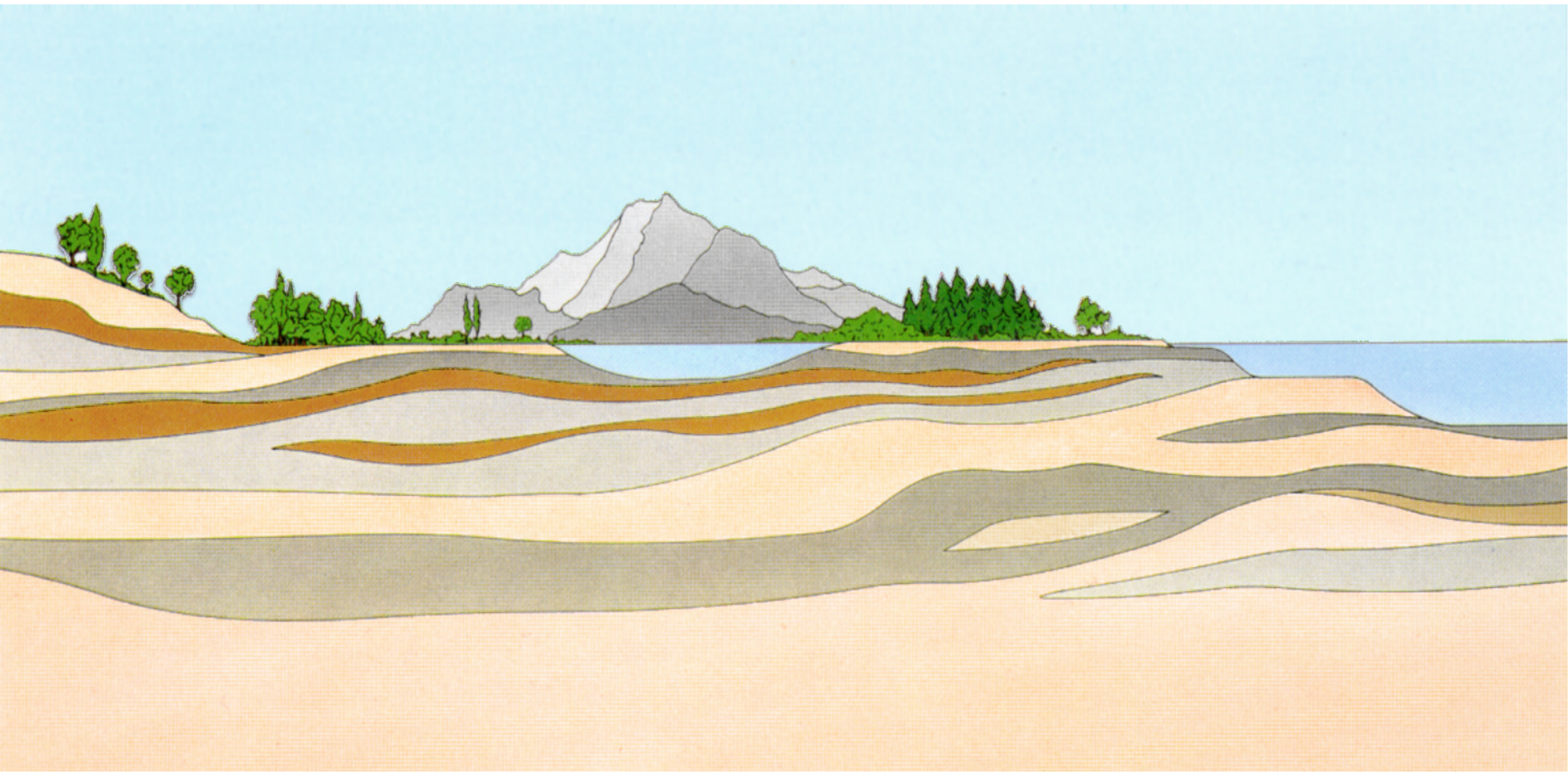
FUGRO WEST, INC., and CLEATH AND ASSOCIATES

FINAL REPORT
PASO ROBLES GROUNDWATER BASIN STUDY

Prepared for:
COUNTY OF SAN LUIS OBISPO
PUBLIC WORKS DEPARTMENT

August 2002



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August 30, 2002
Project No. 3014.005

County of San Luis Obispo
Public Works Department
County Government Center, Room 207
San Luis Obispo, California 93408

Attention: Ms. Christine Ferrara

FINAL REPORT
Paso Robles Groundwater Basin Study

Dear Ms. Ferrara:

Fugro West and Cleath & Associates are pleased to submit this FINAL REPORT of the Paso Robles Groundwater Basin Study. The purpose of the project was to investigate the hydrogeologic conditions and quantify the water supply capability of the basin.

