Paso Robles Groundwater Basin Model Update

Executive Summary

DRAFT

PREPARED FOR:

San Luis Obispo County Flood Control and Water Conservation District

December 8, 2014

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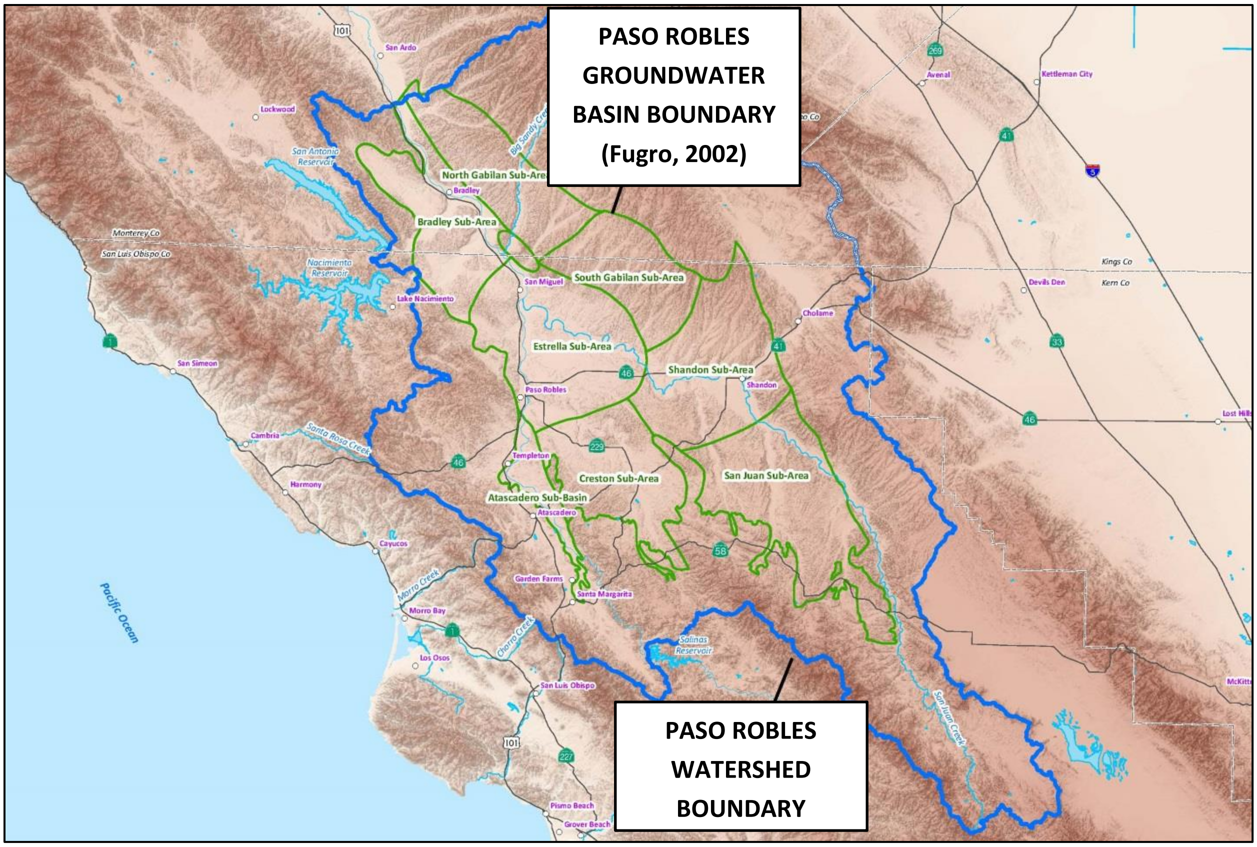
1.0 EXECUTIVE SUMMARY

1.1 Introduction

Local agencies, including the San Luis Obispo County Flood Control and Water Conservation District (District) and local stakeholders are working cooperatively to manage the Paso Robles Groundwater Basin (Basin). Work has included extensive monitoring, development of a management plan, conduct of studies, and development in 2005 of a numerical groundwater flow model (Basin Model). This report summarizes the Basin Model Update, which was undertaken to extend the model study period over water years[1] 1981-2011, to improve the water balance assessment and refine the perennial yield, and to evaluate the Basin's response to "Growth" and "No Growth" scenarios projected over the period water years 2012-2040.

The study area consists of the Paso Robles Groundwater Basin which encompasses 790 square miles in the upper Salinas River watershed in northern San Luis Obispo County and southern Monterey County. The initial Basin Model was constructed using MODFLOW, the widely-accepted groundwater flow modeling code developed by the United States Geologic Survey. Development of the initial Basin Model involved definition of the geologic framework including basin boundaries (such as the boundary between the Atascadero subbasin and the remainder of the Basin) and four layers representing the recent alluvial deposits and portions of the Paso Robles Formation. The initial Basin Model also included estimation of aquifer properties and evaluation of the water balance for the period water years 1981-1997. This Basin Model Update did not change the geologic framework, but focused on update and refinement of the water balance.

