TECHNICAL MEMORANDUM No. 4

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TO:	John Gray URS Corp., Santa Barbara, CA	DATE: March 7 & 21, 2001 Rev. December 22, 2001
FROM:	Peter M. Pyle	JOB NO.: 1815
RE:	Cachuma Water Rights EIR Alternatives - Results of the USGS and HCI Lompoc Ground Water Flow and Transport Models	

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1. Introduction

The purpose of this document is to summarize the use of the U.S. Geological Survey (USGS) and Hydrologic Consultants, Inc. (HCI) flow and solute transport models for evaluation of Cachuma Water Rights EIR Alternatives. This report was originally issued as two draft technical memoranda. The first, Draft Tech Memo #4, dated March 7, 2001, addressed the results of the USGS models. The second, Draft Tech Memo #5, dated March 21, 2001 addressed the results of the HCI models. They were originally produced separately since acquisition and operation of the USGS model was successfully completed prior to that for the HCI model. Since some of the same information was presented in both draft memos, and comments received on the first drafts suggested more information was needed comparing the results of the HCI and USGS models, the two documents have been combined into one.

The objective of this analysis is to simulate the relative change in the quality of ground-water in the Main Zone aquifer of the Lompoc Plain that will result from various Cachuma Reservoir operational Alternatives to be considered in the EIR. This analysis will be focused on the total dissolved solids concentration (TDS) of ground-water in one of the four aquifers in the Lompoc Plain, called the Main Zone of the Upper Aquifer. This aquifer has historically been the primary source of water for irrigation and municipal wells in the Lompoc Plain. However, it has been reported (Balance Hydrologics, Inc, 2001) that at least one large farm in the western Lompoc

Plain has increased its withdrawals from the Middle Zone aquifer in recent years and decreased its withdrawals from the Main Zone. The Middle Zone aquifer directly overlies the Main Zone.

The USGS and HCI flow and transport model simulations for the Cachuma EIR Alternatives both use the same Santa Ynez River flow and TDS input data at the Lompoc Narrows produced as output by the Santa Ynez River Hydrology Model (SYRHM), described in Stetson Engineers Tech Memo's 1, 2 and 3. The SYRHM was developed to provide monthly average flow and TDS at the Narrows for each EIR Alternative during the hydrologic base period of October 1941 - September 1993.

Output from the SYRHM was used as input to the ground water models with modifications to adjust to the incremental time periods of the USGS models. The USGS model calibration period was January1941 to December 1988. The HCI model calibration period was October 1941 to September 1994. Although the models were run for their respective calibration periods, the hydrologic period selected for evaluation of EIR Alternatives using the ground water models is 1952 to 1988. This period was selected for averaging the effects of model results for each alternative because it was a more balanced hydrologic period that overlaps the calibration periods of both sets of models, and because it limits the effect of using the same initial conditions for all EIR Alternatives. The effect of starting from the same initial conditions reduces the difference between alternatives for the first several years of simulation.

The most significant modifications made to the ground-water flow and transport models from the calibrated versions that were provided by the USGS and HCI as a starting point was to utilize the 1988 ground-water pumping data as a constant throughout the simulations. The purpose in using constant pumping is to better represent current conditions, and allow for a suitable comparison between EIR Alternatives, including Alternative 4A, in which reduced pumping is simulated at a constant rate.

A brief description of the models is provided in the following sections to facilitate understanding of the models and results. The reader is referred to the USGS (1997) and HCI (1997, 1999) reports that provide a detailed description of the models. While, this report attempts to provide a comparison of the key differences between the HCI and USGS models, a more detailed analysis of the models and basic data would be required for a full and complete understanding of the differences between them and the EIR Alternatives.

2. Description of the USGS Models

The USGS developed the flow and transport models for their study, *Evaluation of Ground-water Flow and Solute Transport in the Lompoc Area, Santa Barbara County, California* (Bright, et. al., 1997), which describes the models in detail. The USGS used the 3-Dimensional finite-difference code, MODFLOW, to simulated flow in the four aquifers in the Lompoc Basin of which the Lompoc Plain is a part (Figure 1). The solute transport model employs a 2-Dimensional finite-element code, SUTRA, which was modified by the USGS for their study to allow time steps of varying length. This 2-D transport model simulates only transport in the Main Zone Aquifer in the Lompoc Plain using output from the flow model that is processed to become input to SUTRA.

The MODFLOW grid uses a uniform spacing of 1/4 mile (Figure 2) and includes four layers (Figure 3) representing the entire Lompoc ground-water basin. Layer 3 of the USGS flow model corresponds to the Main Zone aquifer of the Lompoc Plain.

The 2-Dimensional USGS SUTRA solute transport model represents one layer only, the Main Zone in the Lompoc Plain. It utilizes a uniform-density finite-element mesh that is rectangular in order to match the geometry of the MODFLOW grid, however, each half-mile wide flow model cell of the MODFLOW grid is assigned nine SUTRA transport model nodes, as shown in Figure 4. A total of 905 nodes were used to represent the Main Zone Aquifer in the Lompoc Plain.

The USGS calibrated their flow and transport models for the period January 1941 through December 1988 with two stress periods per year of a varying duration. The length of each stress period is based on the number of consecutive days in each year that were classified by Bright and others (1997) as wet, and the number classified as dry. The length of the wet periods varies from 0.13 to 0.85 years. Conversely, the range in length of dry periods is from 0.87 to 0.15 years. All input data that is related to hydrology is then tied to the length of the stress periods for a given year such as initial and boundary conditions, pumping rates and recharge. The fact that the length of each stress period is determined by historical conditions, particularly the flow of the Santa Ynez River, may introduce some uncertainties when converting monthly SYRHM output to USGS stress periods. It can result in a different classification or an offset in wet and dry periods in some years relative to that specified by the USGS. The degree to which this affects the comparison of results appears to be minor.

Ground-water pumping used in the USGS model of the Lompoc Basin for the calibration period is shown in Figure 5. It ranges from about 4,000 afy in 1941 to about 31,000 afy in 1988. Simulated pumping in 1988 was used in the EIR Alternative simulations for reasons discussed in greater detail in Part 8 of this study. Note that the rates of pumping shown in Figure 5 represent the entire basin, not just the Lompoc Plain where the transport model is used to represent the TDS of the Main Zone.

The measured, and USGS flow model simulated water levels for the Main Zone and Lower aquifer for Spring 1988 are shown in Figure 6. These water levels were used as initial conditions for the EIR Alternatives.

The measured and simulated TDS in the Main Zone aquifer during 1987-88 is shown in Figure 7. The simulated TDS at the end of the USGS model calibration were used as initial conditions for the EIR Alternatives for the simulations using the USGS model. The TDS of the USGS transport model boundary conditions are shown in Figure 8 and 9. These were held constant during the EIR Alternatives as they were for the most of the USGS calibration period. Note the high TDS values for the Lower Aquifer and consolidated rocks (Figure 9) compared to the Middle Zone (Figure 8). The USGS (Bright, et. al., 1997) determined that the lower aquifer and consolidated rocks provide a significant contribution of salt to the Main Zone when pumping induces flow from these formations.

Since historical TDS data for Santa Ynez River flow at the Narrows is limited, the USGS used the available data in the early 1990's to make assumptions for the historical model calibration. They assumed a fixed value of river TDS at the Narrows for all wet periods of 800 mg/l, and 1,300 mg/l for all dry periods. The USGS assumed the TDS of subflow associated with the river at the Narrows was 1750 afy (Figure 9) based on their analysis of available river TDS data at low flows.

