Las Posas Basin Groundwater Model Simulations of ASR Wellfield Operations and Development of Design Criteria For Wellfield No. 2

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Introduction

This technical memorandum summarizes the results of groundwater model simulations of potential Las Posas Basin ASR wellfield operations and establishes design criteria, specifically, maximum discharge rates and associated low groundwater levels, on which to design the pumps and motors for Las Posas Basin Aquifer Storage and Recovery (ASR) Wellfield No. 2 (WF2).

Background

Calleguas Municipal Water District (Calleguas) and the Metropolitan Water District of Southern California (Metropolitan) are constructing the Las Posas Basin ASR wellfield to provide emergency, drought, and seasonal peaking capacity to Calleguas' water delivery system. The current plan includes a 100 cfs of capacity, which is to be developed from 30 ASR wells. Currently, there are 4 ASR wells at Wellfield No. 1, which will be on line in the Fall of 1998 and the Fairview ASR well that Calleguas completed in 1993. Wellfield No. 2 is under construction and includes 12 additional ASR wells, for a total of 17 ASR wells. Efforts are underway to identify potential properties that could be acquired for construction of additional ASR wells to complete the current 100 cfs capacity plan.

The Las Posas Basin ASR wellfields will be operated to meet emergency, drought or peak seasonal demands, so these ASR wellfields will not be operated continuously. Unlike the design of a conventional wellfield, where it is important to provide spacing of wells to minimize drawdown and interference effects of wells, Calleguas and Metropolitan desire to maximize pumping rates from wells located close together. Such a high density wellfield(s) will minimize initial capital expenditures for property, pipelines and other appurtenances, but result in less than optimal operations cost. Optimizing operations cost is not considered a primary objective by Calleguas and Metropolitan because the wellfields are not expected to be operated on a continuous basis.

Purpose

The purpose of this study is to identify the maximum extraction rates that can be achieved from wells at Wellfield No. 2 and to identify those low groundwater-level conditions associated with these pumping rates. The maximum extraction rates and associated groundwater levels provide those design criteria for selecting appropriate pumps and motors to be installed at Wellfield No. 2.

Evaluation of injection rates are not included as a part of this study. It is assumed that each well will be capable of injecting approximately 1,000 gpm on average. In general, the reliability of the ASR program is not as sensitive to injection capacity as it is to extraction capacity. Typically, the time available to put water into storage greatly exceeds the time needed, so there is an inherent safety factor under most conditions in the event that injection rates average less than 1,000 gpm.

Scope

The approach to identifying maximum groundwater extraction rates and associated low groundwater-level conditions is to use a numerical groundwater model to simulate operations of the wellfields. CH2M HILL developed a groundwater model of the Las Posas Basin for Metropolitan (CH2M HILL, 1993) and updated the model with current hydrology and pumping conditions through 1996 (CH2M HILL, 1997). A base case, extending from 1997 through 2016, was developed as part of the CH2M HILL (1997) study that included planned cut backs in pumping based on the Fox Canyon Groundwater Management Agency's plan to achieve safe yield of the basin. The Las Posas Basin model used in these earlier studies (CH2M HILL, 1993 and 1997) is appropriate for basin-wide assessments, but the grid is too coarse for evaluating drawdown in the Las Posas Basin ASR wellfields. Therefore, the tasks to be completed as part of this study included the following:

1. Densify the Las Posas Basin Model grid for use in simulating groundwater conditions at ASR wellfields
2. Develop wellfield operations scenarios
3. Simulate wellfield operations and evaluate results
4. Establish design criteria for Wellfield No. 2 pumps and motors
5. Summarize results in a technical memorandum

The remainder of this memorandum includes the following section: Grid Refinement of Las Posas Basin Model, Wellfield Operations Scenarios, Summary of Groundwater Model Simulation Results, Wellfield No. 2 Pump and Motor Design Criteria, Limitations and Uncertainties of Model Simulations, and Recommendations.

Grid Refinement of the Las Posas Basin Model

The Las Posas Basin model is based on the CFEST three-dimensional finite element computer code. The original grid is shown in Figure 1. Figure 2 shows the refined finite element grid used in this study. The features of this grid are summarized as follows:

- The grid retains the features of the previous grid, including a grid perimeter that closely follows the basin boundaries, denser gridding along faults and other structures, and three layers to represent the Fox Canyon Aquifer (FCA), the Aquitard between the FCA and the Grimes Canyon Aquifer (GCA), and GCA.
- The grid is increased in density in the vicinity of Wellfields No. 1 and 2 to better approximate groundwater levels in ASR wells during injection and extraction. ASR wells are assigned to individual nodes in the grid.
- Hydrogeologic properties from the previous model have been mapped into the new grid.
- Boundary conditions, recharge conditions, and pumping by others have been retained from the previous model.

