HAHN WATER RESOURCES, LLC

REPORT ON

SUSTAINABILITY OF THE BEAUMONT BASIN AND BEAUMONT MANAGEMENT ZONE

FOR

SAN GORGONIO PASS WATER AGENCY

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1. BACKGROUND

The San Gorgonio Pass Water Agency (Agency or SGPWA) will adopt its first Urban Water Management Plan (UWMP) in late 2010. Among other things, this plan is required to "...describe and evaluate sources of supply, reasonable and practical efficient uses, and reclamation and demand management activities..." and serve as a "... long range planning document for water supply..." (DWR, 2005). These goals are not expected to change substantially as the requirements of the UWMP are updated in 2010/2011.

The Agency requires reliable information on the existing ground water resources within its service area, as these will form one component of the future water supply within the Pass area. In addition, the Agency requires a quantitative assessment of the ability of the Beaumont Management Zone (BMZ) "... to meet local water demands during both the next five years and the next 20 years, based on historic and current withdrawals, safe yield studies, the Beaumont Basin judgment, and Watermaster and STWMA studies." (San Gorgonio Pass Water Agency, 2009).

A judgment for adjudication of the Beaumont Basin was entered in 2004. One important element of the adjudication is the declaration of a 160,000 acre foot (AF) surplus in the basin. The adjudication also specifies the division of water between the "overliers" (generally those having a right to pump water within the basin by virtue of land ownership) and the "appropriators" (those having the right to pump water from within the basin by virtue of having acquired the right to water from an overlier, or through other legal means), thereby providing a framework for division and future use of the "surplus". Planning by the Agency, as well as planning by other water purveyors within the Beaumont Basin, relies on the availability and allocation of resources prescribed by the adjudication. Forecasts of future supplies and demands, and projections of the future state of overdraft are intimately tied to the terms of the adjudication.

The principal objectives of this study were: 1) refine the ground water model of the Beaumont and Banning ground water basins originally developed by the U.S. Geological Survey (USGS); 2) update the model to reflect the current state of the Beaumont and Banning Basins and the BMZ in terms of current supplies and current uses; and 3) use the model to predict basin response to the probable range of future supplies and demands. The reliability of alternative water supply sources (i.e. imported water sources) is being evaluated by the UWMP Contractor in a separate, parallel study.

2. APPROACH

2.1 Beaumont/Banning Ground Water Model Revisions

The principal tool to be used in the analysis of Beaumont and Banning Basin hydrologic conditions is the Beaumont/Banning Basin Ground Water Model. This model, completed by the USGS in 2006, provides a transient simulation of hydrologic conditions during the period 1926 through 2003. It is based on MODFLOW, a numerical ground water modeling program.

MODFLOW is a modular finite-difference modeling program developed by the USGS (McDonald and Harbaugh, 1988) that can simulate ground water flow. After dividing the area of study into rectangular blocks, or "cells", users provide MODFLOW with a set of initial conditions (water levels), boundary conditions, and values for parameters needed to describe the ground water flow system, by cell. MODFLOW then solves a series of ground water flow equations for each cell in order to determine the changes in the groundwater system over time. These equations are partial differential equations based on Darcy's Law of flow through porous media and on the principle of continuity (the idea that the flow of water into each cell must equal the flow of water out of each cell plus or minus the change in storage).

Inputs to MODFLOW consist of files, or "packages," that describe conditions (actual or predicted) in each cell during sequential time periods or "stress periods." For example, the well package allows users to input cell locations and pumping withdrawals (in units of volume per time) for each cell during each stress period. Other packages allow for the simulation of the effects of streams, lakes, springs, irrigation, precipitation, evapotranspiration and other factors that impact the ground water system. By solving the ground water flow equations with user specified inputs, MODFLOW can estimate the hydraulic head within each cell. MODFLOW also produces a detailed water budget that can show changes in the water balance over time due to stresses like pumping. These outputs provide a three-dimensional view of the ground water system, under actual or forecast conditions, and can assist in describing or predicting ground water movement and availability. The Beaumont/Banning Basin Ground Water Model was built using the 1996 (MODFLOW '96) implementation of MODFLOW. Among other changes made during this project, the model was updated for execution using a more current version of MODFLOW (MODFLOW 2000).

2.1.1 Model Changes

In addition to updating the model for compatibility with the MODFLOW 2000 program, this project included several modifications to the model to strengthen its defensibility and its reliability in forecasting basin hydrologic behavior. Principal changes to the model are summarized in the following paragraphs.

The USGS model employed a grid consisting of 1,000 foot by 1,000 foot cells. This grid was refined to provide greater numerical resolution and to provide greater resolution in describing physical and hydrogeologic features within the model domain. The majority of the 1,000 foot model cells were divided into 200 foot by 200 foot cells, such that most cells in the original model are now each represented with 25 cells. The approximate boundary of the active cells within the model is shown in Figure 1.

The original model simulated the period beginning in 1926 and ending in 2003 (78 years) on a calendar year basis. This simulation period was extended in the revised model to take advantage of hydrologic data collected since the completion of the original model. The extended simulation runs for an 83-year period, from 1926 through 2008, also on a calendar year basis. The year 2008 was chosen as the final year of the historical simulation as it was the last year for which relatively complete records were available.

The grid refinement process combined with the extension of the model simulation period required that model boundaries be modified. The modifications were done in such a way as to preserve, as much as possible, the effect of the original boundaries in terms of fluxes into and out of the model and the effects of the boundaries on water levels within the model domain. For example, where the original boundary condition cell had one face in contact with regions outside of the active domain (no-flow cells), the five cells corresponding with the outer face of the original cell were assigned a boundary condition equivalent to that of the original cell.

2.1.2 Ground Water Model Benchmarking and Peer Review

Once the changes to the USGS model were completed, the revised ground water model (hereinafter the "revised model" or simply "the model") was run through the historical period (1926 through 2003) using the same set of hydrologic conditions as were used in the original USGS ground water model. The objective of this exercise was to compare the water budget values and the water levels as predicted by the original USGS model with those predicted by the revised ground water model. Some differences in these values can be expected as a result of changes in the representation of boundaries, the precision with which wells are located, and other changes associated with the process of refining the model. However, these differences should be small compared to the overall water budget and the overall magnitude of water level changes predicted by the models. The process of benchmarking the revised model provides some assurance that the revised model is faithful to the original model in its representation of the basin.

Figure 2 is a comparison of the terms of the water budget as predicted by the original USGS model with those predicted by the revised model for the steady-state simulation. This figure suggests good agreement in the values of the water budget as predicted by the original USGS model with those predicted by the revised model. Figure 3 is a comparison of the terms of the water budget as predicted by the original and the revised model for the transient simulation, through 2003. Some changes to the historical pumping were made in the process of revising the USGS model. These changes reflect updated estimates of pumping within the basin as recorded by the Agency. These changes, while minor, had a small effect on the water budget components in latter years of the simulation. In general this figure suggests good agreement in the values of the water budgets predicted by the original and revised models.

Figures 4, 5, and 6 contain hydrographs of water levels predicted by the revised model compared with those predicted by the original model at several locations within the model domain. Well hydrographs were chosen from each of the five "areas" comprising the model's domain as defined by the USGS. These hydrographs also suggest good agreement between water levels predicted by the original and with those predicted by the revised model.

A final step in the model refinement process involved a third-party, peer review of the revised model. This review was performed by Thomas Harder and Company. The review concluded that the revised model was suitable for use in forecasting of future hydrologic conditions in the basin and in predicting basin response to future supply and demand conditions.

2.2 Supply/Demand (S/D) Model

A model of the probable future supplies and demands for water within the Agency boundaries was developed by others in connection with their on-going work on an Urban Water Management Plan (CDM, 2010). The model includes detailed accounting of the supplies and demands for all of the principal water users within the Agency's boundaries. The model is based in large part on information furnished directly by the users, including their estimates of future supply sources (e.g. stormwater recharge, re-use, etc.). The model includes estimates of future supply conditions (both local supplies and State Water Project (SWP) water. These estimates are based on past hydrologic conditions recorded and/or estimated for a 77-year period running from 1927 through 2003. The model begins its forecasting with the year 2010 and continues through 2045. For a given set of demands, the model attempts to capture the variability in supply conditions by varying the starting year, such that each simulation includes 77 possible outcomes. This array of outcomes can be used to identify statistical averages and/or extremes that reflect the probable variability in future water supplies. Further information on the S/D Model is on file with the Agency.

The S/D Model attempts to balance future water supplies and demands on an annual basis. The balance is achieved by varying the prediction of several "variables" within the model. The two variables of significance to the ground water model are: 1) the amount of water placed into ground water storage on an annual basis and 2) the amount of ground water pumped on an annual basis. In some instances, water is placed into storage for recovery in subsequent years when there is a shortfall in supply. This is typically water that has been placed into storage by one or more of the water retailers. In other cases, water is placed into storage in an effort to mitigate basin overdraft. This is typically water placed into storage by the Agency. The S/D model differentiates the quantities of water pumped and stored by the water users, and produces these results for each year of the simulation. These results are used directly by the ground water model in its 20-year simulation.

2.3 Sub-Basin Water Budgets

The boundaries of the Beaumont Basin are not everywhere coincident with the boundaries of the BMZ. Whereas the Beaumont Basin is defined more or less by hydrologic features (e.g. Banning Fault), the BMZ includes several areas contiguous to the Beaumont Basin. Specifically, the BMZ includes an area known as the South Beaumont Basin to the south, and the Edgar Canyon alluvial system to the north. The locations of these basins are shown in Figure 1. Also, the southeast boundary of the Beaumont Basin is defined by the Banning Fault, a northeast-southwest trending fault that provides some hydraulic separation between the Beaumont Basin and the adjacent Banning Basin. The southeast boundary of the BMZ lies a short distance to the northwest of this fault. Both the Edgar Canyon and South Beaumont Basins have well defined boundaries, and share a boundary with the Beaumont Basin. Further, the data critical to the analysis of hydrologic conditions in these basins has been collected as a part of the broader data collection efforts of the Agency in cooperation with the USGS. Accordingly, these basins were analyzed separately, using a time-series water budget approach. The area contained within the Beaumont/Banning Ground Water Model that lies outside of the limits of the BMZ represents a relatively small portion of the model. The area does not contribute significantly to the model in terms of sources of recharge, nor does it represent a major source of well pumping. And, while it is possible to isolate the model's representation of this area, there are no distinct hydrologic boundaries that would justify treating this area separately. Accordingly, there were no adjustments made to the model to isolate or separately account for this area.

2.3.1 Development of the Annual Water Budget

The goal of the sub-basin analysis was to determine long-term yields for outlying storage units within the Agency's boundaries that contribute water to the BMZ, and correspondingly the Beaumont/Banning model domain, specifically the South Beaumont Basin and the Edgar Canyon Basin. Using open source data from the Agency and the USGS, a water budget was created to account for the dynamic equilibrium of each of these storage units during an average year. From this average-year water budget, a detailed water budget was produced for the years 1988 to 2008. The following water balance equation was used to create these water budgets:

Inflow – Outflow = +/- Change in Storage

Following is a summary of terms used in estimating sub-basin water budgets:

Precipitation: For the average annual water budget, long-term precipitation in Beaumont, CA (1876-2004) is reported to be 18.32 inches per year (Rewis, et al, 2006). By applying this depth of rainfall to the estimated surface area of each storage unit, a total rate of precipitation (in acre-feet per year, or AFY) was calculated.

Infiltration: Infiltration was not calculated directly but instead was found as the remainder of precipitation not lost to ET and surface run-off. Assumed rates of infiltration varied by land use and topography. For instance, infiltration was assumed less in urban areas and on terrain with steep slopes.

Surface Flow In / Out: Surface flow was divided into two parts: surface run-on/off and stream flow. Surface run-off consists of rainfall that does not infiltrate or evaporate and flows over land and out of the area of the storage unit. Surface run-on is run-off from outside the boundaries of a storage unit that flows into the surface boundaries. Overland run-off was varied by land use and topography. For instance, run-off was assumed to increase in urban areas and on terrain with steep slopes. Estimates of run-off and run-on were calculated in direct proportion to the contributing area around the storage unit surface boundaries.

Stream flow is the flow of perennial, intermittent and/or ephemeral streams into and out of the storage unit's surface boundaries. Stream flow was determined by gage reports (where available) and interpolation and estimation elsewhere.

Underflow In /Out: Underflow consists of ground water that moves in and out of storage units, laterally and vertically, beneath the surface due to changes in hydraulic head. Using Darcy's Law and the principles of ground water flow, underflow was estimated as the flow rate of water crossing low-permeability boundaries between specific storage units. In order to estimate underflow, reasonable estimates were made about hydraulic gradients, the cross-sectional areas of discharge points and hydraulic conductivities.

For the Edgar Canyon storage unit, the mapped boundaries of the storage unit are significantly smaller than the overlying watershed boundaries. Because of this, a portion of the rainfall infiltrating anywhere in the watershed – not just within the contributing surface area - could ultimately reach the aquifer. This assumption accounts for an increase in proposed inflow to the canyon storage unit, occurring mainly as underflow.

Recharge: Recharge includes return flows from pumping and other irrigation located within storage unit surface boundaries where the pumped water is applied or used within the storage unit. In the case of Edgar Canyon, most of the pumping from within that storage unit is exported for use in the Beaumont Storage Unit, and therefore generates no return flows within the Edgar Canyon storage unit.

Evapotranspiration (ET): ET is an estimate of actual evaporation of rainfall that has not percolated into the ground water storage unit or left the storage unit surface boundaries as run-off. This remaining water has been intercepted by vegetative or urban cover, ponded on semi-permeable or impermeable surfaces (and evaporated) or is consumed and transpired by plants. As with other parameters, ET varied by land use and topography. For instance, ET was assumed to decrease in urban areas and on terrain with steep slopes.

Production: Production is a measure of water withdrawn from the ground water storage units by wells above each respective storage unit.

2.3.2 Storage Unit Annual Water Budgets

The results of the average annual water budget were used to develop annual water budgets for each storage unit for each year beginning in 1988 and ending in 2008. These water budgets used the same inflow and outflow categories as the average annual water budget: Precipitation, Surface Flow In/Out, Underflow In/Out, ET, Recharge and Return Flows, and Pumping. The variation in annual values for precipitation, surface runoff, infiltration, etc. were estimated by taking the recorded rainfall from the Beaumont rain gage for a specific year and dividing this yearly precipitation total by the average annual precipitation. This calculation produced a "precipitation factor" - an indicator of how wet each year was in comparison to the average. For instance, a result less than 1 means that year received less rainfall than average – a result greater than 1 means that year received more rainfall than average. Using the assumption that a year with more rainfall would also have greater surface run-off, more underflow and more ET, the precipitation factor was multiplied by the total volume of water in each category to adjust for the relative amount of water introduced into the system by precipitation during each particular year.

Using the continuity equation, outflows were subtracted from inflows leaving a net change in storage. This change in storage, when divided by the assumed specific yield (S_y) of the aquifer, produced an estimate of the expected net change in water level. The cumulative change in water level was plotted and compared to water level recordings from various wells within each respective storage unit as a way of "calibrating" the sub-basin water budgets. Inflow and outflow parameters were subsequently adjusted in an effort to improve the match between predicted and observed water levels. Although this was not a rigorous calibration process, it provided an indication that the terms of the sub-basin water budgets were reasonable.

