503c	503f	506c	502a			504a	504b	503a	503c	503f	506c	502a
Hopyard-6	-10	177	276	200	162	185	139	176	171	178	174	89	13	**-25**	**-2**	**-48**	**-11**	**-16**	**-9**	**-13**
Hopyard-9	115	92	161	71	54	74	30	42	46	71	50	184	94	77	97	53	65	69	94	73
Mocho-1	135	195	143	81	52	77	35	65	62	87	65	83	21	**-8**	17	**-25**	5	2	27	5
Mocho-2	135	95	145	75	58	82	39	65	64	90	68	185	115	98	122	79	105	104	130	108
Mocho-3	55	30	221	161	107	132	88	124	119	142	122	246	186	132	157	113	149	144	167	147
Mocho-4	-120	-170	397	339	267	291	247	283	278	302	281	447	389	317	341	297	333	328	352	331
Stoneridge	-125	95	409	350	301	324	276	317	310	334	314	189	130	81	104	56	97	90	114	94
Pleasanton-5	185	196	102	19	32	48	**1**	14	19	48	23	91	8	21	37	**-10**	3	8	37	12
Pleasanton-6		180	287	204	217	233	186	199	203	233	207	107	24	37	53	6	19	23	53	27
Pleasanton-7		198	277	180	209	228	184	195	201	225	204	79	**-18**	11	30	**-14**	**-3**	3	27	6
Pleasanton-8	115	155	197	110	125	135	86	94	95	117	100	157	70	85	95	46	54	55	77	60
CWS-24												353	239	302	305	260	253	265	272	271
CWS-20												363	204	311	313	277	270	281	287	286
San Francisco North					206	220	160	159	183	211	186	287	177	206	220	160	159	183	211	186
San Francisco Middle					207	221	168	166	186	214	189	287	178	207	221	168	166	186	214	189
San Francisco South					207	221	169	167	186	215	190	287	178	207	221	169	167	186	215	190
Bernal North	30	130	257	147	187	202	140	139	164	192	167	157	47	87	102	40	39	64	92	67
Bernal South	30	130	264	147	171	180	152	150	160	180	161	164	47	71	80	52	50	60	80	61
Busch Valley	50	150	256	171	188	201	147	159	153	183	157	156	71	88	101	47	59	53	83	57
Chain of Lakes	50	150	293	166	246	250	170	162	179	194	189	193	66	146	150	70	62	79	94	89
Gravel Pit	50	150	287	165	246	251	176	170	187	201	196	187	65	146	151	76	70	87	101	96
Harvest Park	50	150	240	130	162	179	134	117	133	177	139	140	30	62	79	34	17	33	77	39
Martin Avenue	0	100	301	217	216	232	171	192	191	230	195	201	117	116	132	71	92	91	130	95
Valley Avenue	50	150	237	153	158	176	117	144	148	177	152	137	53	58	76	17	44	48	77	52

Impact Summary for modeling v3.xls -- Impacts -- 10/13/2003

TABLE 2.5-3
POTENTIAL WATER LEVEL IMPACTS AT INDIVIDUAL MUNICIPAL WATER SUPPLY WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN

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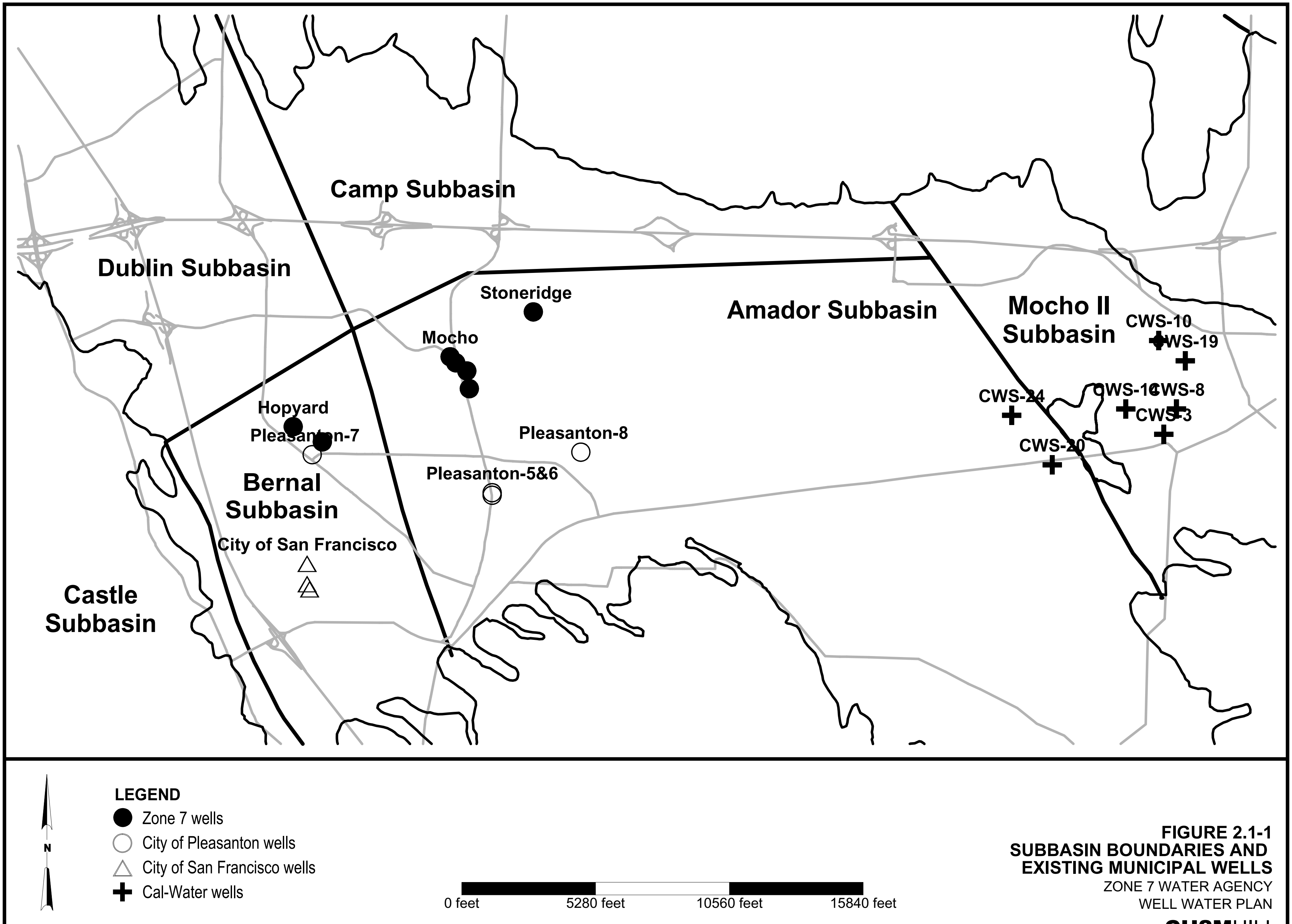
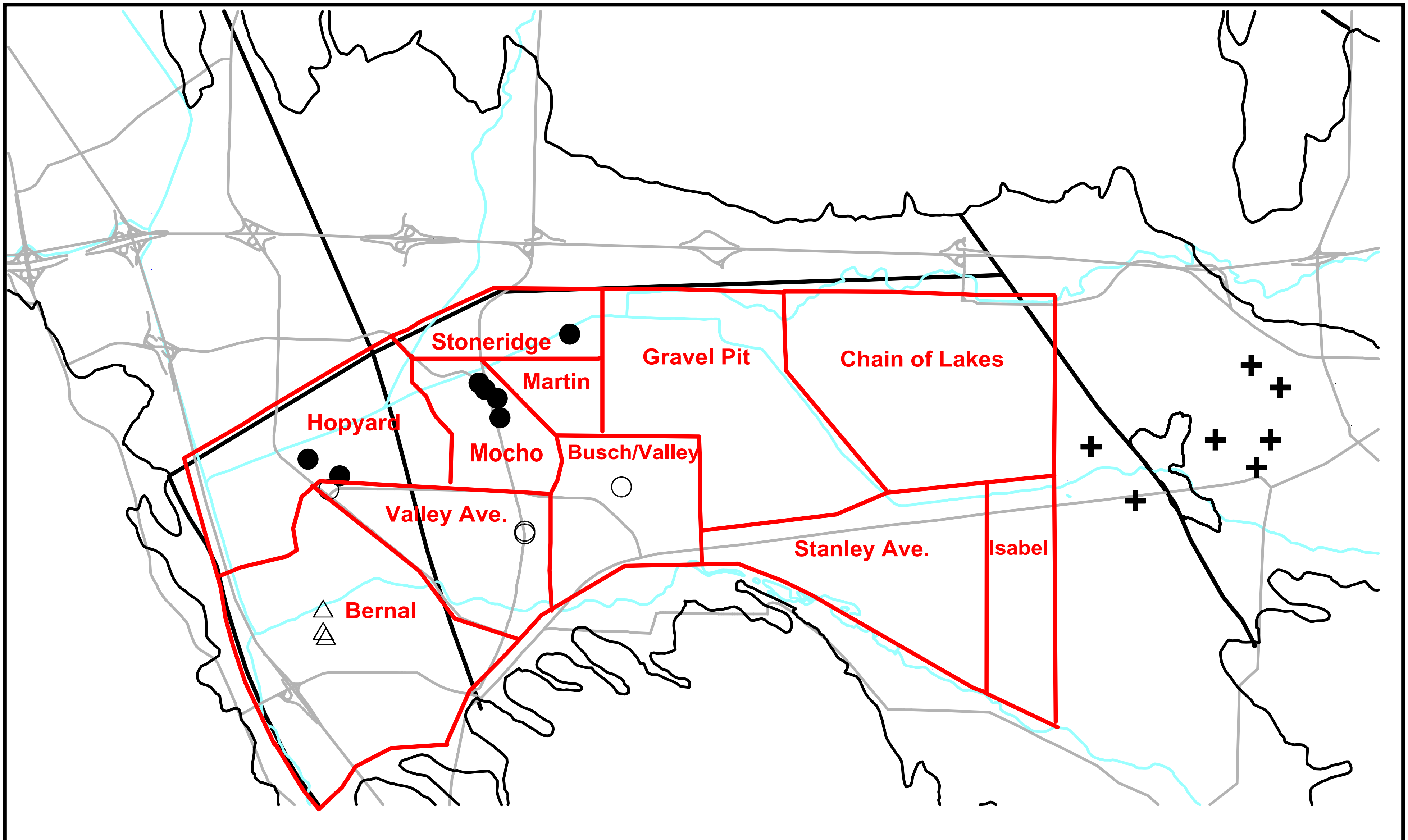


FIGURE 2.1-1
SUBBASIN BOUNDARIES AND EXISTING MUNICIPAL WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.1-1_10/10/03_ccc



N

LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.1-2
POTENTIAL NEW
WELLFIELD LOCATION
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.1-2_10/10/03_ccc

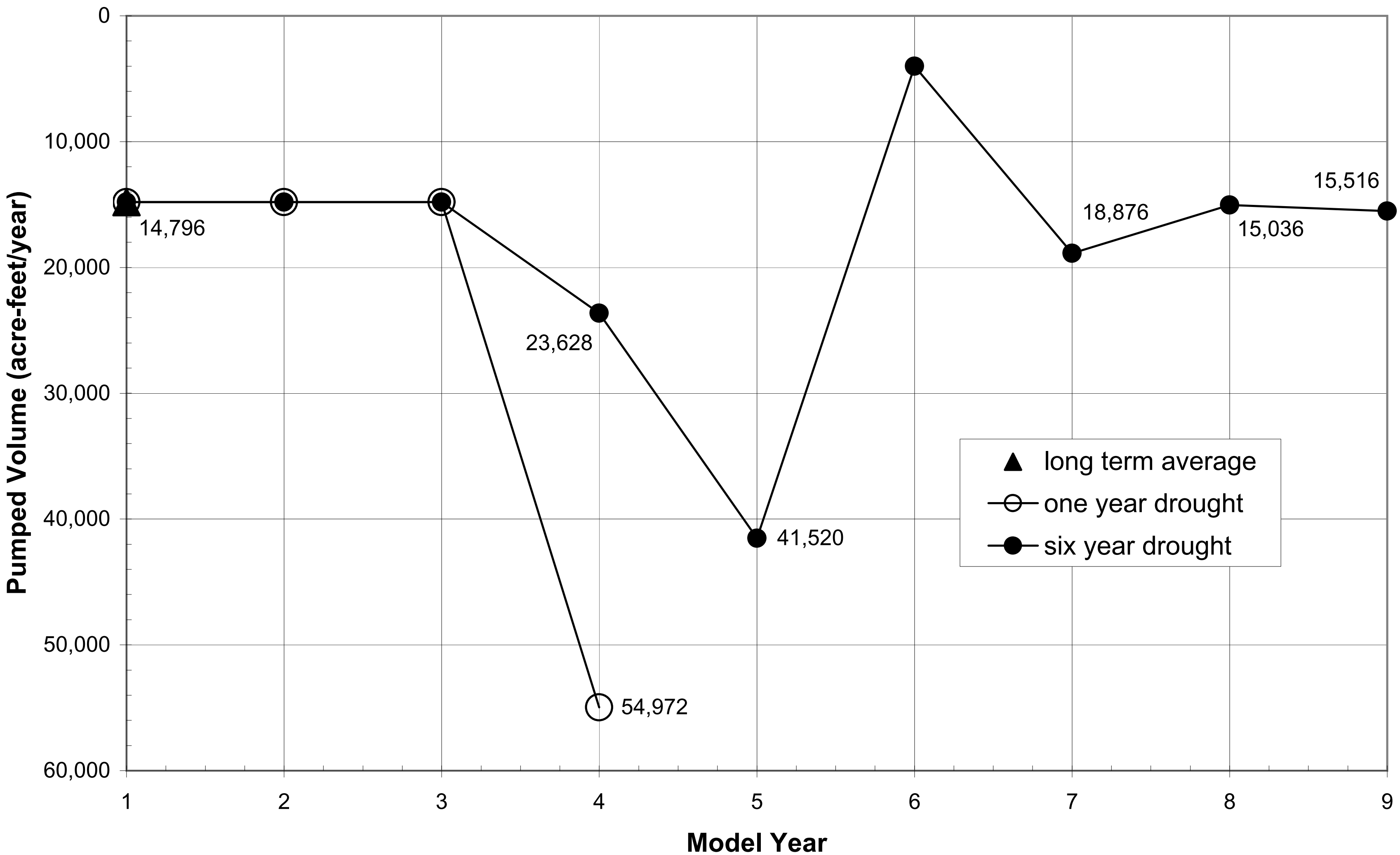


FIGURE 2.2-1
ZONE 7 PUMPAGE ASSUMPTIONS FOR MODEL SCENARIOS BASED ON 70 MGD MAXIMUM PUMPING CAPACITY
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.2-1_10/10/03_ccc

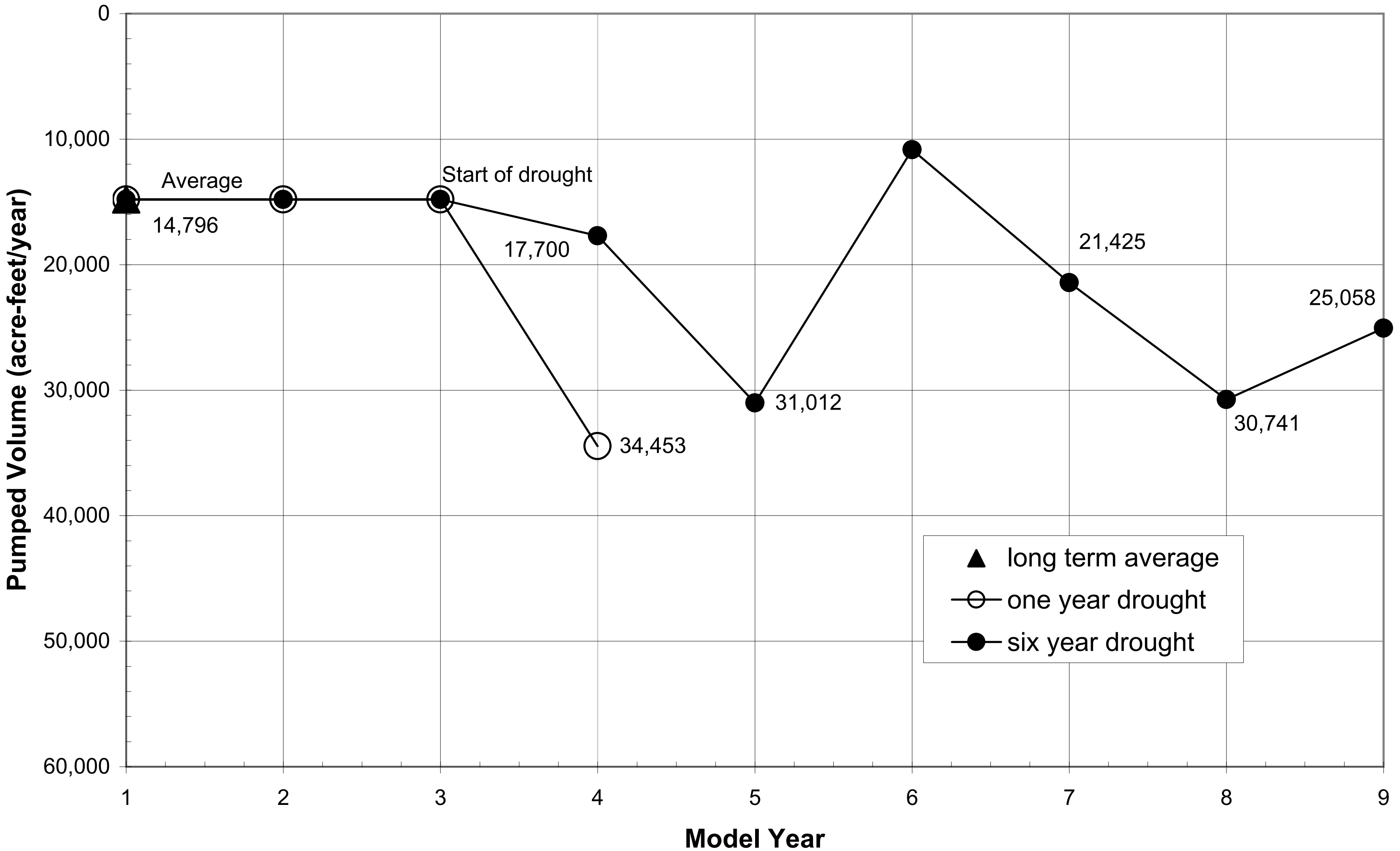


FIGURE 2.2-2
ZONE 7 PUMPAGE ASSUMPTIONS FOR MODEL SCENARIOS BASED ON 45 MGD MAXIMUM PUMPING CAPACITY
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