Once the new grid was generated, simulations were conducted to confirm that the previous model and the new denser-grid model produced comparable simulation results. Figures 3 and 4 present the calibration (1977 through 1996) and base case (1997 through 2016) simulation results for the coarse-grid model and Figure 5 and 6 present the simulation results for the denser-grid simulation results. Comparison of the hydrographs in these figures indicates that the two models produce comparable results.

Wellfield Operations Scenarios

Results for 15 ASR wellfield operations scenarios are presented in this technical memorandum. These scenarios include variations on the ASR wellfields that could be constructed and operated (up to three wellfields), variations in the extraction capacity of ASR wells (varied from 1,500 to 3,000 gpm), and variations in the operations of the ASR wellfields, i.e., "put and take" operations. These scenarios were developed to provide insight into the potential groundwater-level responses over a large range of potential wellfield layouts and operating conditions.

In order to simulate the range of wellfield scenarios and operating conditions, ASR wells were assigned to individual nodes of the denser-grid model as shown in Figure 7. Thirty three ASR wells and the Calleguas Fairview ASR well are shown in Figure 7. ASR-1 through ASR-4 represent wells at ASR Wellfield No. 1. ASR-5 through ASR 18 represent wells at Wellfield No. 2. ASR-17 and ASR-18 represent actual ASR wells ASR-6B and ASR-7B, respectively. ASR-17 and ASR-18 labels were used because the naming convention for the actual wells was not decided at the time this work was performed. Although ASR-6 and ASR-7 are assigned to nodes they were not simulated because it was decided to relocate these wells to the north of WF2, at locationsASR-6B and ASR-7B. ASR-19 through ASR-31 represent a potential new ASR wellfield located to the east of Wellfield Nos. 1 and 2, which are used in some simulations to assess groundwater level conditions with 30 ASR wells in operation. ASR-32 and ASR-33 represent two potential ASR wells located immediately to the west of Wellfield No. 1. For convenience of referencing in this memorandum, wells ASR-19 through ASR-31 are referred to as Wellfield No. 3 and ASR wells ASR-32 and ASR-33 are referred to as Wellfield No. 4.

All ASR wellfield operations scenarios were developed as an overlay on the base case model developed by CH2M HILL (1997). The period of simulation of the ASR wellfields scenarios is from 1997 through 2016: a 20-year period. The model is based on 40 six-month time steps, so all injection and extraction rates are averaged over six months. In general, the injection rates and extraction rates used in most simulations represent the maximum capacity of the ASR wells for a given ASR wellfield configuration, as opposed to some averaged capacity over the six-month time period. Therefore, ASR well simulated drawup and drawdown are representative of maximum conditions, except as noted below. The base case model includes simulation of a five percent cut back in production by others every five years until safe yield is achieved over a 20-year period. A naming convention has been adopted in this study to designate a scenario as Scen-5X, where the number 5 represents the five-percent per five-year cutback on pumping and "X" is a letter representing the ASR wellfield operation scenario.

Following is a brief overview of the scenarios that have been evaluated in this study. Figures 8 though 22 present graphs of six-month injection and extraction rates and cumulative volume of water placed into storage over the 20-year simulation period. Table 1 summarizes for each scenario the injection and extraction quantities in acre-feet for each six-month time step of the simulation. Table 2 summarizes for each scenario the injection and extraction quantities in cubic feet per second for each six-month time step of the simulation. Table 3 summarizes for each scenario the injection and extraction quantities in gallons per minute (gpm) per well and total gpm for all wells for each six-month time step of the simulation.

- Scen-5A, Scen-5B1, Scen-5B2, Scen-5C, Scen-5D, Scen-5E, and Scen-5F. These scenarios are based on a three-year "put" operation followed by a fourth year "take" operation. Injection occurs in only a six-month period during the "put" operation. A third wellfield is included in Scen-C, Scen-5D, and Scen-5E.

- Scen-5G and Scen-5H. These wellfield simulations are also based on a three-year "put" operation followed by a fourth year "take" operation; however, they include a significant (3.5-year) storage period (no recharge or extraction), followed by an 18-month extraction event.