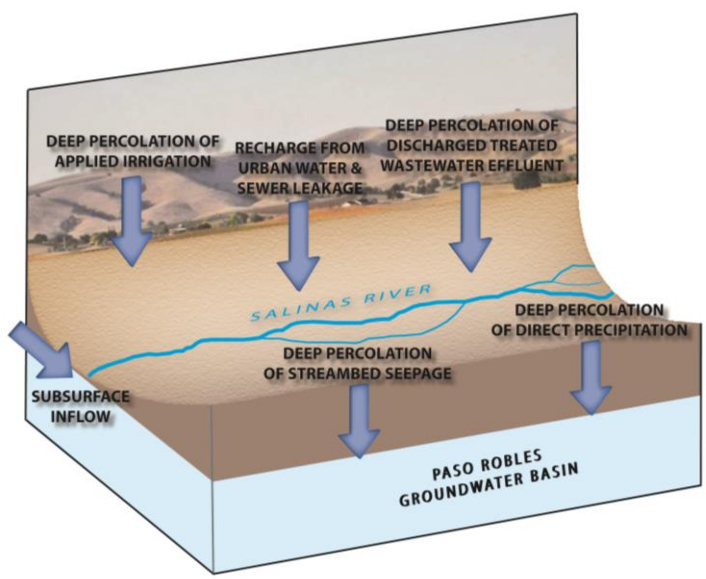
[1] A water year is defined as the period from October 1 through September 30.



1.2 Water Balance Estimation

The Basin Model Update evaluated each component of the water balance independently using available data. The primary groundwater recharge components for the Basin are:

- Deep percolation of direct precipitation,
- Deep percolation of streambed seepage,
- Deep percolation of applied irrigation water,
- Subsurface inflows through the Basin boundary,
- Deep percolation of discharged treated wastewater effluent, and
- Recharge from urban water and sewer pipe leakage.

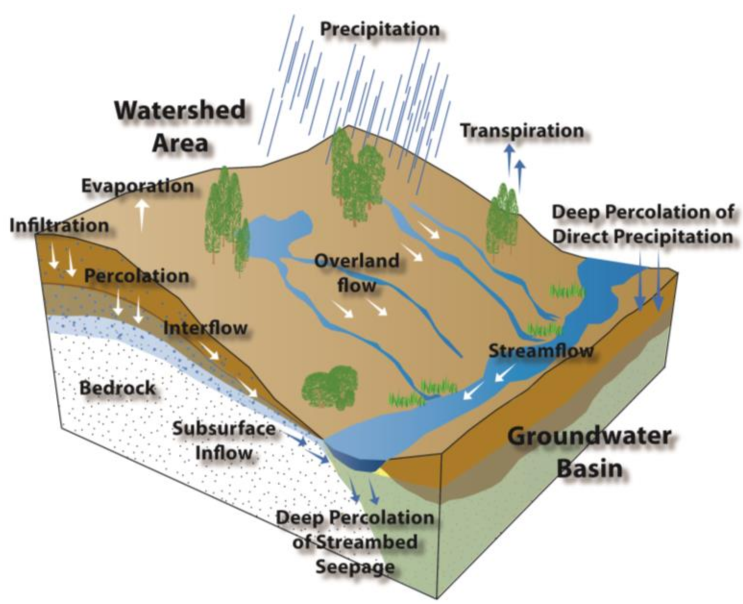


This report provides detailed description of the data and methodologies used in evaluating each recharge component.

A major new feature was development of a rainfall-runoff model[2] of the watershed that is tributary to the Basin. Such watershed hydrologic modeling uses extensive data to characterize the water balance and hydrologic processes that occur in a watershed. These data include land surface elevations, soil types, land use, precipitation, evaporation, streamflow, surface diversions, reservoir releases, wastewater recharge, crop coefficients, and irrigation efficiency. Historical data were collected, compiled (mostly in spreadsheets and a GIS database), and reviewed prior to incorporating them into the Basin Watershed Model. The available data are summarized in this report and have been made available to the District.

In addition, this report describes the primary steps used to construct the Basin Watershed Model involving 81 defined sub-watersheds and calibrating to four streamflow gaging stations with relatively long records. These gaging stations include the Salinas River near Bradley (at the outlet of the Basin), Salinas River above Paso Robles, Estrella River near Estrella, and Santa Margarita Creek near Santa Margarita; comparison of model-simulated and measured streamflow indicates a very good match for the Salinas River near Bradley gaging station and good or fair matches for the other stations.