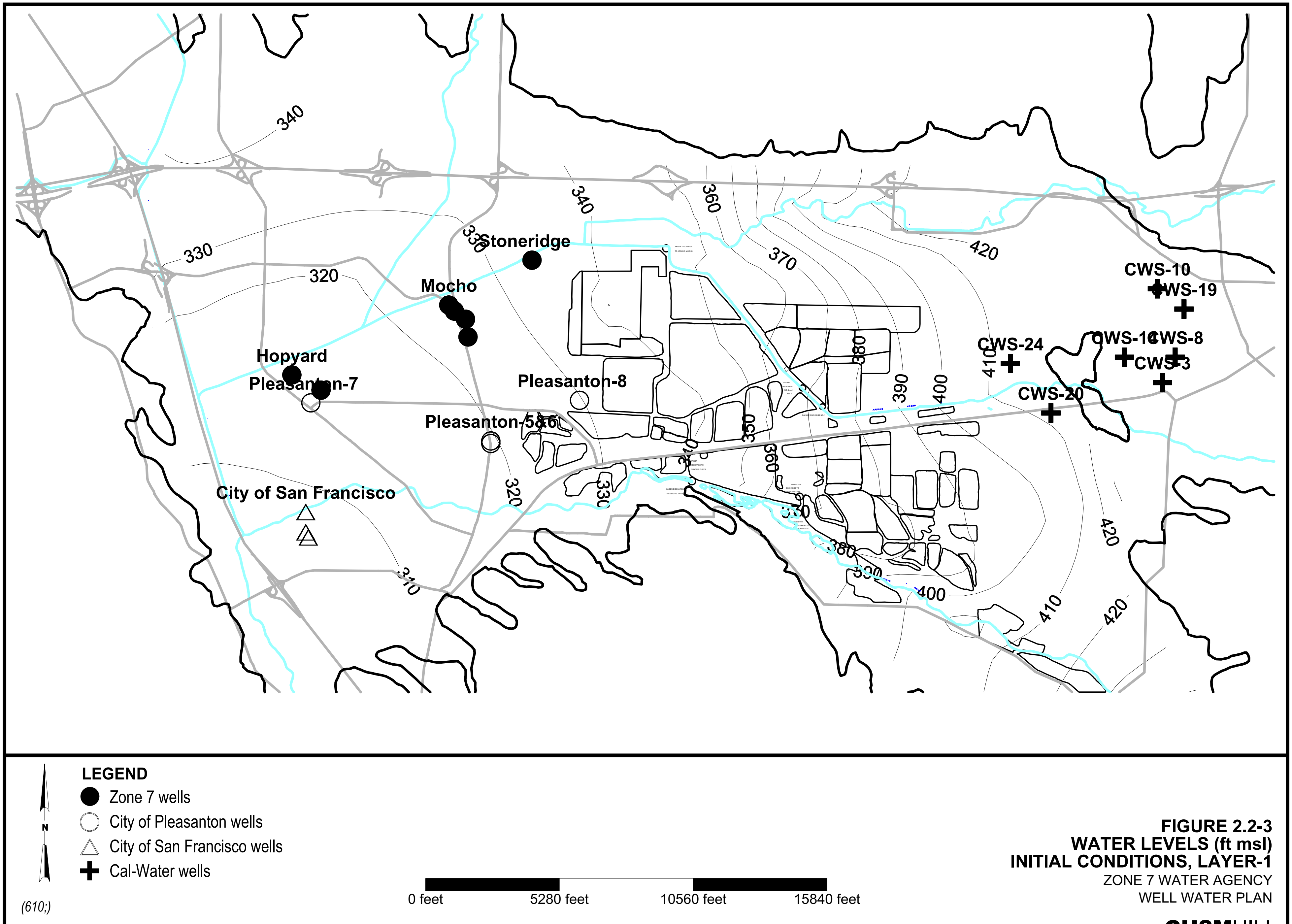


FIGURE 2.2-3
WATER LEVELS (ft msl)
INITIAL CONDITIONS, LAYER-1
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.2-3_10/10/03_ccc

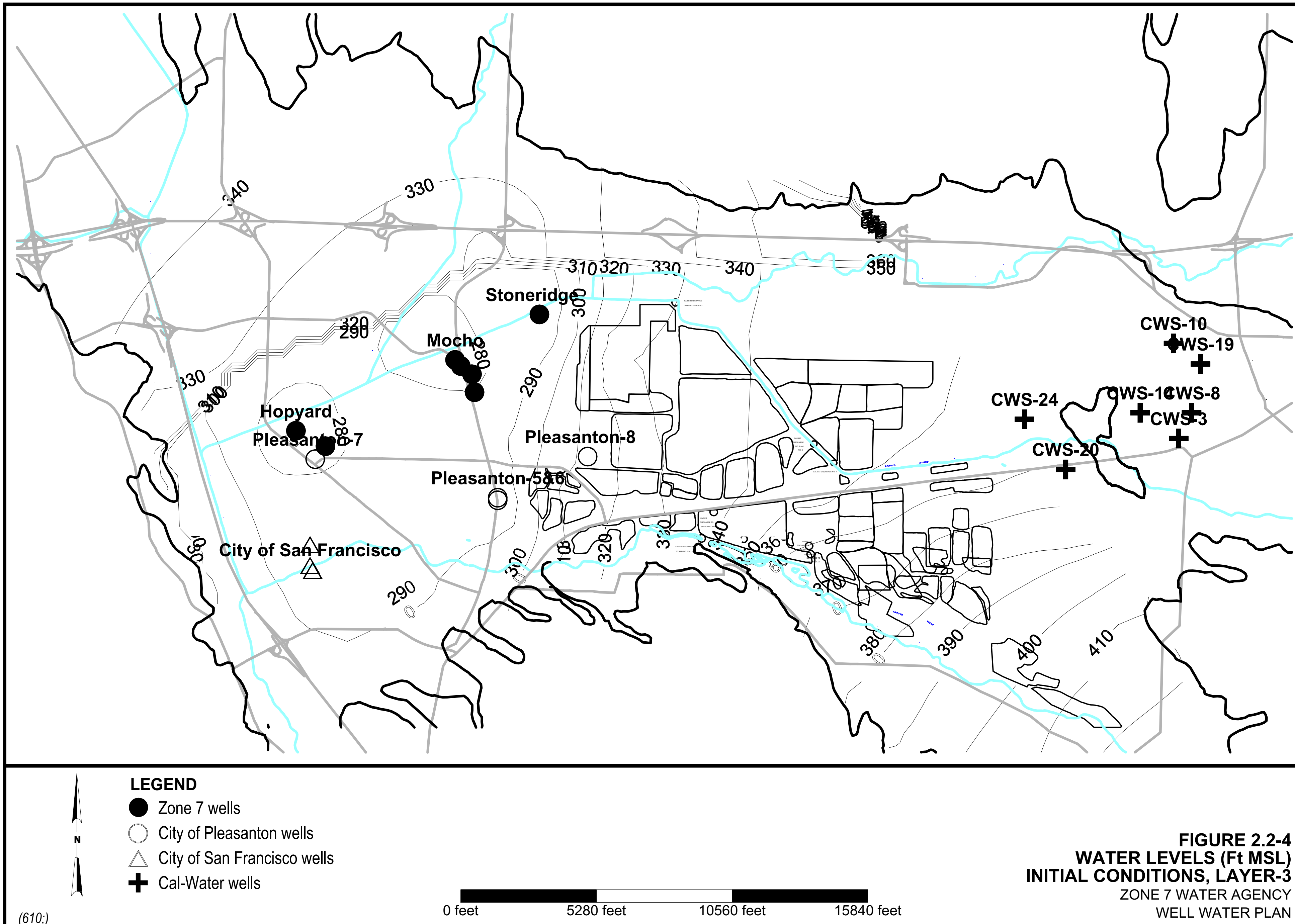


FIGURE 2.2-4
WATER LEVELS (Ft MSL)
INITIAL CONDITIONS, LAYER-3
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.2-4_10/10/03_ccc

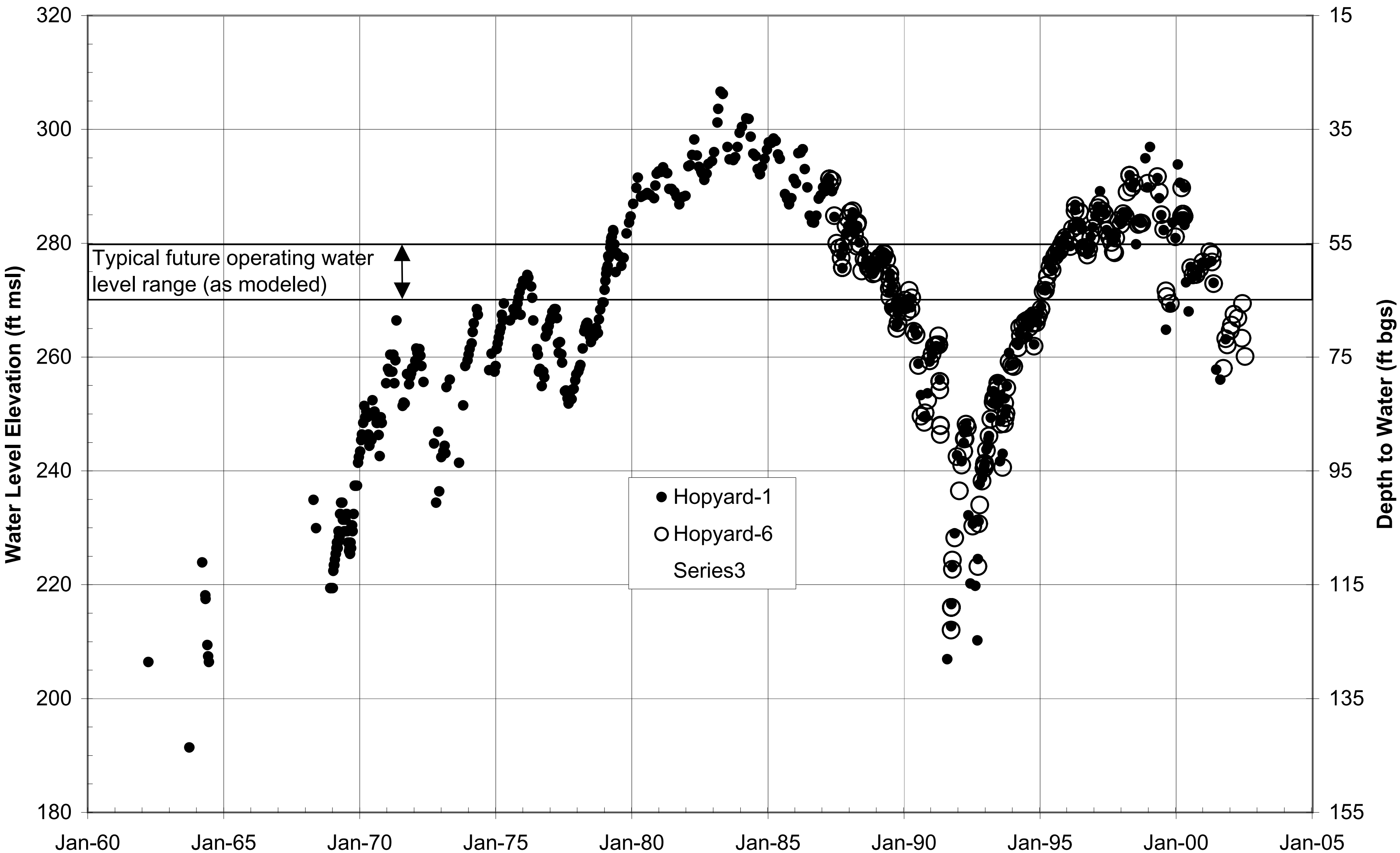
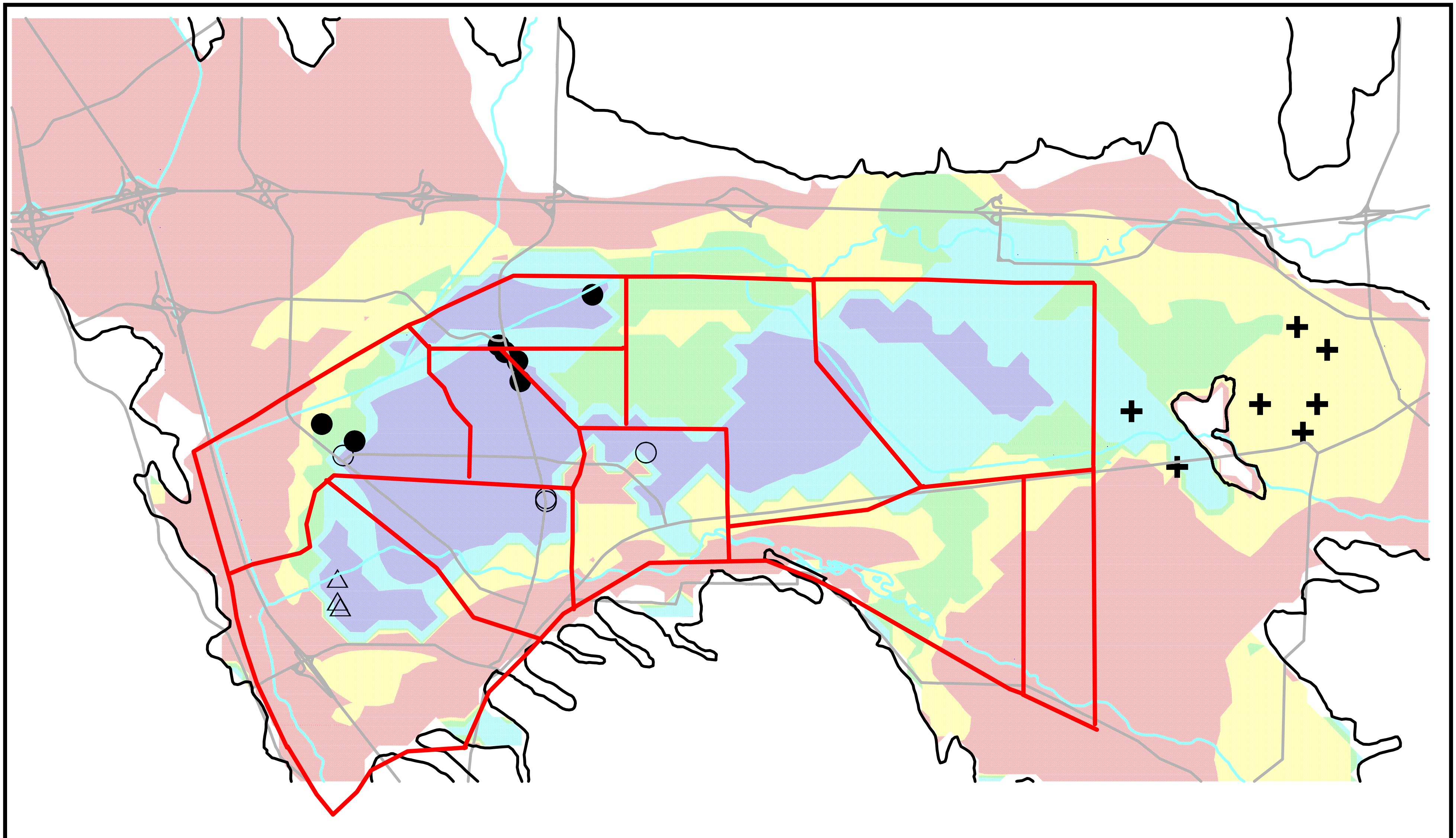


FIGURE 2.2-5
HYDROGRAPH OF HOPYARD-1
AND HOPYARD-6
ZONE 7 WATER AGENCY
WELL WATER PLAN

Hop 6 and Hop 1 WLs.XLS -- Chart2 -- 10/06/2003

CH2MHILL



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

N

5,000 25,000 50,000 100,000 300,000

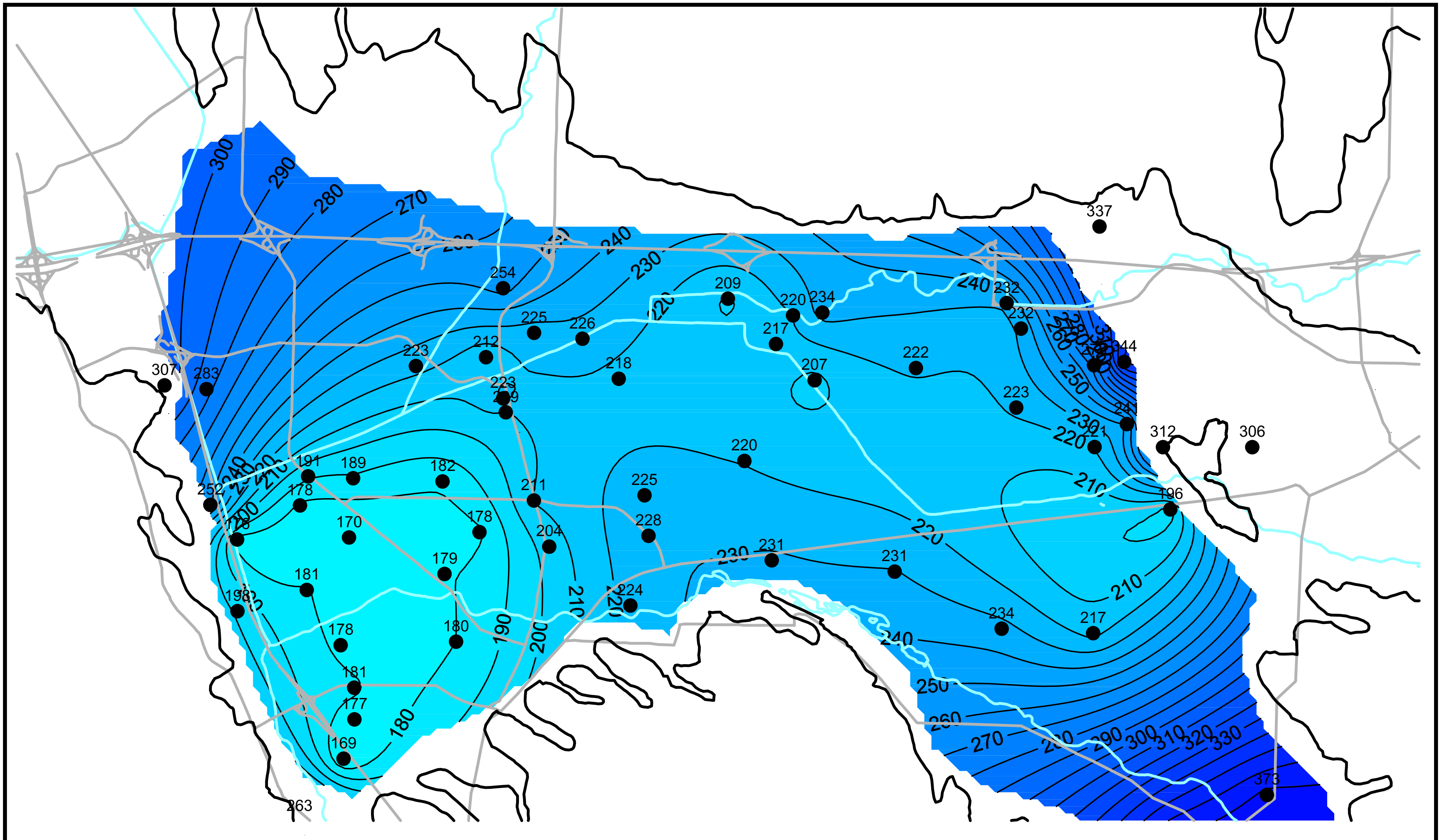
(gpd/ft)

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.2-6
TRANSMISSIVITY DISTRIBUTION IN THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.2-6_10/10/03_ccc