The study defined the lateral and vertical extent of the groundwater basin, evaluated groundwater flow and movement within the aquifer, reported on current water quality conditions and trends, and calculated the perennial yield of the basin. A single subbasin, the Atascadero subbasin, was defined as a hydrogeologically distinct portion of the basin

The study concluded that the perennial yield of the Paso Robles Groundwater Basin (including the Atascadero subbasin) is 94,000 acre feet per year under current conditions. The perennial yield of the Atascadero subbasin is 16,500 acre feet per year.

Basin pumpage in 2000 was approximately 82,600 af, compared to the perennial yield estimate of 94,000 afy. This statement must be tempered, however, because water demand and gross groundwater pumpage may increase in the future as the population of the region continues to grow, and as municipal and agricultural pressures on the basin increase. For instance, the San Luis Obispo County Master Water Plan Update projects 2020 water demands of 120,000 afy for the area covered by the Paso Robles basin. Furthermore, although the overall basin is relatively stable, concentrated pumping centers have created localized pumping depressions and declining water levels in parts of the basin. As an illustration, the area immediately east of the City of Paso Robles, along Highway 46 between Paso Robles and Whitley Gardens, has experienced dramatically declining water levels over the past five to ten years.

Pumpage in the Atascadero subbasin in the year 2000 was 11,100 af. The County Master Water Plan Update projects 2020 water demands in the subbasin area of approximately 16,000 to 20,000 afy.

In closing this phase of work for the San Luis Obispo County Public Works Department, we would like to express our appreciation to the Public Works Department staff, the Technical Review Committee, and the North County Water Resources Forum for their interest and cooperation throughout the study. It has been both a pleasure and a challenge to conduct this investigation, which we know is of utmost importance to the community. We will remain available at your convenience to discuss this report or to answer any questions.

Sincerely,

FUGRO WEST, INC.

Paul A. Sorensen, RG, CHg
Senior Hydrogeologist

CLEATH & ASSOCIATES

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Principal Hydrogeologist

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FINAL REPORT
PASO ROBLES GROUNDWATER BASIN STUDY

EXECUTIVE SUMMARY

GENERAL

This Final Report of the Paso Robles Groundwater Basin study presents the results of efforts to investigate and quantify the hydrogeologic conditions of the basin. The work was conducted jointly by Fugro West, Inc. and Cleath and Associates, in conjunction with Peter Canessa, P.E. and ETIC Engineering, Inc.

The Paso Robles Groundwater Basin study was a technical investigation intended to provide the San Luis Obispo County Public Works Department, North County public water agencies, and overlying landowners and water users a better understanding of the basin by answering questions related to the quantity of groundwater in the basin, the hydraulic movement of groundwater through the basin, sources and volumes of natural recharge, and trends in water quality. Although this study does not address specific planning or water management issues, it provides the foundation that the community needs to participate in water resource planning. The knowledge gained by this study, including the comprehensive compilation of key data, is necessary for the community to develop a confident and consensus based decision-making process.

BASIN DEFINITION AND BASIN BOUNDARIES

The Paso Robles Groundwater Basin encompasses an area of approximately 505,000 acres (790 square miles). The basin ranges from the Garden Farms area south of Atascadero to San Ardo in Monterey County, and from the Highway 101 corridor east to Shandon.

Internally, a single hydrologically distinct subbasin was defined. The Atascadero subbasin encompasses the Salinas River corridor area south of Paso Robles, including the communities of Garden Farms, Atascadero, and Templeton.

GROUNDWATER OCCURRENCE, LEVELS, AND MOVEMENT

Water level data show that over the base period from July 1980 through June 1997 there is no definitive upward or downward water level trend for the whole basin. However, different water level trends are observed at specific locations in the basin. Water levels have declined, in some areas rather dramatically, in the Estrella and San Juan areas, with rising water levels in the Creston area.

In general, groundwater flow moves northwesterly across the basin towards the Estrella area, thence northerly towards the basin outlet at San Ardo. The biggest change in groundwater flow patterns during the base period is the hydraulic gradient east of Paso Robles, along the Highway 46 corridor, which has steepened in response to greater pumping by the increasingly concentrated development of rural ranchettes, vineyards, and golf courses.

WATER QUALITY

In general, the quality of groundwater in the basin is relatively good, with few areas of poor quality and few significant trends of ongoing deterioration of water quality. Historical water quality trends were evaluated to identify areas of deteriorating water quality. A major water quality trend is defined as a clear trend that would result in a change in the potential use of water within 50 years, if continued.

Six major trends of water quality deterioration in the basin were identified, including:

1. increasing total dissolved solids (TDS) and chlorides in shallow Paso Robles Formation deposits along the Salinas River in the central Atascadero subbasin;

2. increasing chlorides in the deep, historically artesian aquifer northeast of Creston;

3. increasing TDS and chlorides near San Miguel;

4. increasing nitrates in the Paso Robles Formation in the area north of Highway 46, between the Salinas River and the Huer Huero Creek;

5. increasing nitrates in the Paso Robles Formation in the area south of San Miguel; and

6. increasing TDS and chlorides in deeper aquifers near the confluence of the Salinas and Nacimiento rivers.