The Basin Watershed Model provided independent analysis of recharge to the Basin, including subsurface inflow and streambed percolation; issues in the estimation of these recharge components had been identified by the initial Paso Robles Basin modelers and later reviewers. These components remain difficult to assess accurately, reflecting a lack of data on percolation rates, streamflow and nearby groundwater levels, particularly around the margins of the Basin. As a result, these components became a major

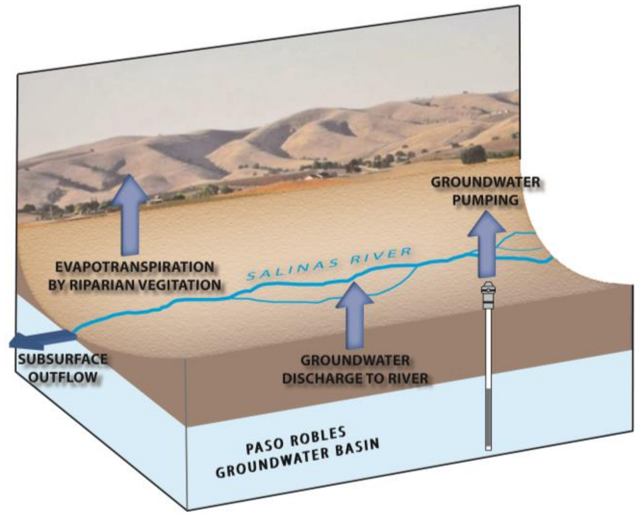


2 The Watershed Model was developed using the Hydrologic Simulation Program – FORTRAN (HSPF), a successor to the FORTRAN version of the Stanford Watershed Model, widely-used codes developed with support of the United States Environmental Protection Agency (EPA).

topic of the peer review conducted near the end of the Basin Model Update process and a focus of subsequent recommendations for additional model refinement.

The primary groundwater discharge components for the Basin are:

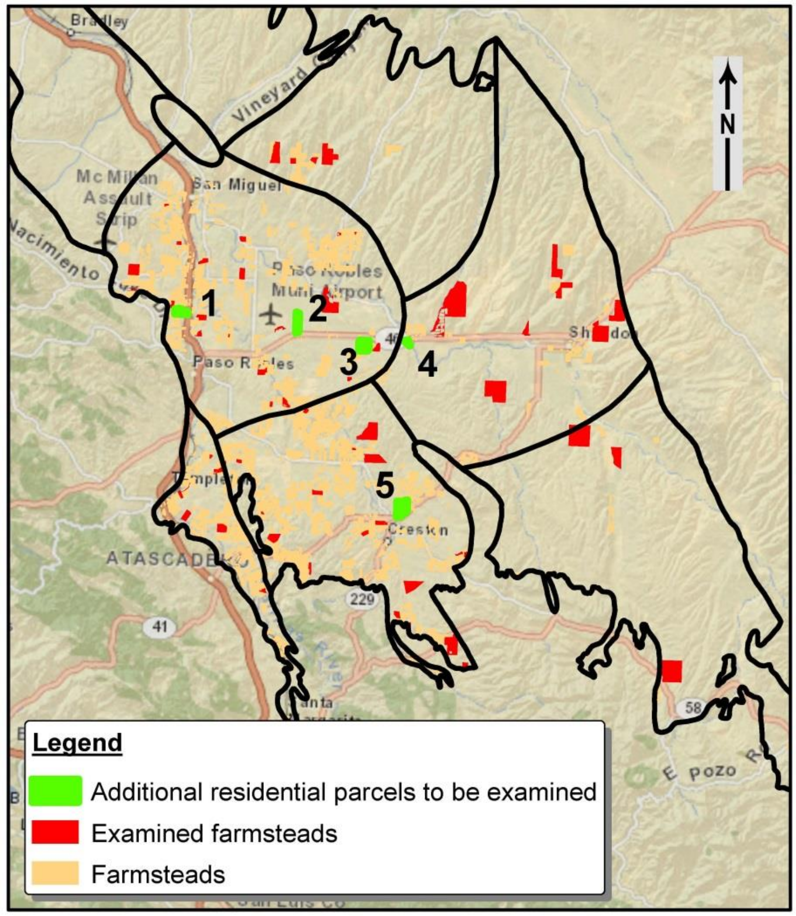
- Agricultural pumping (average 68% for 1981-2011),
- Municipal pumping (11% for 1981-2011),
- Private Domestic pumping (3% for 1981-2011),
- Small commercial pumping (2% for 1981-2011),
- Evapotranspiration (ET) by riparian vegetation (3% for 1981-2011),
- Groundwater discharge to rivers (12% for 1981-2011) and
- Subsurface outflow (1% for 1981-2011).