3. Description of the HCI Models

HCI developed flow and transport models for their study, *Development of a System of Models for the Lompoc Ground-Water Basin and Santa Ynez River* (HCI, 1997). Several surface water and ground water flow and transport models were developed for that study. Of those, only the Lompoc Basin Flow, Lompoc Plain Flow and Lompoc Plain Transport (Salinity) Models were used for this study. The numerical codes used are FEMFLOW3D and TRANS3D, developed by Tim Durbin and others for the USGS. FEMFLOW3D was published in 1997 as USGS Open File Report 97-0810. Documentation for the TRANS3D code is not believed to have been published to-date.

The HCI Lompoc Basin Flow Model domain is shown in Figures 10, 11 and 12. A finite element grid is used that and includes four layers representing the Shallow, Middle, Main and Lower aquifers, similar to the USGS flow model. There are a total of 689 nodes in the HCI basin flow model. This model uses monthly stress periods, therefore, the time series input is directly compatible with that of the SYRHM output at the Narrows.

The HCI Lompoc Plain flow model, which provides output for use in the transport model, covers a smaller area and uses a more refined grid than the HCI Lompoc Basin flow model. It consists of a total of 3936 nodes (Figure 13). It has 7 layers (4-Shallow, 2-Middle, 1-Main) (Figure 14). The Lower Aquifer is not represented in the HCI Lompoc Plain flow and transport models. Instead a no flow boundary represents the contact between consolidated rock and the Main Zone in the Western Plain and along the southeast and northwest margins of the Lompoc Plain ground-water basin. A constant head boundary is used to represent the contact between the Lower Aquifer and the Main Zone in the Central and Eastern Plain that uses output from the Basin Flow model to determine the head within the modeled area and flux across the boundary.

The HCI Plain flow model does not extend westward to the Pacific shoreline as the USGS model does. A constant head boundary to the west allows inflow or outflow depending upon whether the head inside the boundary is higher or lower than that specified. The salinity at the western boundary of the Plain flow model was set at 2000 mg/l, which appears to correspond to measured data for the Main Zone in that area (Figure 7).

The HCI Lompoc Plain model simulates salt loading of applied water and rainfall as it percolates through unsaturated zone before it enters the saturated aquifer in the Shallow Zone. The rate of dissolution of salts from soil into percolating water is simulated based on a series of equations (HCI, 1997). These equations include coefficients that account for the type of land use, initial soil salinity, salinity of applied water, a threshold concentration above which no dissolution of salts in the soils can enter, and a transfer rate coefficient. The transfer rate is reportedly the most sensitive of these parameters. It was initially obtained from limited data in the technical literature and analysis of limited local soil samples. The transfer rate for each subarea was held constant during simulation, but was adjusted from initial estimates in order to achieve calibration.

A limit was set by HCI on the maximum TDS of percolating water in each subarea that can cause additional leaching of salts from soils. Only salts occurring as solids in the unsaturated zone are simulated by the model as contributing to the salinity of ground water. The transport model does not simulate the exchange of salts between the aquifer matrix and ground water within the saturated zone, but allows for hydrodynamic dispersion (mixing) of recharged and stored ground water within subareas and layers.

The HCI Lompoc Plain transport model has the same structure as the Plain flow model, however, it operates on annual, rather than monthly, stress periods. For this reason, the model results generally fluctuate to a lesser degree than if output monthly or biannually.

For the purposes of this study, where Santa Ynez River flow and TDS data are generated by the SYRHM up to the Lompoc Narrows, the HCI ground-water models are run sequentially, beginning with the Basin flow model, followed by the Plain flow model, and the Plain transport model. Each model provides input to successive models. The end results are simulated ground-water levels and TDS within each layer represented for each aquifer in the Lompoc Plain.

One of the key features of the TRANS3D code that is used for the HCI transport model is that, unlike the SUTRA code used for the USGS transport model, it accounts for changes in aquifer TDS due to changes in applied water. As groundwater is pumped from any well for irrigation, the TDS of water that is pumped is tracked according to the time and location and aquifer from which it is produced, and applied onto specified locations on the land surface. Whatever portion of the applied water that percolates will carry its salt load that will change as it percolates through the unsaturated zone, based on soil salinity in that area. This simulated recycling effect can provide a more realistic method of calculating the change in aquifer salinity over time based on land and water use practices. It allows for trends to develop as water quality increases or decreases based, in part, on the quality of water applied at the surface. However, the accuracy of this approach to ground-water salinity modeling is dependent upon the extent to which the additional input data and assumptions required are constrained by measured values or some other empirical data.

Figures 15 and 16 show the simulated of the Middle and Main Zones in 1991. The 1988 results of this model were used as initial conditions for the EIR Alternative simulations to be compatible with the end of the simulation period of the USGS model. Figure 17 illustrates the TDS values used in HCI's Lompoc Plain transport model along the lateral and lower boundaries. Inflow beneath the Central and Eastern Plain from the Lower Aquifer is assigned a TDS range of about 600 mg/l to over 1000 mg/l. In the Western Plain, where the Main Aquifer overlies consolidated rocks, the HCI model represents this contact as a no flow boundary.

Ground water pumping simulated in the HCI Basin Flow model is shown in Figure 18 along with the 1988 constant pumping rate used in the EIR Alternatives for this study. The monthly distribution of pumping by the City of Lompoc is shown in Figure 19 along with that assumed for EIR Alternative 4A. Modifications to model input data for the EIR Alternative simulations are discussed in more detail in Section 5.

A summary of the USGS and HCI models is provided as Appendix A.

4. Key Differences between the USGS and HCI Ground Water Models

Although an extensive evaluation of and comparison between the USGS and HCI models has not been performed as a part of this study, some significant difference have emerged as a result of preparing input data and processing output data for the EIR Alternatives.

a) Model Code

The USGS study was developed in the late 1980's early1990's, at which time they determined the 2-D SUTRA code, one of few available at the time, to be most suitable for this application. This choice required that the transport model boundary conditions of TDS in overlying (Middle Zone-Upper Aquifer) and underlying aquifers (Lower Aquifer) would be predetermined based on historical data and can not change over time based on changes in pumped and applied water salinity. The TDS of flow from the Middle Zone to the Main Zone and from the Lower Aquifer to the Main Zone is held constant at the TDS assigned to the node associated with the flow cell (Figures 8 and 9). The model was calibrated to historical measured data in selected wells by adjusting the TDS in the overlying and underlying aquifers, in conjunction with calibration of the flow model.

The transport code used by HCI allows simulation of TDS in all layers and the TDS in each can vary over time due to variations in the quality of applied water, hydrology and pumping rates as well as leaching of salts in the unsaturated zone. Since, TDS was not fixed in relation to some specific historical period, it can better react to changing conditions. This is an improvement in numerical simulation, but the results are dependent on the validity of additional assumptions and input data. The TDS at the boundary of the USGS transport model could be manually adjusted for each stress period to approach the dynamic adjustment achieved by the TRANS3D code but would require significant additional input data development and iterative simulations.

The actual equations used to represents flow and mass transport in the any of the USGS or HCI model codes have not been compared or evaluated relative to standard references in the literature for this study. Nor was documentation available for the TRANS3D, including results of benchmark testing using standard problem sets.

b) Model Structure

The USGS flow model includes a layer for the Lower Aquifer that they consider to be a significant source of high TDS water that flows into the Main Zone when pressures/heads are lower in the Main zone than in the Lower Aquifer. The USGS transport model has a boundary condition that assigns a TDS to flow from the Lower Aquifer depending upon location (Figure 9).

