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BROWNSTEIN HYATT FARBER SCHRECK, LLP

Spadra Basin Groundwater Modeling Report

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LIST OF ACRONYMS AND ABBREVIATIONS

acre-ft/yr	acre-feet per year
bgs	below ground surface
gpm	gallons per minute
GHB	general head boundary
DWR	California Department of Water Resources



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1. INTRODUCTION

This report documents those activities that were conducted to produce a three-dimensional groundwater flow model for the Spadra Basin. This groundwater flow model was prepared for Brownstein Hyatt Farber Schreck, LLP in response to their scope of work for the City of Pomona.

The modeled area includes the Spadra Basin and the northwestern portion of the Chino Basin. The model was constructed to investigate two predictive scenarios. The first scenario simulated a new well in the central portion of the Spadra Basin and the second scenario modeled the safe yield of the Spadra Basin.

The two scenarios were selected by the City of Pomona as documented in a memorandum included in Appendix 1. A detailed discussion of the purposes and assumptions for the modeling scenarios are included in Section 4.



2. HYDROGEOLOGY

The Spadra Basin is located in Los Angeles County south of the Six Basins within the City of Pomona. The basin occupies the eastern end of the San Jose Valley between Puente and San Jose Hills. The Spadra Basin is a relatively small (4,200 acres), horn shaped, alluvium filled, basin southwest of the Pomona Basin, west of the Chino Basin and northeast of the Puente Basin. The Spadra Basin is bound to the north and west by the San Jose Hills and to the south by the Puente Hills. The southwestern boundary of the Spadra Basin is located in a narrow neck where it joins the Puente Basin to the west. In addition, there are two faults that bound the Spadra Basin. These include the San Jose and Chino faults (Figure 1).

The San Jose Fault is thought to be a hydrologic barrier to groundwater flow from the Pomona Basin to the Spadra and Chino Basins except in the Pomona Narrows where groundwater underflow emanates from the Pomona Basin through a notch in the San Jose Fault, which was cut by the San Jose Creek. This underflow is considered a significant source of groundwater recharge in the Spadra Basin and northwestern Chino Basin.

The Chino Fault is expected to impede flow between the Spadra and Chino Basins, but is not a hydrologic barrier.

Groundwater flow within the Spadra Basin is generally to the southwest. Local groundwater flow is greatly affected by basin production wells. In the vicinity of all production wells, flow is toward the wells. Some groundwater exits the basin via the Puente Narrows. The amount of groundwater discharged to the Puente Basin is dependent of the water levels in the Spadra Basin. Groundwater underflow from the Spadra Basin to the Puente Basin has been estimated by the California Department of Water Resources (DWR) at approximately 200 acre-feet per year between the 1933/34 and 1959/60 water years (DWR, 1966).

The aquifers of the Spadra Basin are comprised of granitic and metamorphic sediments derived from the San Antonio Canyon formations from the hillsides along the basin margins. These alluvial deposits consist of sands with some gravel and silts and clays. There are two primary sand and gravel deposits that form the primary aquifers in the basin (Aquifers 1 and 2). The two aquifers are separated by finer grained silt and clay deposits. Water bearing gravels are located principally in the central portion of the basin. Clay deposits present in much of the basin are derived from the decomposition of gravels. Figures 1 through 3 illustrate the hydrostratigraphy of the Spadra, Chino and Pomona Basins.

In March 2008, JR Associates performed a geophysical investigation in the Palm Lake Golf Course Welch Park area located in the southeastern portion of the Spadra Basin. This report is included in Appendix 2. Five potential production well locations were investigated using five resistivity profiles generated by individual dipole-dipole arrays temporarily installed in the study area. Based on the



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results of this investigation, bedrock occurs between approximately 120 and 210 feet below ground surface (bgs) in the study area. Although bedrock was greater than 200 feet bgs in the Hansen Avenue profile, the area where bedrock is greater than or equal to 200 feet bgs is relatively narrow (200 feet across). In four of the resistivity profiles, an alluvial channel was identified. The alluvial channel is approximately 500 feet in width in the northern portion of the study area and narrows to the southeast where it is approximately 190 feet wide. The depth of the alluvial channel was not delineated, but it extends vertically to at least 240 feet bgs. The depth to bedrock within the alluvial channel is unknown. The findings of this report indicate that the bedrock is up to 220 feet shallower than anticipated in the southeastern portion of the basin. The implications of this finding are discussed in Section 3.1.