Of the discharge components, agricultural pumping accounts for the major portion (averaging about 68% over the model study period). Agricultural pumping is not metered and thus was subject to detailed analysis. As described in this report, this included development of crop-specific daily soil moisture water balances accounting for soil available water capacity, daily rainfall and reference evapotranspiration, crop water coefficient, bare soil evaporation, and increasing irrigation efficiency over time. Annual crop acreages estimated from Department of Water Resources (DWR) land use maps, digital San Luis Obispo County crop coverage maps for 2000 through 2011, and digital coverage of Monterey County 2012 crops. Crop acreages within groundwater basin boundaries from 2000 to 2010 were corrected/verified based on review of historical aerial photography.

Given the rapid increase in vineyards to dominate irrigated acreage (vineyards are more than 80% of irrigated acreage in the Basin), considerable attention was given to factors in vineyard water demand such as frost protection, reduced deficit irrigation (RDI) management, and increasing use of RDI management over time.

A relatively small but increasing discharge component is rural domestic pumping. This was a subject of concern because it is largely unmetered. Because meter data are lacking, previous studies (including the Phase I Study) relied on application of an assumed water demand factor of 1.7 AFY per dwelling unit (DU). The 2012 MWP also assumed a single water demand factor, in this case, 1.0 AFY/DU. This was significantly smaller and highlighted the uncertainty. Moreover, rural residences are quite variable—ranging from modest farmsteads to landscaped estates—suggesting that the variability of associated water demand was not evaluated adequately, particularly with regard to the extent of irrigated landscaping.



This concern was addressed in a special survey for this model update and in a parallel survey for the concurrent Salt Nutrient Management Plan. The SNMP investigation focused on a San Luis Obispo County land use category termed *farmstead*, examined 59 farmsteads across the groundwater basin, and measured the landscaped areas, which averaged 0.13 acres per farmstead. For this model update, a slightly different survey was performed focusing on five rural residential areas across the basin. The average landscape area was determined, resulting in a representative value is 0.13 acres per parcel, which happens to be the same value as that derived from the SNMP survey. Accordingly, both studies showed that rural residents irrigate a limited and fairly uniform acreage. For this study, available rural water demand information was used to estimate water demand per rural residential at 0.75 AFY/dwelling unit. This is a reasonable estimate of rural domestic use based on actual data. Of this amount, an average 38% is used indoors and can be assumed to return to the basin through onsite septic systems. An average of 62% is used outdoors and can be assumed consumed or lost to ET.

The residual of the water balance equation (i.e., recharge minus discharge) is change in groundwater storage. For each of the years 1981 through 2011, all of the recharge and discharge components were tallied, and the change in groundwater storage was calculated. These calculations indicate an average decline in groundwater storage over the study period of an estimated 2,473 acre-feet per year (AFY).

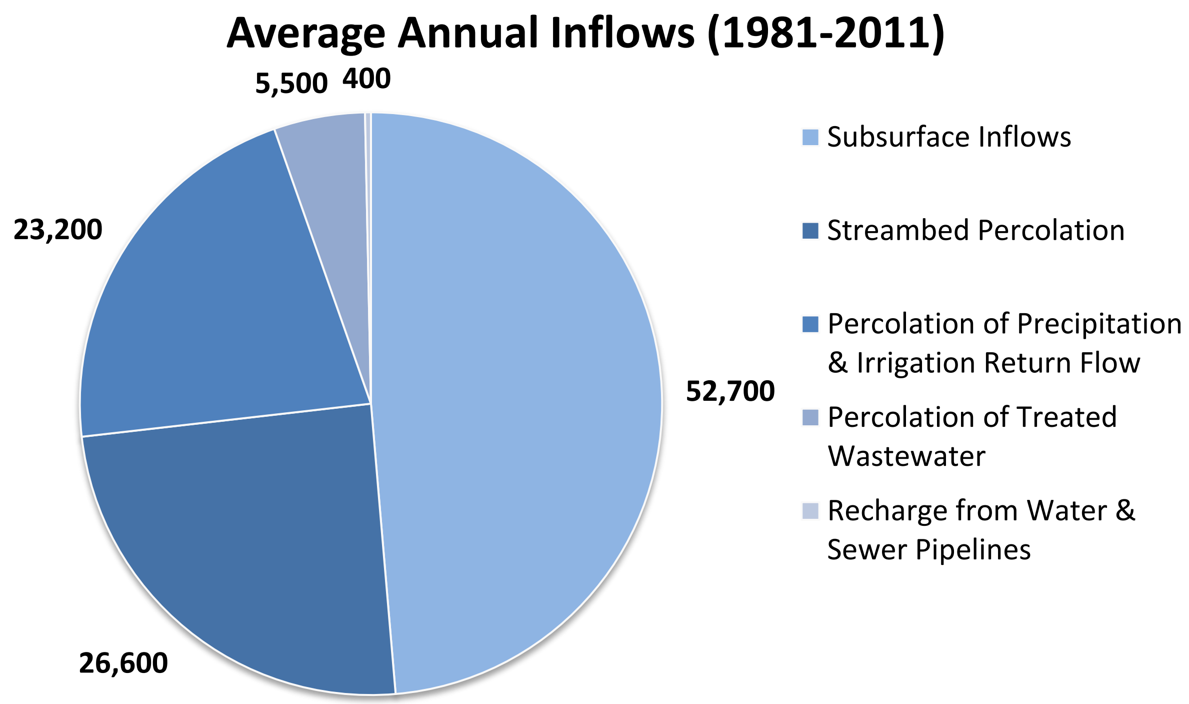
1.3 Hydraulic Separation of Atascadero Sub-basin