The HCI model does not have a layer representing the Lower Aquifer in the flow or transport model of the Lompoc Plain and do not allow flow where the Main Zone contacts consolidated rocks. They do not consider the consolidated rocks or the Lower Aquifer a significant source of salt that moves into the Main Aquifer. Instead, the primary source of salt entering the Main Zone in the HCI model is the dissolution of salts in the unsaturated zone that are entrained in percolating recharge from irrigation return flow, precipitation and stream losses.

The USGS model simulates the flow the Santa Ynez River from the Lompoc Narrows to the Pacific Ocean. However, the TDS of the Santa Ynez River at the Narrows is input directly into about 20 transport model nodes in the Main Zone just down stream of the Narrow, equivalent to three flow model cells (Figure 8). The apparent basis for this approach is that only the Main Zone is simulated in the transport model and there is very high vertical conductivity near the Narrows such that percolation from the river reachs the Main Zone with little mixing and no significant change in TDS.

At times, when surface flows pass the three flow model cells that are used to represent the river bed infiltration below the Narrows, the infiltration of River water is influenced only by the specified TDS of in areas underlying the river representing the Middle Zone (Figure 8). The actual TDS of the river flow below the Narrows simulated by the SYRHM is <u>not</u> used in the ground water models.

The HCI models have identical layering for both flow and transport in the Lompoc Plain, such that the TDS percolating to the Main Zone in that area has to move through six other layers representing the Shallow and Middle aquifers first and may be diluted or increased in TDS through mixing before it reaches the Main Zone.

c) Model Calibration

The approach to calibration is discussed in detail in the USGS (1997) and HCI (1997) reports. Some of the significant differences are discussed below;

i. The USGS approach was to calibrate the flow model to match water levels and then adjust the TDS of aquifers bounding the main zone, within a reasonable range determined from available ground water TDS data collected over time. This resulted in a good match of simulated and measured TDS for the Main Zone, but since it was, in effect, “hardwired” for that result it could be less adaptable for future simulations, unless the boundary conditions in over and underlying formations are changed based on current and future data or updated during simulations.

HCI had a similar as the USGS for flow modeling. But the approach used by HCI to calibrate the transport model was to first develop an average TDS for each layer for each decade from the 1940’s to the 1990’s. This was for use as a calibration target for each layer. This approach was used because HCI felt historical TDS data was inadequate for matching individual well TDS over time, but sufficient to determine trends within aquifers over long time periods. This assessment of data quality was based on the sporadic spatial and temporal nature of the available data, differences in sampling and analysis methods that could result differences in data quality, and the fact that many wells were completed into more than one aquifer or that leakage may occur between layers along the outside of casing. This evaluation of the available water quality data also may have influenced HCI’s use of annual stress periods in the transport model.

These differences in approach (along with the stress period length, discussed below) is the primary reason that the HCI model is generally exhibits smaller variations in TDS over time at a given layer or node than the USGS model.

ii. The USGS flow and transport models use two variable stress periods per year which contribute to the variability shown in the output. The HCI flow models use monthly stress periods. The HCI transport model uses annual stress periods, which contributes to the dampened response shown in the output.

iii. Initial conditions in the HCI model were the same (1200 mg/l TDS) for all layers at the beginning of model calibration based on limitations in TDS data available for that period. The USGS transport model had large variations in TDS within the Main Zone and in the over and underlying aquifer boundary conditions (Figures 7, 8 and 9). This can affect the change in TDS during the calibration, but may not significantly affect the simulated difference between EIR Alternatives, since those simulations were run using common initial and boundary conditions and constant pumping for a given model (HCI or USGS). However, there were differences in initial and boundary conditions between these two models as used to simulated the EIR alternatives.

iv. The HCI and USGS models were calibrated over slightly different periods. The USGS calibration period was January 1941 to December 1988, ending in a significant dry period. The HCI calibration period was October 1941 to September 1993, ending in a relatively wet period. The HCI calibration period ends about six years later than the USGS calibration period. Although the model were run for their respective calibration periods for the EIR alternatives, results were averaged over a common period for analysis.

v. The USGS used a salinity of 1750 mg/l for subsurface inflow at the Lompoc Narrows and HCI used 1000 mg/l. Both were held constant for the entire simulation period of each model. The rate of underflow was variable in the USGS model depending upon the simulated head in the aquifer. The rate of underflow in the HCI model was fixed at 1900 afy. These input data were not changed for the EIR Alternative simulations and may affect results at low flows near the Narrows.

Although the primary differences between the transport models provide somewhat different results for a similar historical calibration period (only the TDS of the Main Zone is commmon to both), it is not clear which model better represents the actual system. This is because they are difficult to compare directly without a thorough evaluation of the historical ground water salinity data and the calibrated model results from year to year. Carefully planned sensitivity analyses would also be needed for a comparison of the models. The models may have to be modified to run on similar stress periods and their output processed both by spatial averaging, and for individual well locations to allow a statistical or other quantitative analysis. A detailed evaluation the models and historical data was not conducted as part of this study.

5. Development of Model Input Data for this Study

The following changes in model input data were made for the simulation of the EIR Alternatives:

> **a)** Stream flow and TDS of the Santa Ynez River at the Lompoc Narrows were generated by the SYRHM for each EIR Alternative and processed to be compatible with the structure and time periods of the ground-water flow and transport models.
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> **b)** Initial water levels and TDS were reset to those simulated at the end of 1988 for the original calibration of each model.
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> **c)** Ground-water pumping and return flow from agriculture are held constant at 1988 levels.
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> **d)** Pumping from the City of Lompoc wells was reduced by 1770 afy in Alternative 4A.
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> **e)** Where the ground-water model simulation periods did not coincide with the simulation period of the SYRHM, flow and TDS input at the Narrows from the original calibration of each model was used.

Modification (a) includes the adjustments necessary to process the monthly flow and TDS output from the SYRHM for each EIR Alternative for input data to the USGS ground-water flow and transport models. This involves averaging flow weighted TDS for each of the variable stress periods of the USGS model. HCI flow models and salinity preprocessing programs read monthly flows and TDS data directly.

Modification (b) was used to better represent current conditions. Simulated and measured TDS for 1988 for Main Zone from the USGS model is shown in Figure 7. USGS model output for 1988 was used as input for all EIR Alternative simulations. The simulated TDS from the HCI model for Fall 1991 for the Middle and Main Zones are shown in Figures15 and 16. Initial conditions for the EIR Alternatives was generated from the HCI model output for 1988 for use in EIR simulations.

Modification (c) was used to allow simulation of constant pumping over the simulation period which better represent current conditions than the increased pumping over the entire historical period. Simulated pumping for 1988 for each of the Lompoc Basin flow models are shown in Figures 5 and 18. The use of a constant pumping rate is important to evaluation of each of the

EIR Alternatives to minimize simulated differences between alternatives that are not related to Cachuma operations. Although there is a difference between the USGS and HCI model in simulated rate of pumping in 1988 of about 4,000 afy (or 13% to 15%), no attempt was made to match the pumping rates. This would have required significant modification to the models and recalculation of 1988 initial conditions. The rates of pumping in the Lompoc Plain may be more similar between the models than the rates for the entire Lompoc Basin, but locations and rates of pumping were not extracted from the models and compared to available data as part of this study.

There are some changes in pumping rates and distribution that have reportedly occurred since 1988 that are not represented in the models. These changes include; 1) at least one landowner in the Western Plain is reported to currently pump a greater amount of water from shallower aquifers and a lesser amount from the Main Zone, and 2) some municipal ground water users outside the Lompoc Plain have begun to use State Project water which may have reduced their pumping and slightly improved the quality of discharge from the Lompoc Wastewater Treatment Plant (WWTP). Details regarding current practices and uses of ground water were not available for this study.