- Scen-5I, Scen-5J, and Scen-5K. These wellfield simulations are based on Metropolitan's Integrated Resources Plan (IRP) model "put and take" scenarios, assuming 100,000 acre-feet of storage, 80 cfs of injection capacity, and 100 cfs of extraction capacity. Scen-5I is the IRP average operations estimate, Scen-5J is the IRP low operations estimate, and Scen-5K is the IRP high operations estimate.

- Scen-5I4, Scen-5J4, and Scen-5K4. These wellfield simulations are similar to the previously described wellfield operations, with the exclusion of a third wellfield. Only 19 wells are assumed to be available for ASR operations (the Fairview ASR well, 4 wells at Wellfield No. 1, 12 wells at Wellfield No. 2, and 2 new wells immediately west of Wellfield No. 1).

Summary of Groundwater Model Simulation Results

For each groundwater model simulation of each wellfield operations scenario, the following results were obtained: groundwater level hydrographs representing key wells) in the basin (the same wells used in the calibration studies, groundwater level hydrographs representing ASR wells, groundwater level contours (of the whole basin and of the wellfield area) for selected time steps (generally, to represent high groundwater levels after an injection period and low groundwater levels after an extraction period), and a water budget summary, including summaries for the basin as a whole and for the east and west sides of the basin. Attachments A through O provide the printouts of the model results developed for this study. Each attachment is organized as follows: 1) three tables summarizing the water budget of the whole basin, west side of the basin, and east side of the basin, 2) a plot of basinwide key well hydrographs, 3) two plots of hydrographs showing groundwater level responses in ASR wells, 4) a set of basinwide groundwater level contour plots for selected time periods and, 5) a set of wellfield area groundwater level contour plots.

The simulation results for each wellfield operations scenario have been evaluated for the following effects: 1) basinwide groundwater level fluctuations, 2) groundwater levels fluctuations in the vicinity of the wellfields, 3) maximum drawup and drawdown in the ASR wells and, 4) water budget changes. Table 4 summarizes the conditions simulated for each wellfield operations scenario and pertinent observations from the simulation results.

As stated in the introduction to this technical memorandum, it is Calleguas' and Metropolitan's goal to maximize the extraction rates from the ASR wellfields. Variations in extraction rates were included in the wellfield operations scenarios. There is a practical limit to the extraction rate, which generally is limited by the available drawdown in the ASR wells. The available drawdown should be limited to "approximately" the top of the screened interval of the ASR wells. Once a groundwater level drops below the top of the screened interval of a well, then the potential for air entrainment exists and the extraction capacity of the well may decrease as the aquifer is dewatered near the pumping well. Figure 23 and 24 shows the screened intervals of wells completed at Wellfield No. 1 and Wellfield No. 2 to date, respectively. The current groundwater level is approximately 200 feet above the National Vertical Ground Datum (NVGD), commonly referred to as mean sea level.

Figures 25 and 26 show hydrographs of groundwater levels simulated for ASR-3 for all scenarios and selected Metropolitan IRP scenarios. Figures 27 and 28 show hydrographs of groundwater levels simulated for ASR-16 for all scenarios and selected Metropolitan IRP scenarios. ASR-3 is located at Wellfield No. 1 and ASR-16 is located at Wellfield No. 2. Generally, these wells exhibit the lowest simulated groundwater levels in their respective wellfields.

The following key observations can be summarized from the information presented in Table 4, Figures 25 through 28, and Attachments A through O:

1. The west half of the Las Posas Basin does not respond materially to ASR wellfield operations on the east side under all scenarios.