GROUNDWATER IN STORAGE

The total estimated groundwater in storage within the Paso Robles Groundwater Basin is approximately 30,500,000 acre feet (af). This value changes yearly, depending on recharge and net pumpage. Between 1980 and 1997, groundwater in storage increased approximately 12,400 af, an approximate 0.04% increase. This represents an average increase in storage of 700 acre feet per year (afy). On one hand, this relatively small percentage could be viewed as an indication of stable basin-wide conditions; however, it is noted that steadily decreasing storage in the 1980's was offset by increased water in storage throughout the 1990's. Furthermore, not all areas of the basin have observed the same trends in water levels and change in storage.

In the Atascadero subbasin, total groundwater in storage averaged about 514,000 af. Approximately 2,600 af more groundwater was in storage in the subbasin in 1997 compared to 1980, a 0.5% increase in total groundwater in storage during the base period. This represents an increase of about 200 afy in storage.

HYDROLOGIC BUDGET

The purpose of a hydrologic budget (or water balance) is to assess all the inflows and outflows of water to the groundwater basin over the base period. The water budget was performed by calculating each component of water inflow and outflow for each year of the base period, and comparing the totals to the annual change in groundwater in storage as determined by the specific yield method. The base period, defined in this study from July 1980 through June 1997, is a representation of the long-term average conditions of water supply.

The hydrologic budget is simply a statement of the balance of total water gains and losses from the basin, and can be summarized by the following equation:

Inflow = Outflow ($\pm$) Change in Storage

where Inflow equals the sum of:

- ⇨ subsurface inflow
- ⇨ percolation of precipitation
- ⇨ streambed percolation
- ⇨ percolation of irrigation return water
- ⇨ percolation of wastewater discharge, and
- ⇨ imported water;

and Outflow equals the sum of:

- ⇨ subsurface outflow
- ⇨ gross agricultural pumpage
- ⇨ municipal, rural domestic, and small commercial systems pumpage
- ⇨ extraction by phreatophytes, and
- ⇨ exported water.

Using this inventory, the sum of all the components of outflow from the Paso Robles Groundwater Basin exceeded the sum of all the components of inflow by an estimated 2,700 afy.

As described earlier, an independent method of calculating the change in the volume of groundwater in storage was performed using the specific yield method and compared to the results of the inventory method. This approach indicated a slight annual increase in groundwater in storage of about 700 afy.

For the Atascadero Subbasin, the sum of all the components of outflow approximately equaled inflow during the base period, with total groundwater in storage of about 514,000 af.

The change in storage calculation showed an annual increase in groundwater over the 17-year base period of about 200 afy.

Reconciliation of the hydrologic budget shows a consistency in the results of the two methods of calculation. At first glance, the results of the hydrologic budget calculations, along with the change in storage calculations and analysis of the water level data, indicate a basin-wide stability. This conclusion, however, is tempered by the recognition that parts of the basin have experienced significant declines in water level over the past several years, particularly in the Estrella area along the Highway 46 corridor from the eastern edge of Paso Robles to Whitley Gardens as a result of relatively concentrated development of rural residential housing, golf courses, and vineyards.

PERENNIAL YIELD

The perennial yield of a basin, as defined in this investigation, is the rate at which water can be pumped over a long-term without decreasing the groundwater in storage. Many definitions of perennial yield (or safe yield) tie the concept of basin yield to the rate of groundwater extraction that will not create an economic impact. However, for the purposes of this study, the concept of perennial yield is more closely tied to the natural rate of replenishment or recharge to the basin, such that there is no decrease in groundwater in storage.

The results of this investigation indicate a perennial yield value of approximately 94,000 afy for the Paso Robles Groundwater Basin (which includes the Atascadero subbasin). Calculated separately, the perennial yield of the Atascadero subbasin approximates 16,500 afy.

BASIN CONDITIONS IN 2000

In the year 2000, groundwater pumpage in the Paso Robles Groundwater Basin was approximately 82,600 af, compared with the perennial yield estimate of 94,000 afy. Similarly, Atascadero subbasin pumpage in the year 2000 was approximately 11,100 af, compared to the perennial yield estimate of 16,500 afy.

Total net groundwater pumpage in the basin (and the subbasin) declined steadily from 1984 through 1998. Groundwater production data since 1998 show, however, that groundwater pumpage may again be increasing. Pumpage in 2000 was higher than at any previous time since 1992. It should also be noted that groundwater pumpage exceeded the perennial yield from the start of the base period in 1980 through 1990. Only in the last decade has pumpage been less than the perennial yield.