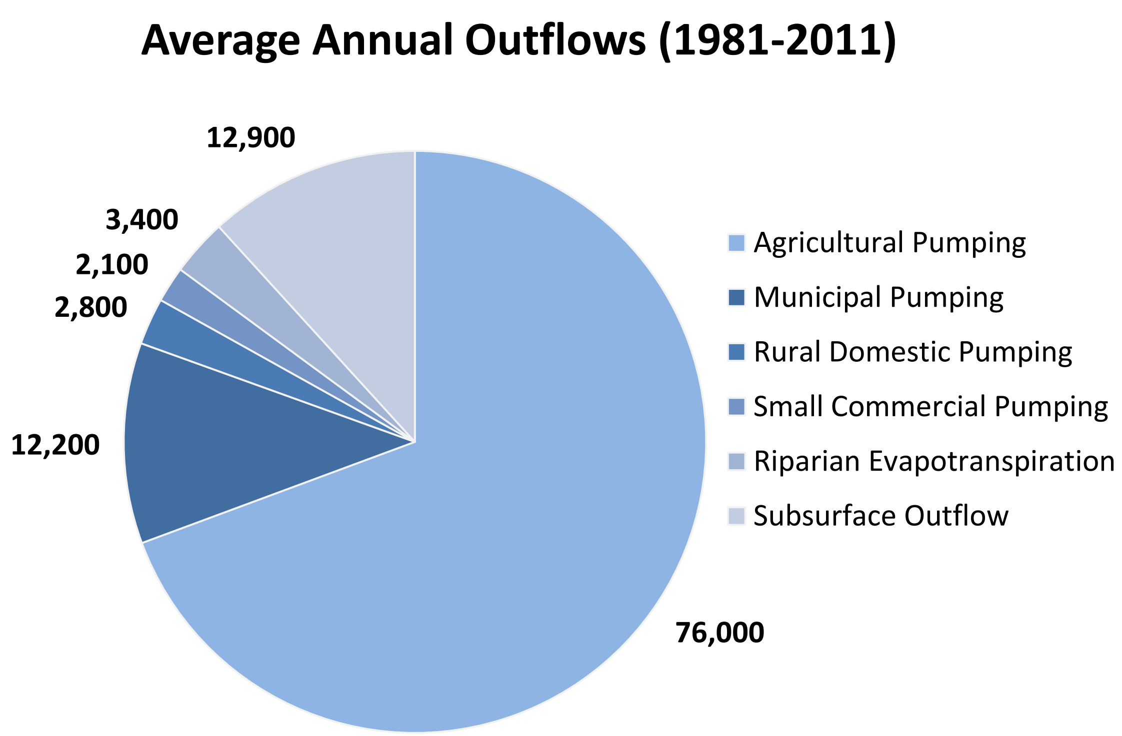
The geologic conceptual model developed during the Phase I Study (Fugro and Cleath, 2002) defined the boundaries and hydrogeologic layers within the Basin, and identified the Atascadero Sub-Basin as a subbasin with significant hydraulic separation across the Rinconada Fault from the remainder of the Basin. The degree of separation was addressed in this study through review of background reports and documents, driller's logs and well construction information, historic groundwater elevations, and historic groundwater pumping for wells located in the area of the reevaluation. This review revealed a lack of wells and respective data in close proximity to the Rinconada Fault. Accordingly, the review was inconclusive and the treatment of the Atascadero Sub-Basin as partially disconnected was retained for Basin Model Update.

1.4 Basin Model Update

The original Basin Model was calibrated for water years 1981 through 1997 with a semiannual stress period. This update extended the model period to water year 2011, and replaced the recharge and discharge terms using the updated water balance analysis. This report provides details on the modeling software (MODFLOW packages) used to handle the estimated Basin inflows and outflows. The model domain, aquifer layering and permeability values were unchanged from the original model. The updated Basin Model was run successfully with semiannual stress periods and evaluated in terms of its ability to produce simulated groundwater level trends that match observed trends; this evaluation triggered a recalibration of the model to improve its accuracy. Recalibration involved adjustments (using professional judgment and staying within reasonable bounds) to aquifer properties, and inflow and outflow terms. The recalibrated Basin Model is able (within industry standards) to simulate observed changes in groundwater levels that are driven by hydrological and groundwater pumping fluctuations.