2. Wellfield operations scenarios including long storage periods (e.g., Scen-5G, Scen-5H, and Scen-5J result in excessive drawdown because groundwater levels decline toward pre-injection levels upon cessation of injection. The starting groundwater level is lower after prolonged storage compared to groundwater levels just after an injection period, so drawdown in the ASR wells is greater than when extraction occurs near the end of an injection cycle.
3. Screened intervals generally are not exposed in wellfield operations scenarios Scen-5A, Scen-5B1, Scen-5B2, Scen-5F, and Scen-5I.
4. Pumping greater than 2,000 gpm from wells at Wellfield No. 2 increases the potential for well screens to be exposed at Wellfield No. 2 under most scenarios.
5. On average, groundwater levels over the 20-year simulation period are higher than groundwater levels simulated in the base case.
6. Simulated groundwater levels within about one-half mile of the wellfields decline from 100 to 150 feet more compared to the base case under most wellfield operations scenarios, but declines of up to 250 feet below the base case are observed in some scenarios. This decline is reduced significantly with distance beyond a half mile from the wellfields.
7. Simulated groundwater levels within about one-half mile of the ASR wellfields rise up to about 100 to 150 feet above the base case groundwater levels for most wellfield operations scenarios, although greater increases are observed for more aggressive recharge scenarios.
8. Simulated groundwater levels do not rise above the ground surface at the ASR wellfields.
9. ASR operations appear to decrease the natural recharge to the Fox Canyon Aquifer on the east side of the basin. Therefore, as illustrated in Figures 29 and 30 for all scenarios and Metropolitan IRP scenarios, respectively, the simulated water balance at the end of the simulation period is less than the base case end of storage quantity plus the net quantity of water placed into storage over the period of ASR wellfield operations. For example, the simulated cumulative storage at the end of the simulated period for Scenario A, should be 100,000 AF greater than the base case cumulative storage at the end of the simulated period, but it is much less than 100,000 AF, which indicates that, 1) water was lost to adjacent aquifers, 2) natural recharge was reduced relative the base case or, 3) both conditions 1) and 2) occurred. The water budget tables in Attachments A through O suggest that both conditions likely exist, i.e., a reduction in recharge and loss of water to adjacent aquifers. The greatest effects occur in those scenarios where there are prolonged storage periods.

Wellfield No. 2 Pump and Motor Design Criteria

Design criteria, specifically extraction rates and low groundwater level conditions, for pumps and motors of Wellfield No. 2 have been developed based on an evaluation of the results of the wellfield operations scenarios described above. Combinations of flow rates and low groundwater elevations have been selected to minimize (but not avoid) drawdown below the top of well screens for wells screened at shallower elevations and yet provide as high as a possible flow rates from deeper wells screened at deeper elevations. Table 5 provides anticipated flow rates and associated approximate groundwater-level altitudes.

Table 5.

Summary of Estimated Wellfield Flows and Associated Groundwater Altitudes

Wellfield/Well Groups	Estimated Combined Flows (gpm/cfs)	Approximate Target Low Groundwater Altitude (feet above NVGD)
Wellfield No. 1/Wells ASR-1, 2, 3, 4	7,000/15.6	0
Wellfield No. 2/ Wells ASR-6B, 7B, 9, 10, 16, 15	12,000/26.7	-100
Wellfield No. 2/Wells ASR-5, 8, 11, 12, 13, 14	9,000/20	0
Two New Wells Close to Wellfield No. 1	3,000/6.7	0
Fairview ASR Well	1,000/2.2	200
Totals	32,000/71.2	

At a meeting on July 24th, Metropolitan requested that CH2M HILL provide estimates of anticipated flow rates, from the high rate upon startup of extraction through the ultimate low rate, when groundwater levels are expected to be at their lowest levels. We anticipate that groundwater levels will stabilize relatively quickly (i.e., within weeks) of startup of the wellfields. Higher flow rates of 10 to 15 percent more than the lower-end design flow-rate flows may be available if extraction were to occur immediately after an injection cycle; however, there is no way to reliably predict when this condition might exist. Therefore, we recommend using the lower-end design flow rates.

In addition, we recommend that future development of wellfields (i.e., more than 20 wells) in the east side of the basin be deferred at least until experience on the basin's response, relative to groundwater levels and water budget effect, is gained from operation of Wellfield Nos. 1 and 2.

Limitations and Uncertainties of Model Simulations

The Las Posas Basin ASR program will result in groundwater level fluctuations over a range that has not been experienced in the basin before. Therefore, the Las Posas Basin model has been used in this study to extrapolate groundwater level responses of the basin based on historical responses to natural recharge and existing pumping, which have been significantly less than the proposed ASR wellfield injection and pumping rates. There are a number of data gaps, as identified by CH2M HILL (1993), which add uncertainty to the model simulation results, some of which are repeated for emphasis below. Therefore, actual operations of the ASR wellfield should be carefully monitored and operated to gain experience in actual responses of the basin to injection and extraction operations. Following is a summary of the limitations and uncertainties, including potential effects of these uncertainties, associated with the groundwater model simulation results:

1. **Range of Basin Groundwater Level Fluctuations.** Simulated future groundwater level fluctuations exceed observed groundwater level fluctuations. The model is being used to extrapolate groundwater levels higher and lower than those ever observed in the calibration studies. There could be geologic conditions or boundary conditions that are not readily apparent from the available data that could cause simulated groundwater level responses to be different from those simulated in this study if those geologic or boundary conditions were taken into account in the model. For example, a fault may exist that doesn't have any observable effect on groundwater conditions under historical groundwater conditions, but may be an important feature under different groundwater conditions, such as injection and extraction operations. The Broadway fault located just north of Wellfield No. 2 is an example of a fault that has an uncertain significance.