Currently, agricultural pumpage comprises 69% of total basin pumpage. Depending on new trends or pressures in the agricultural industry, it is likely that basin pumpage will approach or exceed the perennial yield in the near future. The San Luis Obispo County Master Water Plan Update (EDAW, 1998) projects future water demands for the area to be 120,620 afy by the year 2020, which suggests that future water demands may soon exceed the 94,000 afy perennial yield of the basin.

In the Atascadero subbasin, municipal, rural domestic, and small commercial water systems comprise 91% of total pumpage in the subbasin. Interpolation of data from the County Master Water Plan projects water demand in 2020 in the Atascadero subbasin to be in the range of 16,000 to 20,000 afy, compared to the perennial yield value of 16,500 afy.

It is important to note that short-term periods of groundwater extractions in excess of the perennial yield will not necessarily result in significant negative economic impacts. Groundwater in storage in the basin is sufficiently large such that short-term overdraft conditions may be acceptable to withstand drought periods.

RECOMMENDATIONS

It is recommended that a basin-wide numerical groundwater flow model be developed for the Paso Robles Groundwater Basin. The model will serve as a tool for quantitative evaluation of existing and future hydraulic conditions across the basin, including changing groundwater level elevations, well yields, natural and artificial recharge, and associated effects on surface water-groundwater interaction and water quality. Specifically, the objectives of the model include:

- Refining uncertain components of the hydrologic budget for the basin;
- Refining estimates of perennial yield for the basin;
- Evaluating water quality trends in response to hydraulic changes across the basin;
- Evaluating potential impacts on groundwater levels and perennial yield as a result of continued and varied basin operations and hydraulic conditions; and
- Defining operational options for comprehensive and/or localized management of groundwater use across the basin.

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CHAPTER 1 – INTRODUCTION

INTRODUCTION AND BACKGROUND

This Report presents the findings, conclusions, and recommendations of a geologic and hydrogeologic investigation of the Paso Robles Groundwater Basin. The study is intended to provide the County Public Works Department, North County public water agencies, and overlying landowners and water users with a better understanding of the basin by answering questions related to the quantity of groundwater in the basin, the hydraulic movement of groundwater through the aquifer, sources and volumes of natural recharge, and trends in water quality.

The Paso Robles Groundwater Basin is situated in the upper Salinas River drainage of San Luis Obispo and Monterey counties (Figure 1). The basin is located in the large inland valley bounded on the west by the Santa Lucia Range (which separates the North County area from the Pacific Ocean coastal region), on the south by the La Panza Range, and on the east by the Temblor and Diablo ranges. Although most of the basin is within San Luis Obispo County, the basin extends into Monterey County along the northern basin boundary. The basin overlies an area of approximately 505,000 acres (790 square miles); the total watershed area covers about 1,980 square miles.

Topographically, the main, central part of the basin is a large valley of minor relief. The Estrella River, which flows westerly from the Shandon area to north of Paso Robles where it merges with the Salinas River, has formed the broad plain that characterizes the central part of the region. The more significant creeks that flow into the Estrella River and contribute to its flow include Cholame, San Juan, Camatta, and Shedd creeks.

By contrast with the topography that characterizes the Estrella River area, the Salinas River, which drains the basin, flows northerly along the western edge of the basin through rolling hills. Numerous creeks are tributary to the Salinas River between its headwaters and its confluence with the Estrella River, including Santa Margarita, Paloma, Atascadero, Graves, and Paso Robles creeks.

The basin is surrounded by rolling hills and low ranging mountains. To the north and northeast, the Gabilan Highlands and Cholame Hills form a broad range of hills with numerous small drainages and seasonal canyons. To the west and south, the basin is bounded by the Santa Lucia and La Panza ranges, both of which rise to elevations of 4,000 feet or more above the basin floor of about 700 to 900 feet MSL.

The climate of the study area is semiarid, with warm and dry summers accompanied by cool, wet winters. Virtually all rainfall is received in the rainy season from December through March, with precipitation averages ranging from 18 inches or more along the western edge of the basin, to as low as five to eight inches in the eastern portion of the basin.

Historically, development has concentrated along the Salinas River corridor, and somewhat along the Estrella River/Highway 46 East corridor from Paso Robles to Shandon. Although the Salinas River corridor is important for its population center, manufacturing, and commercial development, the historical economic base of the area has been the agricultural industry, both irrigated and non-irrigated, throughout the remaining portion of the basin.

PURPOSE AND SCOPE

The hydrogeologic investigation of the Paso Robles Groundwater Basin was formally initiated in September 2000. The purpose of the study was to conduct a detailed geologic and hydrogeologic investigation and analysis to evaluate and assess the perennial yield of the basin. The overall purpose of the study is to provide the overlying water purveyors and San Luis Obispo County planning agencies with foundational data that will enable them to plan for future water supply development and optimize both immediate and long-term water supply programs.