LEGEND

● Observation Well

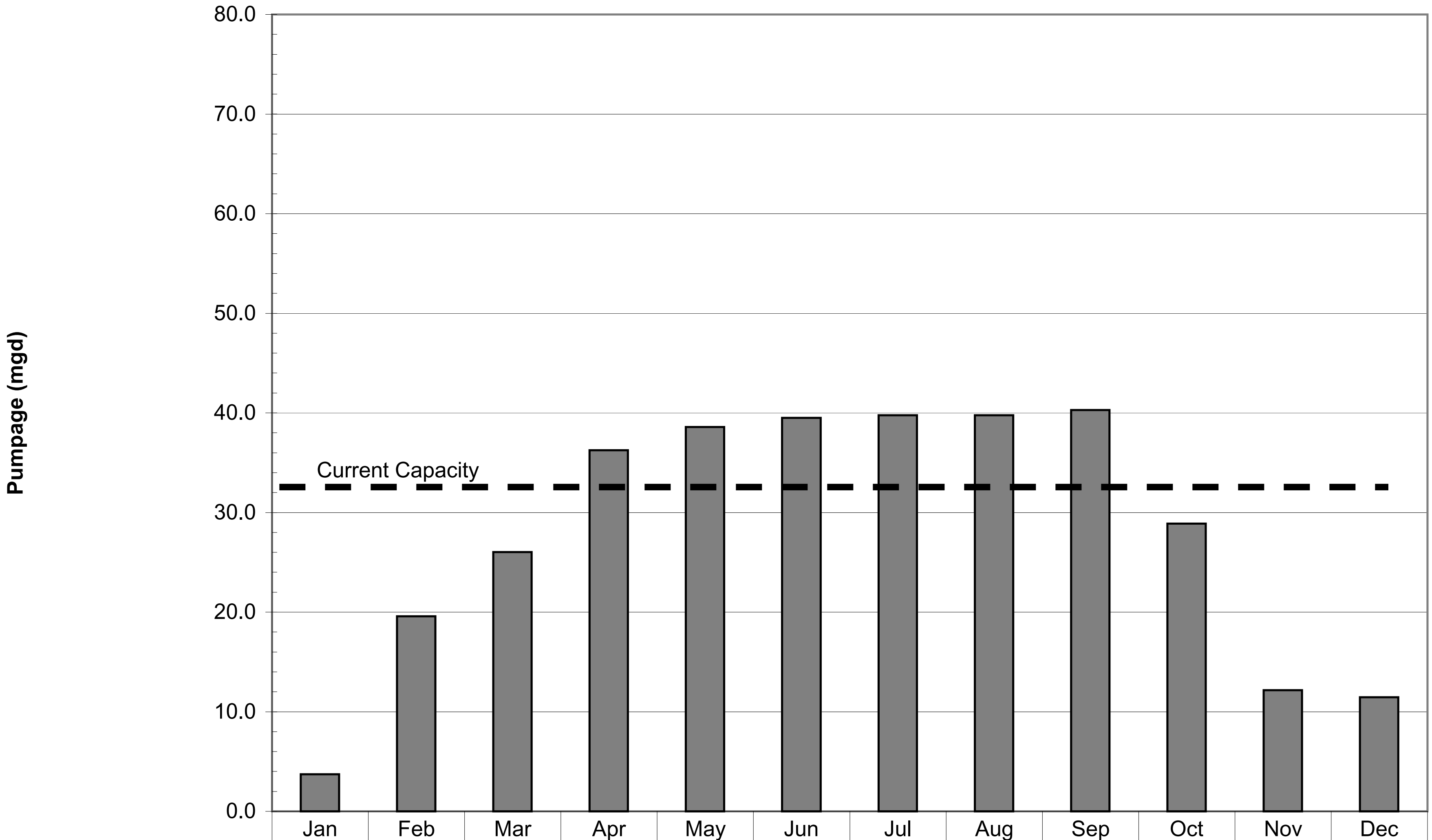
N

0 feet | 5280 feet | 10560 feet | 15840 feet

FIGURE 2.2-7
HISTORIC COMPOSITE LOW WATER LEVELS IN THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

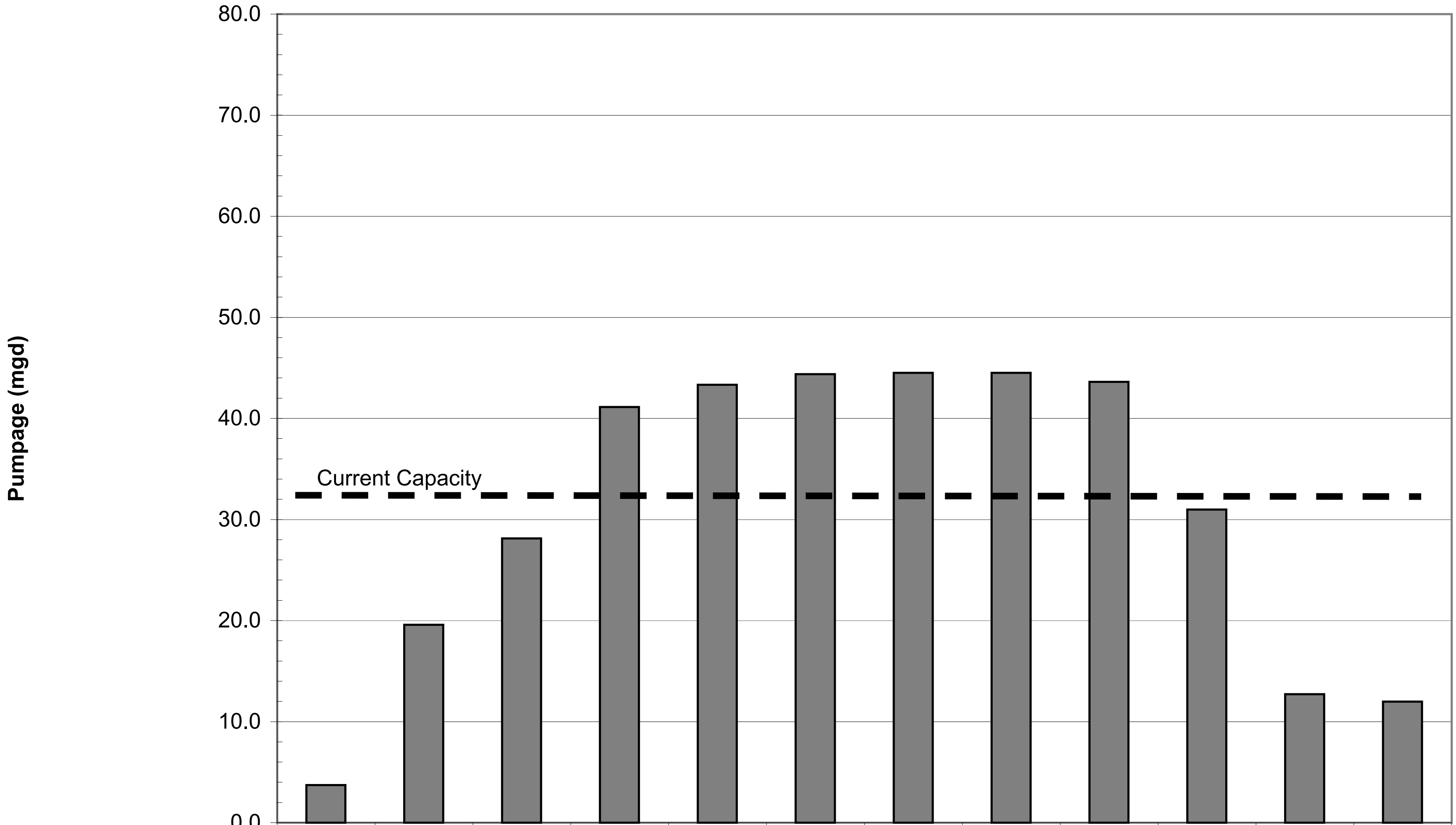
163304.WM.06_W102003001SFO_Z7 FIGURE ES-2-2 w OBs_10/23/03_mai



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
■ Total GW Production	3.7	19.6	26.0	36.2	38.6	39.5	39.8	39.8	40.3	28.9	12.2	11.5

FIGURE 2.2-8
ZONE 7 GROUNDWATER PUMPAGE DURING PEAK OF DROUGHT 24% SWP DELIVERIES & 2020 DEMAND
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

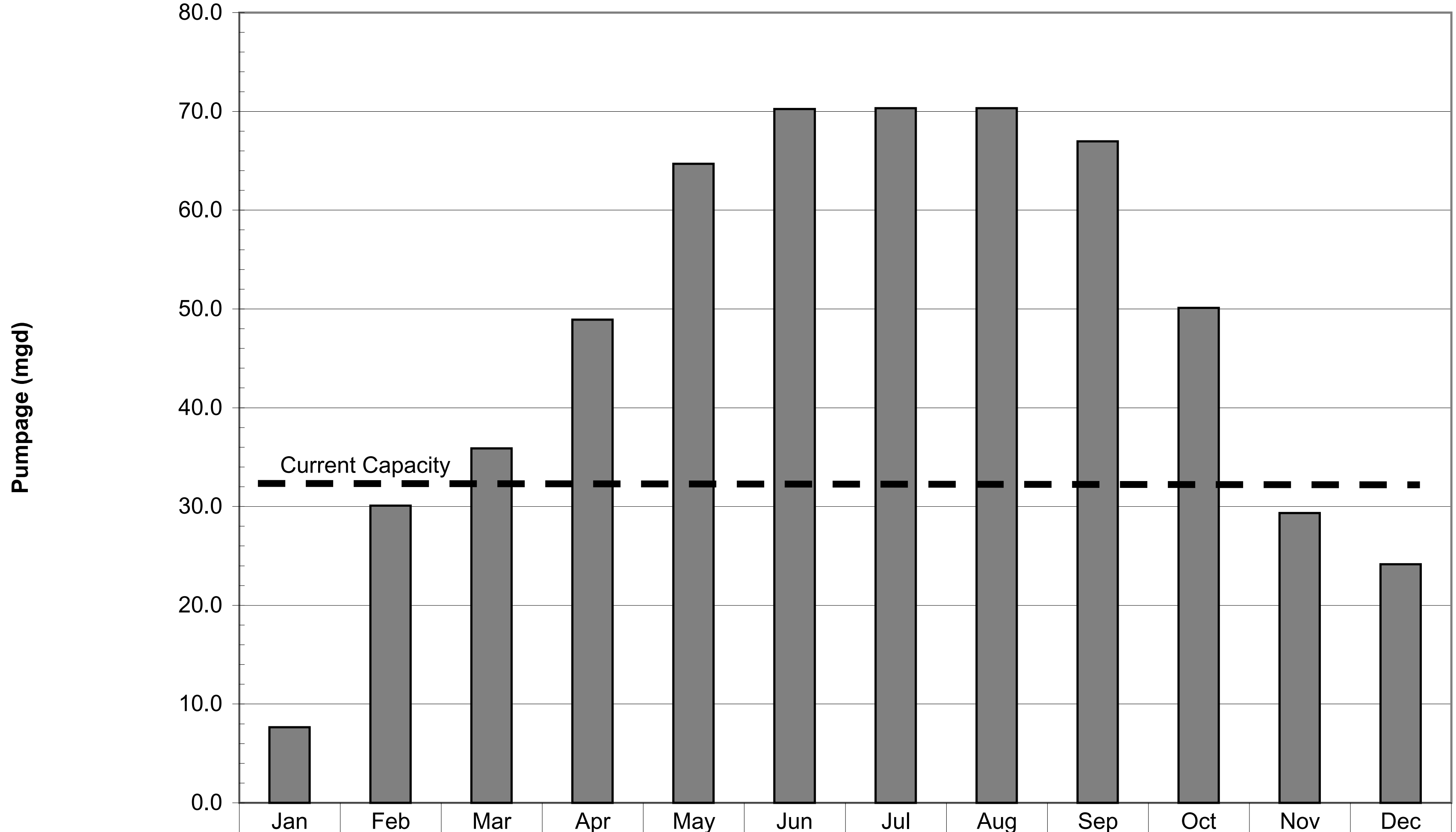


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total GW Production	3.7	19.6	28.1	41.1	43.3	44.4	44.5	44.5	43.6	31.0	12.7	12.0

FIGURE 2.2-9
ZONE 7 GROUNDWATER PUMPAGE DURING PEAK OF DROUGHT 20% SWP DELIVERIES & 2020 DEMAND
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

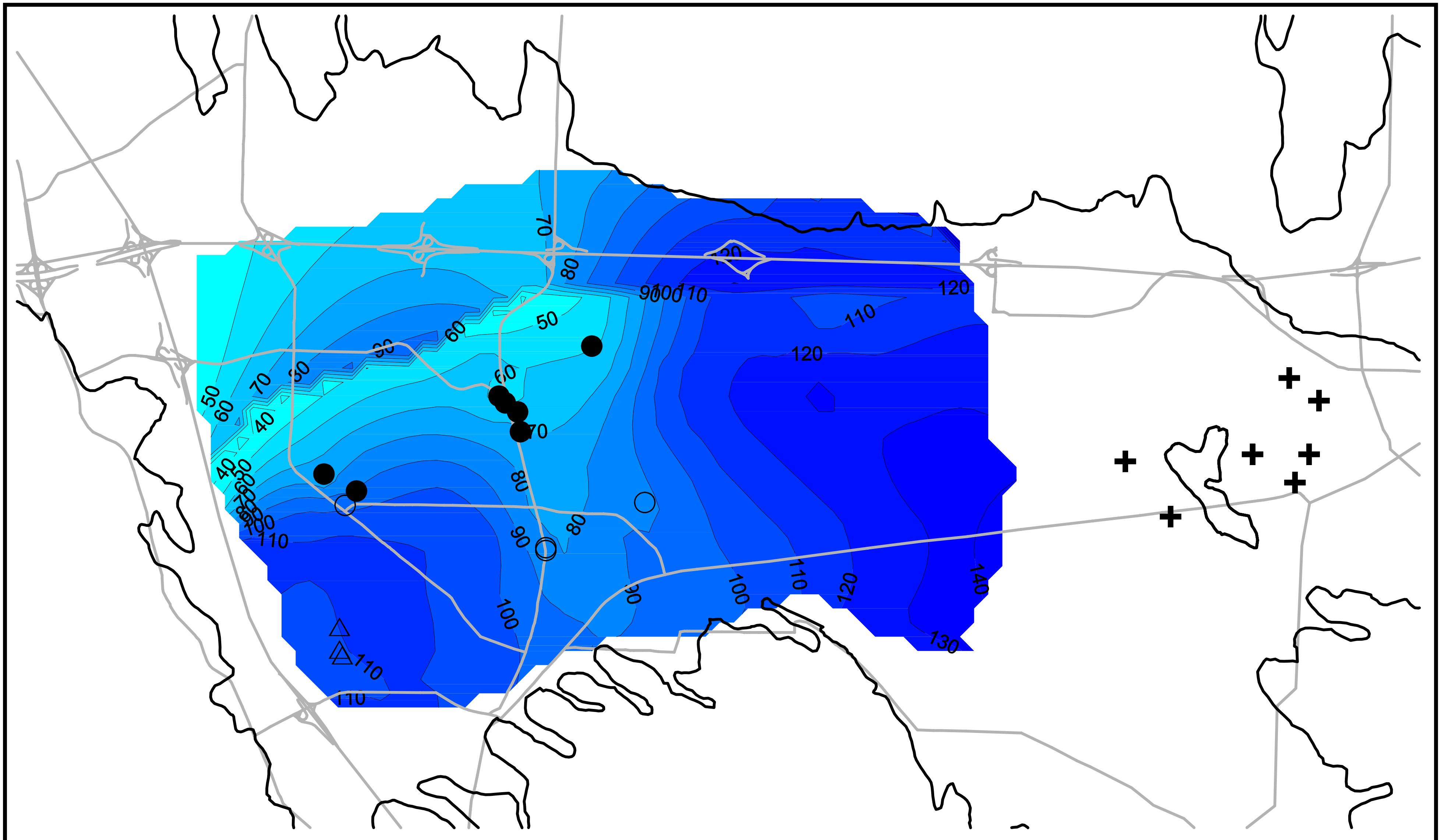
163304.WM.06_W102003001SFO_Z7 FIGURE 2.2-9_10/13/03_ccc



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total GW Production	7.7	30.1	35.9	48.9	64.7	70.2	70.3	70.3	67.0	50.1	29.3	24.2

FIGURE 2.2-10
ZONE 7 GROUNDWATER PUMPAGE DURING PEAK OF DROUGHT 11% SWP DELIVERIES & 2020 DEMAND
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL



N

LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

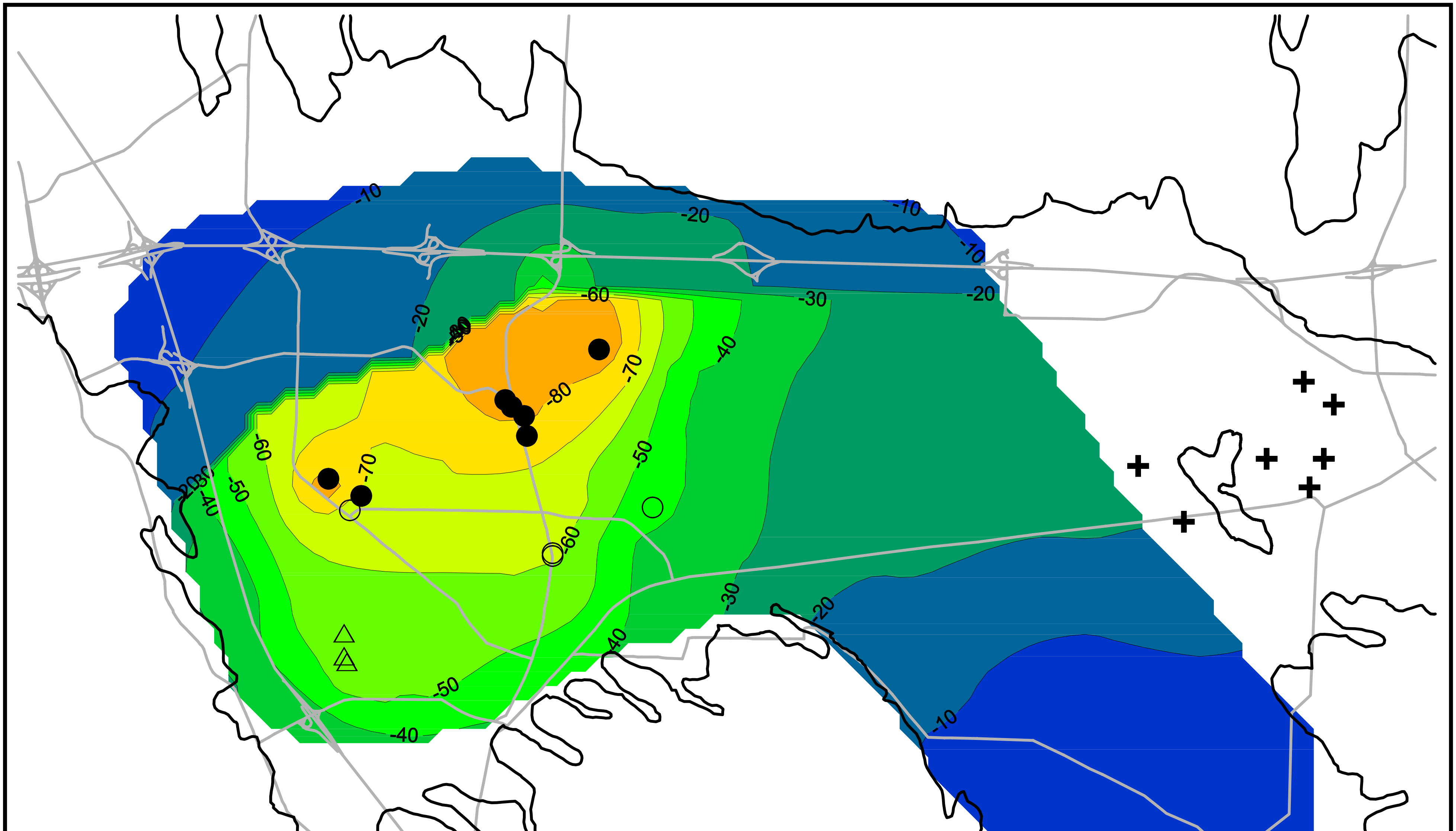
0 feet | 5280 feet | 10560 feet | 15840 feet

FIGURE 2.3-1
WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER AVERAGE FUTURE CONDITIONS MINUS HISTORICAL LOW

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 3-4-1_10/08/03_ez_sfo



LEGEND

- ● Zone 7 wells
- ○ City of Pleasanton wells
- △ City of San Francisco wells
- ✚ Cal-Water wells