Based on results of the recalibration run, total annual inflow for 1981-2011 ranged from 24,700 AF to 384,300 AF with an annual average of 108,400 AFY. Total annual outflow ranged from 84,400 AF to 142,160 AF with an annual average of 110,800 AF over the period 1981-2011. Annual average change in groundwater storage for the same period is -2,400 AFY.


Average Annual Inflows (1981-2011)
5,500
400
23,200
52,700
26,600
Subsurface Inflows
Streambed Percolation
Percolation of Precipitation & Irrigation Return Flow
Percolation of Treated Wastewater
Recharge from Water & Sewer Pipelines


Average Annual Outflows (1981-2011)
12,900
3,400
2,100
2,800
12,200
76,000
Agricultural Pumping
Municipal Pumping
Rural Domestic Pumping
Small Commercial Pumping
Riparian Evapotranspiration
Subsurface Outflow

Sensitivity analysis was performed on the recalibrated Basin Model in order to assess the model input parameters that have the greatest effects on the model's simulation results. The sensitivity analysis indicates that the Basin Model is most sensitive to changes to groundwater pumping and recharge from streambed percolation.

1.5 Perennial Yield Estimate

The maximum quantity of water from a groundwater basin on a perennial basis is limited by the possible deleterious side effects that can be caused by both pumping and operation of wells within the basin. The perennial yield, for purposes of this report is defined as:

Perennial Yield = Groundwater Pumping +/- Change in Storage

For the purposes of discussing perennial yield, the base period 1982 to 2010 covers wet, dry and average hydrologic cycles for the groundwater basin. The updated estimate for the perennial yield based on that period is 89,700 AFY.

1.6 Groundwater Model Predictive Scenarios

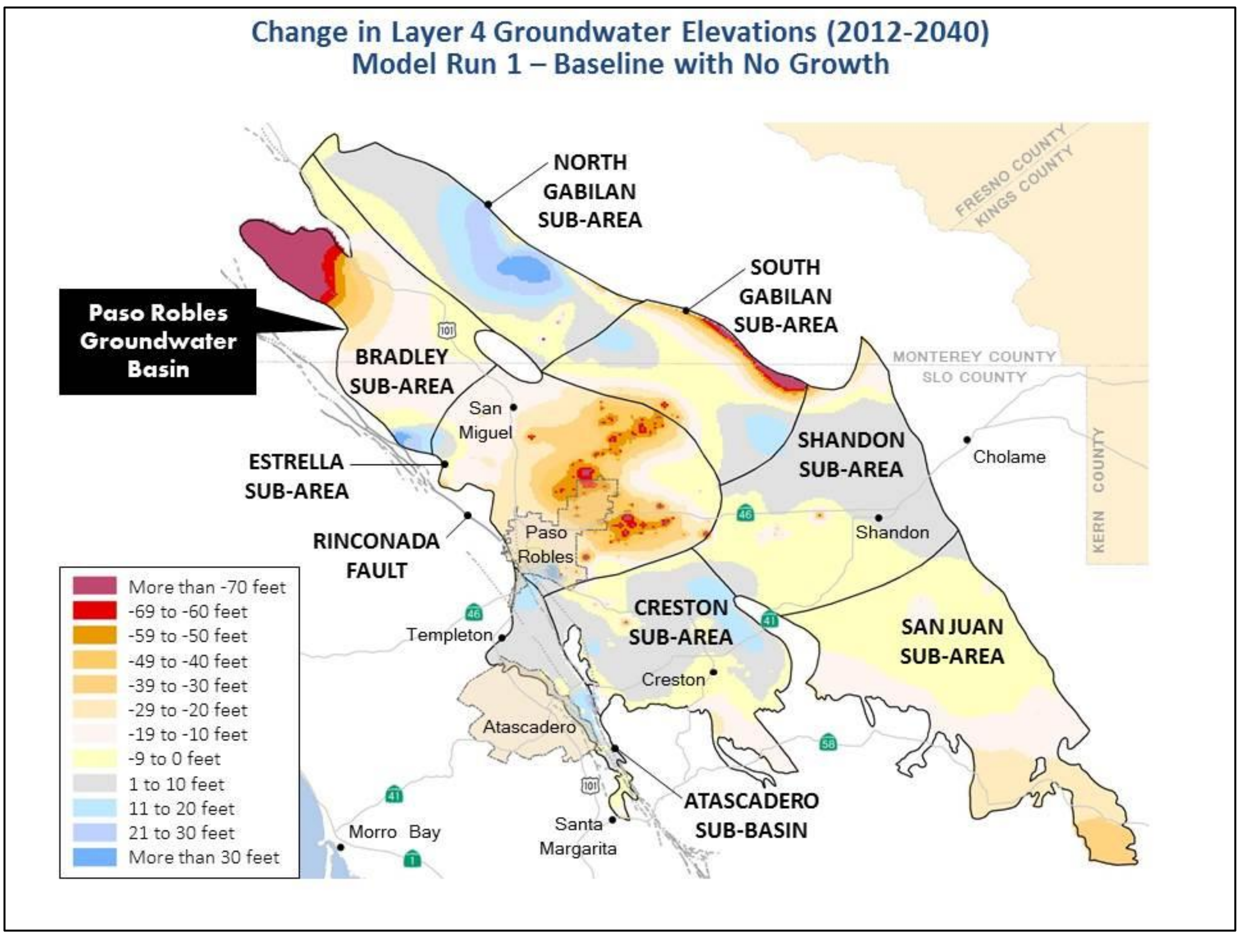
Two predictive scenarios were examined using the updated and recalibrated Basin Model to evaluate how groundwater levels and storage respond to varying groundwater use and recharge conditions. The model runs were simulated for a period of 29 years (water years 2012-2040) with a monthly stress period. For the two scenarios, the hydrologic conditions (e.g., rainfall) that occurred during the hydrologic base period (the 29 years from October 1981 through September 2010) were simply repeated for 29 years into the future. As discussed in the report, the hydrologic base period was selected to be representative of historical, long-term conditions.