This final report presents a comprehensive and detailed description of the Paso Robles Groundwater Basin. The scope of this Phase I project included:

- Task 1 presented the results of collecting, compiling, and reviewing available data;
- Task 2 presented a detailed geologic and hydrogeologic evaluation of oil well and geothermal well logs, water well logs, geologic mapping, and fault investigations which resulted in delineation of the lateral and vertical extent of the basin and the definition of a hydrologically distinct (Atascadero) subbasin;
- Task 3 reported on the aquifer characteristics and hydraulic parameters across the basin that were subsequently used to estimate various components of the hydrologic budget (water balance);
- Task 4 involved collection and evaluation of water quality data throughout the basin;
- Task 5 consisted of preparation of a hydrologic budget and calculation of the perennial yield for the basin; and
- Task 6 consisted of preparation of a final report to document the results of each prior task.

The conclusion of each task was followed by presentation of an Interim Report, which presented the findings of each task and provided an opportunity for review and public comment throughout the process.

This Phase I investigation of the Paso Robles Groundwater Basin was conducted by a consultant team, coordinated by the San Luis Obispo County Public Works Department. An eight-member Technical Review Committee was appointed by the Public Works Department to provide guidance to the consultant team and provide oversight throughout the study through a series of meetings held every two to three weeks (usually by teleconference). An Oversight Committee, consisting of 23 members of the North County Water Resources Forum, provided review and critique of each Task Interim Report. The project team members include:

a. Prime Consultant:

- Fugro West, Inc. - Project Management, Hydrogeology, GIS, Admin. Support
  - Paul Sorensen, Senior Hydrogeologist, Project Manager
  - David Gardner, Principal Hydrogeologist
  - Robert Marks, Project Hydrogeologist

b. Subconsultants:

- Cleath & Associates - Hydrogeology, Hydrology, Water Quality
  - Timothy Cleath, Principal Hydrogeologist
  - Spencer Harris, Project Hydrogeologist
  - David Williams, Staff Geologist
- Peter Canessa, P.E. - Agricultural Water Demand and Land Use
  - Peter Canessa, Agricultural Engineer
- ETIC Engineering, Inc. - Groundwater Modeling, QA/QC
  - Mehrdad M. Javaherian, Ph.D., P.E., P.Hg.

c. County Staff:

- Christine Ferrara, P.E. – Project Manager, Utilities Division Manager

d. Technical Review Committee:

- Christine Ferrara, County of San Luis Obispo
- Doug Filipponi, water well contractor, agricultural representative
- Robert Hopkins, San Luis Obispo County Agricultural Commissioner's Office
- Susan Litteral, County of San Luis Obispo
- Frank Mecham, Mayor, City of Paso Robles
- Iris Priestaf, Ph.D., Todd Engineers
- Ken Weathers, Atascadero Mutual Water Co.
- Alan Young, agricultural representative

AVAILABILITY OF BASIC DATA

General

The initial efforts of the study concentrated on the collection, compilation, and review of available data. The kinds of data collected and evaluated included:

- Water well completion reports
- Oil and gas well logs
- Water level data
- Precipitation records
- Water quality
- Stream flow
- Agricultural water demand

- Municipal and community water demand
- Rural domestic water demand
- Water well pumping tests

Water Well Completion Reports

In California, water well drilling contractors are required to submit Completion Reports of all wells to the State of California Department of Water Resources (DWR). The DWR Water Well Completion Reports were used in this study to interpret hydrogeologic conditions and in the preparation of geologic cross sections. The reports are stored and maintained at the San Luis Obispo County Environmental Health Department, at the Monterey County Water Resources Agency, and at the California Department of Water Resources (DWR) Southern District. Completion reports are filed at the Department of Environmental Health according to the Permit Number. Until the mid 1990's, copies of the reports were forwarded on to the San Luis Obispo County Engineering Department and filed according to location by Township and Range. Completion Reports were obtained from the Engineering Department and the Water Resources Agency and not from the Department of Environmental Health because of the efficiency of obtaining reports of wells in the study area filed by Township and Range.

Water well data for 5,428 wells drilled in the study area were obtained in database format (Microsoft Access) from the Department of Environmental Health. The database includes well identification number, Assessor's Parcel Number, owner's name, address, location area, date of installation, total depth of borehole, dates of any well improvements, screened interval, depth of gravel pack, seal, depth to first water encountered, static water level, yield, latitude/longitude, and Department of Water Resources well number.

There have been several format revisions to the Well Completion Report over the years (1968, 1976, 1986, and 1990). In general, each well completion report includes information on the following:

- Well owner;
- Driller's name;
- Dates drilled;
- Well location by address and Township, Range and Section;
- Map of well location;
- Type of drilling equipment used;
- Casing diameter;
- Perforation intervals;
- Gravel pack placement and size;
- Annular seal placement;
- Total depth of boring;
- Static water levels;
- Well tests;
- Formation log; and
- Proposed use.