3. FORECASTING MODEL

3.1 Forecasting Model Setup

The revised model was further modified so that it could be used in a forecasting mode. The resulting model is hereinafter referred to as the Forecasting Model. The Forecasting Model was designed to simulate a 20-year period beginning in 2010 (the starting year of the S/D Model) and extending through 2029. The final water levels predicted for 2008, the final year of the historical simulation, were taken to represent the initial condition for the forecasting model. Boundary conditions for the Forecasting Model (general head, drains, faults, etc.) were assigned values as they existed in 2008. These values were held constant through the forecasting period. Recharge from rainfall was treated as a constant in the historical model and was treated in a similar manner in the Forecasting Model. Return flows from applied irrigation water and return flows from septic systems in the Cherry Valley area were also treated as constant in the Forecasting Model, and set at rates equal to those estimated for 2008 of the historical model. Return flows from applied irrigation water and septic system returns were set to constant values for several reasons. First, the growth in future pumping is likely to be associated with municipal supplies, rather than development of new agricultural areas. Second, as the use of reclaimed wastewater expands, some of the return flows that might have been associated with the growth in municipal pumping (e.g. residential lawn watering) will be replaced by return flows from reclaimed water. Third, in many parts of the basin, the travel times required for infiltrating water to reach the water table extend well beyond the forecasting period. As a result, changes in recharge that occur within the forecast period will have limited or no effect on the simulation.

Water to be recharged artificially was assigned to specific recharge facilities according to the source of the water (SWP, storm water, reuse water), the availability of facilities to accomplish the recharge, and the estimated capacity of those facilities, as follows:

Table 1. Summary of Recharge Facility Attributes

Name of Facility	Owner	Year On-Line (from start of future simulation)	Estimated Capacity (AF/Y)
Cherry Valley	SGPWA	0	1,500
Noble Creek (west)	BCVWD	0	15,000
Brookside South	SGPWA	3	3,650
Noble Creek (east)	BCVWD	10	15,000
Beaumont (unnamed) Site	SGPWA	6	15,000
Banning (unnamed) Site	Banning	6	5,900

SGPWA – San Gorgonio Pass Water Agency; BCVWD – Beaumont Cherry Valley Water District

The S/D Model supplies predictions of the allocation of SWP water among the various recharge facilities based on information supplied by the retail agencies and communities and prevailing hydrologic conditions for each year of the simulation. The S/D Model also supplies predictions on the volume and disposition of stormwater and wastewater that is planned for recharge, again based on information supplied by the retail agencies and prevailing hydrologic conditions for each year of the simulation.

With the exception of one existing well in the Banning Basin, all future pumping was allocated to existing wells in proportion to an individual well's share of pumping in 2008, the final year simulated in the historical model. This approach is consistent with the way in which future pumping was simulated by the USGS in their prior analyses of future water management scenarios. However, in the case of one well in the Banning Basin, it was found that even relatively small increases in pumping caused excessive lowering of water levels in the model cell hosting the well. Accordingly, pumping at this location was redistributed evenly between the existing location and two new locations, both within the Banning Basin. This resulted in a reduced concentration of pumping and significantly lessened the impact on water levels.

3.2 Description of Future Water Management Scenarios

Two water management scenarios were identified jointly with the Agency for analysis with the revised ground water model: 1) ***Maximum Recharge Scenario*** and 2) ***Limited Recharge Scenario***. The specific water supply and demand conditions for both scenarios were developed using the S/D Model. Both scenarios involve a 20-year forecast period, consistent with the Department of Water Resources requirements for the UWMP.

3.2.1 Maximum Recharge Scenario

The ***Maximum Recharge Scenario*** is designed to test the region's ability to accept recharge water at a rate of recharge in excess of that needed to simply balance annual supply and demand, over a 20-year planning horizon, and to test the basin's response to the supplemental recharge. Conditions of this scenario are characterized by comparatively aggressive acquisition and storage of SWP water. The Agency is assumed to store 20% of available SWP water in each year of the simulation. Rates of extraction and recharge are defined using the S/D Model.

3.2.2 Limited Recharge Scenario

The ***Limited Recharge Scenario*** is designed to test the region's ability to sustain pumping at rates needed to fully meet the region's projected demands over a 20-year planning horizon, under limited recharge conditions. This scenario is characterized by heavy reliance on in-basin ground water supplies, including the temporary surplus storage specified in the Beaumont Basin Adjudication, storm water capture, reuse, and acquisition and storage of SWP water only as needed to meet future demands. Under these conditions, water users acquire supplemental water (such as SWP water) only as needed to offset any shortfalls in in-basin supplies and make no attempt to acquire SWP water for long-term storage. The Agency is assumed to store 10% of available SWP water in each year of the simulation, limited by the capacity of their recharge facilities. Rates of extraction and recharge are defined using the S/D Model.

3.2.3 Model Representation of Alternative Scenarios

The S/D Model incorporates two variables that together can be used to characterize the degree to which the region relies on acquisition and storage of State Water Project water in meeting existing demands and building storage to help in offsetting future demands, or in the alternative, the degree to which the region relies on in-basin resources, including ground water storage, storm water capture, reuse, etc. in meeting existing and future demands. These variables are described in the S/D Model as follows:

> *A. Fraction (%) of Table A SWP water above demand that is purchased for long-term storage*
> *B. Fraction (%) of Table A SWP water allocated for mitigating basin overdraft*

These variables may be specified in the range of 0 to 100 percent. In developing the maximum recharge scenario, variable A was set to 100%, while variable B was set to 20%. In developing the limited recharge scenario, Variable A was set to 0% while Variable B was set to 10%.

The S/D Model incorporates annual hydrology for a sequence of years beginning in 1927 and ending in 2003. Recognizing that supply and demand may change as a function of the hydrology in any given year as well as the hydrology of a sequence of years, the model includes provision for specifying the starting year of simulation. This provides a means for testing the changing demand against variable hydrologic conditions.

Both scenarios were constructed by "rolling through" each year beginning with 1927 and ending with 2003 and recording the S/D Model's prediction of total, maximum, and minimum values for recharge and extractions over a 20-year forecast period (2010 –

2029). These statistics were subsequently used to set the corresponding conditions (recharge and extraction) to be incorporated in the ground water model for both scenarios.

For example, the matrix that was generated in connection with developing the limited recharge condition included predictions of total pumping, maximum single-year pumping, and years during which basin recharge was at a minimum. This combination of extremes can be expected to produce maximum impacts (drawdown of water levels in the basin). Once the starting year that produced these extremes was identified, the model was used to predict the sequence of recharge and extractions corresponding with that starting year. In the case of basin extractions, the year 1969 was one of several that produced the extremes described above.

4. RESULTS

4.1 Estimates of Sub-Basin Water Budgets

The objective in developing the sub-basin water budgets was to estimate the yield of the South Beaumont and Edgar Canyon sub-basins. In this case, yield is defined to be equal to the sum of the inflows to the sub-basin. This definition implies that when net pumping (pumping less return flows) exceeds a basin's yield, the basin will be in an overdraft condition and water levels will decline accordingly.

Results of the water budget analysis indicate a yield of between 700 and 1,000 AF/Y for the South Beaumont Storage Unit. This estimate is consistent with a prior estimate of safe yield (Boyle Engineering Corporation, 1988) which indicated a safe yield of 750 AF/Y. Results of the water budget analysis indicate a yield of the Edgar Canyon Storage Unit in the range of 2,000 to 2,800 AF/Y. The upper limit of this estimate is higher than prior estimates of yield of the Edgar Canyon Storage Unit (Boyle Engineering Corporation, 1988) which indicated a yield of 2,000 AF/Y. The USGS completed a detailed rainfall – runoff model of the Edgar Canyon basin (Rewis, 2006) as a part of their modeling of the Beaumont/Banning basins. Their model estimated that the Edgar Canyon basin (Little San Gorgonio Creek watershed) was delivering approximately 2,330 AF/Y to the Beaumont basin. This suggests a sustained inflow to the Edgar Canyon Storage Unit of a similar amount. However, in the process of constructing and calibrating the ground water model, the USGS reduced inflows to the Beaumont basin from 2,330 to about 350 AF/Y. It is unclear what role pumping, particularly in recent years, may have played in justifying these revisions. Alternatively, water levels measured in Edgar Canyon during the period 1988 to 2008 are generally rising while the pumping during this same period has averaged about 2,900 AF/Y, suggesting that the yield is likely higher than the 2,330 AF/Y. In light of this, yield of the Edgar Canyon sub-basin is estimated to be in the range of 2,300 to about 2,800 AF/Y.

It is unclear to what extent the yield of the Edgar Canyon sub-basin contributes to the yield of the Beaumont Basin. The USGS (Rewis et al, 2006) reported that pumping from the canyon would intercept water that might otherwise contribute to the Beaumont Basin, and suggested that inflows to the Beaumont Basin be adjusted accordingly, after first accounting for the significant time delay for the effects of pumping to be felt in the Beaumont Basin. In such a case, development of the full yield from the Edgar Canyon sub-basin would require an offsetting reduction in the assumed yield of the Beaumont Basin. The relationship between yield of the Beaumont Basin and the Edgar Canyon sub-basin should be re-evaluated periodically as additional information on production and water levels becomes available. Revisions to the way in which the combined yields are treated may be warranted at some point in the future.

4.2 Modeling Results

The following table identifies locations at which water levels are predicted in simulating the future scenarios. In some cases, these locations coincide with wells that are actively monitored and reported by the Agency or by the USGS. In other cases, these locations coincide with artificial recharge sites. Locations associated with recharge sites provide water levels in layer 1, the uppermost layer of the model. The purpose in monitoring water levels at recharge sites is to determine the degree of water level mounding caused by the recharge and whether or not water levels rise to the extent that they would impinge on the floor of the recharge facility.

Table 2. Locations for Water Level Predictions

Map ID	Well or Site ID	Model Row, Column	Layers Monitored	Approximate Elevation
18A1	1S1E18A1	98,263	1,2	2422
18C1	3S1E18C1	104,245	1,2	2455
33L1	2S1W33L1	79,127	1,2	2566
27L1	2S1W27L1	40,146	1,2	2809
25B1	2S2W25B1	61,46	1,2	2300
23H1	2S2W23H1	48,21	1,2	2387
29M1	2S1W29M1	61,88	1,2	2590
4A1	3S1W4A1	84,143	1,2	2605
22P3	2S1W22P3	26,141	1,2	2909
3K3	3S1W3K3	89,166	1[a)]	2634
1N1	3S1W1N1	88,205	1[a)]	2606
8P1	3S1E8P1	91,272	1,2	2415
NC-W	BCVWD Noble Creek West	44,144	1[b)]	2770
NC-E	BCVWD Noble Creek East	49,147	1[b)]	2760
SG-N	SGPWA (unnamed) Site	61,144	1[b)]	2670
BR-N	Brookside (north end)	63,138	1[b)]	2640
BR-S	Brookside (south end)	78,134	1[b)]	2590
CH-V	SGPWA Cherry Valley	24,141	1[b)]	2920
BANN	Banning (unnamed) Site	103,269	1[b)]	2400

a) Layer 2 not present at this location.
b) Recharge from these facilities will be to Layer 1.

Results of the two modeling scenarios (maximum recharge scenario and the limited recharge scenario) are described in the following sections and contrasted in terms of the projections of pumping, recharge, net water balance, and water level impacts. In the following discussion, the term "basin" is used to describe the active model domain, representing both the Beaumont and Banning Basins.

Figure 7 shows the projection of pumping for the maximum recharge scenario. Total pumping is forecast to increase from about 15,000 AF/Y at the start of the simulation, to about 37,000 AF/Y by the end of the 20-year planning horizon. Total pumping in the limited recharge scenario is identical to that predicted for the maximum recharge scenario. This results from the fact that the forecast demand is identical for both scenarios and supplied entirely by wells.

Figure 8 shows the projection of recharge for both scenarios. In this case, recharge under the maximum recharge scenario is consistently higher than recharge under the limited recharge scenario through year 2025. In the two subsequent years, recharge under the limited recharge scenario actually exceeds that under the maximum recharge scenario. One of the variables incorporated in the S/D model is used to represent the maximum volume of water that can be stored in the basin. This value was tentatively set at 100,000 AF, based in part on estimates of the amount of water that has been mined (in excess of 100,000 AF). In this case, the maximum basin storage is reached by the year 2025 under the maximum recharge scenario. As a result, the amount of water that can be recharged in subsequent years is capped under this scenario.

Figure 9 shows the "net water balance" of the two scenarios for the Beaumont Basin only. The Banning Basin water balance is not reflected in this figure. Net water balance is taken as the difference between total (artificial) recharge and total pumping projected to occur in the Beaumont Basin. As expected, a more favorable balance exists under the maximum recharge scenario. Figure 9 also compares the net water balances of the two scenarios with the safe yield of the Beaumont Basin, estimated to be between 5,000 and 6,000 AF/Y (Boyle Engineering Corporation, 2002). In general, some restoration of basin storage may be expected whenever the net water balance exceeds the basin's safe yield.

Figure 10 shows the projected operation of recharge facilities owned and operated or planned for possible development by the SGPWA. The Cherry Valley Spreading Grounds are operated in each year of the 20-year planning period. The Brookside South Spreading Grounds are presently under construction, and tentatively planned to come online in both scenarios by 2014. The facilities at both locations are operated at capacity in at least some years in both scenarios. As expected, this occurs more frequently in the maximum recharge scenario. Additional recharge capacity was postulated as being available at a location known as the Unnamed Recharge Site. As shown in Figure 10, this capacity is required to be available in year 2021 in the maximum recharge scenario and in the year 2023 under the limited recharge scenario. The use of a substantial fraction of the capacity at this site occurs in 2021 under the maximum recharge scenario and in 2025 under the limited recharge scenario.

Figures 11 through 15 show predicted water levels at key locations within the basin including several that are monitored and reported by the Agency in their Annual Report on Water Conditions. Water levels are predicted for both layer 1 (upper layer) and layer 2 (lower layer) of the model. These figures indicate that in both scenarios, the basin was able to sustain the projected increases in pumping over the 20-year forecast period without major impairment of basin water levels. Water levels are projected to increase over much of the basin under both scenarios. Water levels are projected to decline in some areas of the basin, although the declines do not appear to trigger dewatering or major losses in well production.

Figures 16 through 18 show predicted water levels beneath each of the recharge facilities that are operating during the 20-year projection. These figures all indicate that the rates of recharge in this scenario can be sustained without unacceptable mounding (water level rise) that would cause water levels to impinge on the floor of the recharge facility or that would give rise to surface discharge (springs) in the area surrounding the recharge facility.

Figures 19 and 20 are maps showing lines of equal water level change throughout the basin for the maximum recharge and limited recharge scenarios respectively. Water level change is calculated as the difference between water levels at the start of the planning period and water levels at the conclusion of the planning period. Negative values indicate areas of water level rise. These figures show that for both scenarios, there are relatively broad areas of the basin that are projected to see increasing water levels.

5. CONCLUSIONS

The S/D Model (developed by others) combines variable hydrology with supply and demand forecasts supplied by each of the major water retailers to produce realistic predictions of future pumping, recharge, stormwater runoff and streamflow capture, and wastewater recharge and reuse. These values were supplied as inputs to a numerical ground water model as part of this investigation of the sustainability of the Beaumont Basin. The ground water model allows testing of the basin's ability to support future demands for water and to investigate the basin's response to the changing supplies and demands. Following are the principal conclusions from this investigation:

- Water supplies are sustainable through the planning period (2010-2029)
- Pumping and recharge configurations are workable
- SGPWA will require additional recharge capacity (above the capacity available with the Cherry Valley Spreading Grounds and the Brookside South Recharge Facility) within about 10 to 12 years
- Supplemental water will be needed to offset the growing demands for water by the retail agencies and to achieve some level of overdraft mitigation.