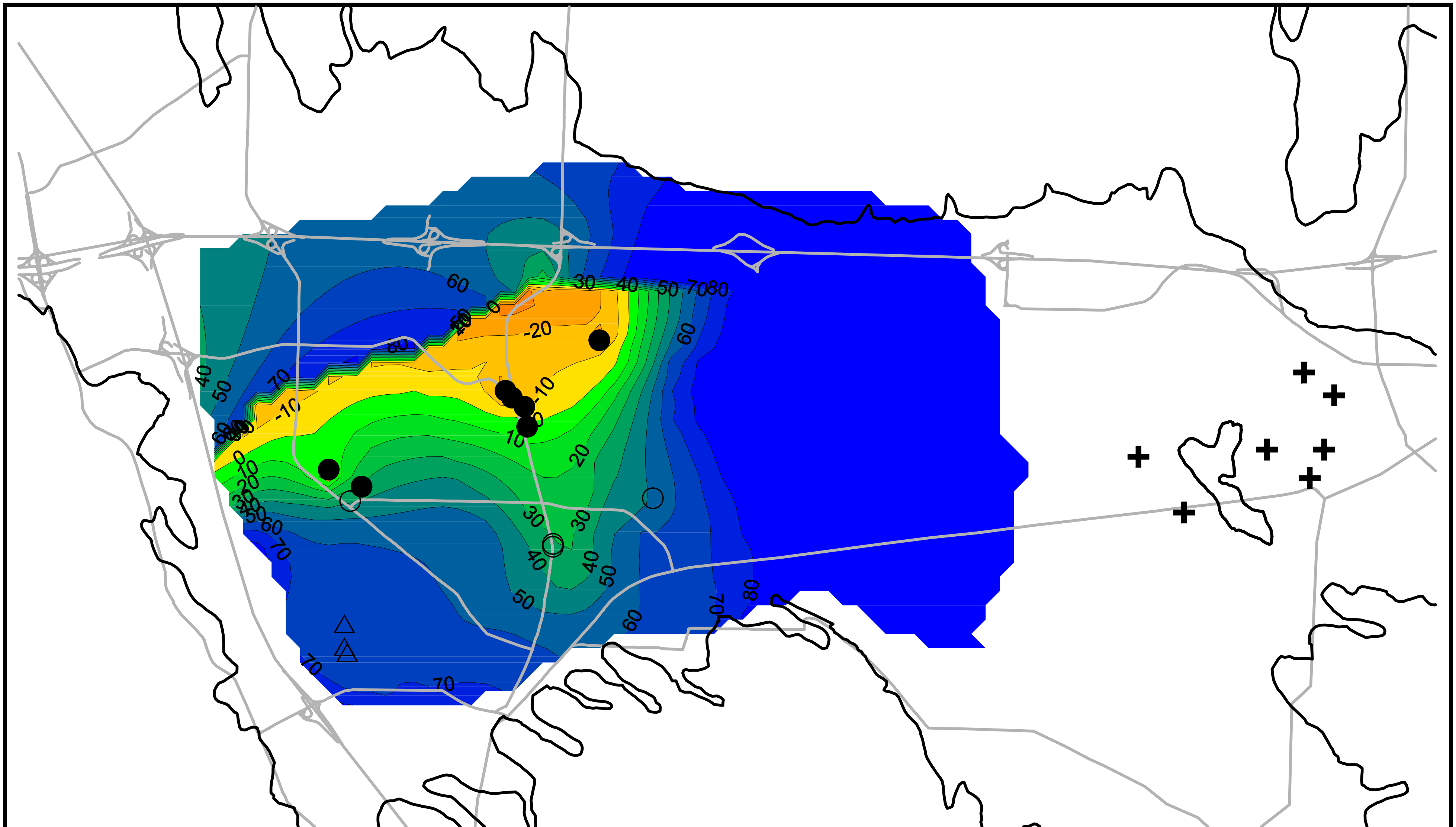
N

0 feet | 5280 feet | 10560 feet | 15840 feet

(S1-DD-Scen504a-L3-SP16)

FIGURE 2.3-2
SCENARIO 1: EXISTING WELLS ONLY,
32 MGD PUMPING CAPACITY
DRAWDOWN MAP FOR THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

N

0 feet 5280 feet 10560 feet 15840 feet

(S1-WL diff-Scen504a-L3-SP16)

FIGURE 2.3-3
SCENARIO 1a: 32 MGD PUMPING CAPACITY
WATER LEVEL DIFFERENCE MAP
FOR THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-3_10/13/03_ccc

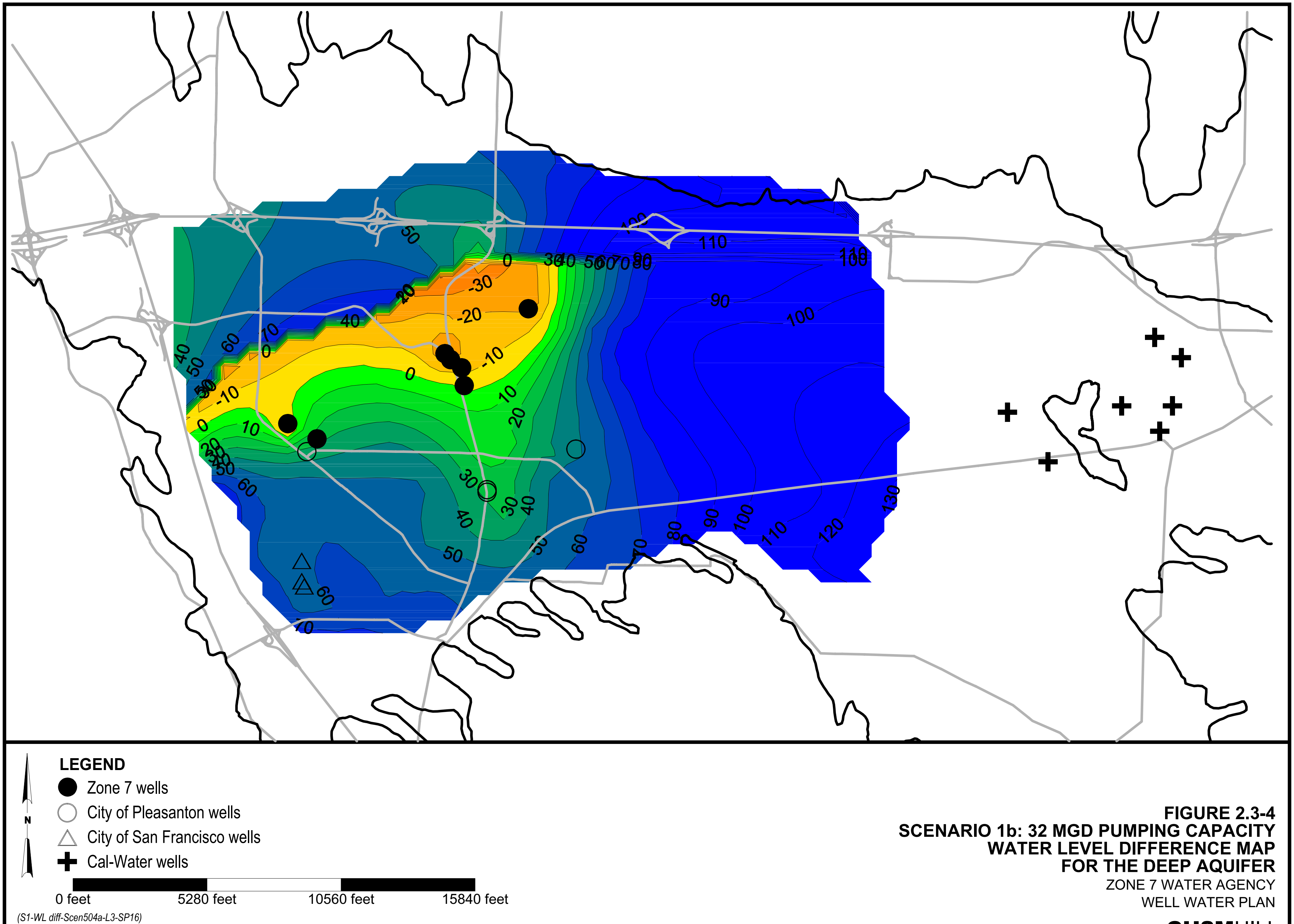


FIGURE 2.3-4
SCENARIO 1b: 32 MGD PUMPING CAPACITY
WATER LEVEL DIFFERENCE MAP
FOR THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-4_10/13/03_ccc

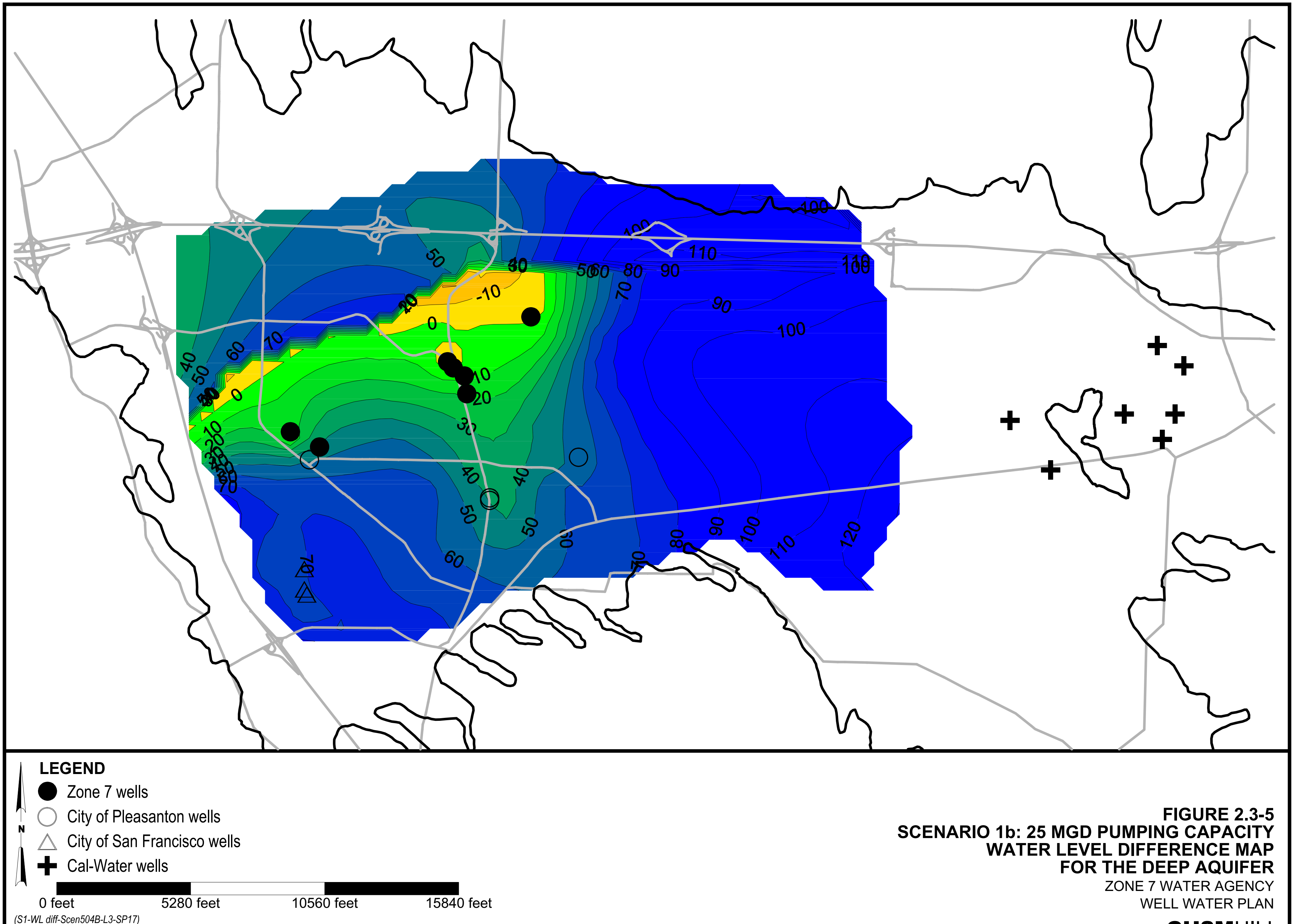
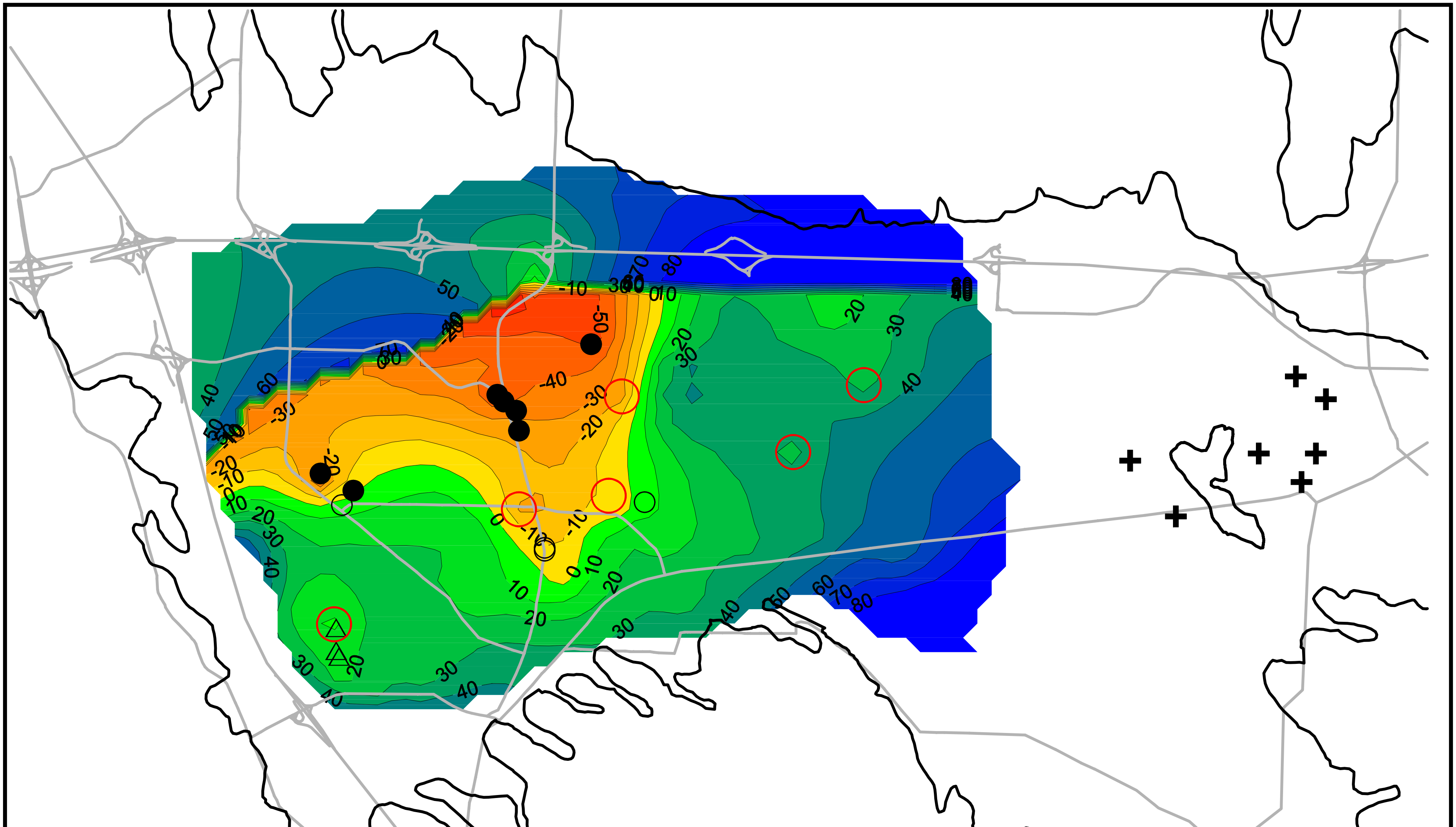


FIGURE 2.3-5
SCENARIO 1b: 25 MGD PUMPING CAPACITY
WATER LEVEL DIFFERENCE MAP
FOR THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-5_10/13/03_ccc



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

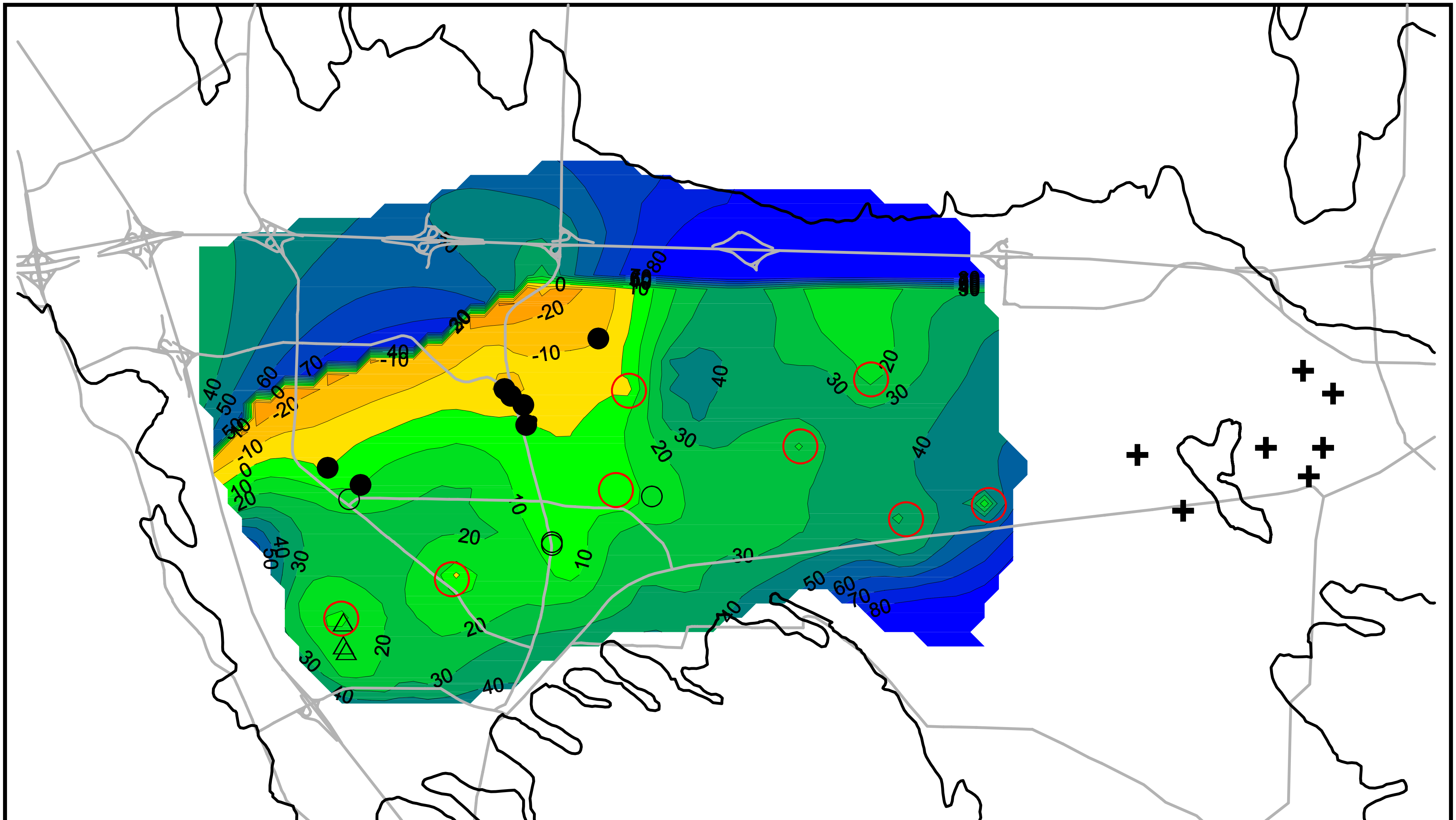
0 feet 5280 feet 10560 feet 15840 feet

(S2-WL diff-Scen503A-L3-SP14)

FIGURE 2.3-6
SCENARIO 2a: 70 MGD PUMPING CAPACITY WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-6_10/13/03_ccc