Modification to the pumping files may allow greater accuracy of model results, but would not necessarily affect the comparison between EIR alternatives using an identical set of input data in all cases. The results of the ground water model simulations for the EIR alternatives should not be considered a precise representation of ground-water quality and water-levels at any particular time period in the future.

Modification (d) was made to simulate direct delivery of 1770 afy of State Project Water (SWP) to the City of Lompoc under Alternative 4A. Ground water pumping by the City was reduced by a like amount for this alternative only. The effect of SWP these deliveries on ground-water pumping by the City of Lompoc are shown in Figure 19. A small reduction in the TDS of WWTP discharge due to these deliveries would be expected since the range of TDS of ground water pumped by the City of Lompoc in the late 1980's ranged from under 1,000 to over 1,500 mg/l. In contrast, the average State Water Project TDS, based on samples taken from the Coastal Aqueduct inlet near Kettleman City, was about 300 mg/l. The estimated proportion of constant SWP deliveries to the City for Alternative 4A, in relation to monthly variable total demand, ranging from about 45% in winter to 25% in summer (Figure 19). Therefore, the SWP deliveries were estimated to reduce the TDS of WWTP discharge, as represented in the USGS model, from about 1,000 mg/l to about 800 mg/l. For the HCI model the TDS of WWTP discharge was similarly reduced. Although the proportionate reduction in TDS is significant, the amount of water is relatively small compared to total recharge and the effect is probably localized. In addition, the WWTP discharge is applied at the surface and must percolate and potentially increase in TDS due to percolation through soils and mixing before it reaches the Main Zone. The effect of this reduction in return flow from the WWTP in each model is difficult to determine without running the models with this modification only, holding all other variables constant and processing model output at selected distances from the point of WWTP discharge.

Modification (e) simplified input and output processing and running of the models, since all programs and data and worksheets were set up for the original calibration periods. The affected periods were January to September 1941 for the USGS model, and October 1993 to September 1994 for the HCI model. The model results were not significantly affected due to the lengthy stress periods for both models. In addition, only the results from the period 1952 to 1982 were processed generate comparative tables showing the average differences between EIR Alternatives.

6. Limitations of the Ground-water Models as Utilized for this Study

Various measures were taken in use of these models to assure that the input data representing flow and TDS at the Narrows be similar for both HCI and USGS models in order that the results of the simulations may be compared equally. The simulations were not expected to predict, with a high degree of accuracy, the TDS and water levels in the future. Rather, they were intended to allow a relative comparison between alternatives with only reasonable model modifications that could be made within the scope of this study. The differences between EIR Alternatives are best viewed within one model rather than between models since the differences in model construction and approach to calibration and the complexity of the system and limitation of data make it difficult to compare the models directly without detailed knowledge of the hydrogeology of the basin and the quality and spatial and temporal of available data.

The predictive capability of these models to simulate ground water quality conditions in the future is limited by; 1) the conversion of monthly SYRHM output into the biannual and annual stress periods of the USGS and HCI transport models, 2) the use of constant 1988 pumping, as originally developed for the model calibration, which may not represent present or future pumping amounts or pumping distribution by aquifer and subregion. In addition, water and land use changes that may affect the distribution and quality or water recharging the aquifers in the future are not accounted for. An evaluation of such changes was beyond the scope of this study.

As previously mentioned, the HCI transport model does account for changes in TDS within each layer and changes in TDS of waters produced from each layer and applied or used, some of which returns as recharge. The USGS transport model does not have this capability, but has a fixed distribution of TDS of the Middle Zone throughout the simulated period.

From the limited evaluation of the models that could be conducted within the scope of this study, it believed that the TDS results models are only accurate for future predictions to within a range of roughly 100 to 300 mg/l, depending upon location, magnitude of changes in input data, hydrologic conditions, length of simulation period and other factors. For use in comparative analysis, such as between EIR Alternatives where changes in input are limited, the differences in TDS between simulations in a single model of less than 100 mg/l may be useful in cases where clear trends are exhibited.

7. Method of Presentation of Model Results

a) Methods Employed by HCI and USGS to Present the Results of Model Calibration and Management Scenarios

i) USGS model

The USGS (Bright, and others, 1997) elected to present the results of their transport model calibration in the Main Zone Aquifer by three methods; 1) plotting the simulated TDS in the Main Zone at selected well locations along with available measured data, considered reliable, at those locations, 2) contour maps of TDS for simulated TDS in the Main Zone for 1941 and 1988, and 3) average measured and simulated water levels at selected sites for 1987 and 1989. For their presentation of model results for management scenarios, in which a constant, average hydrology was used, the USGS elected to present only contour maps of TDS in the Main Zone for each alternative and the difference in TDS between alternatives, at the end of a 25 year simulation period.

ii) HCI model

HCI presented the results of their transport model calibration as a graph of points representing the calculated 10 year average TDS in each aquifer, along with the simulated average TDS for each year of the simulation period and a contour map of simulated TDS in each aquifer for 1991. Individual well history matching was not used as basis for calibration.

b) Methods Developed to Present the Results for the EIR Alternatives

1For this study two well locations were selected from each of the primary subareas, Eastern, Central and Western Plain in order to evaluate the effects of each alternative in the regions of the majority of ground water pumping (Figure 1). The wells were selected on the basis of location, availability of measured water quality data at that location, and the fact that they were used as calibration wells by the USGS (Bright, and others, 1997). USGS personnel indicated they selected these wells carefully, based on well construction and evaluation of the available geochemical data and determined the data for these wells could be reliably attributed to the Main Zone aquifer alone. The USGS flow model row and column and transport model node was specified for each of the wells they used for calibration of the transport model. Wells used by the USGS for their model calibration were favored since the wells and data were not independently evaluated for this study. Identifying nodes related to wells was not straightforward because well locations were not overlain on grid maps and no geospatial data was available to develop such data electronically with greater accuracy. However, there are some node numbering typos in the USGS report (Bright, and others, 1997), and an average simulated TDS from two nodes is used in some cases where measured data for different periods from two nearby wells was used to represent a continuous record.

The TDS output from the models that is presented herein as representative of each of the six selected wells are the results for a <u>single</u> node in each transport model that was determined to be closest to the selected well location. For pumping wells, the location nearest the center of the pumping cell in the flow model was used although the TDS may vary by over 100 mg/l in neighboring cells and one flow model cell has nine associated transport model nodes in the USGS model. In addition, a single well symbol on published maps may overlap multiple SUTRA nodes in the USGS model.

Pumping wells were associated with particular model nodes by HCI for their models, but output was by grid element not by node, so an element had to be selected by creating maps with the model grid superimposed over the well locations. In the case of some pumping wells a specific node wase located as closely as possible using coordinates assigned to each node in the input data and maps of well locations. There are no existing maps that show numbered nodes and well locations.

c) Presenting Simulated City of Lompoc Well TDS

HCI developed a program for calculating the simulated TDS of the Lompoc City wells on an average annual basis which includes, a) a weighted average of simulated TDS for multiple nodes immediately adjacent to pumping well/node, b) calculates a weighted average TDS produced by each well based on flow, thickness and pore volume of layers/aquifers opposite the screened portion of the well, and c) calculates a flow weighted TDS for combined City well production based on the amount of water pumped in 1988 by each of the eight City wells. The average production weighting for 1988 based on HCI model input is approximately 57% from Well 3(27Q2), 22% from Well 1 (34B1), 11% from Well 2 (34F6), with the remaining 9% from Wells 4, 7, and 5.