There is uncertainty in the forecasting of future hydrology, and predictions of future supply and demand. In light of this uncertainty, it is appropriate to incorporate some contingency in the quantities of future supplies that need to be acquired, in sizing of future facilities, and in timing the construction of new facilities. The level of contingency that is adopted for planning purposes should reflect a balance between this uncertainty of the forecast and the consequences of shortfalls in supply.

6. REFERENCES

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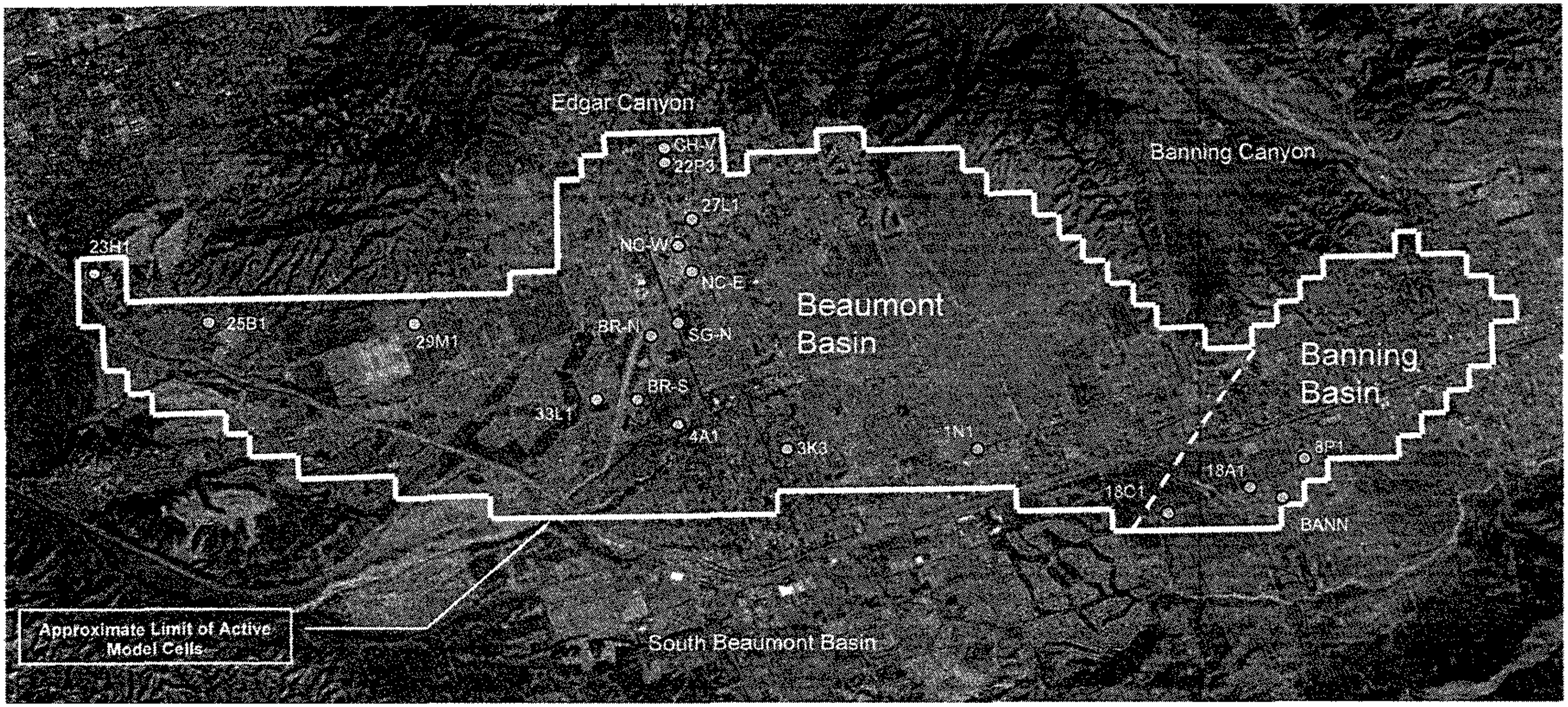
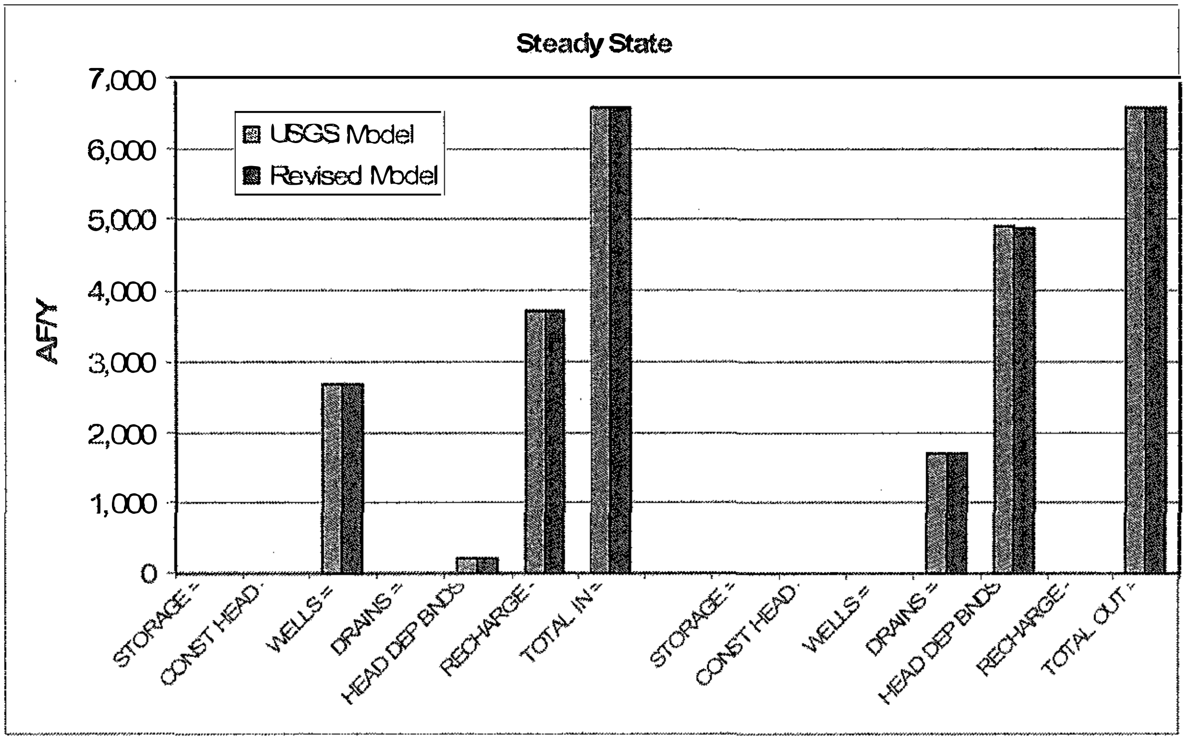


18A1 Location of Water Level Observation Location. See report for complete Well Designation

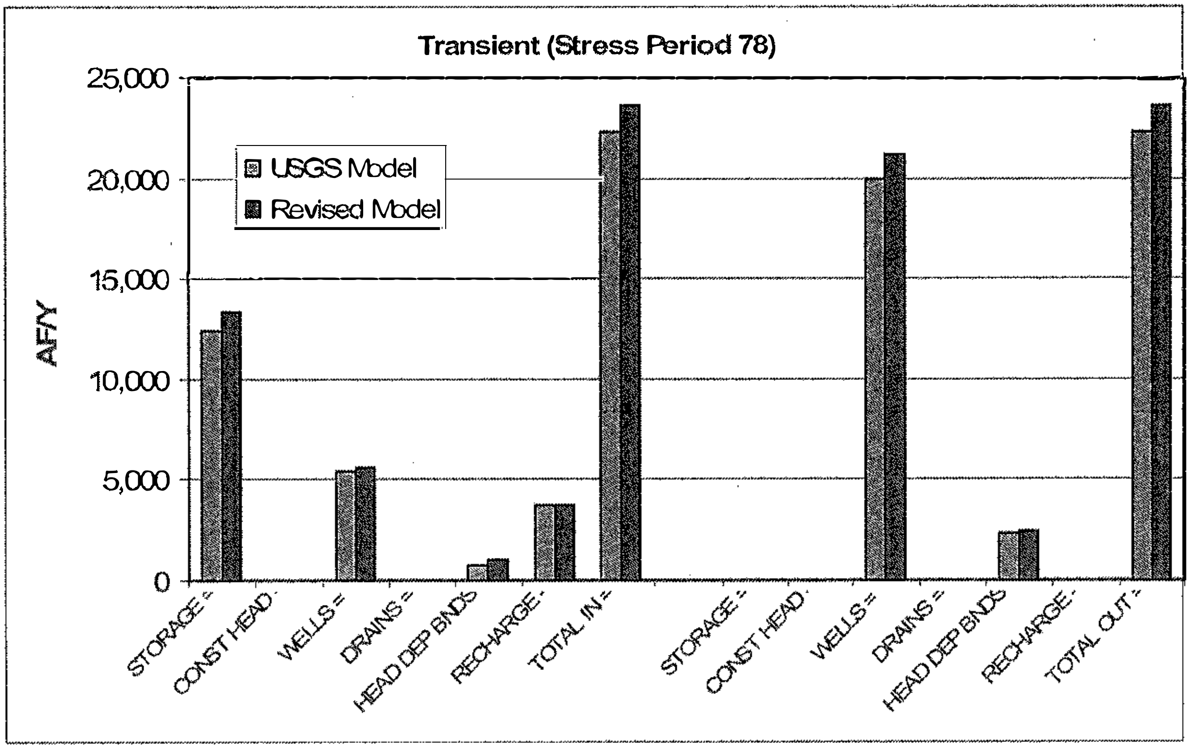
0 1 2 MILES

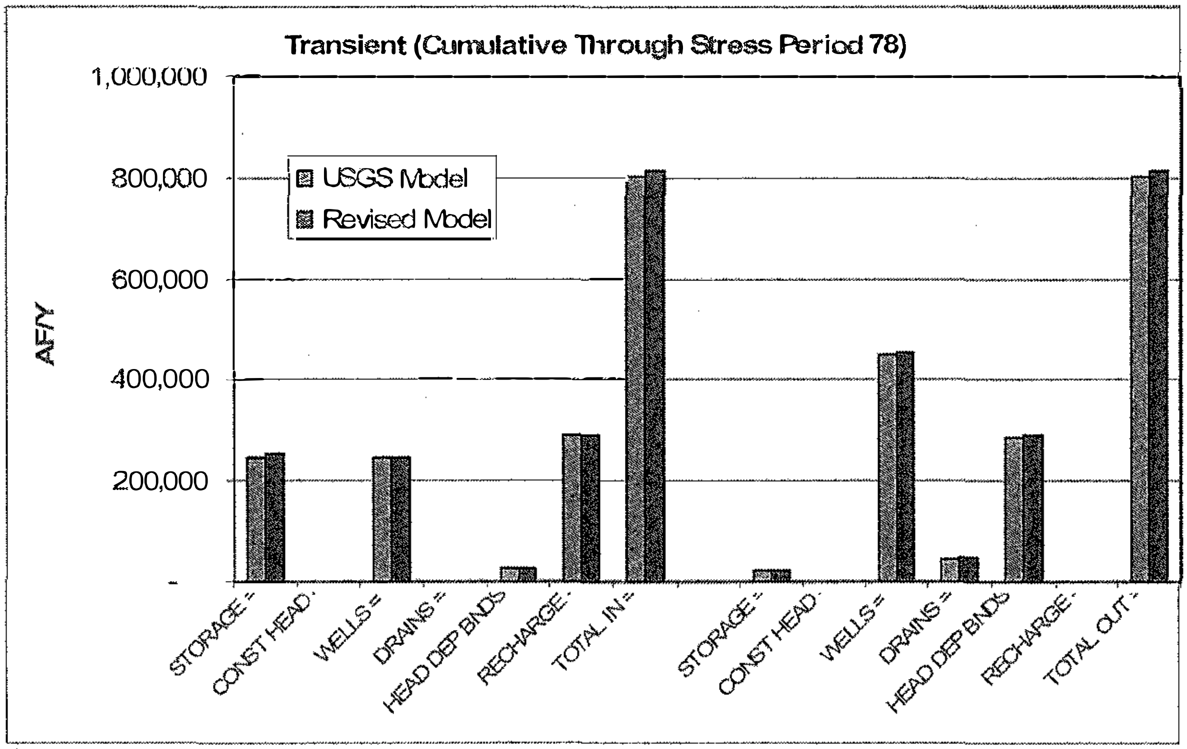
Source of Image: Google Earth, 2010

10/30/10	Study Area and Locations of Water Level Observations	Figure 1
HA-109	San Gorgonio Pass Water Agency – Evaluation of Supply and Demand in the Beaumont Basin	



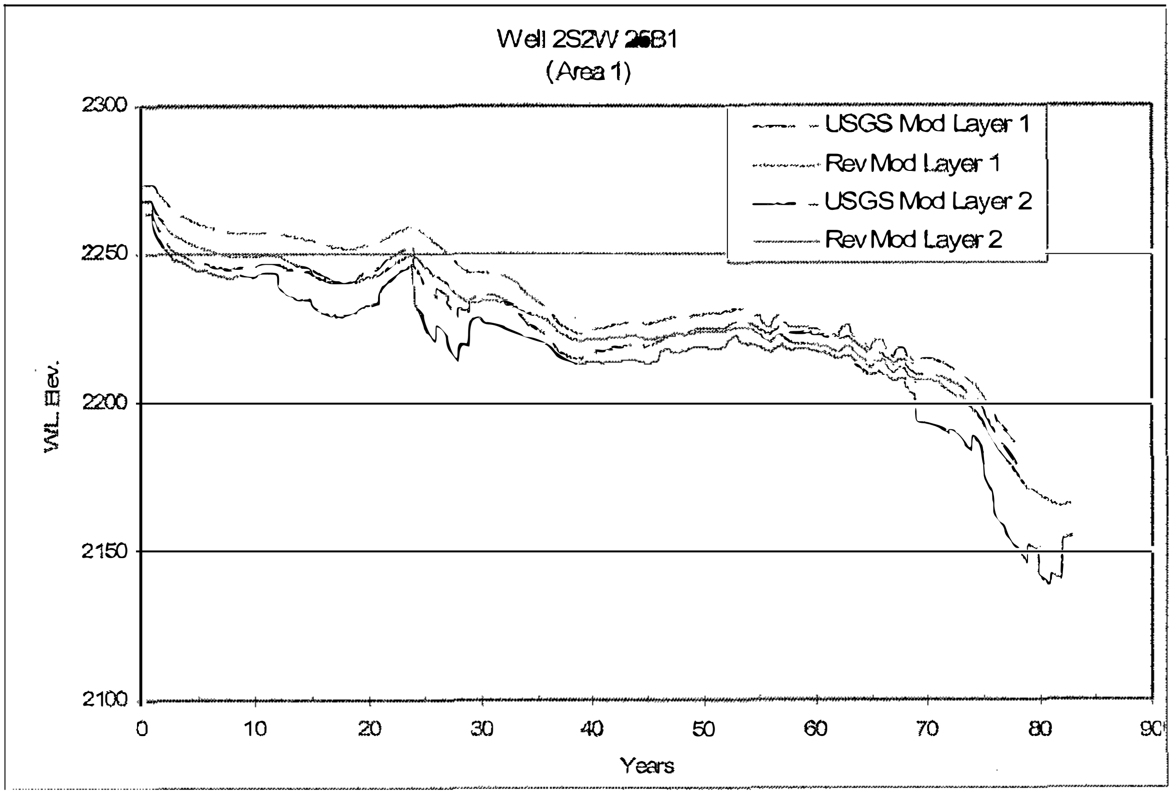
	Comparison of Water Budget Components for the Steady State Simulation	
10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 2
HA-101	HAHN WATER RESOURCES, LLC	