3. GROUNDWATER MODEL

3.1 Conceptual Model

The conceptual model was developed based on interpreted geologic and hydrogeologic data in the study area, which includes the Spadra Basin and the northwestern portion of the Chino Basin. The conceptual model is generally comprised of a stratified alluvial valley underlain by volcanic and metamorphic rocks. The basement rock is assumed to be impermeable and forms the base of the model. The boundary conditions of the conceptual model are discussed in Section 3.3.2.

The valley sediments are comprised of three hydrostratigraphic layers (Layers 1, 2, and 3). The layers in the Spadra Basin communicate with the layers in the Chino Basin across the Chino Fault. The layers are generally comprised of unconsolidated to semi-consolidated sand and gravel with interbeds of silt and clay. Fine grained aquitard materials separate the layers.

As discussed in Section 2, a geophysical survey was conducted in the southeastern portion of the Spadra Basin. The findings of this investigation indicated that the depth to bedrock was up to 220 feet shallower than delineated in the conceptual model. The conceptual model was completed in 2006 and the geophysical investigation was conducted in April 2008. A request was made to revise the conceptual model based on the results of the geophysical data; however, due to budgetary constraints, it was decided by the City of Pomona to proceed with the groundwater modeling using the 2006 conceptual model. As such, there is a known discrepancy with respect to the depth to bedrock in the southeastern portion of the Spadra Basin. This discrepancy will result in the overestimation of groundwater in storage in the Spadra Basin, which directly affects the results of the predictive scenario simulations.

3.2 Groundwater Flow Model

The USGS three-dimensional finite difference model, MODFLOW 2000, (McDonald and Harbaugh, 2000) was used as the flow model for simulating flow within the Spadra Basin and the northwestern portion of the Chino Basin. The McDonald-Harbaugh model is a finite difference groundwater flow model developed by the USGS. It is widely used and well documented. It is a true three-dimensional flow model, except for the assumption that the vertical component of flow is aligned with gravity. It has the capability of simulating a heterogeneous aquifer with evapotranspiration, variable well pumpage, drains, rivers, variable recharge, and different boundary conditions under either artesian or water table conditions.

Groundwater Vistas Version 4.28 (Rumbaugh, 2004) was coupled with MODFLOW. Groundwater Vistas is a pre- and post-processing modeling environment for Microsoft Windows that couples a model



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design system with comprehensive graphical analysis tools. This program provides visualization of model development and results, and allows for enhanced model quality and accuracy. Although Groundwater Vistas supports a wide variety of flow and transport models, it was used in this project for the development of MODFLOW modeling files and for processing modeling results.

3.3 Groundwater Flow Model Design

The groundwater flow regime at the Site was simulated based on the conceptual model described in Section 3.1 and the hydrogeologic conditions described in Section 2. The model was initially designed and calibrated to represent March 1989 steady-state conditions. The model was then modified to incorporate changes in recharge and pumping from March 1989 to March 2004 and compared to measured groundwater elevations collected from 36 wells with available water level data to verify the hydraulic flow field.

3.3.1 Model Grid

The grid framework was imported directly to MODFLOW from the hydrostratigraphic model discussed in Section 3.1 (Layers 1, 2, and 3). The model domain, shown in Figure 4, consists of 220 columns, 165 rows, and 3 layers. Grid spacing for the flow model is 200 feet.

3.3.2 Boundary Conditions

Recharge

Aerial recharge resulting from the infiltration of precipitation and return flow from irrigation, water main leakage, and sewer pipe leakage is modeled based on eight percent of average measured annual rainfall measured and about 20 percent of production pumping as return flow. This value was changed slightly during model calibration.

No Flow Boundaries

No flow boundary conditions were placed along much of the southern boundary to reflect the highlands that do not contribute to the water balance of the basin. The northern boundary, representing the San Jose Fault is also represented using no flow boundary conditions. The exception is the notch in the San Jose Fault where underflow is simulated using general head boundaries. Figure 5 summarizes the boundary conditions used in the model.



General Head Boundaries

The GHB (general head boundary) boundary condition is a head-dependent boundary condition. In a GHB cell, the flow of water into or out of the aquifer is dependent on the head assigned to the GHB and the conductance term. The head is compared to the computed head in the aquifer for the cell containing the GHB. If the aquifer head is higher than the GHB head, then the GHB removes water from the aquifer. The amount of water removed is based on the conductance term.

GHB conditions were used to represent the Chino basin sediments at distances great enough to not be affected by pumping in the Spadra Basin. This distance was generally set at 5,000 feet. GHB conditions were also implemented to simulate underflow from the Pomona Narrows.

3.3.3 Flow Model Parameters

Hydraulic Conductivity

Hydraulic conductivity is a measure of the ability of groundwater to flow through the aquifer material. Higher values of hydraulic conductivity indicate a greater ease of groundwater movement through the aquifer material.