One of the most important items on the reports, the formation log, is not available in electronic form, therefore, copies of the well completion reports of wells drilled within the Paso Robles Groundwater Basin study area were obtained and photocopied from files at the San Luis Obispo County Engineering Department, and at the Monterey County Water Resources Agency. Copied files were organized and filed according to location by Township, Range, and Section. Copies of 2,277 reports were obtained for wells drilled in the study area.

Oil and Gas Well Logs

Records of exploratory oil, gas, and geothermal wells are maintained at the office of the California Department of Conservation, Division of Oil, Gas, and Geothermal Resources (DOGGR), District 3, located in Santa Maria. Records include electric logs and formation logs of individual wells. Logs are available in hardcopy and filed on microfilm and microfiche. A copy of the Regional Wildcat Map for District 3 was obtained. A summary of oil and gas wells drilled in District 3 was obtained in database format (Microsoft Access) from the DOGGR Internet File Transfer Protocol (FTP) site.

Geophysical electric logs indicate spontaneous potential, electric resistivity, and various other parameters of geologic units. The logs are used to determine characteristics of geologic formations and characteristics of fluid within the formations. Formation logs include descriptions of drilled cuttings or cores. Other types of information that may be found in oil and gas data files that are useful to water resource studies include water shut-off depths, the base of fresh water, temperature logs, daily logs of activities (which may describe artesian pressures or difficulties in sealing the fresh water zone), and formation contacts.

The locations of 214 oil or gas wells drilled in the study area were tabulated and reviewed. Fields describing each well include the name of the map showing the well location; name of the well field; operator; lease; well name; status of the well; Township, Range, and Section; total depth; and latitude and longitude.

Selected data on 99 warm water wells and warm springs in the Paso Robles Groundwater Basin (location, depth, water temperature, and artesian flow rates) were tabulated from a California Division of Mines and Geology report (Campion, 1983). Records for known warm water wells on file at the DOGGR and Environmental Health were copied by the project team and used to develop the structural relationship between geothermal-bearing formations and basin sediments.

Water Levels

Water level records from monitoring wells in San Luis Obispo County are stored and maintained in database format (Microsoft Access) by the San Luis Obispo County Engineering Department. A copy of the entire database was obtained from the County. The County Engineering Department provided a Microsoft Excel spreadsheet including latitude and longitude for plotting well locations. Static water levels measured at the time the well was drilled are also included in the Environmental Health Department database (Microsoft Access). Water levels are used to generate groundwater elevation contour maps and hydrographs, which are used for groundwater storage calculations and yield analyses.

Files in the Engineering Department database contain 163 Well Level Reports for observation wells in the study area. Water Level Reports generally include the date of the report; owner name; groundwater basin name; area; well number; depth to top of perforation; reference point elevation; dates sampled; depths to water; pumping status; season; and elevation of water. The Environmental Health Department database (5,428 wells) also includes static water levels measured following well completion. Other sources of water levels include water purveyors (municipal, County Service Areas, and private), small water systems files from Environmental Health, and regulated discharge site files from the Regional Water Quality Control Board.

Precipitation

Precipitation data was obtained in database format (Microsoft Access) from the San Luis Obispo County Engineering Department. Precipitation data is an important component of the hydrologic budget, and was used in combination with other data (evapotranspiration, runoff/streamflow) to estimate the amount of deep percolation recharging the basin.

The database files obtained from the Engineering Department contain data for precipitation stations located throughout the County of San Luis Obispo as well as several stations in Monterey and Kern Counties. Records for 188 stations were obtained. Of these, approximately 56 of the stations are located within the study area.

The database contains monthly totals for each precipitation station. The period of record for the precipitation stations ranges greatly. For example, the station at Paso Robles Water Department (Station No. 10) has an essentially continuous period of record beginning in 1887 (100+ years). Many more stations, on the other hand, have much shorter periods of record. Some of these stations have only recently begun operation, while others have been discontinued.

Of the 56 precipitation stations in the study area, 26 have been discontinued and/or data is unavailable after 1990. For this study it was important to use precipitation data that was as consistent as possible with the period of record available for data of the other components of the study (e.g., production data, water levels, etc.). For example, data for a precipitation station with 30 years of record that ends in 1945 is of little value when comparing with water level data, which is mostly available only after 1960. Of the remaining 30 stations, there are 18 stations in the study area with significant periods of record.

The currently available precipitation data is generally more extensive, both spatially and temporally, when compared to the precipitation data used by DWR in its last study of the Paso Robles Groundwater Basin (DWR, 1979). The DWR study evaluated only four rainfall stations over a period of 15 years (1960-1975). The quantity and quality of the precipitation data available for this study is, therefore, significantly greater than that used by DWR in 1979.