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

0 feet 5280 feet 10560 feet 15840 feet

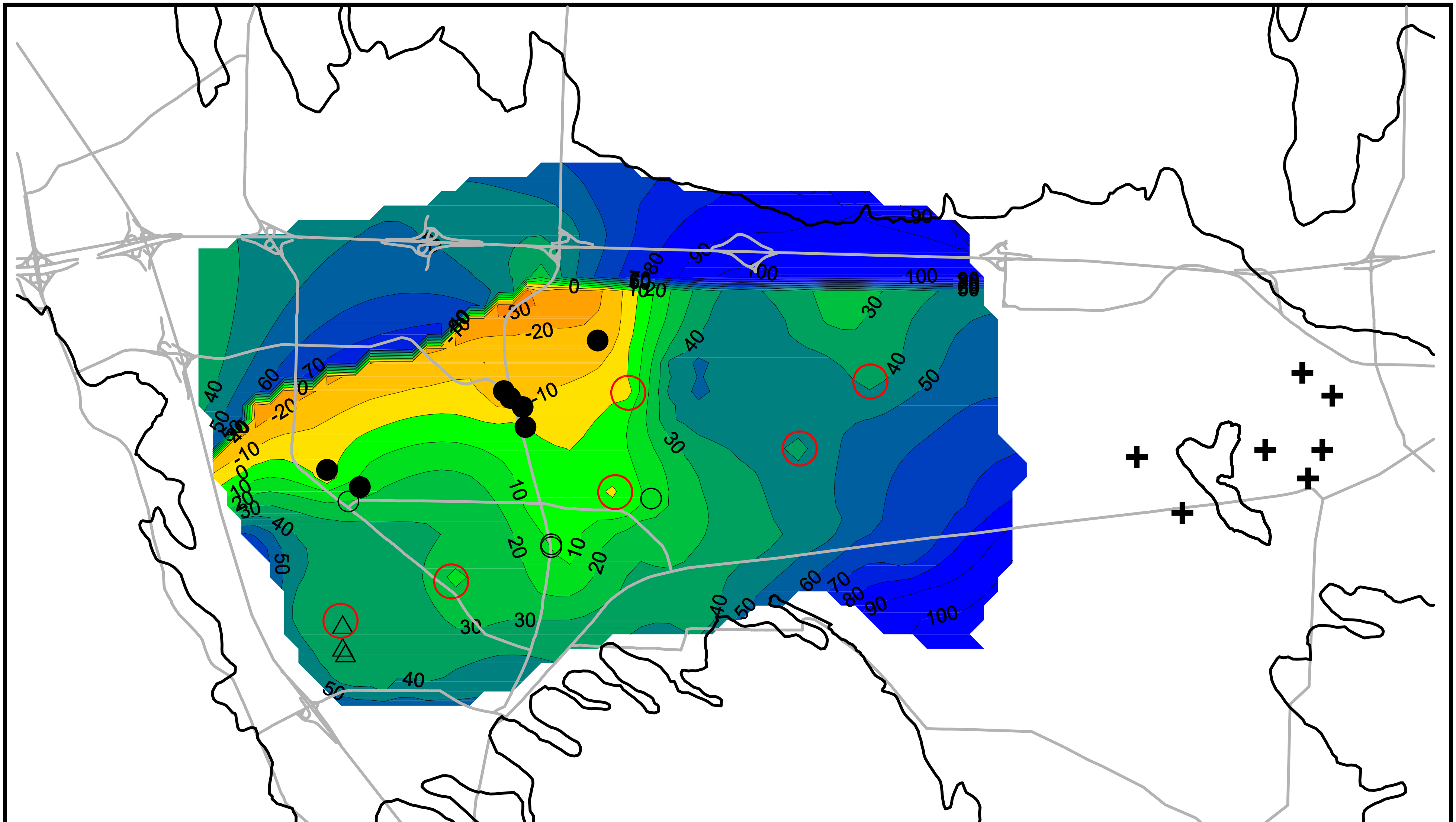
(S2-WL diff-Scen503C-L3-SP14)

FIGURE 2.3-7
SCENARIO 2b: 70 MGD PUMPING CAPACITY WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-7_10/13/03_ccc



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

0 feet | 5280 feet | 10560 feet | 15840 feet

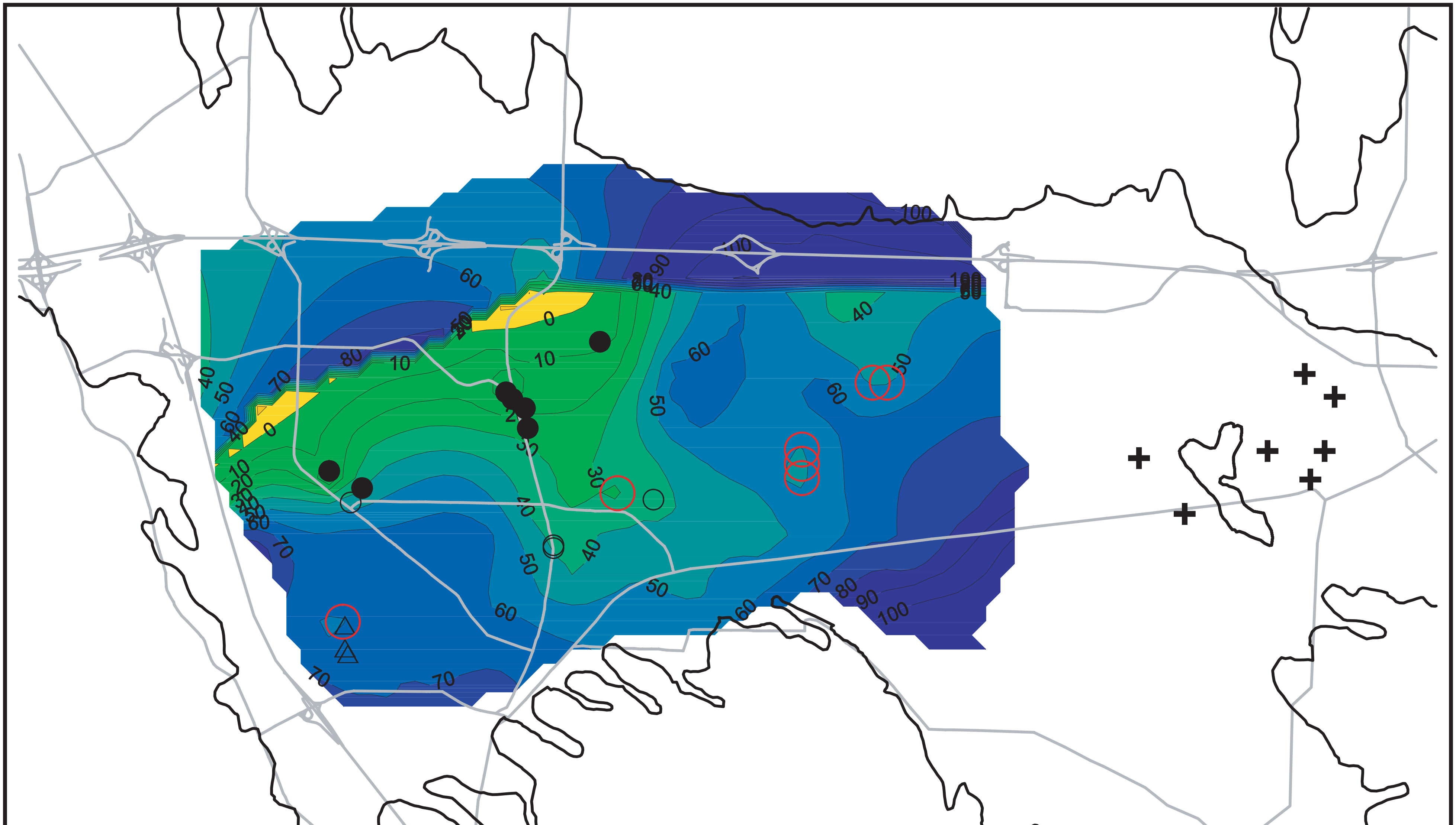
(S2-WL diff-Scen503F-L3-SP14)

FIGURE 2.3-8
SCENARIO 2c: 55 MGD PUMPING CAPACITY WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-8_10/13/03_ccc



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

0 feet 5280 feet 10560 feet 15840 feet

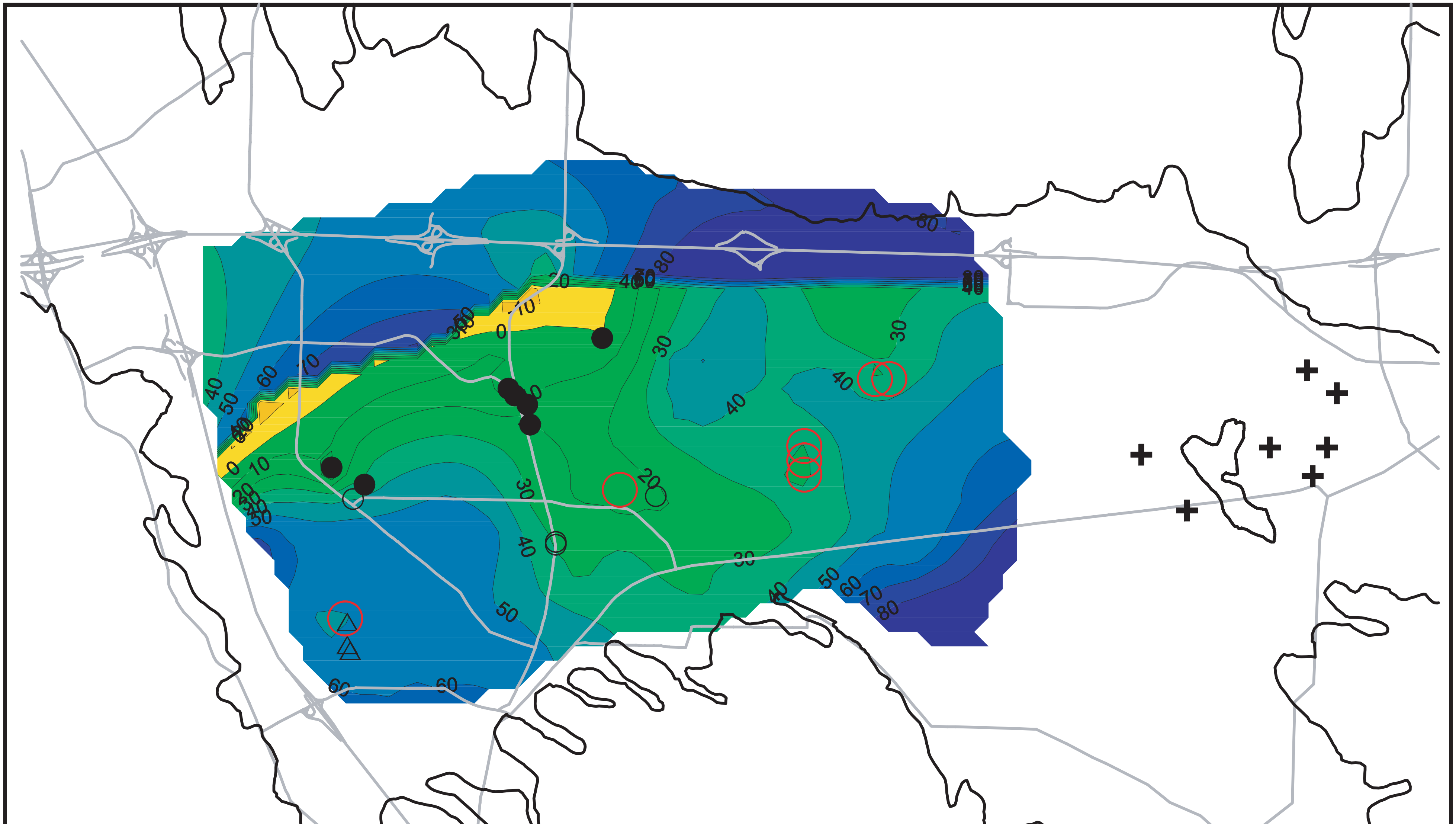
(S2-WL diff-Scen506C-L3-SP14)

FIGURE 2.3-9
SCENARIO 2d: 45 MGD PUMPING CAPACITY WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER AT HEIGHT OF 1-YEAR DROUGHT

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-9_4/16/04_mai



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

0 feet | 5280 feet | 10560 feet | 15840 feet

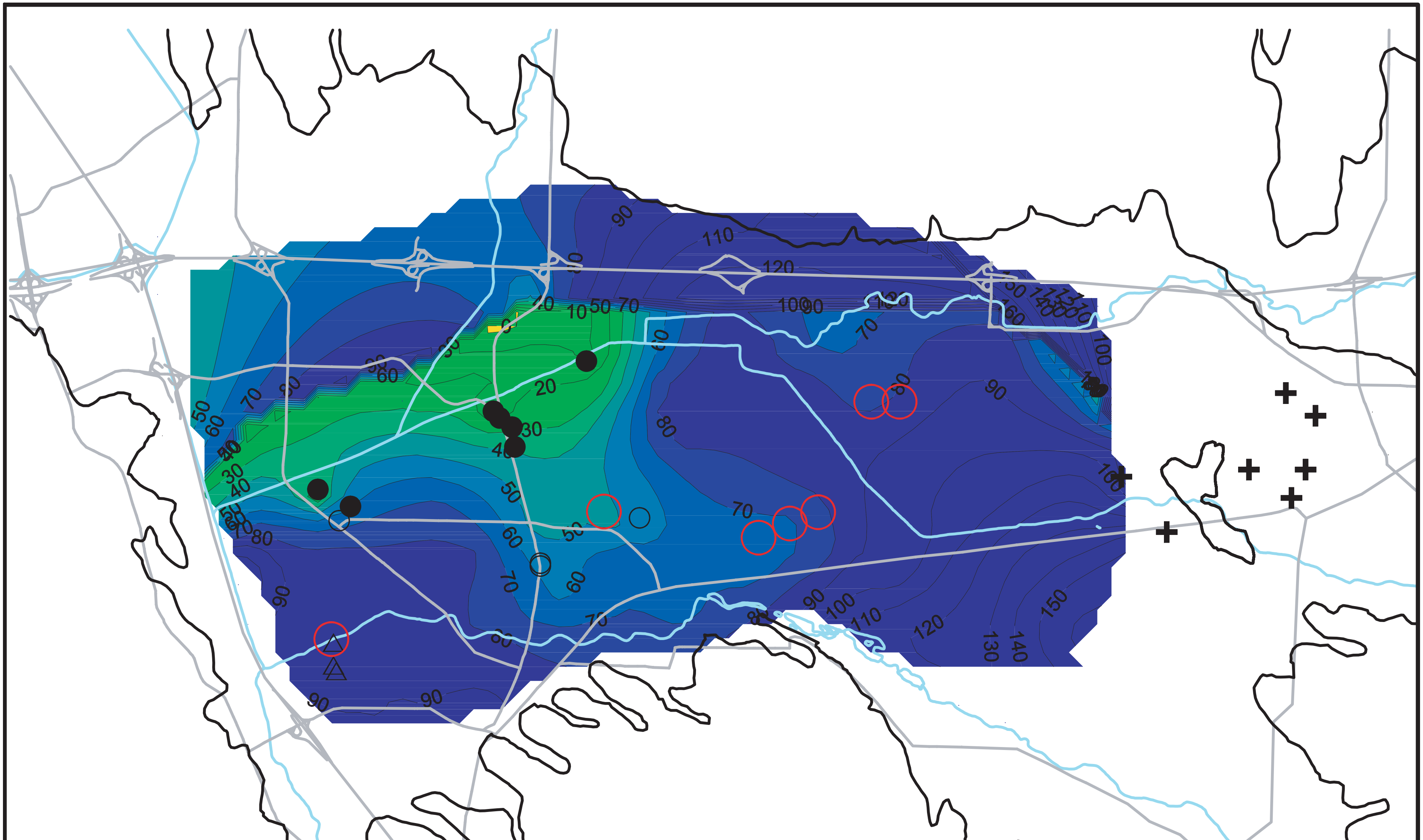
(S2-WL diff-Scen406C-L3-SP33)

FIGURE 2.3-10
SCENARIO 2d: 45 MGD PUMPING CAPACITY
WATER LEVEL DIFFERENCE MAP FOR
THE DEEP AQUIFER AT HEIGHT OF 6-YEAR DROUGHT

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-10_4/16/04_mai



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

(S4-WL diff-Scen805-L3-SP10)

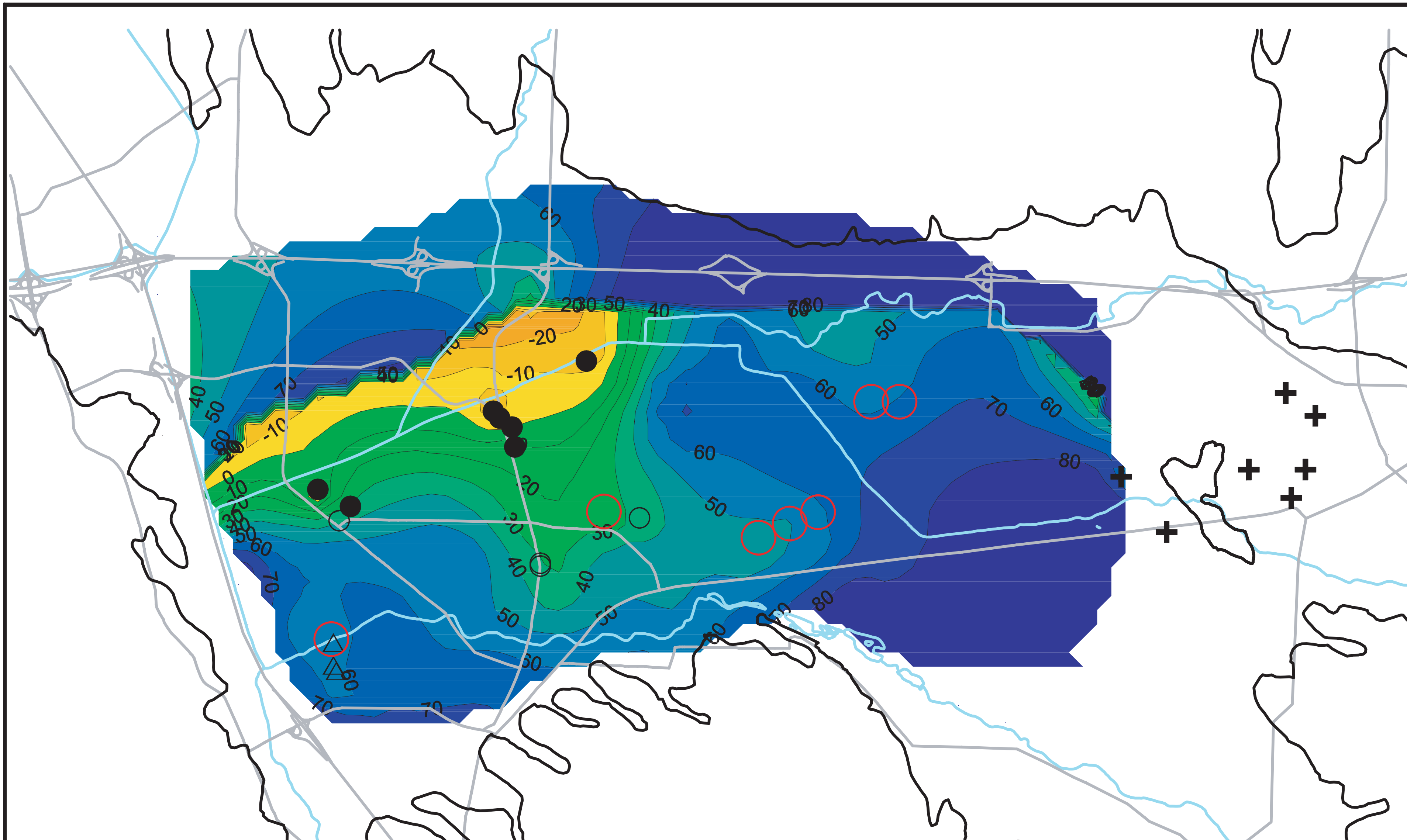
0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.3-11
SCENARIO 2: MAX DAY DEMAND PUMPING AT 52 MGD FOR 4 DAYS WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-11_4/19/04_mai



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

(S4-WL diff-Scen805-L3-SP14)