No long-term pumping tests were conducted on the wells within the Spadra Basin. Hydraulic conductivity values for the sediments were estimated from specific capacity tests.

Hydraulic conductivity values for the aquifers were initially set at 80 feet per day in the Spadra Basin and 60 feet per day in Chino Basin. Aquitards were initially assigned a hydraulic conductivity of 10 feet per day. These values were later modified to obtain a better correlation between measured and modeled values of head. Figures 6, 7 and 8 illustrate the calibrated hydraulic conductivity for Layers 1, 2, and 3, respectively.

Storage

Storage properties have four components, S (specific storage coefficient), S_y (specific yield), effective porosity, and total porosity. The specific storage is the amount of water which a given volume of aquifer will produce, provided a unit change in hydraulic head is applied to it while it still remains fully saturated. Specific storage has units of inverse length and is the primary mechanism for storage in confined aquifers. It can be expressed as the volume of water released from storage per unit decline in hydraulic head in the aquifer, per unit volume of the aquifer. The value of specific storage is typically very small, generally 0.0001 1/ft or less.



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Specific yield, also known as the drainable porosity, is a ratio, less than or equal to the effective porosity, indicating the volumetric fraction of the bulk aquifer volume that a given aquifer will yield when all the water is allowed to drain out of it under the forces of gravity.

If a volume of saturated aquifer material is completely dried, the water volume removed reflects the total porosity of the material, or the fraction of pore space within the total volume of solids plus open spaces. The effective porosity can be thought of as the volume of pore space that will drain in a reasonable period of time under the influence of gravity. Effective porosity is always less than total porosity, sometimes (as in the case of clays) much less. "Good aquifers" tend to have values of effective porosity in the range of 10-30%, although examples of higher and lower values can be found. Figures 6, 7, and 8 depict the steady-state calibrated storage used in Layers 1, 2, and 3, respectively.

Model Top Elevation

The model top elevations were developed using the geologic information available from borehole logs for the area. The model tops used in the model are shown in Figures 12, 13, and 14.

3.4 Flow Model Calibration

The objective of the calibration process is to refine the numerical model by adjusting model input parameters so that model output more accurately represents observed data. The model was calibrated to the average annual groundwater elevations measured on March 1989. The calibrated flow model was then compared to a transient dataset beginning in March 1989 and extending to March 2006.

Steady-state calibration was conducted using data from March 1989. Steady-state conditions assume that no groundwater is being added or subtracted from storage. Although this assumption is never fully satisfied, the change in storage is small enough to be considered negligible in this case. To achieve the most accurate calibration possible, a piezometric head map was prepared using available head data and professional interpretation. The model parameters were adjusted to match this head surface in Layer 1. The calibration statistics suggest that the steady-state model adequately predicts the steady-state targets. Calibration statistics are included in Table 1 and are summarized on Figure 15. Final calibrated steady-state heads for Layers 1, 2, and 3 are presented in Figures 16, 17, and 18, respectively.

As a means of verifying the calibration, a transient simulation was conducted using data from March 1989 to March 2004. Pumping rates for each well were adjusted to match the observed pumping rate. The results of the transient verification are illustrated in selected hydrographs showing measured versus computed heads. These hydrographs are contained on Figures 19 through 26.



4. PREDICTIVE SIMULATIONS

The purpose of the groundwater model was to simulate two predictive groundwater pumping scenarios. These scenarios were selected by the City of Pomona as documented in Appendix 1. A description of the scenarios is as follows.

The first scenario simulated a new well in the central portion of Spadra Basin located between the Orange Freeway (57) and the Chino Valley Freeway (71) on the southwest corner of South Campus Drive and Ridgeway Street in the City of Pomona. The proposed well location is located in an undeveloped greenbelt park owned by the City of Pomona. The hypothetical well was simulated in the lower aquifer (Aquifer 2), using a 80 foot screened interval from approximately 260 to 340 feet bgs. In this area of the basin the top of Aquifer 2 is likely at approximately 260 feet bgs and the base of this aquifer is likely at 340 feet bgs, which is the depth to bedrock. This is based on evidence collected during the advancement of the near-by test boring (KB-1). Screening a well in the lower aquifer (Aquifer 2) will likely yield better water quality than the upper aquifer (Aquifer 1). Nitrate contamination has reportedly impacted the upper aquifer in this area of the basin. In addition, the City of Pomona does not have any wells that penetrate Aquifer 2 and this aquifer is likely less developed than the overlying aquifer (Aquifer 1). The City indicated that a combined total production rate of 1,000 gallons per minute (gpm) should be used for wells 19, 28, and 31 for this scenario. The desired production rate for the proposed well is between 300 to 400 gpm.