Stetson Engineers created a method for providing a weighted average TDS of Lompoc City wells based on output from the USGS model for comparison to the HCI output. A simpler approach was used due time and data constraints, and differences in model structure. A single node from the USGS model was used to represent the TDS in the Main Zone for each City pumping well. The TDS each node was then weighted by pumping for each well based on the pumping schedule in the model as simulated in 1988. This effort required selection of the appropriate nodes, program testing and QC.

8. Simulation of EIR Alternatives

Seven Cachuma Reservoir operations alternatives were evaluated using the USGS flow and transport models. These are described elsewhere in detail and are briefly listed below:

Alternative 1 - (WR 89-19 Operations): No Action

Alternative 2 - (Post WR 94-5): Pre-Biological Opinion Operations

Alternative 3A - Operations Incorporating BO Actions (0.75 feet surcharging)

Alternative 3B - Operations Incorporating BO Actions (1.8 feet surcharging)

Alternative 3C - Operations Incorporating BO Actions (3 feet surcharging)

Alternative 4A - Operations Incorporating BO Actions, Plus Below Narrows Exchange Project
(Direct Delivery of State Project Water for Municipal Use)

Alternative 4B - Operations Incorporating BO Actions, Plus Below Narrows Exchange Project
(Recharge of State Project Water below Lompoc Narrows)

The differences in the simulated flow and TDS of the Santa Ynez River at the Narrows for each Alternative are discussed in detail in Stetson Engineers' Tech Memo #3. These differences are discussed briefly here in order to facilitate the understanding of the degree to which a simulated response in the TDS of ground water is due to flow and TDS at the Narrows or inherent characteristics of the ground water models.

The primary differences between Alternatives 1, 2 and 3 are the operation of Cachuma Reservoir and resulting discharge and TDS at the Narrows. The EIR Alternatives are similar with respect to the timing, rate and TDS of flows at the Lompoc Narrows, but the flows for the Alternatives generally differ from historical conditions in that peak flows are reduced and flows during dry periods are increased (Figure 20). The flows for Alternative 4B are consistently higher than the others because, although Santa Ynez River flow up to the Lompoc Narrows is identical for both Alternative 4A and 4B, Alternative 4B flows include an additional direct discharge 1770 afy of imported State Project water at or just below the Narrows.

The monthly average simulated flows for the SYHRM for the period 10/1941 to 9/1993 are shown in Figure 21. The differences between the Alternatives are most apparent during summer months. The greatest differences exist between Alternatives 1, 2 and 3, which are very similar, and Alternatives 4A and 4B. In Alternative 4B, State Project water is recharged directly at or below the Narrows and increases the flow significantly in dry months. In Alternative 4A, State Project water is not discharged to the River, but delivered directly to the City of Lompoc, resulting in lower river flows during dry months.

The SYRHM simulated average annual flow weighted TDS of river flows at the Narrows for historical conditions and EIR Alternatives is shown in Figure 22. The monthly average TDS of flows simulated at the Narrows under historical conditions and for each EIR alternative is shown in Figure 23. These graphs clearly show the inverse relationship between flow and TDS. The TDS for Alternative 3A, B and C are very similar. There is less similarity in the TDS for Alternatives 1, 2 and 4. Alternative 4B stands out because, at low flows, the effects of discharging State Project water below the Narrows for recharge significantly reduce the average TDS, even though the amount of water discharged is relatively small. Note that the TDS data used by the USGS for inflows at the Narrows for the historical calibration is not shown on these graphs because of the variable length of stress periods they used.

The difference between the TDS input to the HCI and USGS models for calibration and for EIR Alternative 2 are shown in Figures 24 and 25 to illustrate one of the primary differences between the USGS and HCI transport models. These differences are most apparent when viewing graphical output that is presented in Part 9 of this report. Only the TDS input for the model calibrations and Alternative 2 are shown for clarity and the fact that the annual and biannual flow weighted average TDS at the Narrows is very similar for each Alternative, except 4B as shown in Figures 22 and 23 for the SYRHM output.

9. Ground Water Model Results for Cachuma EIR Alternatives

The following is a summary of the simulated water levels and TDS for selected sites within the Main Zone of the Lompoc Plain for each of the Cachuma EIR Alternatives. The USGS and HCI model results for the seven Cachuma EIR Alternatives are represented by two well locations within each of the three main subareas within the Lompoc Plain (Figure 1). The results are presented for each Alternative as tables representing the average TDS at each location over the period 1952 through 1998, and time series graphs of TDS and Water Levels representing the results for the entire simulated period used in the USGS and HCI models. The graphs also show results generated from the original model calibrations for each of the model for comparison to each of the Alternatives, primarily to illustrate differences in the magnitude of historical changes in TDS compared to the relatively minor differences simulated for most of the EIR Alternatives.

A) Average Simulated TDS over the 1952 – 1982 Base Period

The average TDS for the Main Zone aquifer in the Lompoc Plain for each subarea at selected locations and the flow-weighted average for the five City of Lompoc active wells are shown in Table 1. The period over which the results were averaged (1952 to 1982) was selected because it was a relatively balanced hydrologic period shared by both HCI and USGS model calibrations and because it limits the effect of the initial conditions of the simulations which were the same for all EIR Alternatives.

The average difference in TDS between Alternative 2 and other alternatives are shown in Table 2 as both a difference in TDS in mg/l and as a percentage. Alternative 2 was selected as the baseline, by which other Alternatives can be compared for the purposes of the Cachuma EIR. Comparisons between all alternatives and river inflows at the Narrows can also be made using Table 2. Another method of comparison between EIR Alternatives is shown in Table 3. These are the average differences between selected Alternatives chosen by URS for the purposes of presenting results in the EIR.

The results shown in Table 1 illustrate the magnitude of the average simulated TDS in each sub area and within a given sub area. This table is more useful for a general comparison between sub areas and, to some extent, between models than Tables 2 and 3, which provide a useful comparison between Alternatives. The values in Table 1 can provide an indication of the relative precision of the model results that, athough presented to the nearest 1 mg/l, may be best evaluated by rounding to the nearest 100 mg/l. As previously noted, the USGS and HCI transport model results are estimated to be accurate for such simulations to within about 100 to 300 mg/l, depending upon various factors. However, for comparisons between alternatives, differences of less than 100 mg/l may be useful where clear trends are observed.

Table 1 shows that, within the HCI model, the overall magnitude of the average TDS ranges from about 2000 to 2300 mg/l in the Western Plain, a relatively uniform 1800 mg/l in the Central Plain, over 800 to 1700 mg/l in the Eastern Plain, and about 900 to 1000 mg/l for the City of Lompoc Wells. The range of TDS in the HCI model is approximately 1500 mg/l basin wide . The differences in results within each subarea range from about 900 mg/l in the Eastern Plain, 300 mg/l in the Western Plain, and no significant difference within the Central Plain.

Within the USGS model, Table 1 shows the overall magnitude of the average TDS ranges from about 2200 to 2900 mg/l in the Western Plain, 1900 to 2200 mg/l in the Central Plain, about 900 to 1800 mg/l in the Eastern Plain, and about 1100 mg/l for the City of Lompoc Wells. The range of TDS in the USGS model is approximately 2000 mg/l basin wide. The differences in results within each subarea range from about 700 mg/l in the Western Plain, about 300 mg/l within the Central Plain, and 800 mg/l in the Eastern Plain,

Table 1 shows that, except very near the Narrows, the USGS model simulates higher overall TDS in the Main Zone than the HCI model by less than 100 mg/l to about 600 mg/l. The greatest differences between the models occurs in the Western Plain where the difference in TDS ranges from less than 200 to about 600 mg/l. This may be because of the difference in the boundary conditions at the base of the models. The USGS model includes a head dependent boundary between the consolidated rocks, a source of high TDS waters, and the Main Aquifer in the Western Plain, whereas the HCI model represents that contact as a no flow boundary.