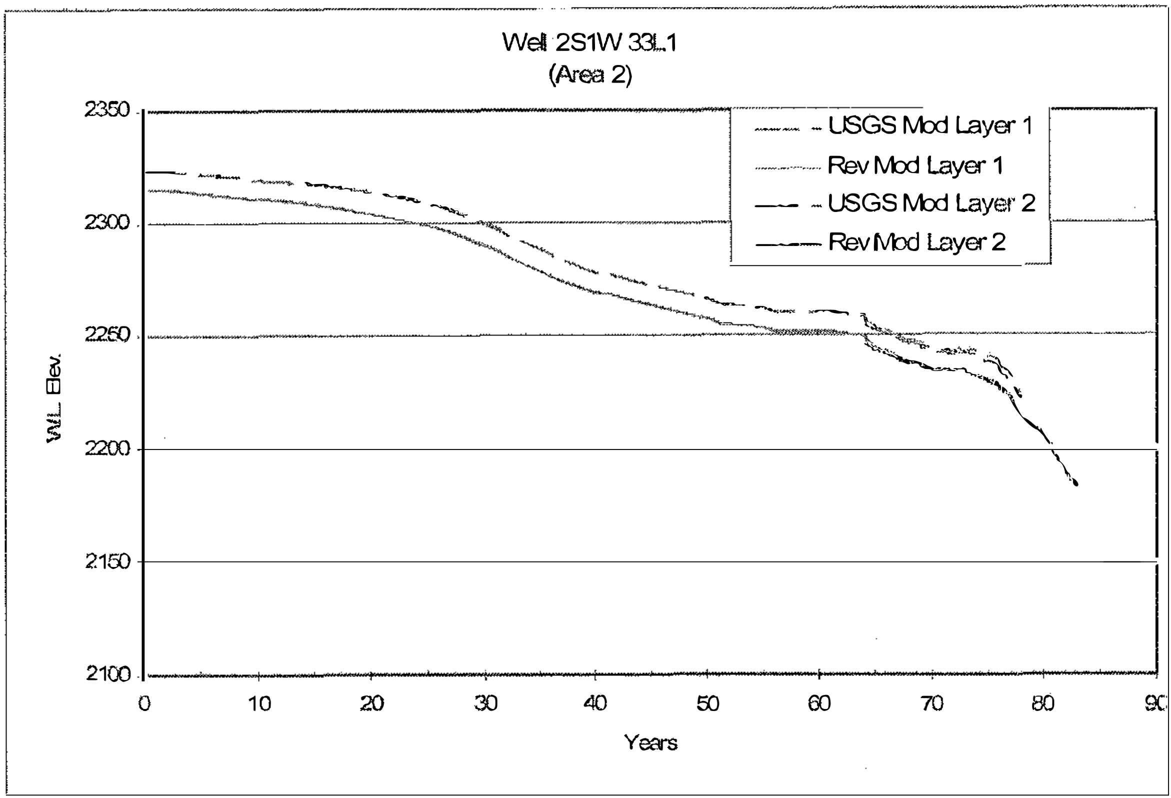




Comparison of Water Budget Components for the Transient Simulation

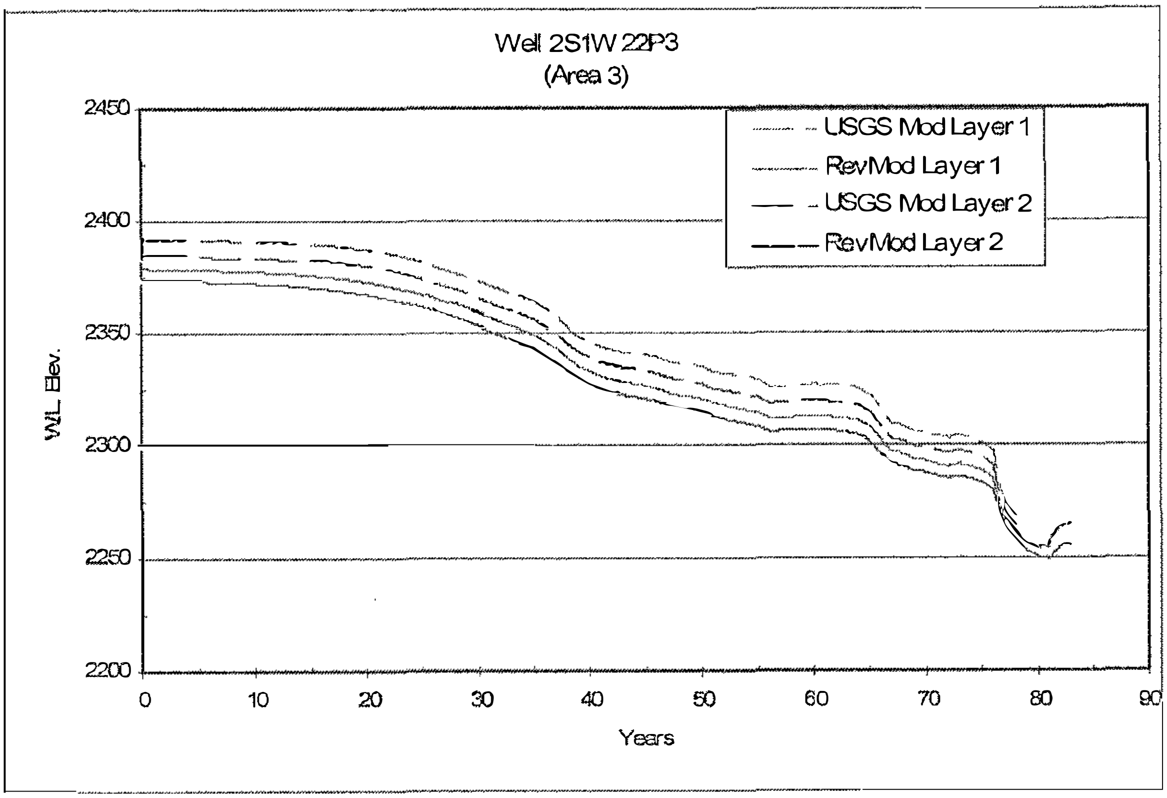
10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 3
HA-101	HAHN WATER RESOURCES, LLC	

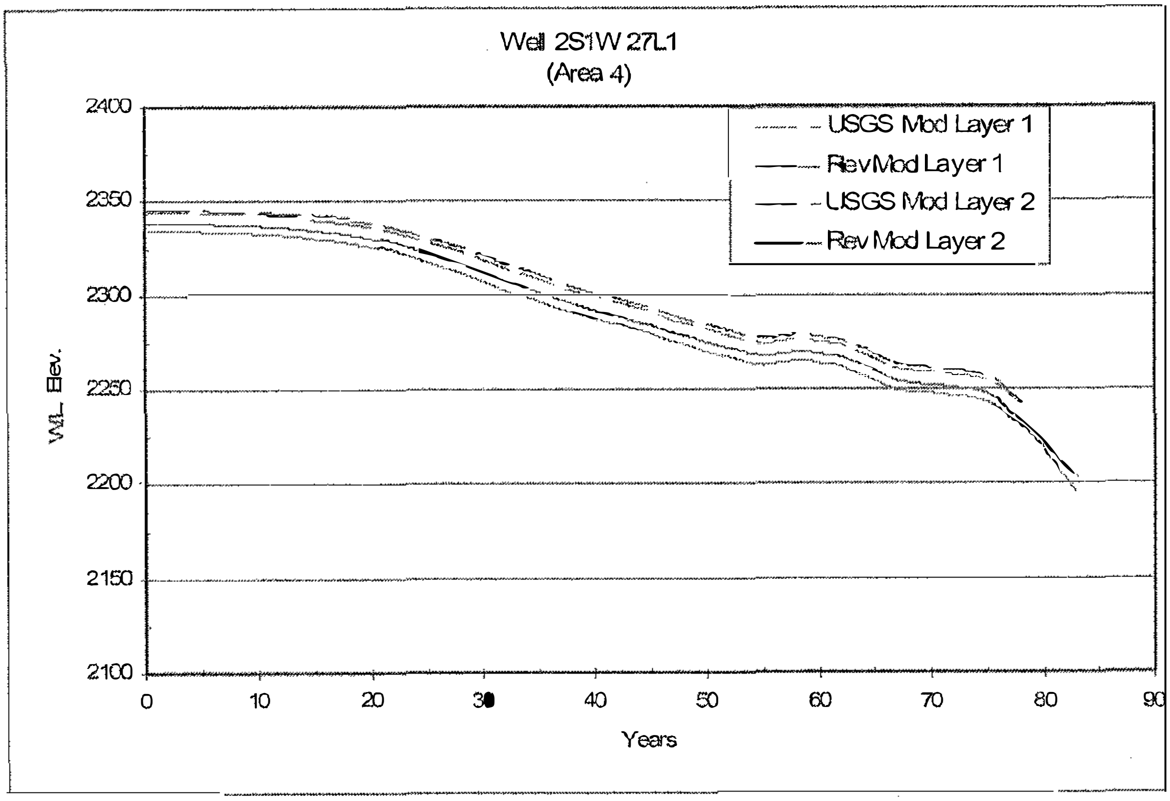




Comparison of Well Hydrographs for the Transient Simulation (Areas 1 and 2)

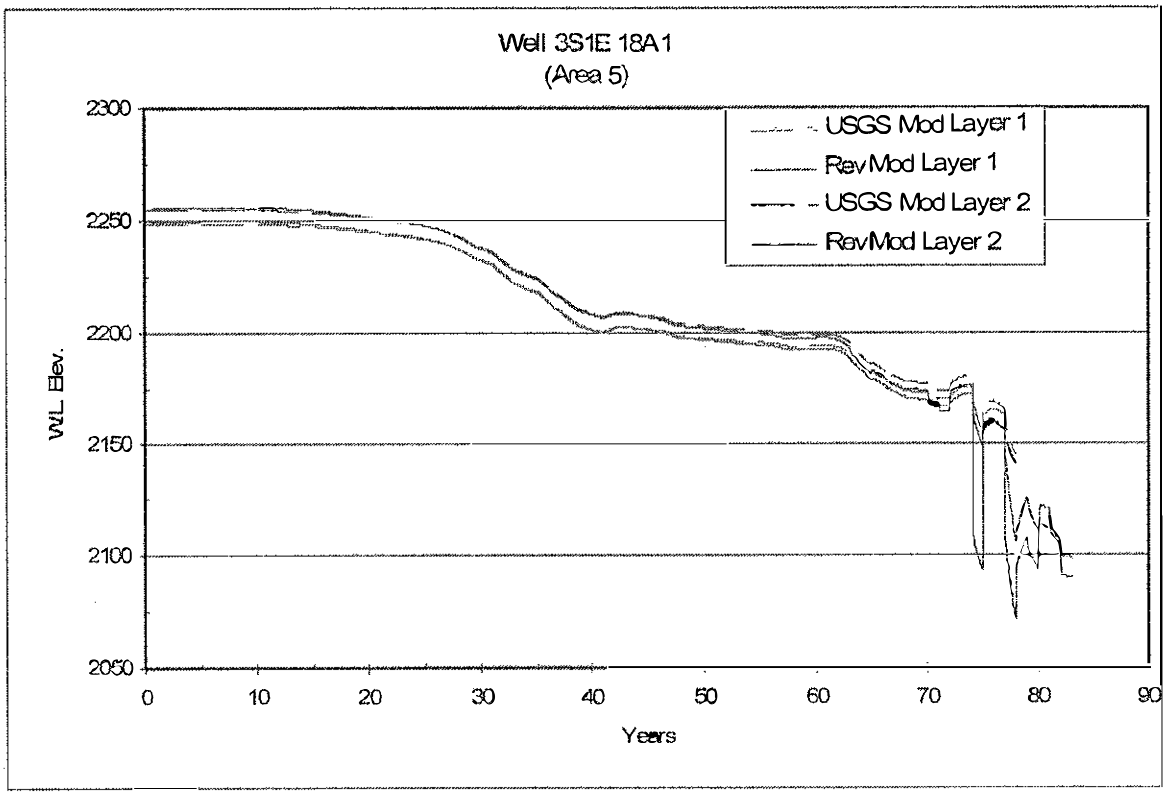
10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 4
HA-101	HAHN WATER RESOURCES, LLC	





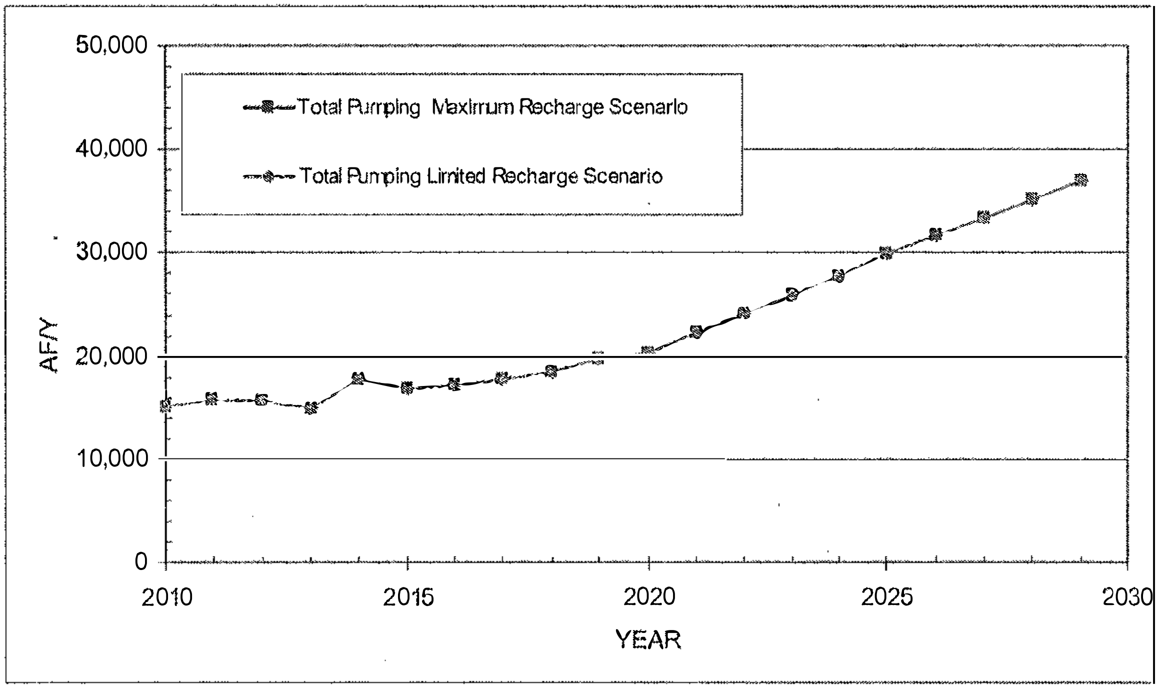
Comparison of Well Hydrographs for the Transient Simulation (Areas 3 and 4)