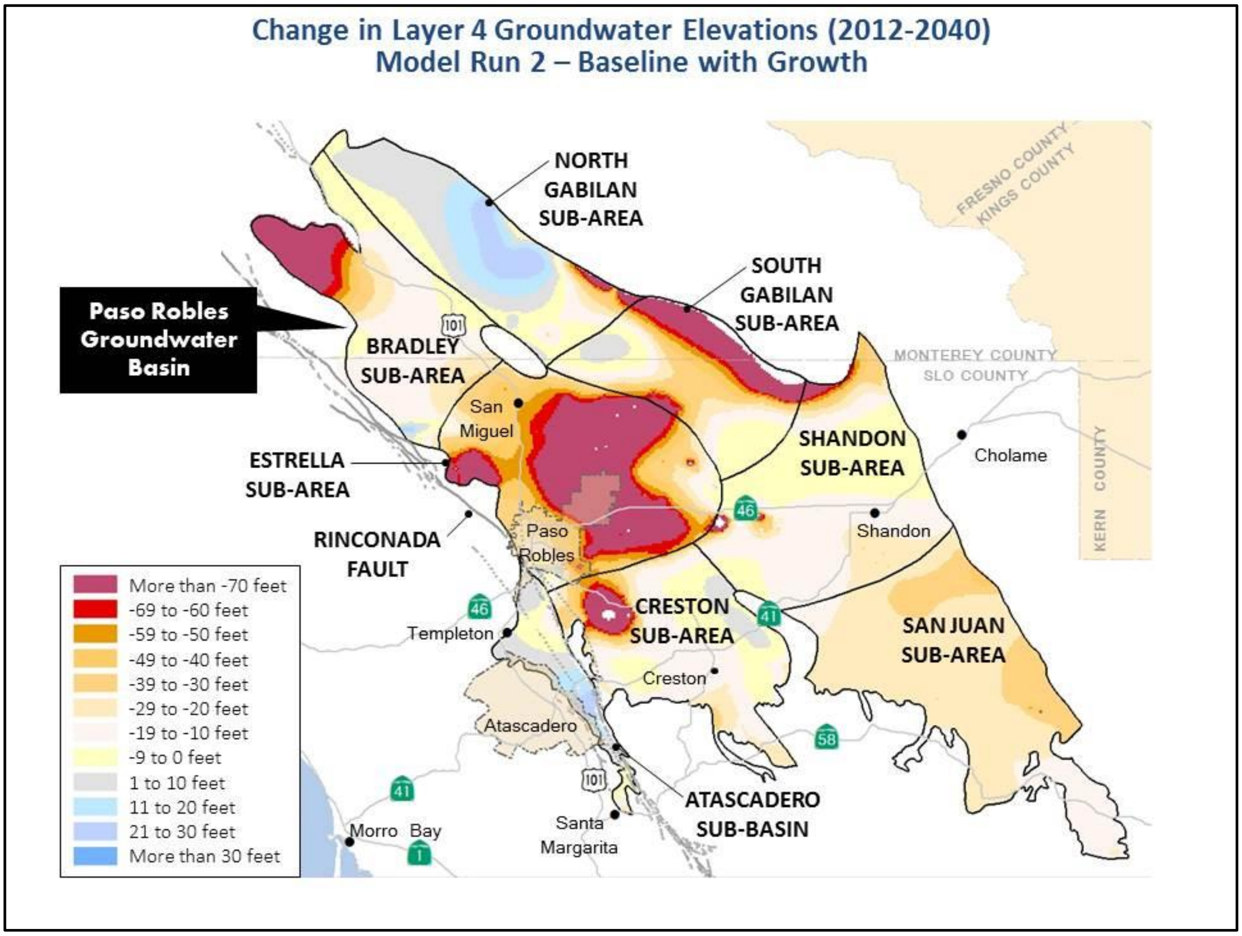
For the two model runs, the variables included the amount of Nacimiento Water Project delivery, water demand, and growth (i.e., change in land use) in the Basin.