In the Central and Western Plain the USGS model also simulates a greater range of TDS and higher average concentrations than the HCI model by about 100 to 300 mg/l. This difference may also be attributed to the lower boundary conditions as well as the difference between the USGS and HCI conceptual models. In the USGS model, the primary source of salts introduced to the Main Zone is poor quality water the lower aquifer and consolidated rocks. In the HCI model, dissolution of salts by percolating recharge from rainfall and irrigation return flows in the unsaturated zone is the primary source of salts.

Table 2 was created to show the extremely small simulated TDS differences between the EIR Alternatives. Results shown in Table 2 have been normalized relative to EIR Alternative 2. The difference in mg/l and TDS between alternatives at a given location may be considered below the absolute accuracy of either model. However, it is hoped that they may exhibit trends that would allow evaluation of the Alternatives.

The results shown in Table 2 are primarily for comparison between Alternatives as simulated by a single model. These indicate only minor differences in the water quality in the Main Zone aquifer of the Lompoc Plain result from minor changes in Cachuma Operations (Alt. 2 and 3A,B,C). Cachuma operations that result in higher dry season and dry period flows provide benefits to the Eastern Plain and possibly to the Western Plain. The Central Plain appears relatively unresponsive to Cachuma Operations. Alternatives that involve changes in operations directly within the Lompoc Plain basin such as Alternative 4A and 4B, which includes reductions in ground water pumping and direct recharge of high quality SWP water in the basin, result in the most significant changes throughout the Main Zone in the Lompoc Plain.

In general, the HCI model results indicate very small differences between alternatives that are less than one percent, probably due to their modeling approach and use of annual stress periods. None of the Alternatives considered for future operations exhibit conspicuous basin wide trends that would suggest it was superior to the others. Alternative 1 is more representative of past operations, but does exhibit a clear trend of inferior water quality basin wide, although the magnitude is relatively minor or even insignificant. Locally, the greatest improvement in ground water quality occurs very near the Lompoc Narrows under Alternative 4B where recharging of low TDS SWP water results in a significant improvement near the City wells, including Well 34B1, possibly due to high vertical permeability which allows localized deep percolation of high quality SWP discharge. Slight improvements in TDS are shown in the HCI model results for Alternatives 3-A, B, and C.

It is more difficult to explain the HCI model response for Alternative 4A. The relative increase in TDS in the Central Plain, Well 34B1 and the City wells in the Eastern Plain may be due to the sensitivity of this model to reduced pumping which reduces the amount of storage available for recharge of good quality high flows from the river. The slight improvement in TDS in the western plain may result from a lesser amount of induced inflow from saline waters to the west, also due to reduced pumping. The TDS for Well 28M2 shows improvement for this Alternative, probably due to the proximity to the waste water treatment plant discharge which was assumed to have a lower TDS for this Alternative only, as discussed in Part 5.

The differences between simulation results shown in Table 2 for the USGS model are generally larger in magnitude compared to the HCI model, except in the extreme eastern portion of the basin. Alternative 1 appears to be generally inferior compared to the other alternatives. Alternative 3A, B, and C show general improvement, except for minor differences near the Narrows. Alternative 4A shows somewhat greater improvement due to reduced pumping and increased inflow of poor quality water from underlying formations and boundaries and then improved quality of waste water discharge near Well 28M2.

The effect of Alternative 4B is a marked improvement in water quality in the Eastern and Central Plain, for the USGS model, relative to the other alternatives, due to direct recharge of high quality SWP waters at low flows. The magnitude of the improvement in the extreme eastern Plain is far less than that simulated by the HCI model, possibly reasons discussed above regarding vertical permeability and the greater TDS of river subflow in the USGS model. The cause of the relative decrease in quality in the Western Plain for this alternative is unknown.

Table 3 shows the results as presented in the EIR. The data are identical to that presented in Table 2 except for some rounding of numbers and the addition of flow-weighted TDS of Lompoc City water supply based on direct delivery and mixing with SWP water for Alternative 4A. These results were not generated by the ground water models, but the flow-weighted model output for water pumped by City wells was combined with 1770 afy of State Project water assuming a TDS of 300 mg/l to obtain a flow-weighted average TDS for the mixed water supply. The results indicate a significant theoretical improvement in the quality of the City’s water supply relative to any other Alternative. The mixing result using USGS output result is proportionately greater reduction based on its simulated aquifer response.

In general, the results for both models are area generally consistent, although some differences in magnitude occur that may be explained by differences in boundary conditions, calibration approach and conceptual models. The ground water model results tend to favor Alternatives 4A and 4B in the Eastern Plain. Results are mixed for Alternatives 4A and 4B and generally neutral for Alternative 3 in the Central Plain. In the Western Plain, Alternaitves 3 and 4A are favored.

B. Time Series Graphs of USGS Model Results

Time series graph of water levels and TDS are presented as Figures 26 to 49 and are discussed briefly below for each of the six locations selected for comparison of EIR Alternatives (Figure 1). In general, the graphs show a degree of similarity between the Alternatives that make it difficult to identify clear difference between them. They are presented for completeness and to show the relative difference between the Alternatives and historical conditions in the Lompoc Plain Main Zone aquifer.

The times series graphs are shown for the entire calibration period of each model, unlike the TDS Tables 1, 2 and 3 which are based on averages from the period 1952-82.

Eastern Lompoc Plain

The simulated TDS in the Main Zone in the eastern Lompoc Plain using the USGS model are shown for two selected well locations in Figures 26 and 27. Figure 26 shows the simulated TDS at Eastern Plain well 34B1. Alternative 4B clearly results in a lower TDS than the others at this location. Overall, the simulated TDS at this location shows a somewhat greater variation for the Alternatives than the historical calibration. One explanation for this response is that the higher (1988) pumping rate (Figure 5) used for each Alternative results in a greater dewatered storage during dry periods relative to the allowing greater amounts of higher quality recharge near the Narrows during high flow-lower TDS events. Part of the variation in TDS for the Alternatives may be due to the greater variation in simulated TDS of river inflows at the Narrows than the USGS used in their historical calibration (Figure 24). This effect may only occur locally very near the Narrows and does not appear to extend far down-gradient. At increasing distances from the Narrows, a greater influence on ground water quality in the Main Zone appears to be the TDS of water in overlying or underlying aquifers or along margins.

Figure 27 shows the simulated TDS in the Main Zone for Well 28M2 on the western side of the Eastern subarea. There is little difference between the results for each Alternative at this location, which begins to show a more subdued response more characteristic of wells in the

Central Plain. The long-term trend shows the effects of hydrologic conditions are similar to those for the historical calibration in the latter half of the period when the pumping rates are more comparable. This similarity is due to the lack of simulated variation in ground water conditions in this area relative to historical conditions, compared to the Eastern Plain which is greatly influenced by flows and TDS at the Narrows.

Figure 28 shows the water level response in the Main Zone near the Lompoc Narrows. It suggests the higher rate of pumping in the Alternative simulations causes greater water level declines during dry periods, until later years when historical pumping begins to approach the 1988 level used for the Alternatives. Figure 19 shows a similar but more subdued water level response. The simulated water level response in the Eastern Plain to all the Alternatives are very similar and none stands out as having a clear advantage over the others with respect to ground water levels in the Main Zone in this area.

Central Lompoc Plain

The simulated TDS response in the Central Plain shows the dampened response to flow and TDS changes at the Narrows with increasing distance (Figures 30 and 31). The lower permeability of overlying sediments and distance from the Narrows has the effect of allowing the simulated TDS for all Alternatives to become very similar. This difference in the response between Well 29N2 (Figures 30) and Well 31A4 (Figure 31) may be due to proximity to the river. There is no clear difference between the Alternatives in this area based on these graphs.