10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 5
HA-101	HAHN WATER RESOURCES, LLC	



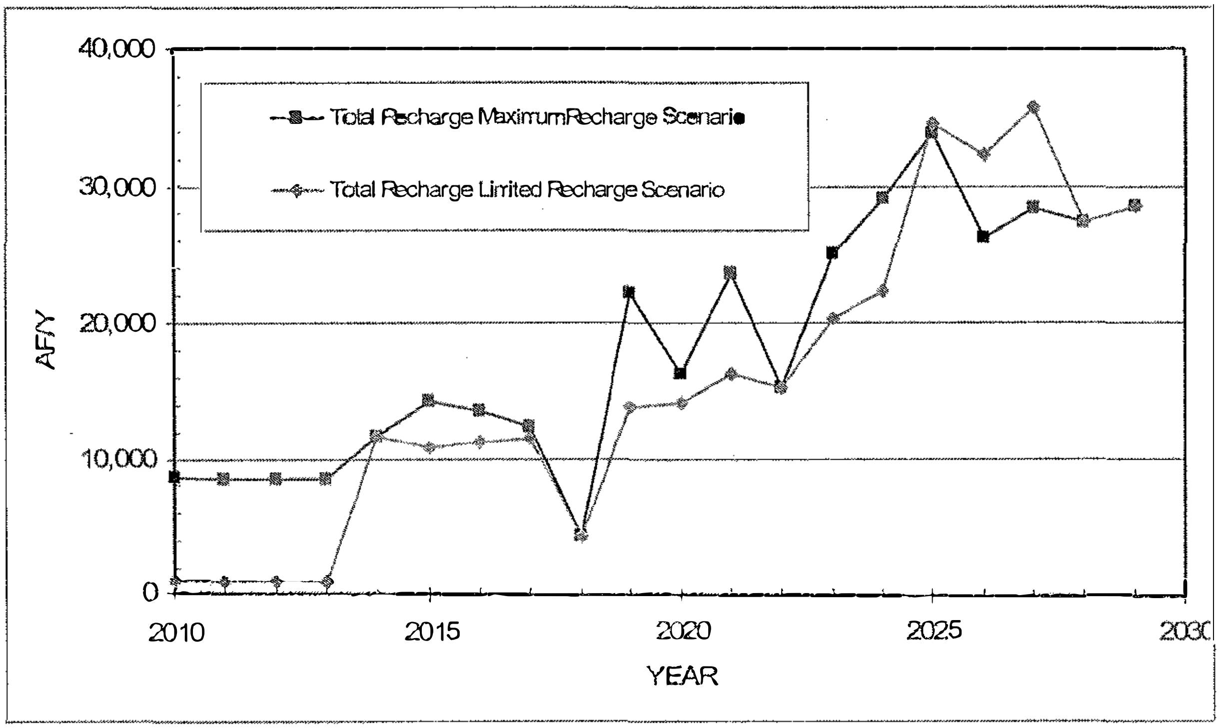
Comparison of Well Hydrographs for the Transient Simulation (Area 5)

10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 6
HA-101	HAHN WATER RESOURCES, LLC	



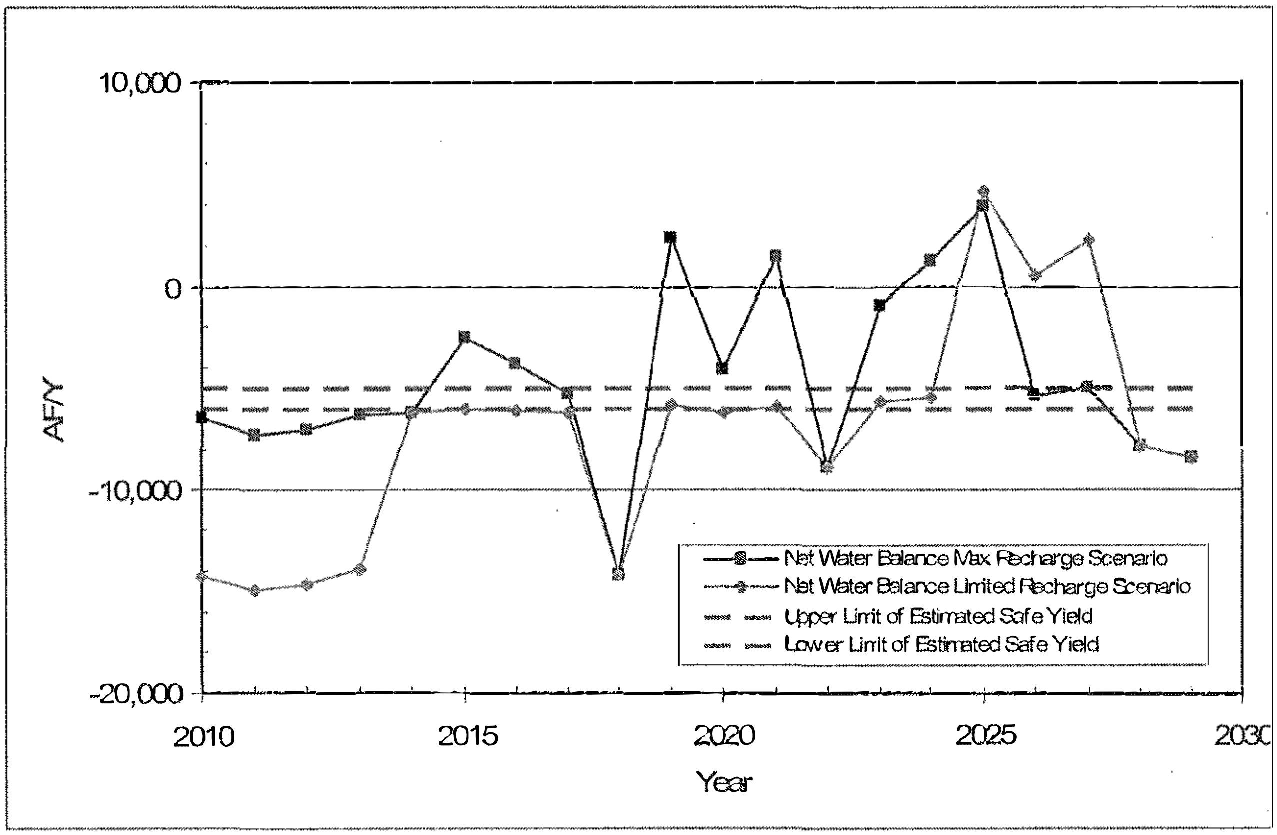
	Comparison of Pumping – Maximum Recharge vs. Limited Recharge

10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 7
HA-101	HAHN WATER RESOURCES, LLC	



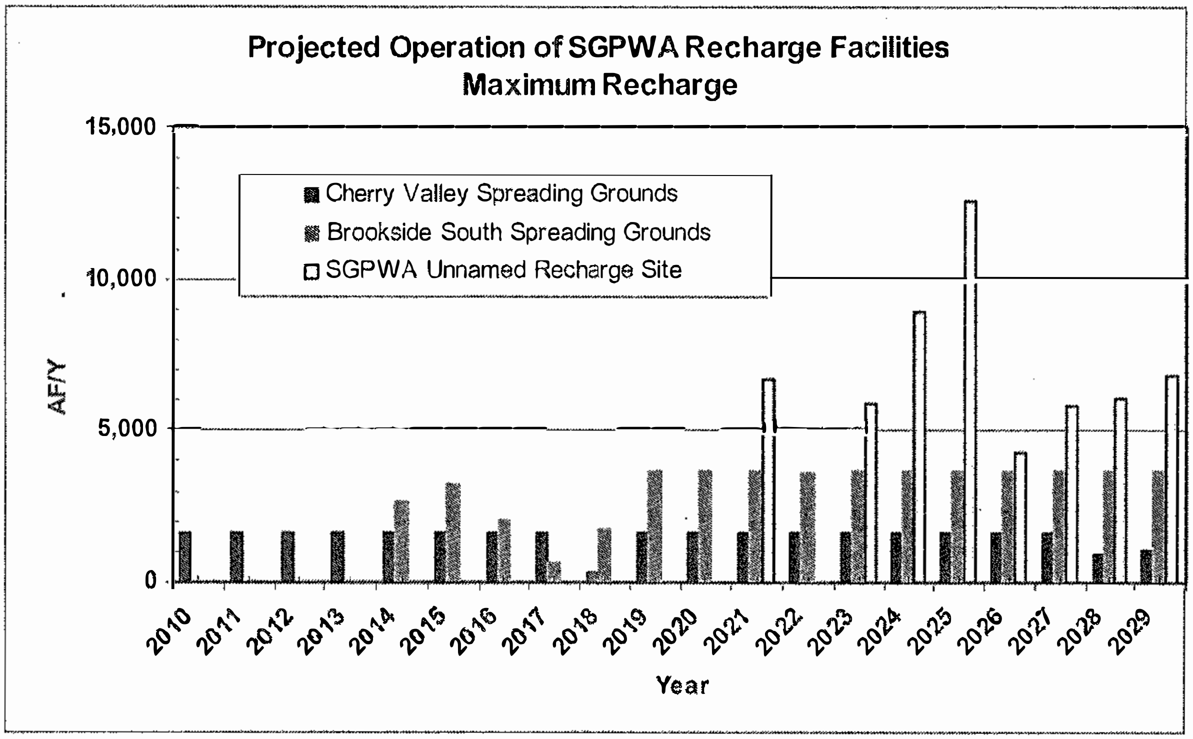
Comparison of Recharge – Maximum Recharge vs. Limited Recharge

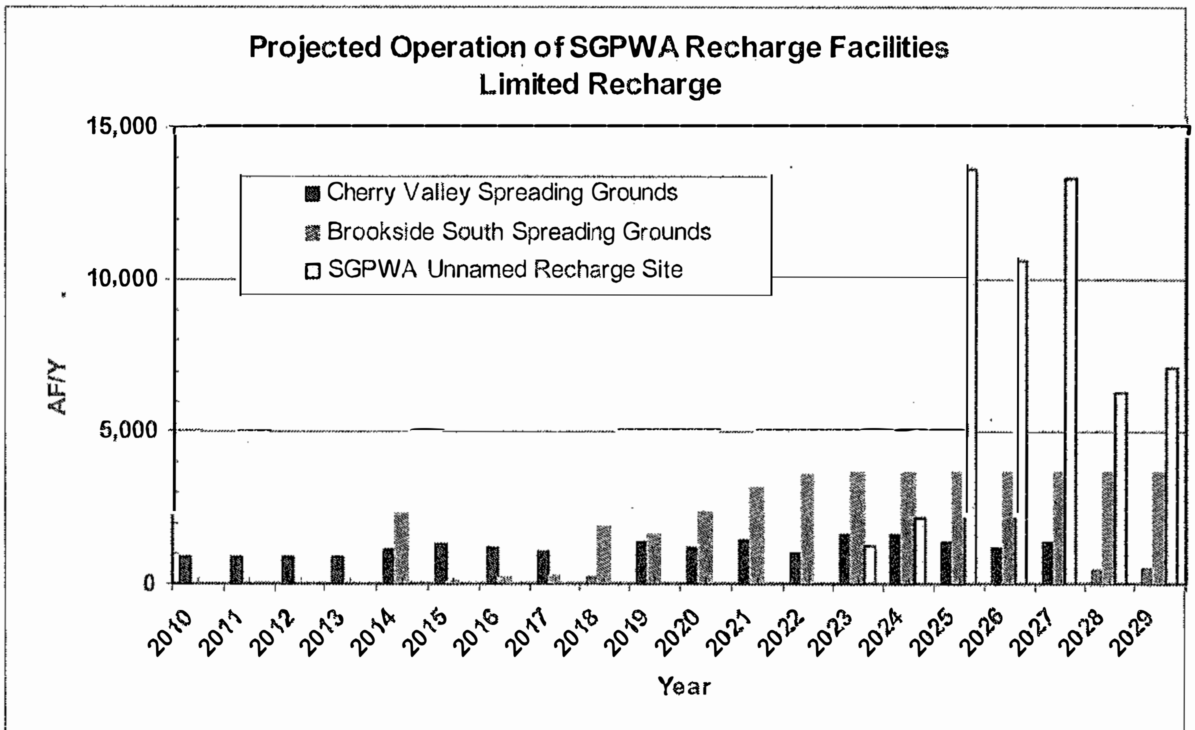
10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 8
HA-101	HAHN WATER RESOURCES, LLC	



Comparison of Net Water Balance – Maximum Recharge vs. Limited Recharge

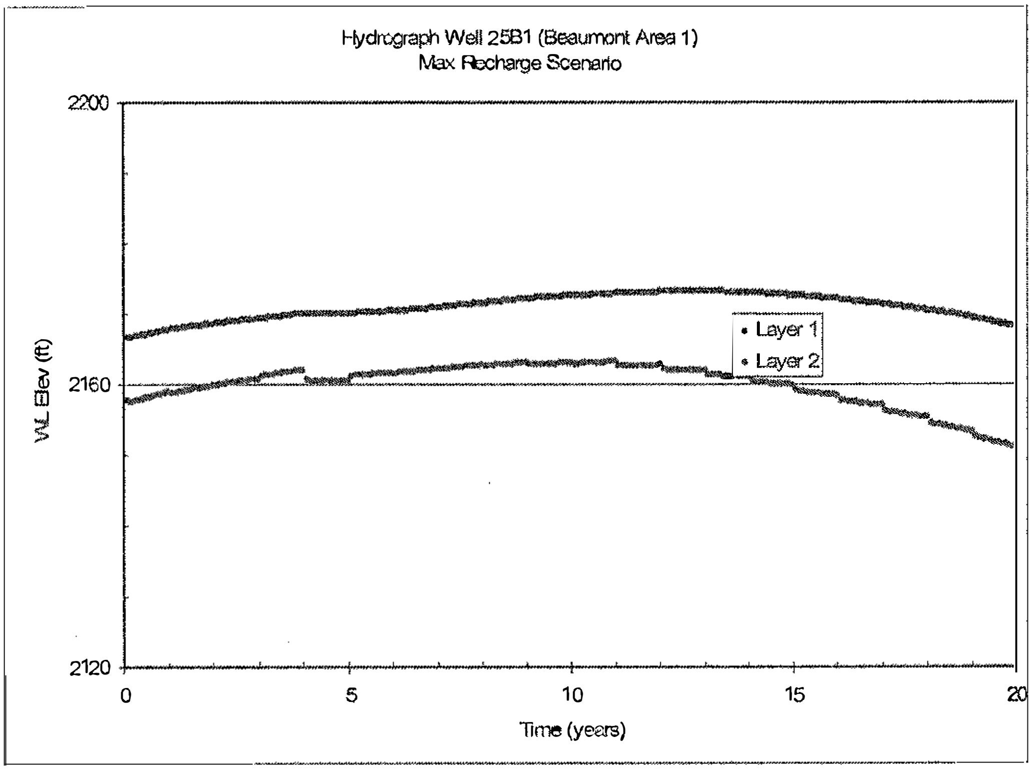
10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 9
HA-101	HAHN WATER RESOURCES, LLC	