Model Run 1, Baseline with No Growth, was developed to determine the response of the Basin to continuation of 2011 Nacimiento Water Project delivery, 2011 water demands, and no growth projected 29 years into the future (2012-2040). Accordingly, actual 2011 Nacimiento deliveries were used as input for every year. For water demands, 2011 values were repeated every year for 29 years with no growth.

Model Run 2, Baseline with Growth, examined the response of the Basin to Nacimiento Water Project deliveries projected to occur after September 2011, projected water demands, and a growth rate of 1% per year projected 29 years into the future. Accordingly, Model Run 2 used actual Nacimiento deliveries for 2012-13 and those forecast for 2014-2040. For agricultural water demand, the 2011 acreages for all non-vineyard crops (e.g., alfalfa,) were kept steady into the future; this is reasonable given relatively flat historical trends. For vineyards in 2012, the actual 2012 vineyard acreages were applied directly. For future years, forecasts developed by the modeling subcommittee for vineyards to be planted by July 2013, 2014, and 2017 were combined with the 2012 vineyard coverage to develop complete vineyard coverages from 2013 through 2017. Thereafter, a 1% growth rate in vineyard acreage was assumed from 2018 to 2040, with the growth applied spatially over the 2017 vineyard coverage. A 1% annual increase was also applied to municipal, private domestic and small commercial pumping.

Modeling results for the two model runs are described in this report in terms of basin storage by year, average annual water budgets, and changes in groundwater levels. The no-growth scenario indicates that outflows would exceed inflows on average by 5,592 AFY, while the growth scenario indicates that outflows would exceed inflows on average by 20,900 AFY. Groundwater levels in the Estrella Sub-Area would decline as much as 60 feet under the no-growth scenario, and more than 70 feet across much of the sub-area under the growth scenario.





1.7 Model Limitations and Uncertainty

The Basin Model is a useful tool for evaluating the effects on Basin water levels due to changing hydrological and land use changes. Nonetheless, it is a simplified approximation of a complex hydrogeologic system and has been designed with built-in assumptions. To address such uncertainty, the Basin Model Update was evaluated independently through a peer review provided by Fugro Consultants. Discussion among GEOSCIENCE, Todd Groundwater and Fugro representatives focused on issues including certain aquifer properties, and the relative amounts and areal distribution of subsurface inflow, streambed percolation and rainfall recharge.

1.8 Recommendations

Based on the post-review discussion by GEOSCIENCE, Todd Groundwater and Fugro, specific tasks have been defined to reevaluate and further refine the Basin Model. These include the following:

- Reevaluate fate and recharge mechanisms of water from the watershed entering the groundwater basin;

- Incorporate Streamflow Routing Package (SFR) to simulate streamflow and groundwater discharges to rivers;
- Reevaluate deep percolation of direct precipitation and agricultural return flows in the groundwater basin; and
- Recalibration of the refined Basin Model.

In addition, the following scenarios have been identified for potential simulation with the refined Basin Model:

Baseline

- Updated Baseline with Growth Run

Specific Action Analyses

- Analysis 1 – Demand Reduction Scenario
- Analysis 2 – Salinas River Recharge
- Analysis 3 – Offset Basin Pumping with Recycled Water

Basin Management Objectives Analyses

- Analysis 4 – Offset Water Demand in Estrella Sub-Area
- Analysis 5 – Additional Releases to Huer Huero Creek System
- Analysis 6 – Additional Releases to Estrella Creek System
- Analysis 7 – Offset Pumping in Creston Sub-Area with Supplemental Water
- Analysis 8 – Offset Pumping in Shandon Sub-Area with Supplemental Water

Refinement of the Basin Model will provide improved understanding and simulation of the groundwater-surface water relationship and response to recharge and discharge components as they vary through time. Also, these predictive analyses using the refined Basin Model will provide Basin managers and stakeholders the means to identify the supplemental water supply options and/or demand reduction options which may be most effective at stabilizing groundwater levels.

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