The simulated water levels for these same locations in the Lompoc Plain are shown in Figures 32 and 33. Both locations show a similar response to each Alternative such that none is clearly superior over the others.

Western Lompoc Plain

The simulated TDS graphs for each Alternative in the Western Plain is shown in Figures 34 and 35. The response for the Alternatives are similar to the USGS historical calibration, but the TDS higher due to a higher initial condition for the Alternative simulations. The TDS response is unique and may be related to wet and dry periods. The differences between Alternatives are small relative to the magnitude of the TDS in the Main Zone in the Western Plain subarea.

The various EIR Alternatives show an overall increase in TDS in this part of the Lompoc Plain probably because pumping, as simulated, remains high. TDS is simulated to increase significantly during dry periods, and remain higher by the end of the simulation. As previously noted, pumping may now be distributed more widely across different aquifers in the Western Plain. The effect of pumping redistribution on simulated TDS in the Main Zone is unknown without well specific data and revised model simulations.

Figures 36 and 37 show the water level response in the Main Zone beneath the Western Lompoc Plain. The water levels in this region show similar responses as those in the Eastern and Central Plain. There appears to be little difference between the Alternatives, but the simulated water levels are lower than under historical conditions which supports the higher simulated TDS values for the Alternatives that are caused by greater inflow of poor quality water from adjacent boundaries of underlying formations.

C. Time Series Graphs of HCI Model Results

The graphs of results for the HCI model contrast with those of the USGS model in the HCI model results appear smoother due to the annual stress periods and other differences in modeling approach discussed under Part 4 of this report.

Eastern Lompoc Plain

The simulated TDS in the Main Zone in the eastern Lompoc Plain using the HCI model are shown in Figures 38 and 39. Figure 38 shows the simulated TDS at Eastern Plain well 34B1. Overall, the simulated TDS at this location shows a general decrease in TDS for all EIR Alternatives relative to the historical calibration. The simulated TDS in the Main Zone is similar for all the EIR Alternatives, except Alternative 4B. In Alternative 4B, the direct recharge of much lower TDS water (approximately 300 mg/l) in the Santa Ynez river bed near this well location, lowers the simulated TDS in the aquifer in that area by about 150 mg/l relative to the other Alternatives. The minor differences in simulated TDS at this location between the other Alternatives is a result of the similarity in the simulated flow and TDS at the Narrows for those Alternatives.

Figure 39 shows the simulated TDS in the Main Zone for Well 28M2 on the western side of the Eastern subarea. There is little significant difference between the results for each Alternative at this location except a small overall improvement in Alternative 4A which may benefit from lower wastewater TDS discharge near this well. The effects of direct recharge of high quality water in Alternative 4B appears to provide little benefit at this distance from the recharge area. The long-term trend is relatively flat, showing little response to hydrology.

The simulated water level response in the Eastern Plain to all of the Alternatives are very similar and none stands out as showing clear advantages over another in the Main Zone. Figure 40 shows the water level response in the Main Zone near the Lompoc Narrows. The higher rate of pumping in the EIR Alternative simulations results in lower water levels than for the calibration. The lower pumping rates simulated in Alternative 4A result in slightly higher water levels than for the other alternatives.

Figure 41 shows a similar water level response to that shown in Figure 40, but is more subdued due to distance from the area of highest recharge and highest degree of hydraulic communication with surface water, near the Narrows.

Central Lompoc Plain

The simulated TDS response in the Central Plain is more subdued than near the Narrows due to the lower permeability of overlying sediments and increased distance from the primary area of stream recharge (below Lompoc Narrows) (Figures 42 and 43). There is no significant difference between the Alternatives in this area, however, the TDS for Alternatives 4A and 4B is slightly higher than for the other Alternatives although they would be expected to be slightly lower. There is no explanation for these apparently anomalous results.

The simulated water levels for these Central Lompoc Plain locations are shown in Figures 44 and 45. Both locations show a similar response to each Alternative, with no apparent advantage of one over the others or that can shed light on the TDS response of Alternatives 4A and 4B.

Western Lompoc Plain

The simulated TDS for each Alternative in the Western Plain is shown in Figures 46 and 47. The results for each of the Alternatives are very similar and show little variation over time, due to hydrology. The simulated TDS values are higher than for the historical calibration, primarily due to the updated initial conditions and continued trend of induced poor quality water from leaching of salt in the unsaturated zone and along model boundaries.

Figures 48 and 49 show the water level response in the Main Zone beneath the Western Lompoc Plain. There is little difference in water levels between the Alternatives and they show only a minor response to hydrologic trends, possibly due to proximity to the western constant head boundary in the HCI model.

Table 1: Lompoc Plain Groundwater Quality
Simulated Average TDS for Selected Locations
Main Zone Aquifer (1952-1982)
[mg/L]

HCI Model

	Alt 2	Alt 1	Alt 3A	Alt 3B	Alt 3C	Alt 4A	Alt 4B
Western Plain							
Well 26F1,3,4,5	2330	2331	2329	2329	2330	2327	2332
Well 25D1,3	2018	2020	2016	2016	2016	2010	2018
Central Plain							
Well 31A3	1784	1786	1782	1784	1782	1809	1803
Well 29N6	1784	1785	1786	1784	1786	1800	1794
Eastern Plain							
Well 28M2	1728	1733	1726	1726	1723	1711	1731
Well 34B1	1009	1019	1005	1006	1002	1019	842
City Wells - Avg	1012	1022	1010	1011	1008	1029	854

USGS Model

	Alt 2	Alt 1	Alt 3A	Alt 3B	Alt 3C	Alt 4A	Alt 4B
Western Plain							
Well 26F1,3,4,5	2885	2901	2849	2844	2850	2794	2906
Well 25D1,3	2273	2291	2234	2231	2235	2174	2284
Central Plain							
Well 31A3	2180	2180	2176	2176	2176	2159	2176
Well 29N6	1937	1933	1936	1935	1935	1906	1928
Eastern Plain							
Well 28M2	1770	1769	1757	1758	1758	1725	1752
Well 34B1	973	984	976	975	974	982	931
City Wells - Avg	1108	1115	1110	1109	1107	1102	1085

Table 2: Lompoc Plain Groundwater Quality
Simulated Average TDS for Selected Locations
Main Zone Aquifer (1952-1982)
[Alternatives - Alternative 2]

HCI Model

	Alt 2		Alt 1		Alt 3A		Alt 3B		Alt 3C		Alt 4A		Alt 4B	
	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%
Western Plain														
Well 26F1,3,4,5	0.0	0.0%	1.4	0.1%	-0.2	0.0%	-0.4	0.0%	0.0	0.0%	-2.7	-0.1%	2.0	0.1%
Well 25D1,3	0.0	0.0%	2.6	0.1%	-1.9	-0.1%	-1.9	-0.1%	-2.0	-0.1%	-7.9	-0.4%	-0.1	0.0%
Central Plain														
Well 31A3	0.0	0.0%	2.3	0.1%	-1.5	-0.1%	-0.1	0.0%	-1.5	-0.1%	25.6	1.4%	19.6	1.1%
Well 29N6	0.0	0.0%	1.0	0.1%	1.3	0.1%	-0.3	0.0%	1.2	0.1%	16.0	0.9%	9.9	0.6%
Eastern Plain														
Well 28M2	0.0	0.0%	5.0	0.3%	-2.5	-0.1%	-1.6	-0.1%	-4.8	-0.3%	-17.3	-1.0%	3.1	0.2%
Well 34B1	0.0	0.0%	9.3	0.9%	-4.1	-0.4%	-3.2	-0.3%	-6.8	-0.7%	9.9	1.0%	-167.1	-16.6%
City Wells - Avg	0.0	0.0%	10.3	1.0%	-1.9	-0.2%	-1.4	-0.1%	-4.5	-0.4%	16.6	1.6%	-158.2	-15.6%