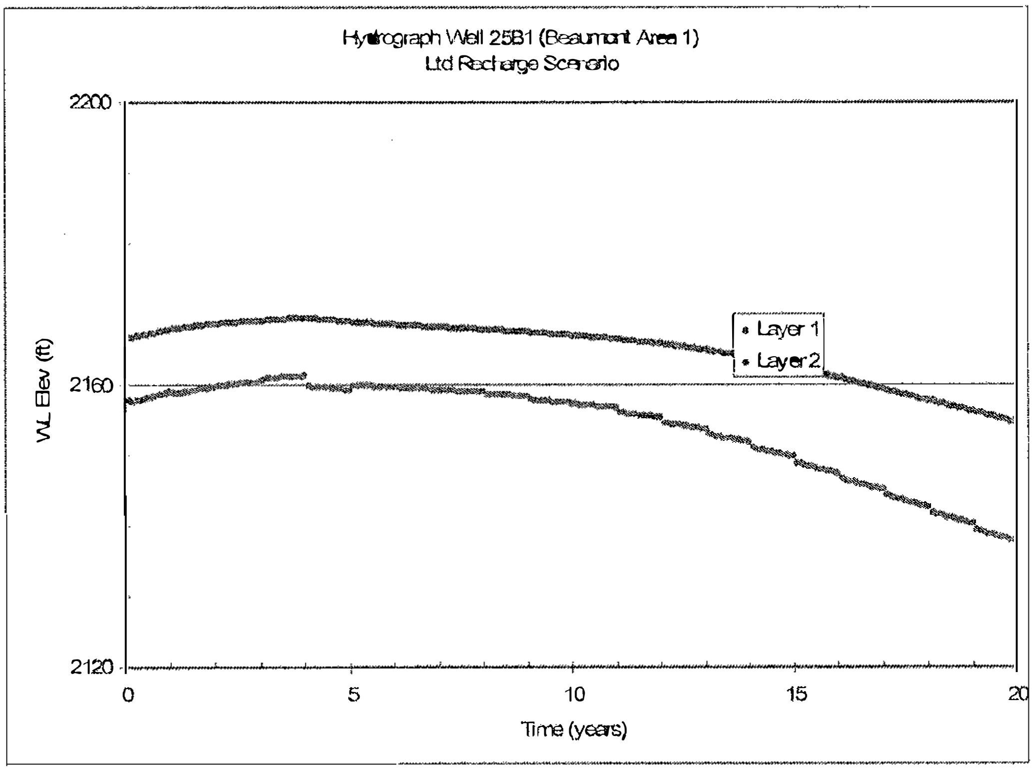




Projected Operation of SGPWA Recharge Facilities – Maximum Recharge vs. Limited Recharge

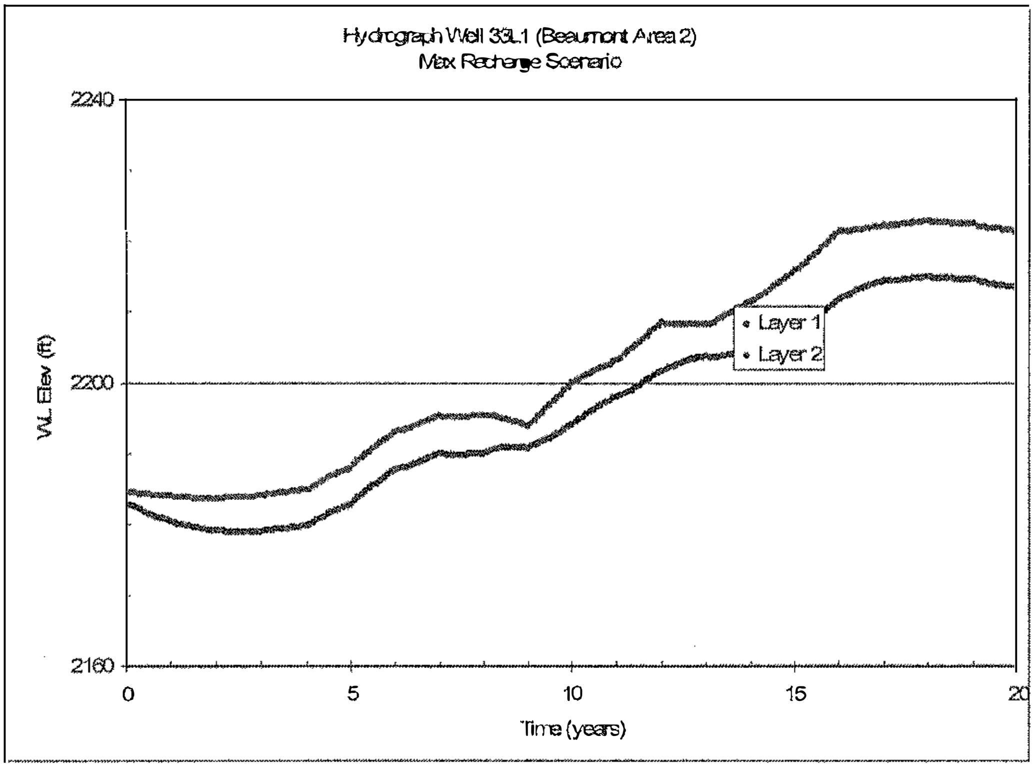
10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 10
HA-101	HAHN WATER RESOURCES, LLC	

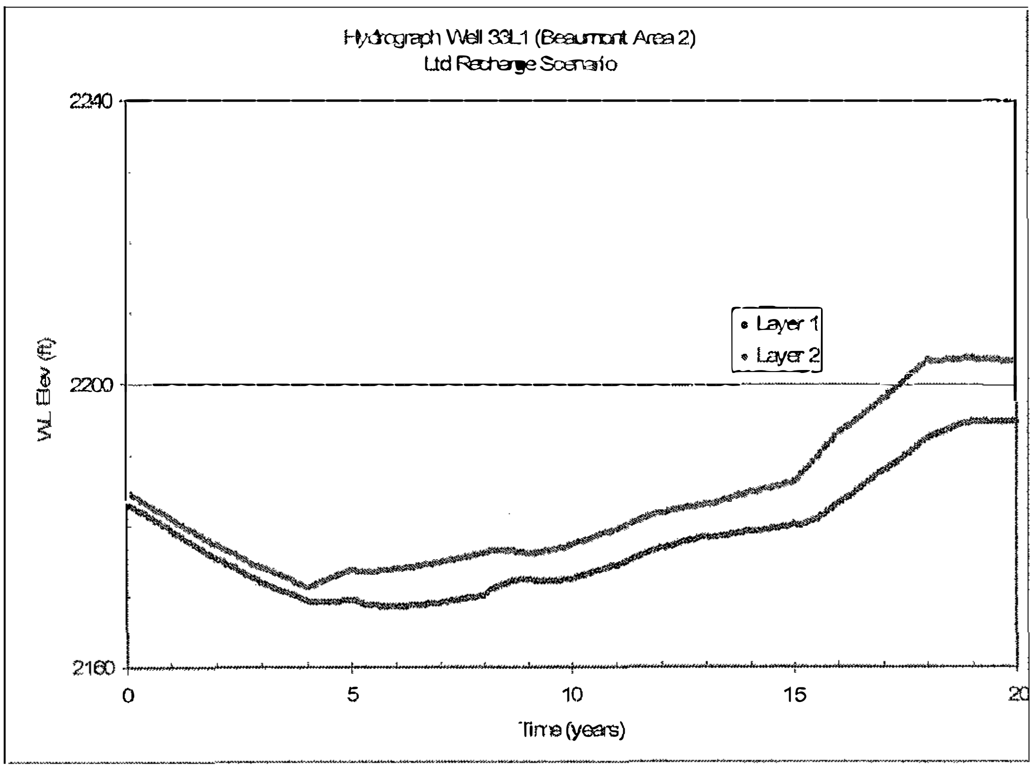




Hydrographs for Area 1 - Maximum Recharge vs. Limited Recharge

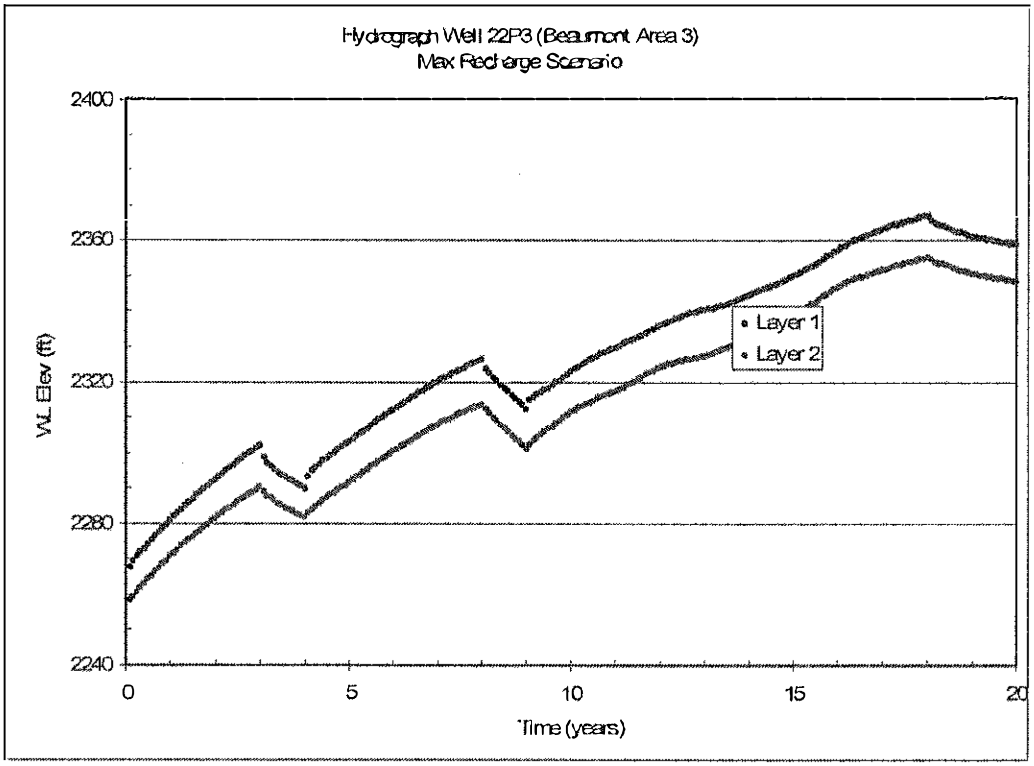
10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 11
HA-101	HAHN WATER RESOURCES, LLC	

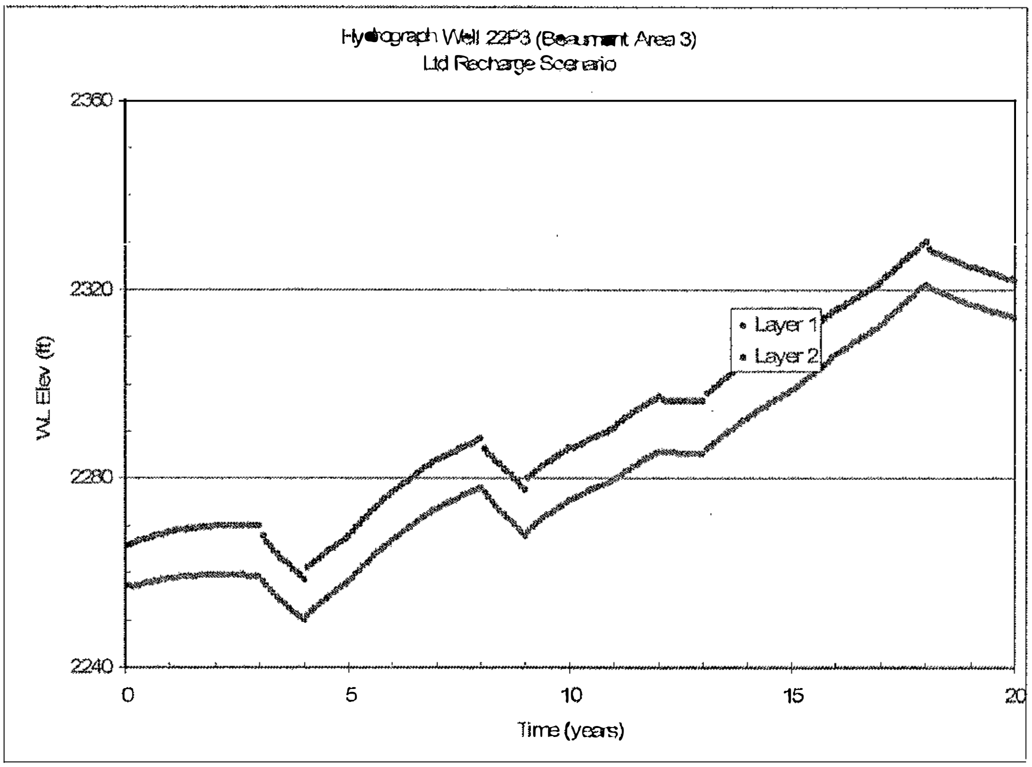




	Hydrographs for Area 2 - Maximum Recharge vs. Limited Recharge

10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 12
HA-101	HAHN WATER RESOURCES, LLC	