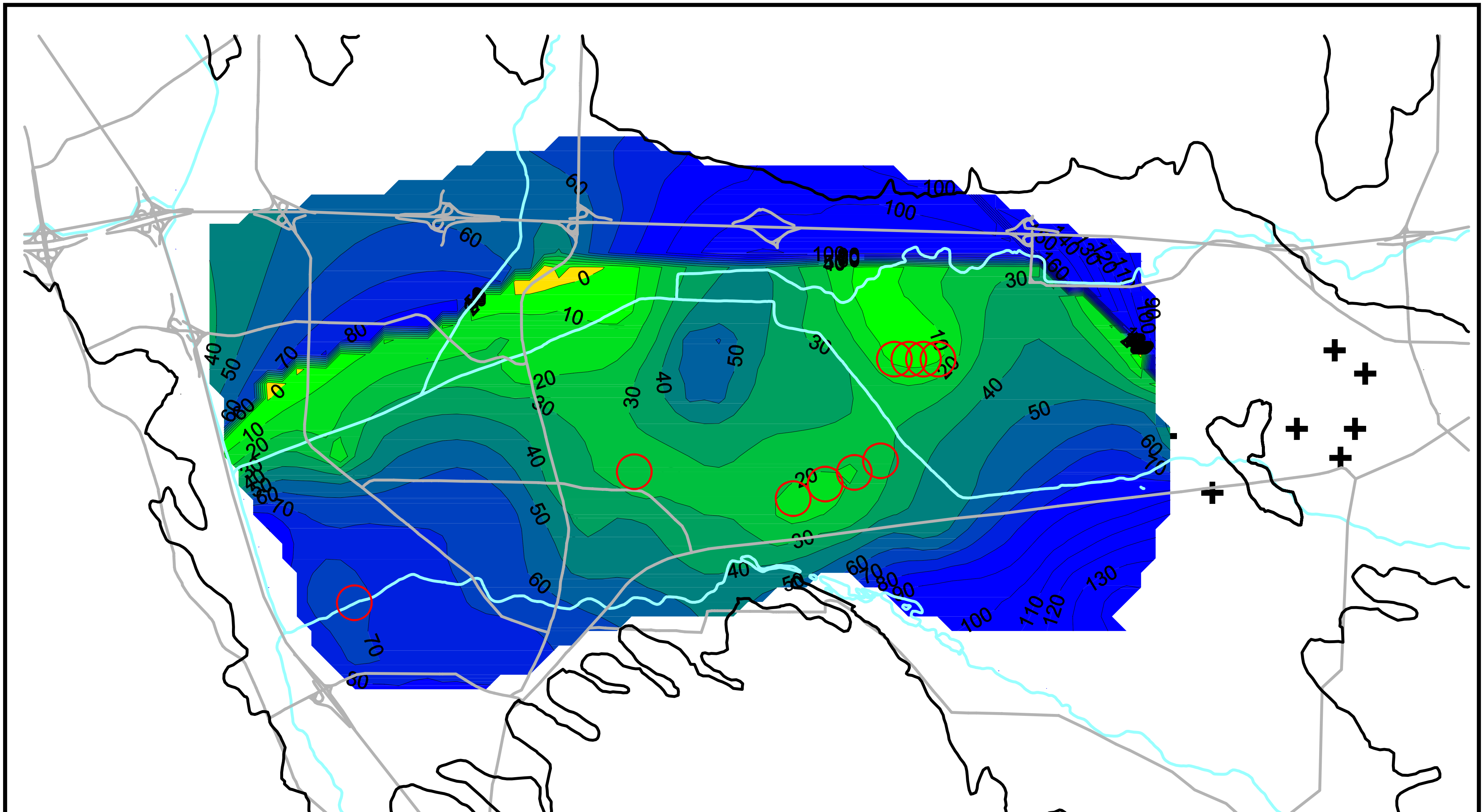
0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.3-12
SCENARIO 4: MAX DAY DEMAND PUMPING AT 52 MGD FOR 30 DAYS
WATER LEVEL DIFFERENCE MAP FOR
THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-12_4/19/04_mai



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

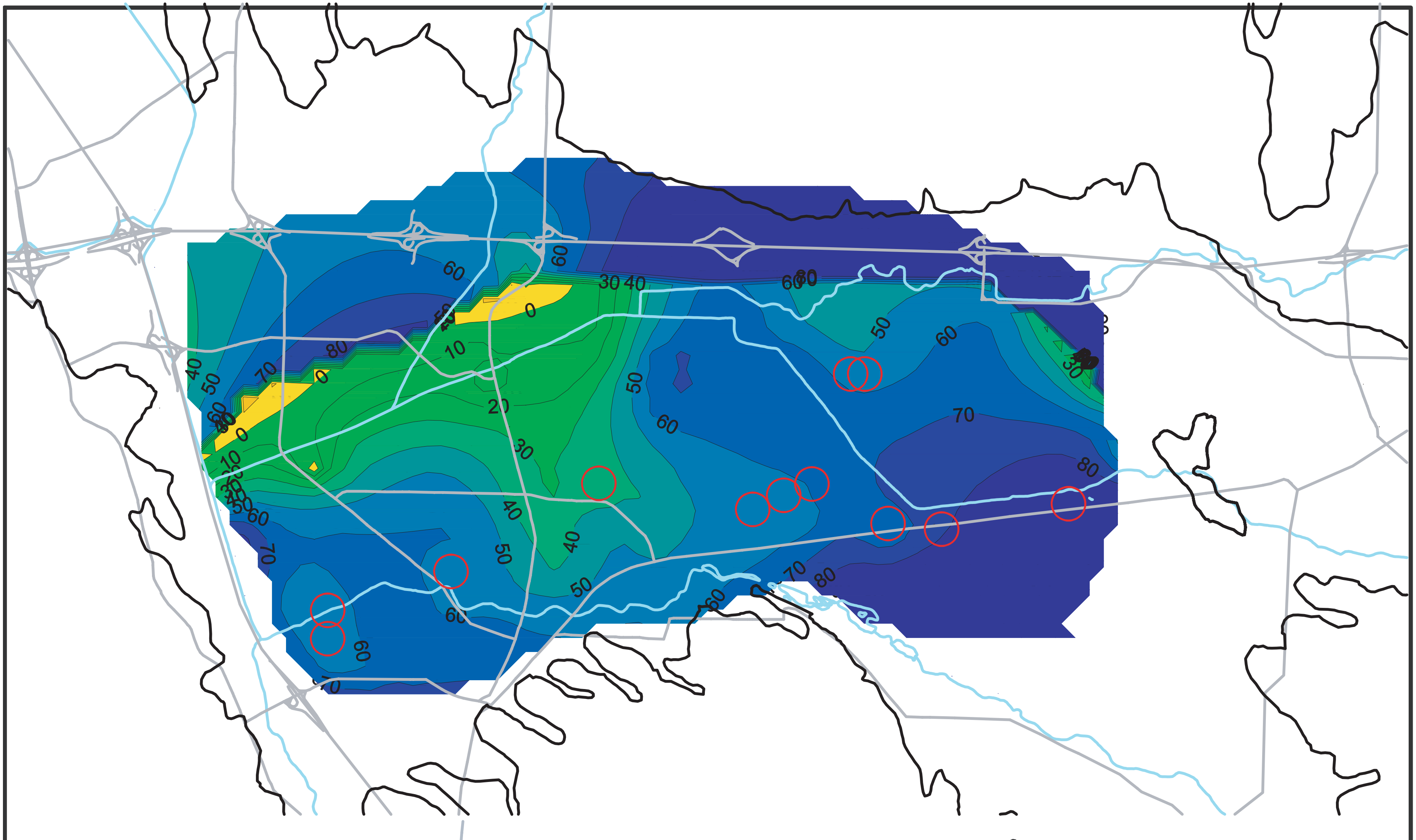
0 feet | 5280 feet | 10560 feet | 15840 feet

(S4-WL diff-Scen806-L3-SP15)

FIGURE 2.3-13
SCENARIO 4: PUMPING 68.2 MGD FOR 60 DAYS
WATER LEVEL DIFFERENCE MAP FOR
THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-13_10/14/03_ccc



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells
- New wellfields

N

0 feet 5280 feet 10560 feet 15840 feet

(S2-WL diff-Scen507-L3-SP14)

FIGURE 2.3-14
SCENARIO 2e: DISPERSED WELLS
HEIGHT OF 1-YEAR DROUGHT, MAX 45 MGD ZONE 7 PUMPING
WATER LEVEL DIFFERENCE MAP FOR
THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-14_4/19/04_mai

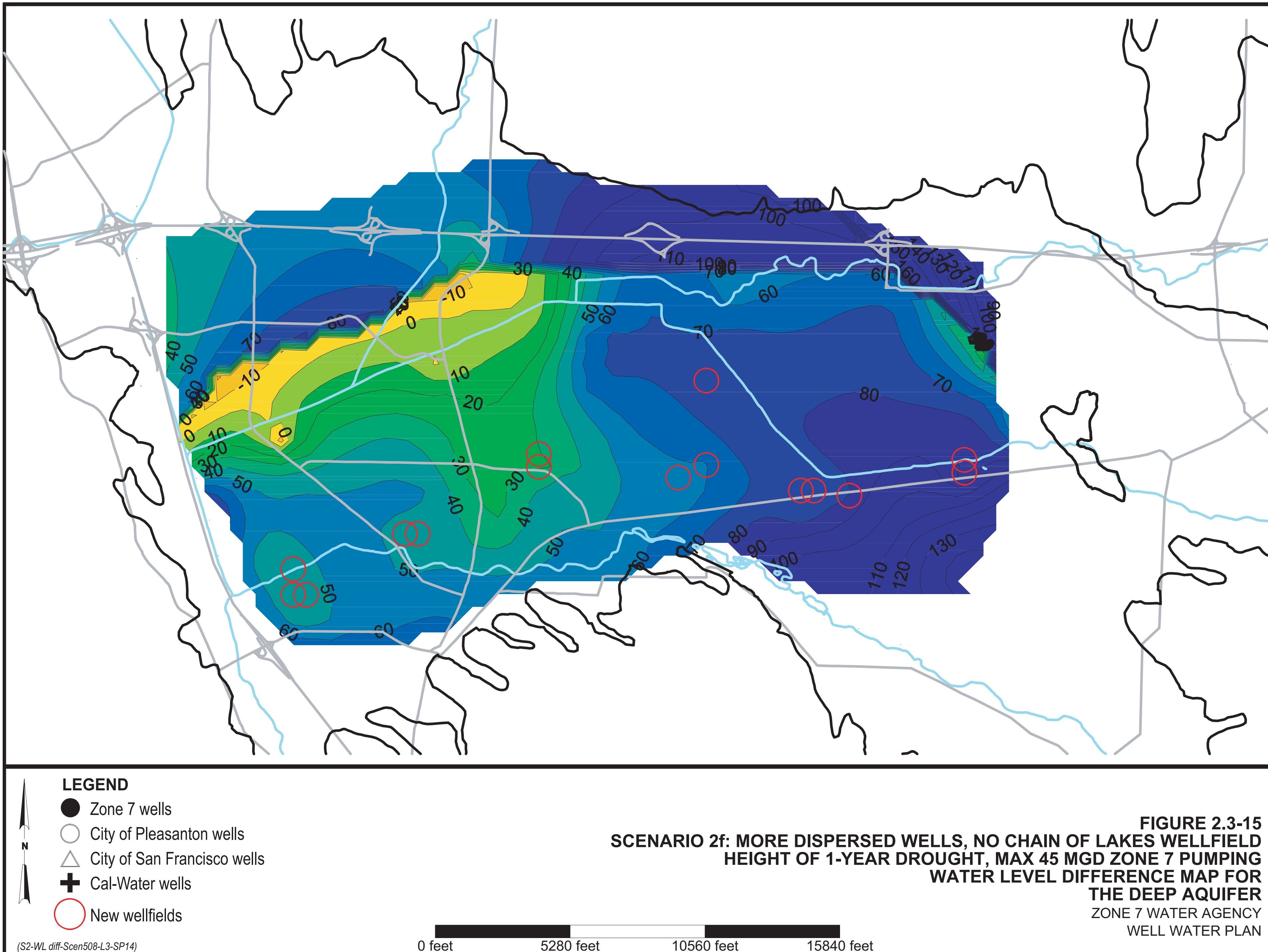


FIGURE 2.3-15
SCENARIO 2f: MORE DISPERSED WELLS, NO CHAIN OF LAKES WELLFIELD
HEIGHT OF 1-YEAR DROUGHT, MAX 45 MGD ZONE 7 PUMPING
WATER LEVEL DIFFERENCE MAP FOR
THE DEEP AQUIFER

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.3-15_4/20/04_mai

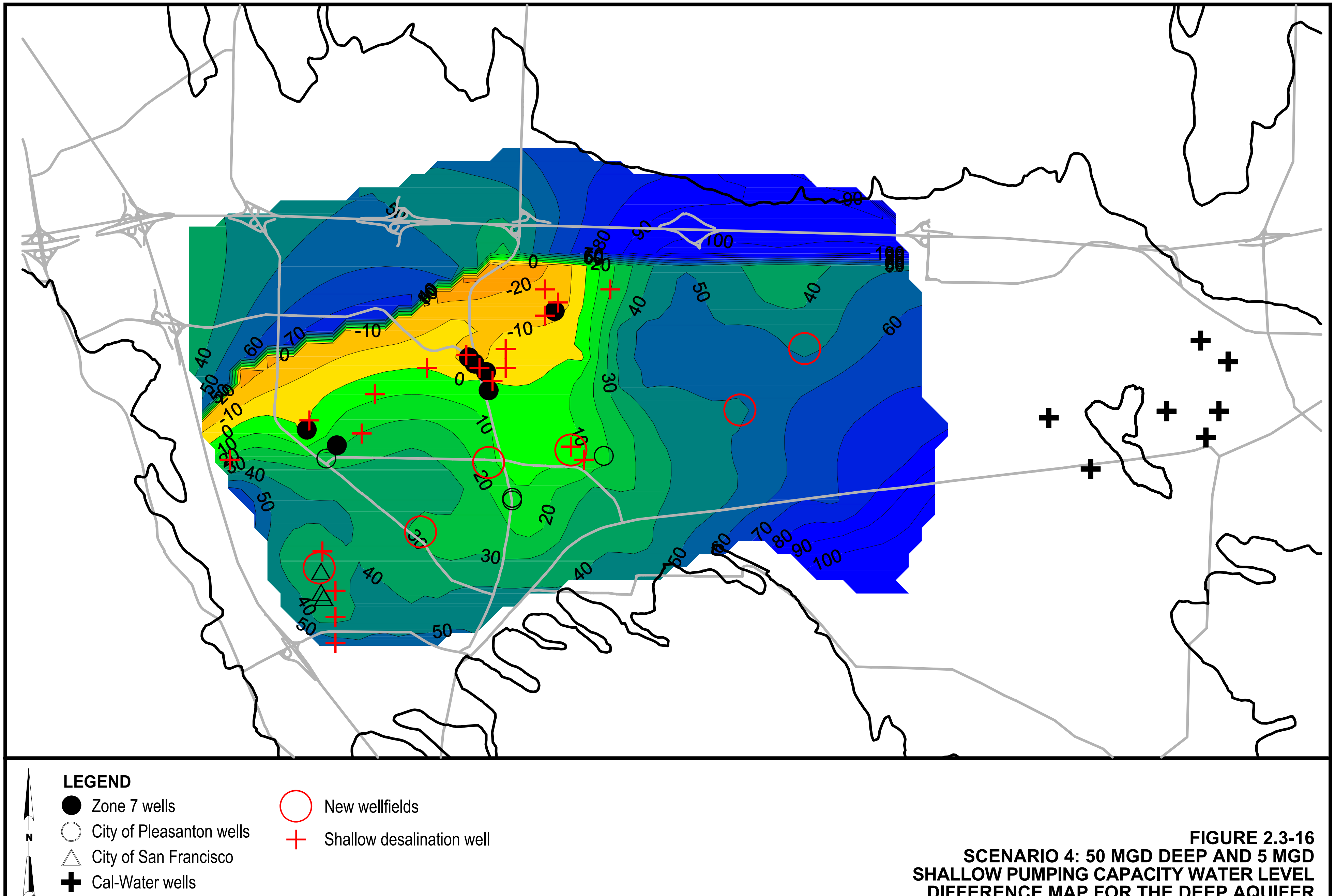


FIGURE 2.3-16
SCENARIO 4: 50 MGD DEEP AND 5 MGD SHALLOW PUMPING CAPACITY WATER LEVEL DIFFERENCE MAP FOR THE DEEP AQUIFER
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

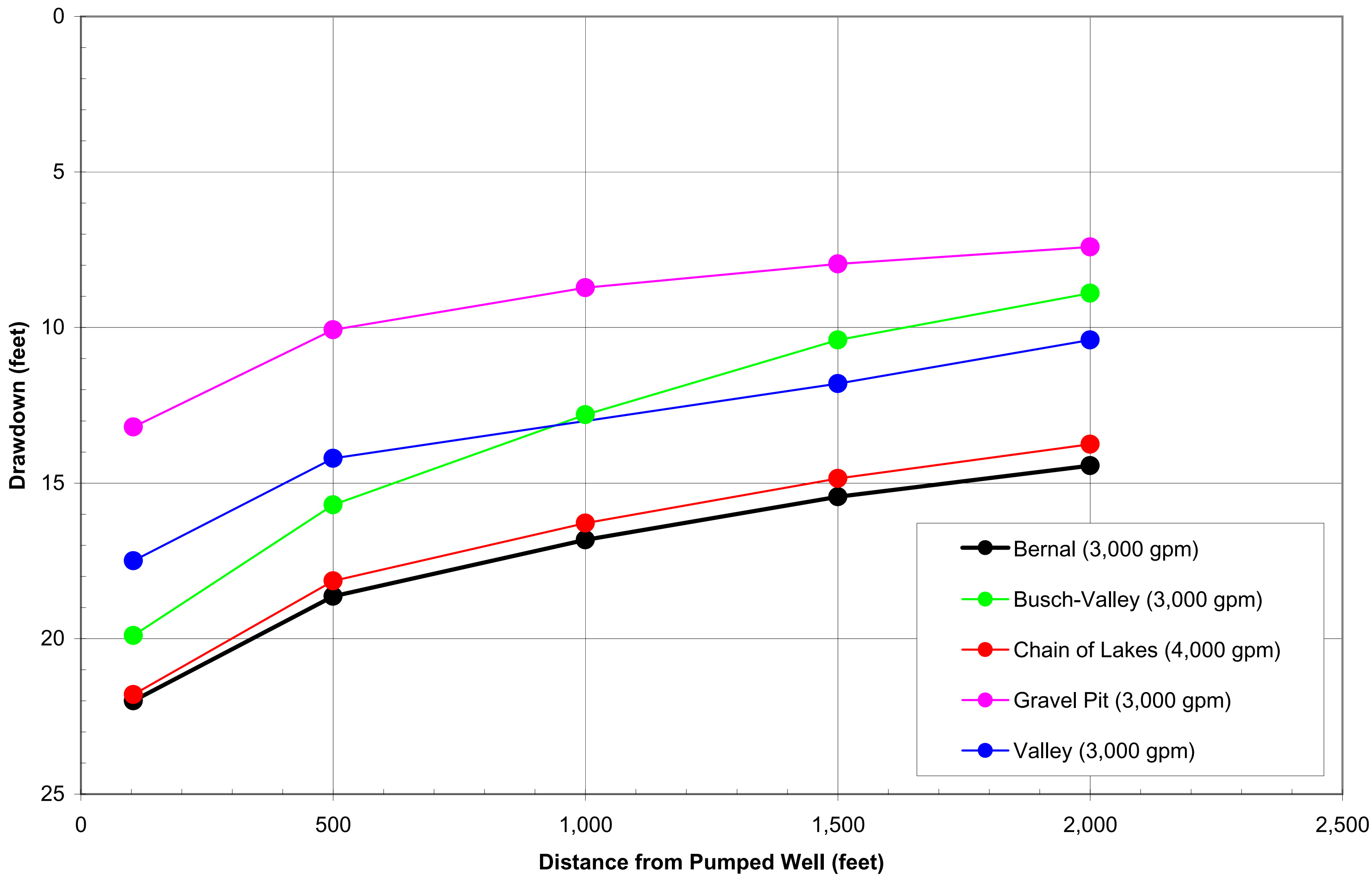


FIGURE 2.5-1
WELL INTERFERENCE: DISTANCE DRAWDOWN GRAPHS FOR PUMPING WELLS (ABOUT 10 DAYS PUMPING AT SPECIFIED RATES)
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.5-1_10/23/03_mai