USGS Model

	Alt 2		Alt 1		Alt 3A		Alt 3B		Alt 3C		Alt 4A		Alt 4B	
	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%	mg/l	%
Western Plain														
Well 26F1,3,4,5	0.0	0.0%	15.5	0.5%	-36.7	-1.3%	-41.0	-1.4%	-35.0	-1.2%	-91.1	-3.2%	21.1	0.7%
Well 25D1,3	0.0	0.0%	17.3	0.8%	-39.0	-1.7%	-42.6	-1.9%	-38.3	-1.7%	-99.3	-4.4%	10.4	0.5%
Central Plain														
Well 31A3	0.0	0.0%	-0.1	0.0%	-4.4	-0.2%	-4.0	-0.2%	-4.0	-0.2%	-20.8	-1.0%	-4.5	-0.2%
Well 29N6	0.0	0.0%	-3.6	-0.2%	-0.8	0.0%	-1.1	-0.1%	-1.2	-0.1%	-30.5	-1.6%	-8.4	-0.4%
Eastern Plain														
Well 28M2	0.0	0.0%	-0.7	0.0%	-13.3	-0.8%	-11.9	-0.7%	-11.9	-0.7%	-44.5	-2.5%	-17.5	-1.0%
Well 34B1	0.0	0.0%	10.8	1.1%	2.7	0.3%	1.7	0.2%	1.6	0.2%	8.7	0.9%	-42.0	-4.3%
City Wells - Avg	0.0	0.0%	7.0	0.6%	1.5	0.1%	1.0	0.1%	-1.1	-0.1%	-6.4	-0.6%	-23.5	-2.1%

Table 3 - Comparison of Lompoc Plain (Main Zone) Ground-Water Quality Results for EIR Alternatives

HCI Transport Model

Average Difference in TDS over the hydrologic period 10/1951 – 9/1982

Area	Well Location	Alt 1 – Alt 2 (mg/l)	Alt 3A – Alt 2 (mg/l)	Alt 3B – Alt 2 (mg/l)	Alt 3C – Alt 2 (mg/l)	Alt 4A – Alt 2 (mg/l)	Alt 4B – Alt 2 (mg/l)
West	26F1	1	<1	<1	<1	-3	2
	25D1	3	-2	-2	-2	-8	<1
Central	31A3	2	-2	<1	-2	26	20
	29N6	1	1	<1	1	16	10
East	28M2	5	-3	-2	-5	-17	3
	34B1	9	-4	-3	-7	10	-167
Lompoc City Wells [1]		10	-2	-1	-5	17/-224 [3]	-158

USGS Transport Model

Average Difference in TDS over the hydrologic period 1/1952 – 12/1982

Area	Well	Alt 1 – Alt 2 (mg/l)	Alt 3A – Alt 2 (mg/l)	Alt 3B – Alt 2 (mg/l)	Alt 3C – Alt 2 (mg/l)	Alt 4A – Alt 2 (mg/l)	Alt 4B – Alt 2 (mg/l)
West	26F1	16	-37	-41	-35	-91	21
	25D1	17	-39	-43	-38	-99	10
Central	31A3	<1	-4	-4	-4	-20	-4
	29N6	-4	<1	-1	-1	-31	-8
East	28M2	<1	-13	-12	-12	-45	-18
	34B1	11	3	2	2	9	-42
Lompoc City Wells [2]		7	2	1	-1	-6/-271 [3]	-24

[1] Weighted by pumping from each production well, includes contribution from other zones.

[2] Weighted by pumping from each production well, Main Zone aquifer only.

[3] Includes direct mixing with 1770 afy State Project water at an estimated TDS of 300 mg/l.

APPENDIX A

Summary of the HCI and USGS Flow and Transport Models

USGS Models

Flow (Lompoc Basin - Uplands and Plain)

- MODFLOW finite-difference
  Four layers
    Upper Aquifer - Shallow Zone
    Upper Aquifer - Middle Zone
    Upper Aquifer - Main Zone
    Lower Aquifer

- Uniform cell size (1320 x 1320 ft.)

- Two variable stress periods per year based on annual hydrologic conditions. Average - 139 days wet period and 266 day dry period.

- Includes stream routing, wells, no-flow, constant flow and variable flow boundaries, ET, areal recharge, irrigation return flow, tributary stream recharge

Transport

- Modified SUTRA, finite-element
  (Code modified to allow variable time steps to accommodate variable wet/dry periods and multiple sources/sinks per node)

- Single layer, 2D, w/ advection and dispersion. Requires specified flux and concentration for selected elements for each stress period

- Four rectangular elements per MODFLOW cell (nodal spacing 660 ft.)

HCI Models

Two Flow models, finite-element USGS published FEMFLOW3D
Lompoc Basin Flow Model (Lompoc Uplands and Lompoc Plain)

- Four Layers w/ triangular mesh, nodal spacing approximately 700 to 7,000 ft.

  - Upper Aquifer - Shallow Zone
  - Upper Aquifer - Middle Zone
  - Upper Aquifer - Main Zone
  - Lower Aquifer

- Includes stream routing, wells, no-flow, constant flow and variable flow boundaries, ET, areal recharge, irrigation return flow, tributary stream recharge

- Provides subsurface ground-water inflows to Lompoc Plain from Lompoc Upland basin

Lompoc Plain Flow Model

- Fine triangular mesh (nodal spacing 700 to 1,100 ft.)
- Seven layers, all representing the Upper Aquifer
  - Shallow Zone (represented as four layers)
  - Middle Zone (represented as two layers)
  - Main Zone (represented as one layer)

- Monthly stress periods
- Provides ground water flow input data for transport model
- SYRHM provides inflow at Lompoc narrows
- Independent stream flow correlations provide stream flow at margins of the Lompoc Plain.
- Includes stream routing, unsaturated flow, pumping wells, no-flow, constant flow and variable flow boundaries, ET, areal recharge, irrigation return flow, tributary stream recharge

HCI Transport model

- USGS TRAN-3D finite element code
- Fully 3D w/advection and dispersion.
- Calculates TDS for multiple aquifers and allows water extracted from each aquifer to increase or decrease over time with that of the aquifer.
- Same finite-element mesh as the Lompoc Plain flow model
- Salinity input data provided by SYRHM at Lompoc Narrows and independent stream flow/salinity correlations for tributaries to Lompoc plain.
- Ground water flow data provided by Lompoc Plain flow model
- Santa Ynez River inflow and TDS provided at the Narrows from results of the SYRHM at Narrows.

INTERFACING SYRHM AND GROUND-WATER FLOW AND TRANSPORT MODELS

USGS Flow and Transport Models

- Convert monthly SYRHM flow and water quality output at the Lompoc Narrows to two seasonal values for input to the USGS ground-water models.
- Use existing interfacing approach developed by the USGS for applying Santa Ynez River Flows and water quality to the Lompoc Basin Ground-water model.
- Due to its 2D format the USGS transport model requires specified flux and concentration for selected elements for each stress period.

HCI Flow and Transport Models

- Input monthly flow data generated by the SYRHM at the Lompoc Narrows directly into Basin flow model and use annual average flow, water level and TDS in the Plain flow and salinity models.
- Remaining input data have been generated during model development by HCI and Navigant.