Hydrographs for Area 3 - Maximum Recharge vs. Limited Recharge

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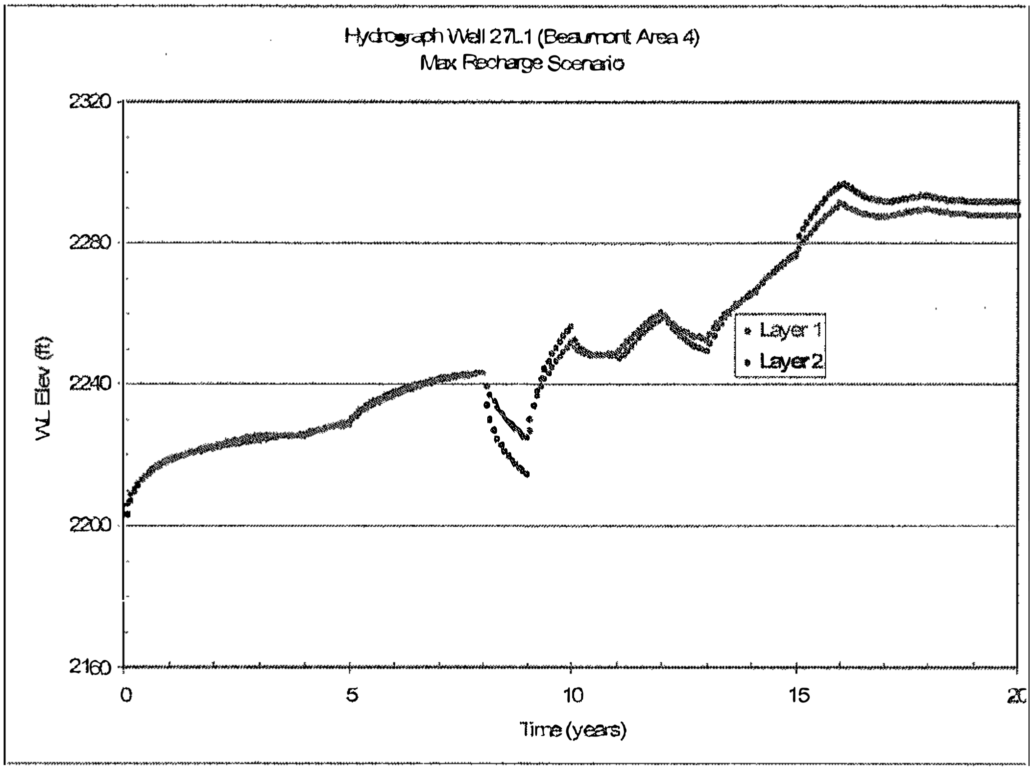
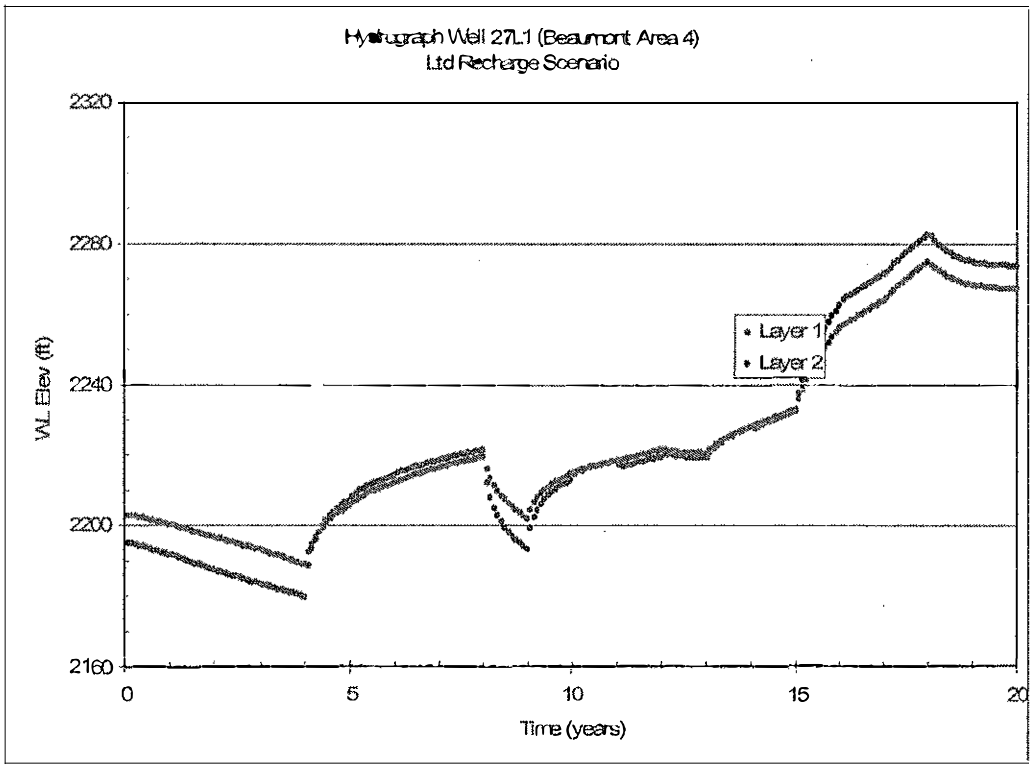
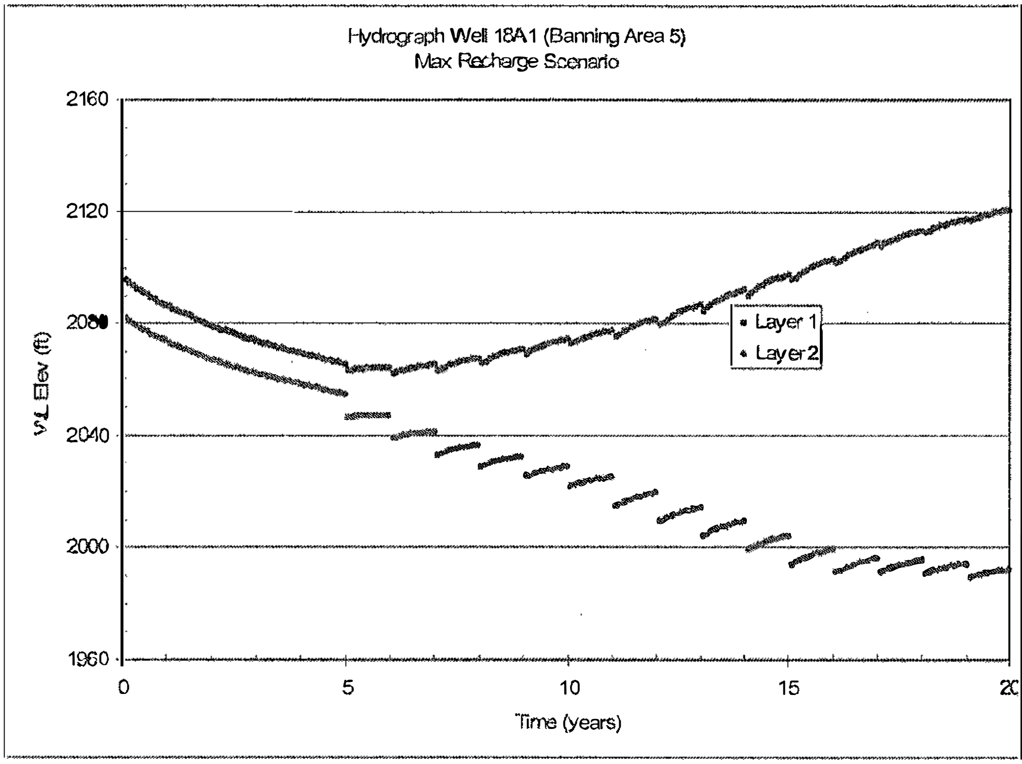
HA-101	HAHN WATER RESOURCES, LLC	

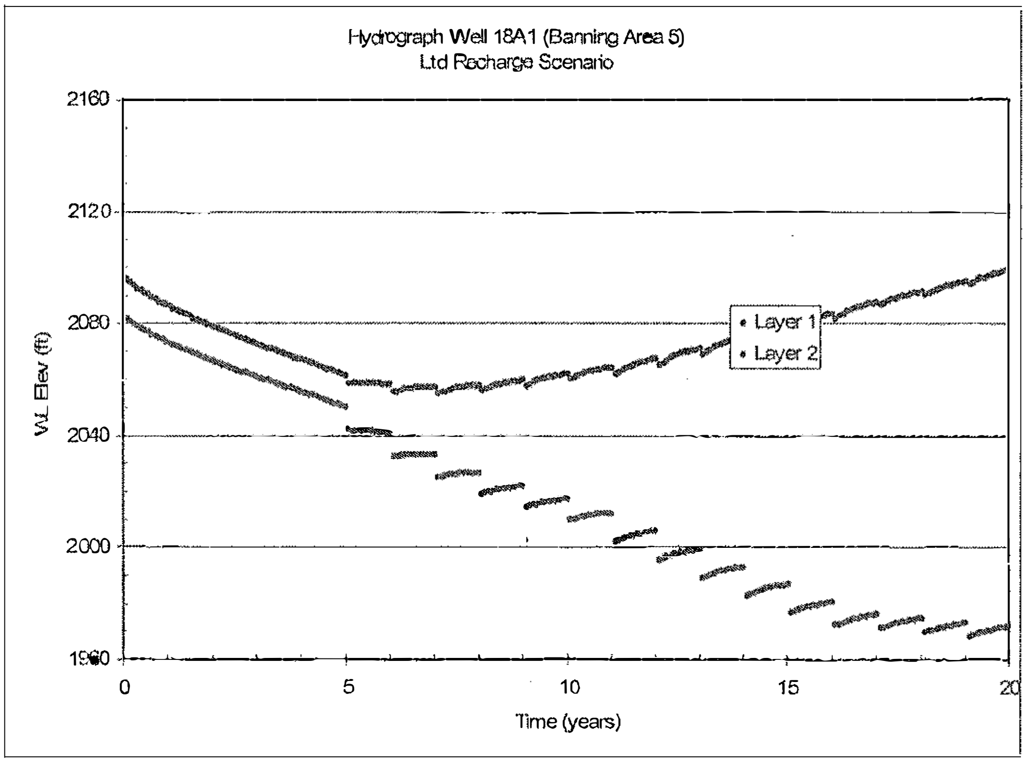




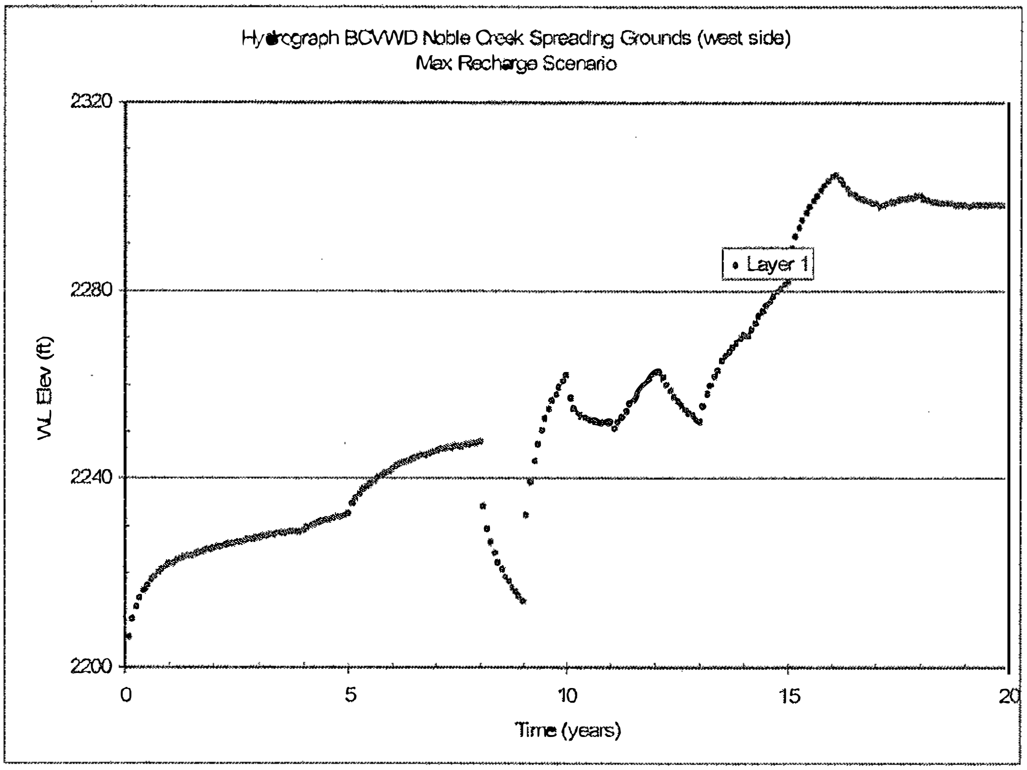
Hydrographs for Area 4 - Maximum Recharge vs. Limited Recharge

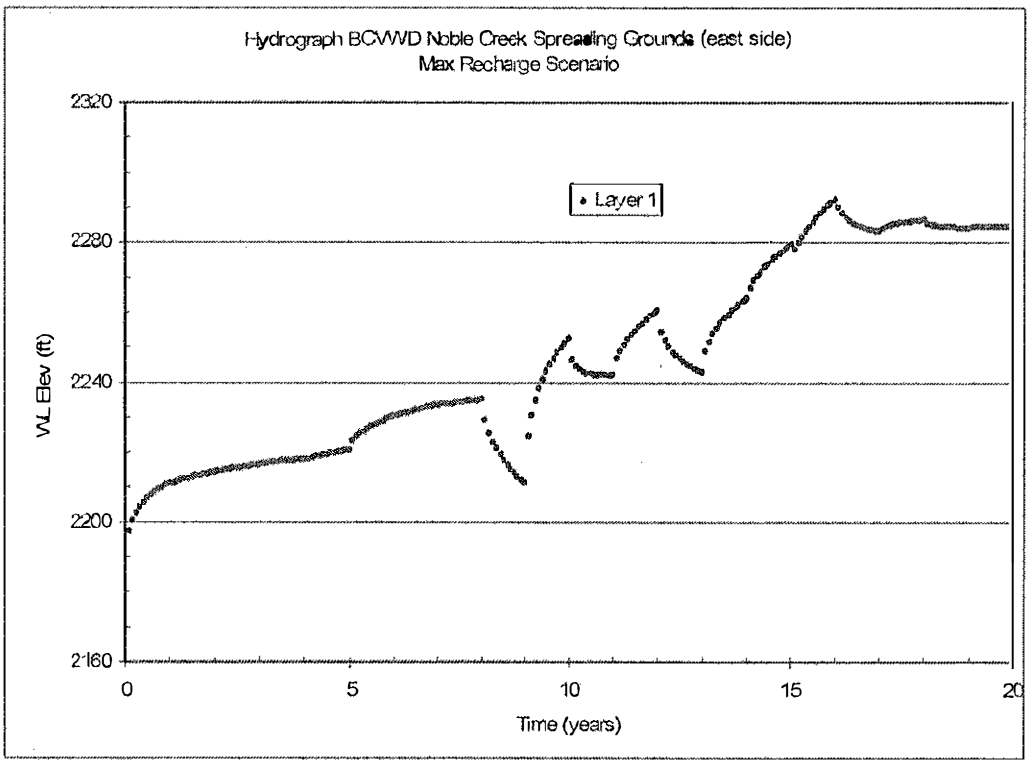
10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 14
HA-101	HAHN WATER RESOURCES, LLC	





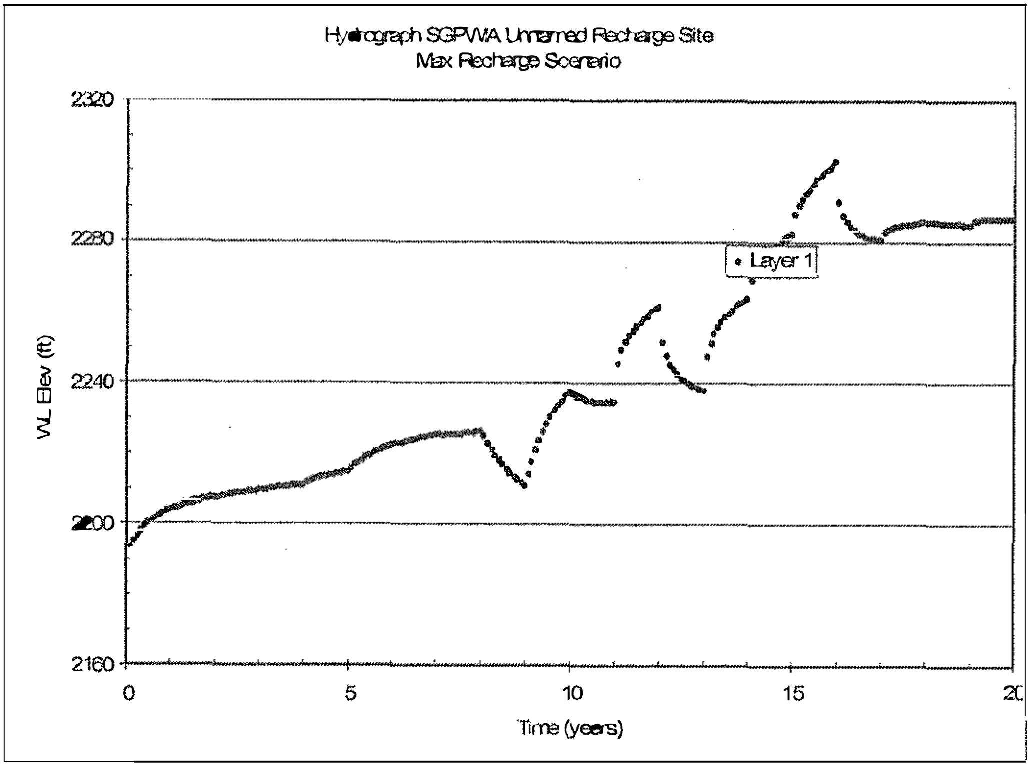
	Hydrographs for Area 5 - Maximum Recharge vs. Limited Recharge	
10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 15
HA-101	HAHN WATER RESOURCES, LLC	