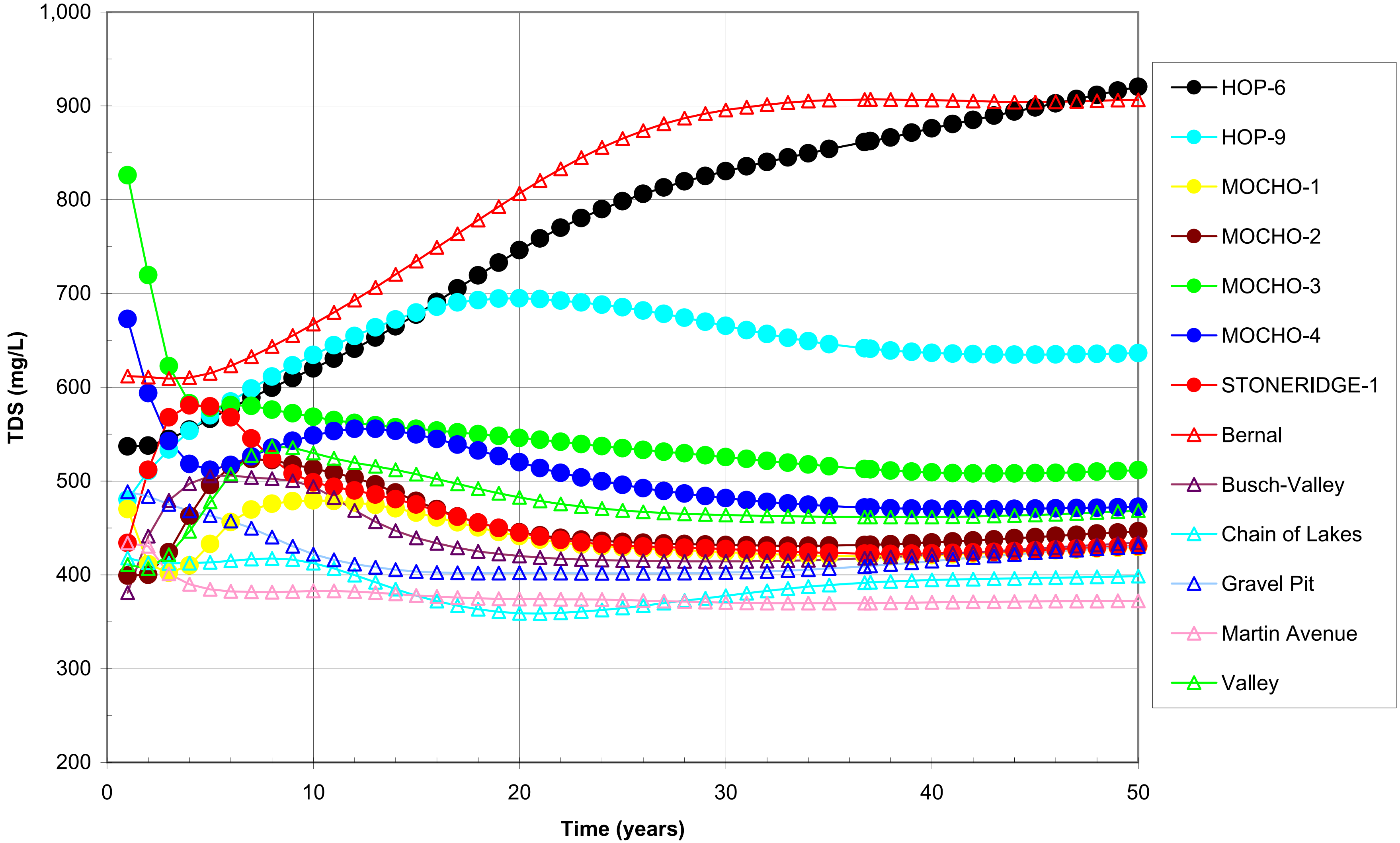


FIGURE 2.6-1
TDS AT SELECT WELLS
SCENARIO 1: EXISTING WELLS ONLY
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

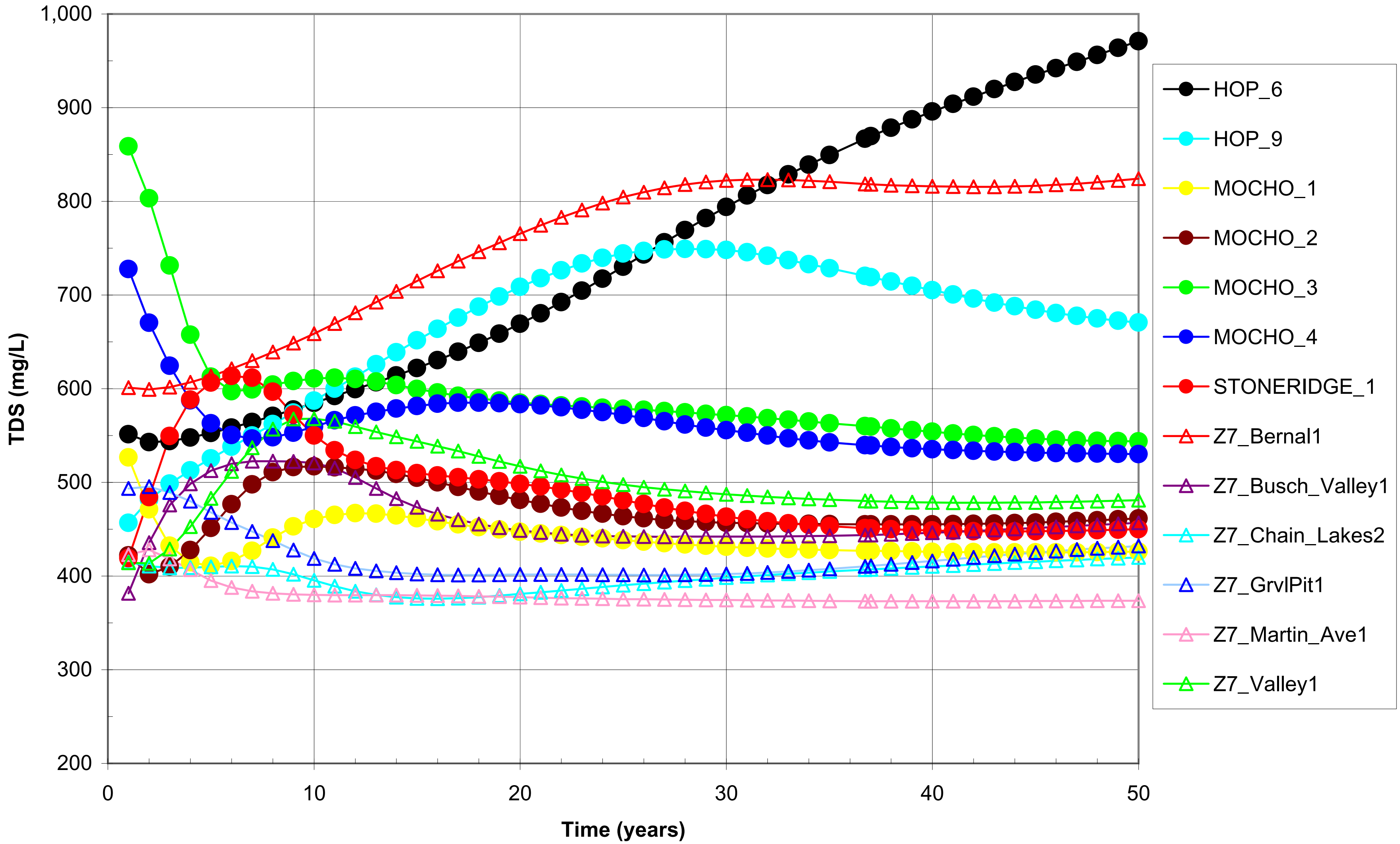


FIGURE 2.6-2
TDS AT SELECT WELLS
SCENARIO 2: EXISTING WELLS, PLUS NEW WELLS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.6-2_10/13/03_ccc

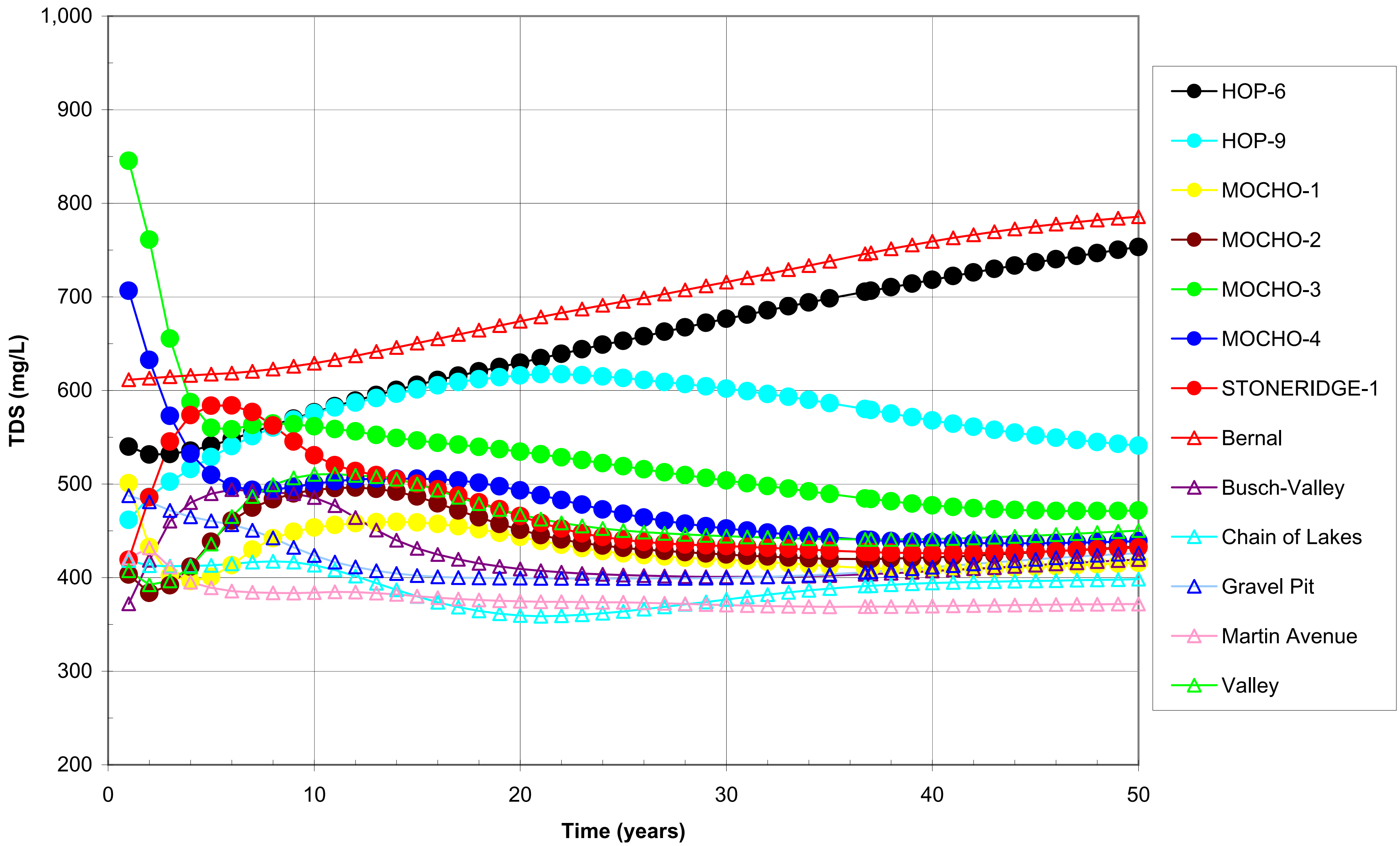


FIGURE 2.6-3
TDS AT SELECT WELLS
SCENARIO 3: EXISTING WELLS PLUS SHALLOW DESALTING WELLS

ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.6-3_10/13/03_ccc

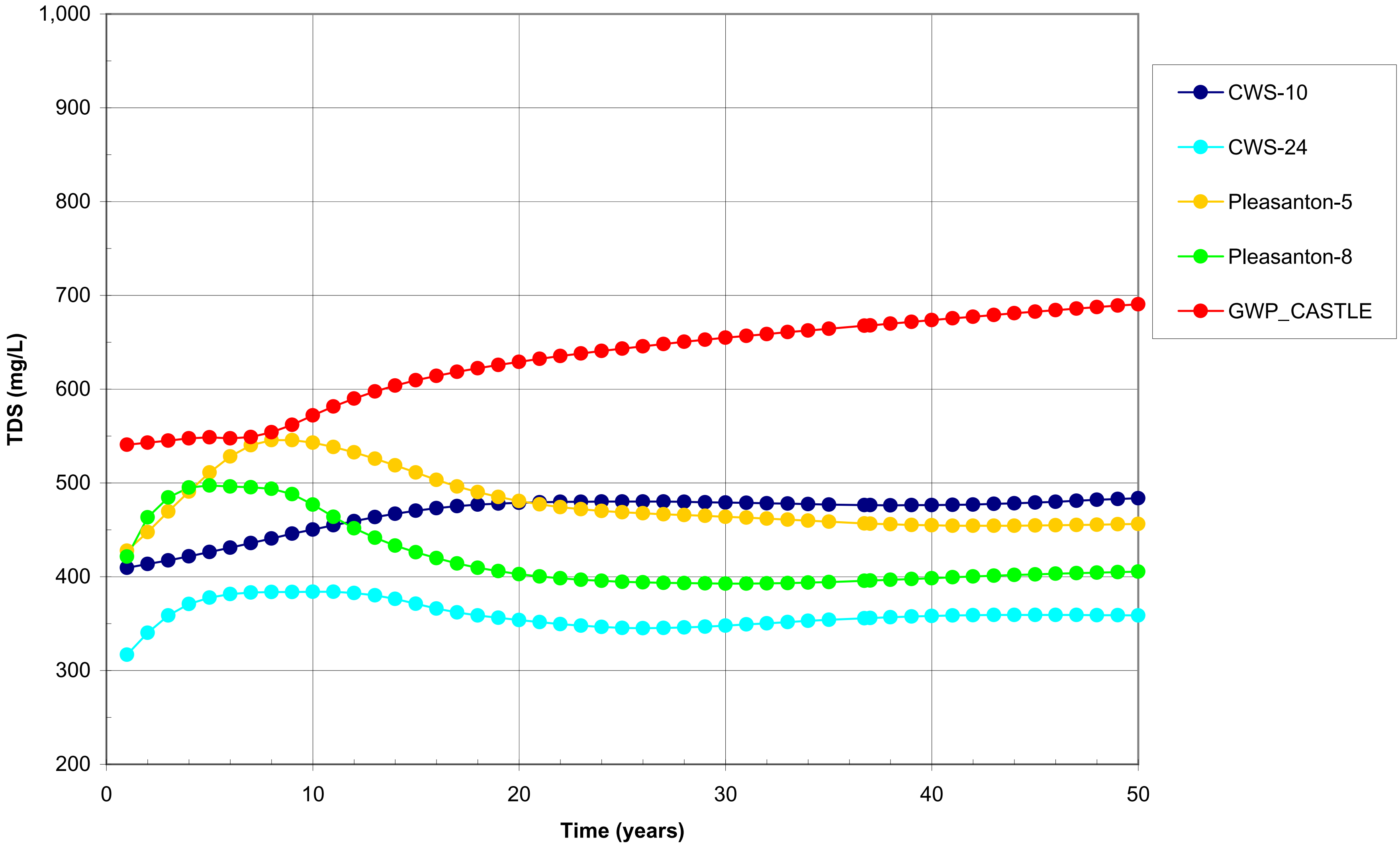


FIGURE 2.6-4
TDS AT SELECT WELLS
SCENARIO 1
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.6-4_10/13/03_ccc

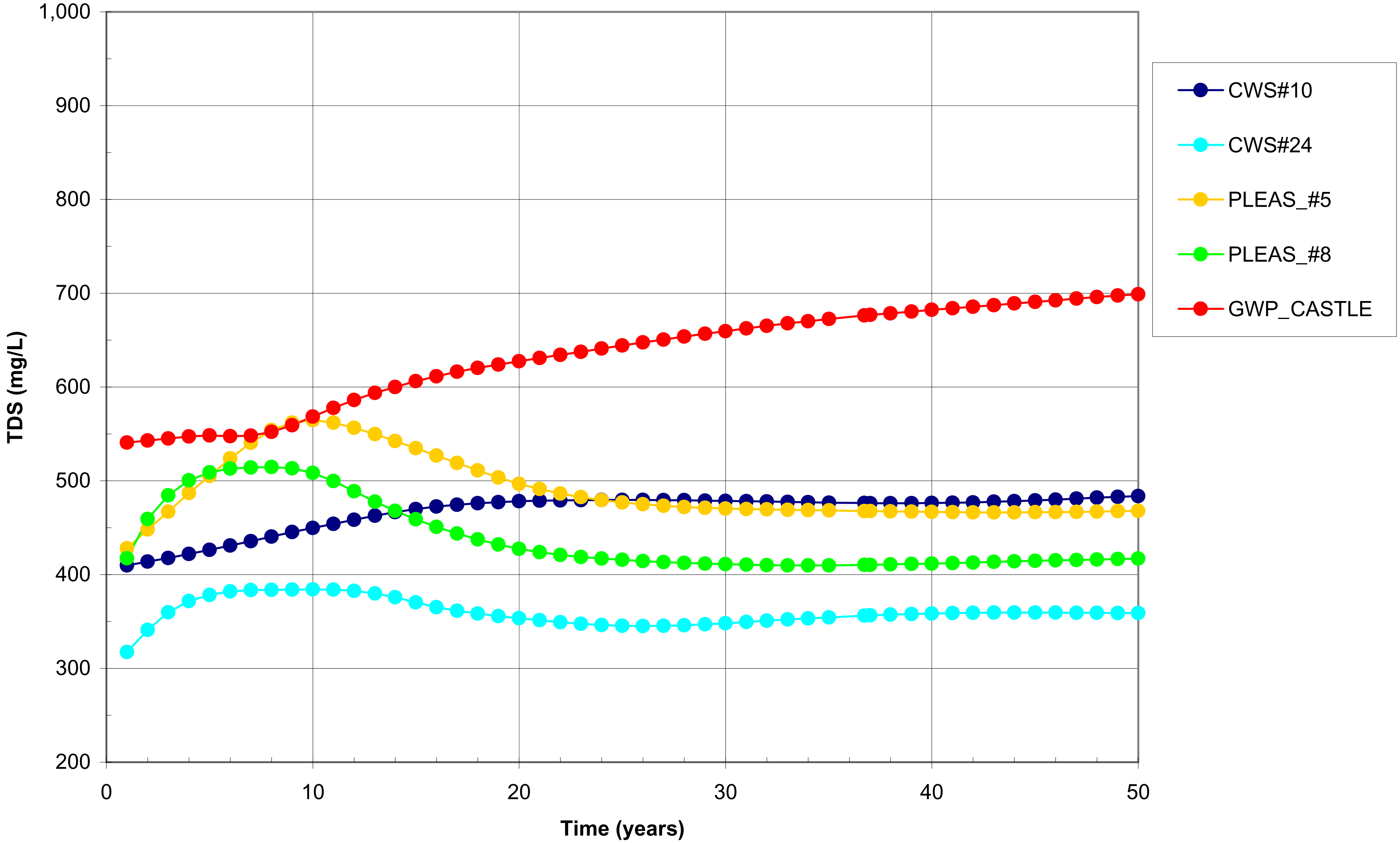


FIGURE 2.6-5
TDS AT SELECT WELLS
SCENARIO 2
ZONE 7 WATER AGENCY
WELL WATER PLAN

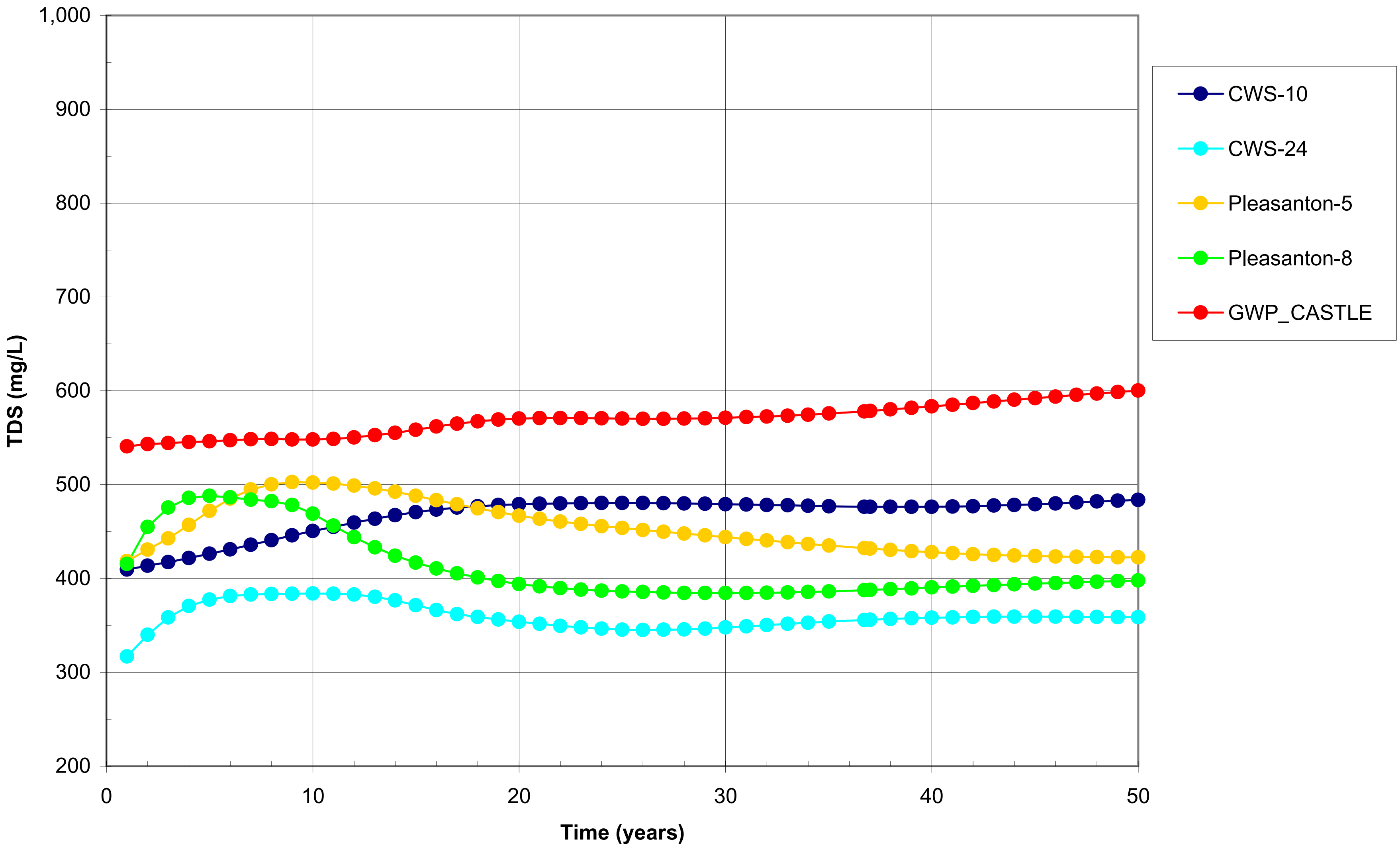


FIGURE 2.6-6
TDS AT SELECT WELLS
SCENARIO 3
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