2. **Hydrogeologic Properties.** Information on hydrogeologic properties is limited in the area of the wellfields; particularly transmissivity and storage properties of the Fox Canyon Aquifer. Transmissivity and storage properties of the Fox Canyon Aquifer are based on model calibration studies and aquifer tests conducted at ASR Wellfield No. 1. If actual transmissivity and storage values are higher than estimated, then actual groundwater level fluctuations would be damped compared to simulated groundwater level fluctuations, assuming all other conditions remain unchanged. Conversely, if actual transmissivity and storage values are lower than estimated, then actual groundwater level fluctuations would be magnified compared to simulated groundwater level fluctuations, assuming all other conditions remain unchanged.

3. **Interaquifer Leakance Conditions.** The hydraulic conductivity of the aquitards above and below the Fox Canyon Aquifer are not well known and have be estimated from model calibration studies, based on sparse groundwater levels in the interbedded zone above the Fox Canyon Aquifer and below in the Grimes Canyon Aquifer. Leakage of water from and into these adjacent zones will affect groundwater level responses in the Fox Canyon Aquifer. Leakage into these adjacent aquifers acts like capacitor: groundwater level fluctuations will be damped more than observed if leakage is greater than estimated and be magnified if leakage is less than estimated.

4. **Recharge From Arroyo Las Posas.** All wellfield operations scenarios simulations assume that recharge from the Arroyo Las Posas will continue as assumed for the base case scenario. As groundwater levels rise, this recharge may be reduced or eliminated in some cases, which would result in less water being placed in storage. In addition, this discharge may be removed and used for up stream reclamation purposes. Potentially, groundwater level rises would not be as high and groundwater level decreases would be further decreased as a result of this reduction in recharge.

5. **Camarillo Hills Gap Boundary Condition.** The groundwater boundary condition at the gap in the Camarillo Hills between the Las Posas Basin and Pleasant Valley Basin is uncertain. Currently, it is treated as a no-flow boundary condition. There is a potential that there may be an exchange of groundwater of the Fox Canyon Aquifer in this area. The impacts on groundwater levels during ASR operations are not known.

6. **Existing Pumping.** Projection of extraction quantities by existing pumpers is based on current wells and pumping records of the Fox Canyon Groundwater Management Agency. Redistribution of wells and pumping rates, particularly any increase of extractions near the ASR wellfields could impact the drawdown at the wellfields.

Recommendations

The following recommendations are provided based on the results of this study.

1. Complete Wellfield No. 2, using the pump and motor design criteria provided above, but wait to determine the feasibility of installing additional ASR wells on the east side of the basin until the limitations and uncertainties described above are further resolved.

2. Investigate the occurrence of the GCA beneath the ASR wellfields and the potential for interaquifer leakage with the FCA. The pilot hole of well ASR-12 could be drilled to approximately –800 feet below NVGD (about 1,500 feet below ground surface). Well ASR-12 is expected to represent an area where the depth to the GCA should be shallow, so this would be the most cost-effective location to investigate the occurrence and characteristics of this deeper aquifer and the potential for interaquifer leakage.

3. Develop a monitoring well network in the Interbedded Unit above the FCA to assess the potential leakage of water into and from this zone. This monitoring well network will include existing wells and new wells. Identify existing wells throughout the eastern side of the basin that are completed in the Interbedded Unit and select wells for regular monitoring (potentially monthly or quarterly during ASR operations and less frequently, such as semi-annually to annually during storage periods). The clustered monitored wells installed by the USGS should be included in this monitoring program. Install several clustered monitoring wells (i.e., screen two to three vertical intervals of coarser-grained sediments) near ASR-12 and ASR-10 at WF2 for monitoring purposes. Assess the potential leakage during ASR well aquifer testing. Monitor these wells during ASR wellfield operations.

4. Evaluate the coverage of monitoring wells in the FCA to assess groundwater levels conditions throughout this aquifer. For example, the monitoring well network should be sufficient to assess the potential impacts on groundwater movement associated with potential faults, such as the Broadway Fault, and recharge from the Arroyo Las Posas.

5. Assess the potential significance of the gap in the Camarillo Hills.

6. Extend the numerical groundwater flow model to include the Interbedded Unit. The model should be calibrated to existing conditions and data obtained as a part of the monitoring programs described above. The extended groundwater model could serve as a future management tool for basin operations.