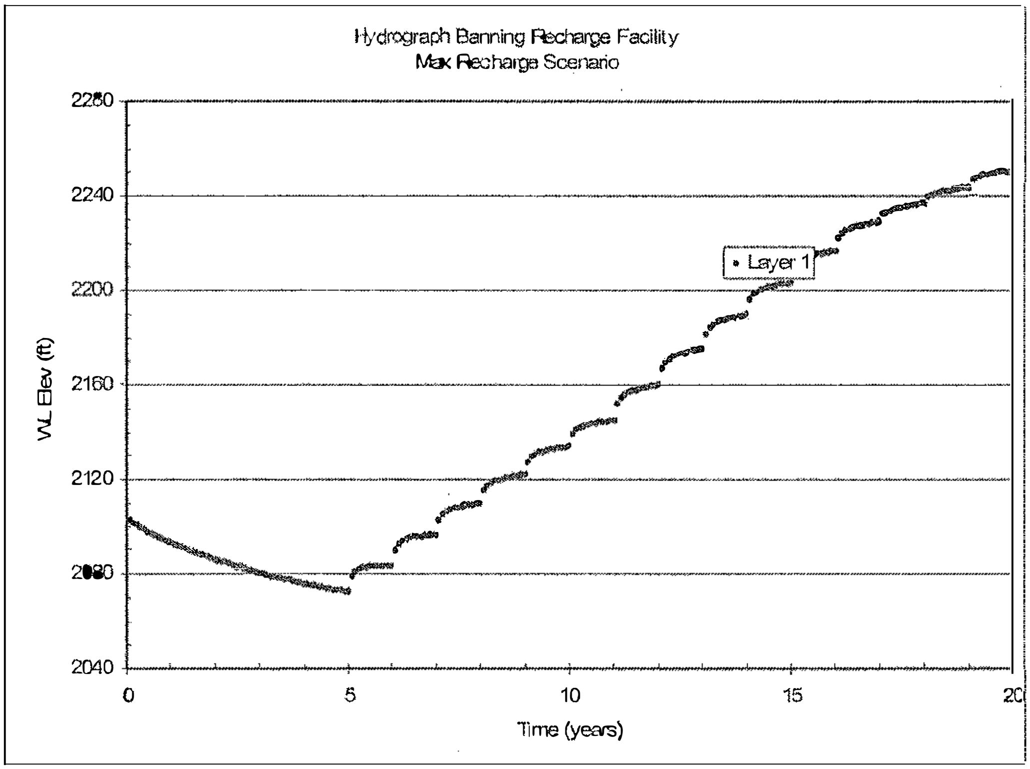




Hydrographs at BCVWD Noble Creek Spreading Grounds - Maximum Recharge

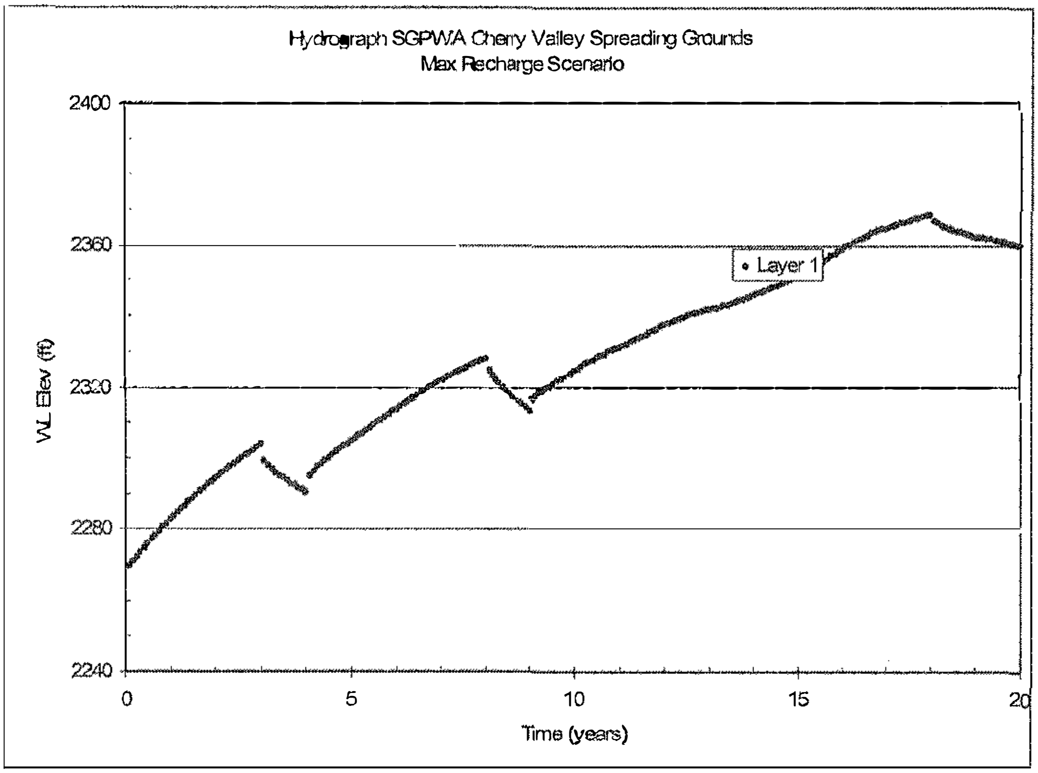
10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 16
HA-101	HAHN WATER RESOURCES, LLC	

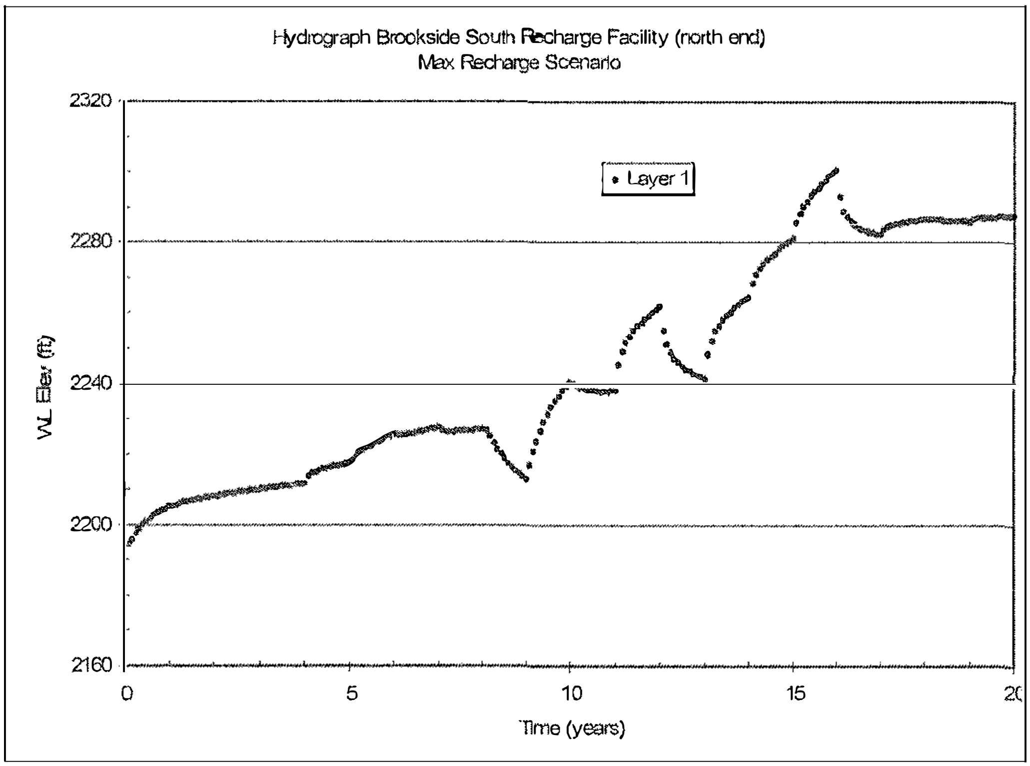




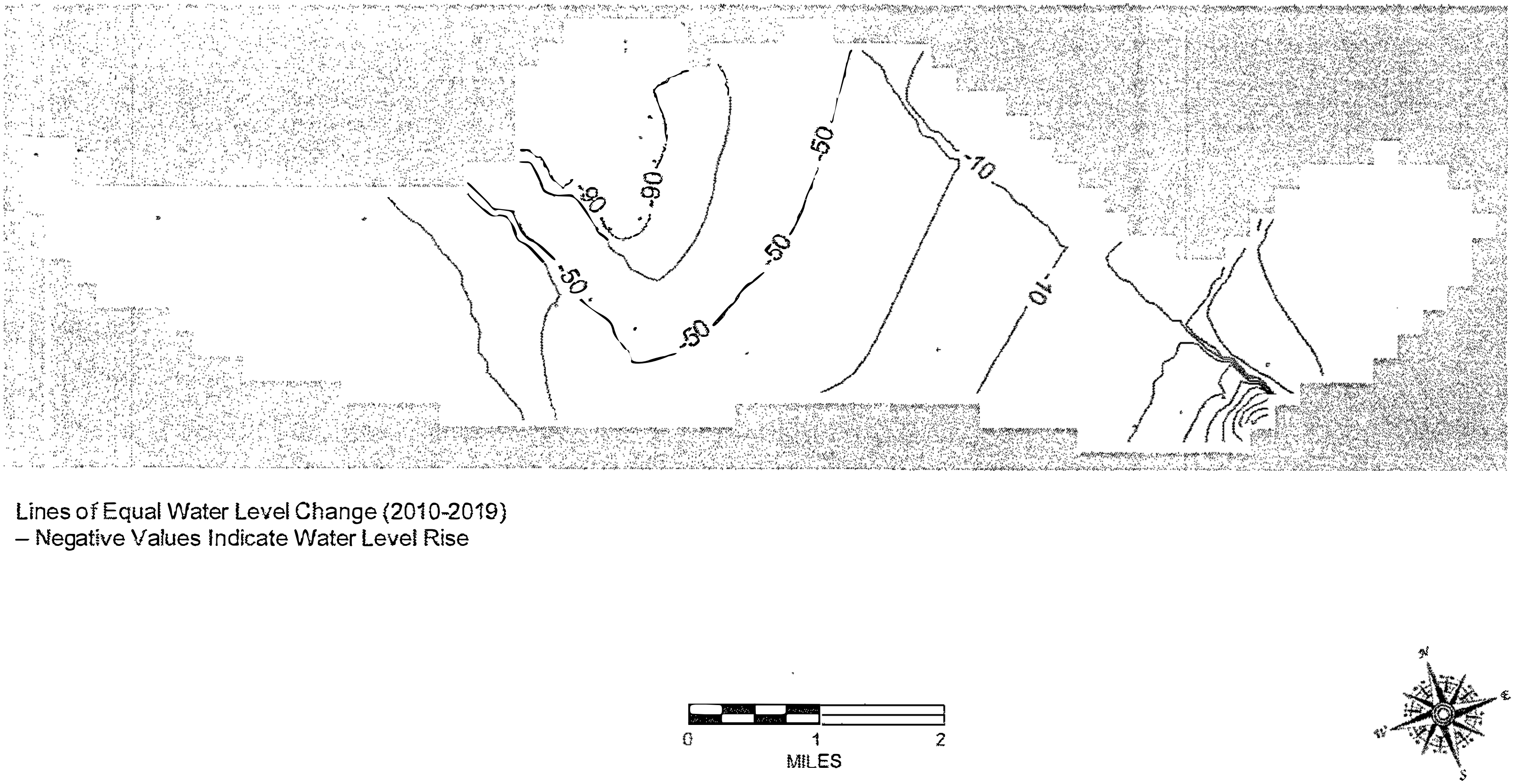
Hydrographs at SGPWA Unnamed Site and Banning Recharge Site - Maximum Recharge

10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 17
HA-101	HAHN WATER RESOURCES, LLC	



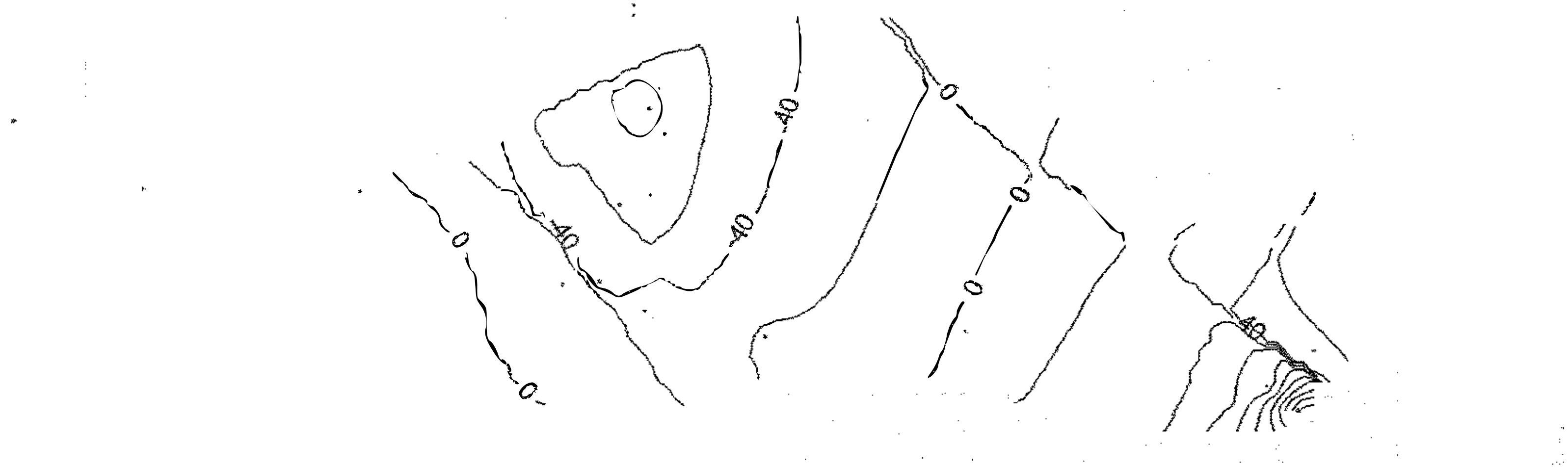


	Hydrographs at SGPWA Cherry Valley and Brookside South Spreading Grounds - Maximum Recharge	
10/30/10	SGPWA – Evaluation of Supply and Demand in the Beaumont Basin	Figure 18
HA-101	HAHN WATER RESOURCES, LLC	



Lines of Equal Water Level Change (2010-2019)
– Negative Values Indicate Water Level Rise

10/30/10	Water Level Change (2010-2029) - Maximum Recharge	Figure 19
HA-109	San Gorgonio Pass Water Agency – Evaluation of Supply and Demand in the Beaumont Basin	



Lines of Equal Water Level Change (2010-2019)
– Negative Values Indicate Water Level Rise

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10/30/10	Water Level Change (2010-2029) - Limited Recharge	Figure 20
HA-109	San Gorgonio Pass Water Agency – Evaluation of Supply and Demand in the Beaumont Basin	