Water Quality

Water quality data is stored electronically by the United States Environmental Protection Agency (EPA) Office of Drinking Water. The EPA maintains two water quality data management systems: the STORET Legacy Data Center, and the Modernized STORET. The Legacy Data Center (LDC) contains historical water quality data dating back to the early 1900s and collected up to the end of 1998. Modernized STORET contains data collected beginning in 1999, along with older data that has been documented and transferred from the LDC. Both systems contain biological, chemical, and physical data on surface water and groundwater. Water quality data may be sorted and retrieved by date, location, or by parameter.

Water quality reports were also obtained in hardcopy from community water systems files at the San Luis Obispo County Environmental Health Department, from regulated discharge sites files at the Regional Water Quality Control Board, and from the Coastal Resources Institute (1993) report. In general, the hardcopy reports duplicate reports stored in the EPA STORET files, although some significant additional water quality data were obtained in hardcopy for areas that were that were not covered in the STORET files.

Files downloaded from the LDC system contain 1,434 water quality data sets from water wells in the study area. A data set represents one sample collection date at a particular well; therefore, one well may have multiple data sets. Each sampling result for water wells in the LDC and in Modernized STORET includes the site location by latitude, longitude, Township, Range, Hydrologic Unit Code, and the site identification. It includes the sample collection date, and the name of the organization that sponsored the monitoring.

Water quality data reports obtained from the LDC typically contain the following parameters for water wells:

- Temperature, water (degrees Centigrade)
- Temperature, water (degrees Fahrenheit)
- Specific conductance (umhos/cm @ 25c)
- pH, lab, standard units SU
- Alkalinity, total (mg/l as CaCO3)
- Bicarbonate ion (mg/l as HCO3)
- Carbonate ion (mg/l as CO3)
- Hardness, total (mg/l as CaCO3)
- Calcium, dissolved (mg/l as Ca)
- Magnesium, dissolved (mg/l as mg)
- Sodium, dissolved (mg/l as Na)
- Potassium, dissolved (mg/l as K)
- Chloride, dissolved in water mg/l
- Sulfate, dissolved (mg/l as SO4)
- Fluoride, dissolved (mg/l as F)
- Boron, dissolved (µg/l as B)

- Hardness, Ca Mg calculated (mg/l as CaCO3)
- Residue, total filterable (dried at 180c),mg/l

Data sets of well water quality obtained from LDC for the study area are filed digitally by Township and Range. It is necessary to use the EPA Internet site or to obtain the STORET program software to sort the data according to sampling date or sampling parameters.

Water quality data available from LDC for surface water includes 302 sampling analyses from 10 stream locations. Sample analyses typically include physical stream parameters such as temperature; suspended sediments; general minerals; metals; dissolved oxygen; and biologic oxygen demand.

Water quality data obtained from 28 community water systems files at the County Environmental Health Department include at least one analysis with general minerals, general physical, and metals. Sites in or near large agricultural operations may also include analyses for organic compounds. Coliform presence/absence is typically tested on a monthly basis for these systems, and analyses for site-specific constituents of concern are typically required every three years.

Copies of files for 21 wastewater discharge sites located in the study area were obtained from the Regional Water Quality Control Board. Files typically included discharger self-monitoring reports with the following information: site ID number; average daily effluent flow for each month; representative effluent samples; water supply samples analyzed for TDS, sodium, chloride, pH, and total nitrogen; septic tank monitoring data; and discharge specifications (maximum flow and discharge criteria).

Stream Flow

Stream gages have historically been maintained and monitored by the U.S. Geological Survey (USGS) and the San Luis Obispo County Engineering Department. Data is stored electronically in National Water Information System (NWIS) files, and is retrievable from the USGS Water Resources Internet site. Data reports for 20 USGS operated stream gages were obtained from the USGS site.

The San Luis Obispo County Engineering Department also stores electronic stream gage data. Data reports for four County operated stream gages were obtained from County Engineering. Stream gage data is used for flood control, water resource management, habitat assessments, and for siting of reservoirs. The data was used in this study to develop estimates of stream seepage (recharge) and for hydrologic budget calculations.

Twenty USGS stream gages and four San Luis Obispo County gages were historically operated in the basin area. Data was also collected from 10 stream gages located outside the study area but within the Salinas River watershed. Of the 20 USGS stream gages in the study area, 18 are daily average gages, which measure the average flow occurring during one day, and two (San Marcos Creek tributary near Paso Robles, and White Canyon Creek above Cholame) are annual peak gages, which measure the highest stream flow for a particular year.

The four San Luis Obispo County gages are crest stage gages that measure the highest stream flow for a particular month.