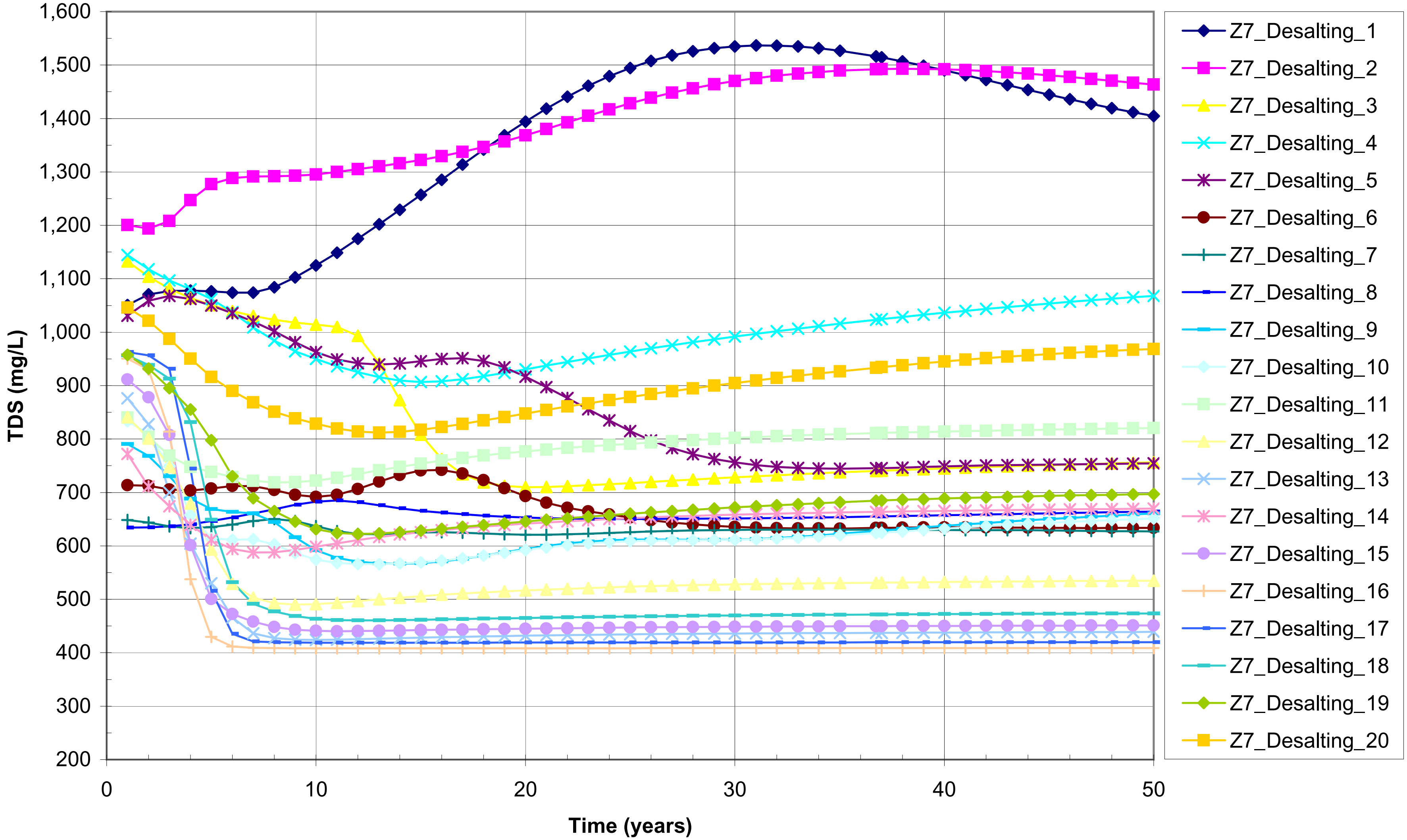


FIGURE 2.6-7
TDS TRENDS AT DESALTING WELLS
SCENARIO 3:
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

163304.WM.06_W102003001SFO_Z7 FIGURE 2.6-7_10/13/03_ccc

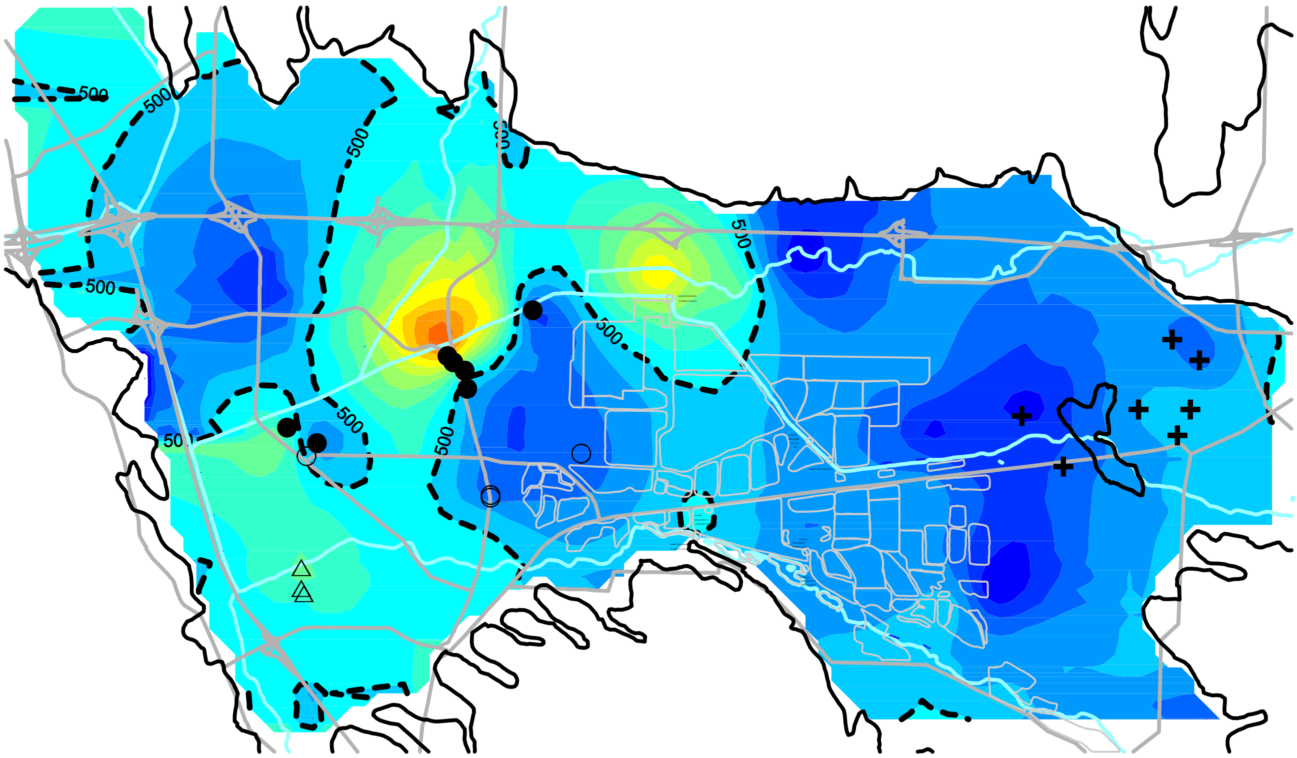
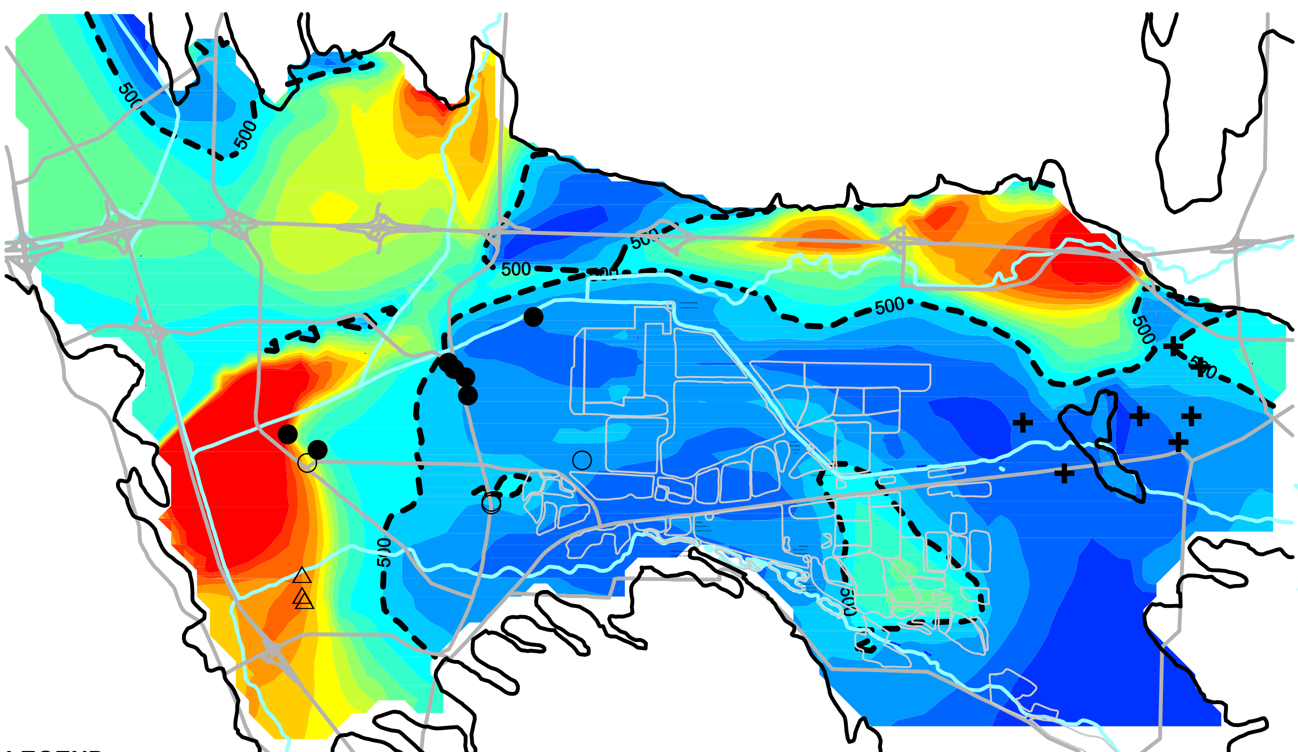


FIGURE 2.6-8
DEEP AQUIFER INITIAL TDS CONCENTRATION



LEGEND

- ● Zone 7 wells
- ○ City of Pleasanton wells
- △ City of San Francisco wells
- ✚ Cal-Water wells

N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.6-9
SCENARIO 1: EXISTING WELLS ONLY
DEEP AQUIFER TDS CONCENTRATION IN 50 YEARS
ZONE 7 WATER AGENCY
WELL WATER PLAN

CH2MHILL

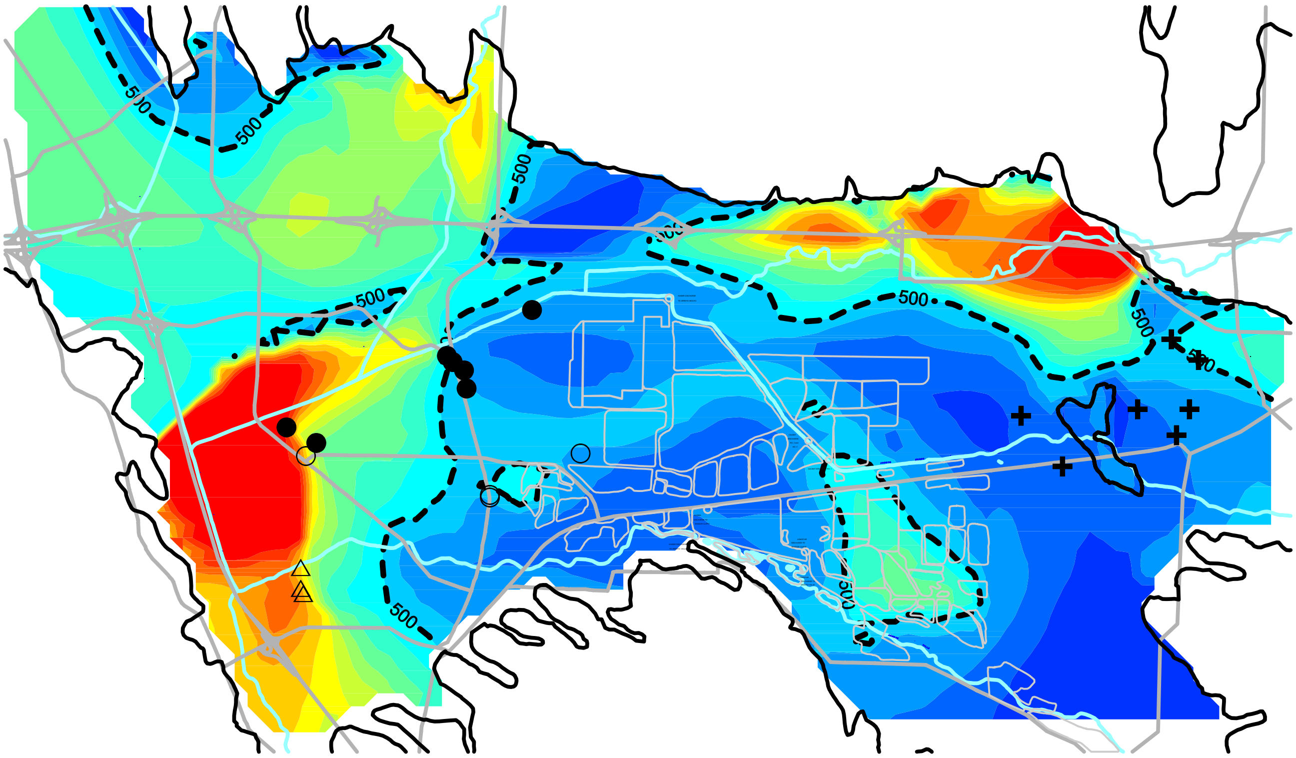
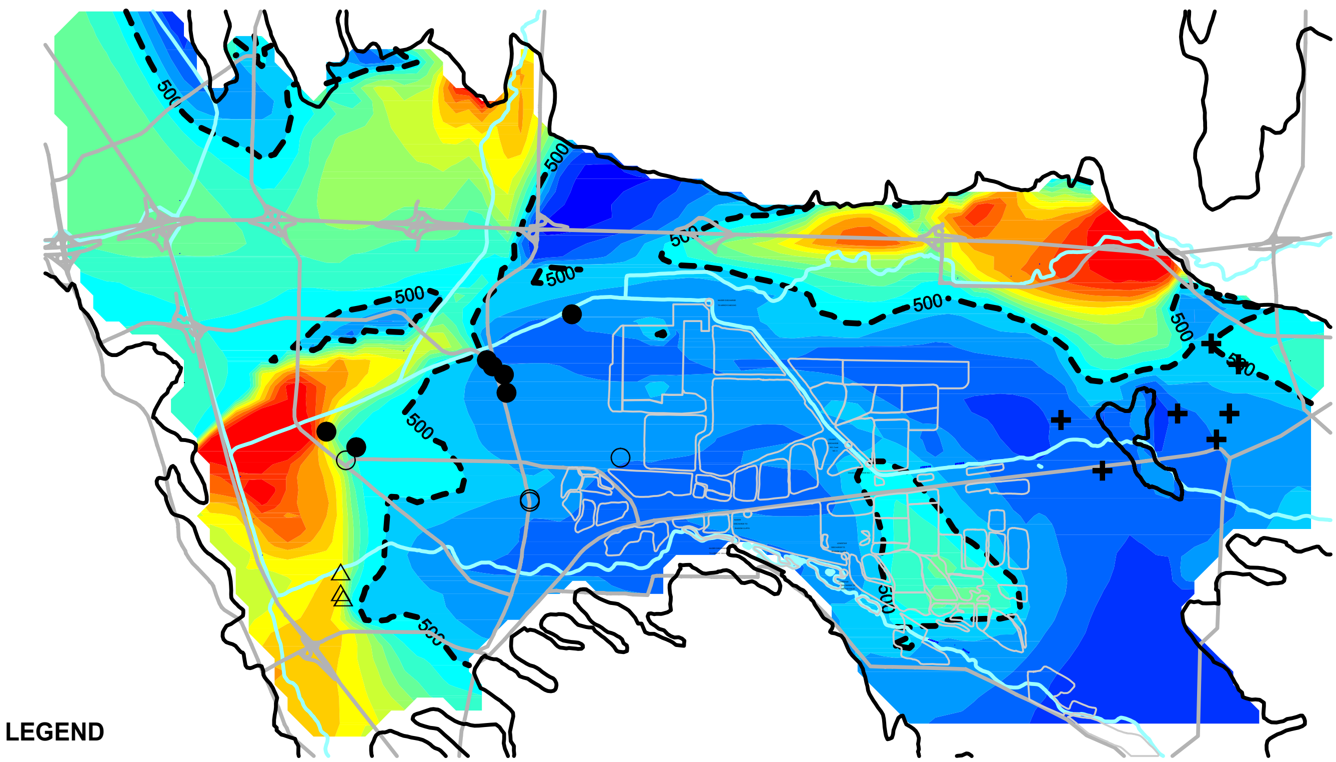


FIGURE 2.6-10
SCENARIO 2: EXISTING AND NEW WELLS
DEEP AQUIFER TDS CONCENTRATION IN 50 YEARS



LEGEND

- Zone 7 wells
- City of Pleasanton wells
- City of San Francisco wells
- Cal-Water wells

N

0 feet 5280 feet 10560 feet 15840 feet

FIGURE 2.6-11
SCENARIO 3: EXISTING WELLS AND SHALLOW AQUIFER WELLS
DEEP AQUIFER TDS CONCENTRATION IN 50 YEARS
ZONE 7 WATER AGENCY
WELL WATER PLAN