The final scenario determined the maximum safe yield that the Spadra Basin can sustain. This estimate will be contingent on the underflow from the Pomona Narrows remaining constant. The methodology increased hypothetical pumping in the Spadra Basin incrementally until the basin was in overdraft, which is indicated by a continuous decline in the groundwater levels during simulated pumping. At this point, groundwater mining is occurring and the safe yield has been exceeded.

As discussed previously, the safe yield of the basin will likely be over estimated because geophysical evidence collected in the southeastern portion of the basin indicates that the depth to bedrock could be up to 220 feet shallower in this area. The feasible pumping rate of the simulated well in first scenario was less affected by the findings of the geophysical survey because this well was simulated in the center of the basin in an area where the depth to bedrock was known during the development of the 2006 conceptual model.



5. ANALYSIS AND CONCLUSIONS

5.1 Safe Yield of the Spadra Basin

The model was used to estimate the safe yield of the Spadra Basin. The methodology used included multiplying the pumping rates of the existing wells in the model domain (Spadra Basin and western Chino Basin [Figure 5]) by unit percentages until the safe yield was exceeded. This was indicated by a continuous decline in groundwater levels in the basin indicating groundwater mining was occurring. It was then assumed that the maximum unit percentage before groundwater mining occurred represents the safe yield (e.g., a stabilized drawdown trend had been established). This occurred at a total Spadra Basin withdrawal of approximately 1.5 million gallons per day (mgd) (1,680 acre-feet per year [acre-ft/yr]) and is considered the estimated safe yield of the basin. Current pumping in the Spadra Basin is approximately 0.81 mgd (912 acre-ft/yr), which represents approximately 54% of the estimated safe yield. Therefore, the basin can currently sustain an additional 0.69 mgd (768 acre-ft/yr) without groundwater mining occurring. Although, the basin can sustain short-term periods of higher withdrawals as long as the long-term average does not exceed the estimated safe yield. Based on historical pumping records for the last ten years, withdrawals in the Spadra Basin reached a maximum of approximately 87% of the estimated safe yield. This occurred during the 2000 to 2001 and 2001 to 2002 water years. The withdrawals during this time included wells 19, 28, and 31 and estimated pumping from CalPoly 1 and CalPoly 3.

Only publicly available groundwater production data from within the model domain was used to estimate the additional available basin yield. As such, it is possible that there are other groundwater consumers in the basin that were not considered and may result in a reduction in the additional available yield.

It should be noted that the estimated safe yield likely overestimates the actual quantity of groundwater that can be safely withdrawn on a long-term basis. Geophysical data suggests that the sediments in the southeastern portion of Spadra Basin are much shallower than simulated in the model. At the direction of the City of Pomona, the conceptual model was not revised to incorporate the actual bedrock depths in this area of the basin, resulting in an overestimation of safe yield due to the reduction of basin storage.

The estimate of safe yield in this report is based on holding groundwater levels constant over the long term and does not take into account the potential for active management of the Spadra Basin to generate multi-year storage for conjunctive use operations. The model could be used to determine the potential and parameters for such active management plans if the City desired to use it for that purpose in the future.



5.2 Additional Well in the Central Portion of the Spadra Basin

Under current pumping conditions, the model results for this scenario indicate that a well screened in the lower aquifer (Aquifer 2) can be installed as suggested in Section 4 and produce groundwater between 300 and 400 gpm without detriment (significant and sustained drawdown) to both the upper and lower aquifers. However, the City indicated that in this scenario should use a combined total production rate of 1,000 gpm (1.44 mgd) for wells 19, 28 and 31 and this production plus the new well production exceeds the safe yield estimated in Section 5.1. As such, it is not feasible to add a new well with a desired pumping rate between 300 and 400 gpm and pump wells 19, 28, and 31 at a combined rate of 1,000 gpm. Based on historical pumping records, wells 19, 28, and 31 have never been pumped at a combined rate of 1,000 gpm. The maximum rate recorded in the last ten years for these wells was approximately 682 gpm.

Although the model is not calibrated to actual conditions due to the geophysical evidence discussed previously, it is likely that the model is less affected in the area of the proposed new well because the depth to bedrock in the central portion of the basin was known during the development of the conceptual model. However, this cannot be confirmed unless the conceptual model is revised with the findings of the geophysical survey and the model is recalibrated.



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6. CLOSURE

We trust that this report satisfies your current requirements and provides suitable documentation for your records. If you have any questions or require further details, please contact the undersigned at any time.

Respectfully submitted,
WorleyParsons

Nathaniel Beal
Project Manager



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