The period of record of the gages ranges from three years to 59 years. The earliest stream flow measurements were recorded in 1922. Of the 24 gages, four USGS gages (Salinas River above Paso Robles, Estrella River near Estrella, Nacimiento River below the Nacimiento Dam, Salinas River near Bradley) and two County gages (Salinas River near Pozo, Santa Margarita) are currently active.

Stream flows measured at the stream gages measure runoff from a total watershed area of more than 3,200 square miles. Each of the 24 stream gages measured flow from individual watersheds ranging in size from 0.59 square miles to 2,535 square miles. Stream gage elevation ranges from 442 feet above sea level on the Salinas River near Bradley to 1,313 feet above sea level on Toro Creek near Pozo.

Data for the USGS gages include station name; station number; latitude and longitude; state code; County; hydrologic unit code; basin name; drainage area in square miles; gage elevation; and the date that the files were retrieved from the NWIS-W. Discharge is listed in cubic feet per second.

Data in tabular form for the County gages include station name, date, gage height, discharge in cubic feet per second, time of measurements, and maximum depth. A description in text format of the gages includes latitude and longitude; Township, Range, Section; descriptive location; gage elevation; drainage area; average precipitation at the gage; USGS Quadrangle map name; date established; construction of gage; nearby elevation bench marks; description of how flow is controlled; and maximum discharge during period of record.

Agricultural Water Demand

Conveyance Losses (CL). Conveyance losses are minimal due to the preponderance of pressurized systems in use in the study area. Evaporation and seepage from reservoirs are the major source of conveyance losses. Although aerial photos obtained from the San Luis Obispo County Engineering Department are available for use in estimating reservoir area, both types of losses were minimal in relation to total irrigation water pumped and total crop water use.

Acreages (Ac). Pesticide use reports from 1996 through 1999 were obtained from the San Luis Obispo County Agricultural Commissioner's Office. This data allowed the identification of total crop acreages and their location to the nearest section as reported by growers. Crop reports containing total acres of the various crops grown in the county and background data used in developing these reports were also available. The results of land use studies conducted by the DWR in 1977, 1985, and 1995 were obtained. The 1995 data is in digital form.

Climate Control (Cli). The main use of water for climate control is for frost protection on the vineyards or other susceptible crops in the area. The predominate system of choice for frost control in the area is overhead sprinklers. Accurate estimates of water applied for Cli require an evaluation of available weather data to determine the occurrence of frost events and data regarding how much acreage is protected by a frost control system. Availability of weather data is discussed below. There are no accurate, publicly available, tabulated data regarding how many acres are protected by frost control.

Reference Evapotranspiration (ETr). DWR has developed a statewide ETo map (ETo is the most commonly used reference ET in California. Specifically it is the ETc of a well-watered, lush pasture grass) that was sufficiently accurate for long-range water-use evaluation. However, weather data in the outlying areas of the basin (i.e. Shandon and Creston) are scarce, so private weather station data was obtained where available.

Crop Coefficients (Kc). Standard crop coefficient curves for the different crops grown in the basin are available. However, accurate estimates of actual crop coefficients for vineyards (heavily dependent on the age of the vine and canopy management) required some in-field appraisals.

Effective Rainfall (PPTeff). The methods for estimating effective precipitation (that rainfall which infiltrates) is described in Section 15, Chapter 2, Part 623 of the National Engineering Handbook for the Natural Resources Conservation Service (NRCS). Although some estimates of important variables were required, this is an accepted rationale for estimating effective rainfall.

Municipal and Community Water Demand

Water demand data for municipal agencies and small community water systems were obtained directly from the City of Paso Robles, Templeton Community Services District, Atascadero Mutual Water Company, and from the San Luis Obispo County Engineering Department and the County Environmental Health Department database. Virtually all municipal and community consumptive water demand is met through groundwater pumping, with the exception of regulated appropriated streamflow takes.

The major public purveyors in the study area include the City of Paso Robles, Templeton Community Services District, Atascadero Mutual Water Company, and County Service Areas/Water Works for San Miguel, Santa Margarita, and Shandon. Monthly production records were obtained from Paso Robles, Atascadero MWC, and Templeton CSD. However, the periods of record for these purveyors vary; the most extensive period of record is that of Atascadero MWC, which extends back to 1972.

Production records for the community service areas operated by the County were obtained from the Engineering Department. These records contain production data on a monthly basis.

The Environmental Health Department database contains records of 28 small community water systems; however, production data is generally lacking. The only indication of production from these systems is estimates based on permit application information. Although these systems are reportedly required to monitor production and submit regular reports to the Environmental Health Department, no records were available.

Rural Domestic Water Demand

There are no organized or centralized means of obtaining data for rural domestic water use. The most extensive recent source of information for rural water use is the San Luis Obispo County Master Water Plan Update (EDAW, 1998).

Rural domestic water demand is the water used by residential dwellings in unincorporated parts of the study area that are not served by small community water systems. This includes the non-agricultural ranchette properties scattered throughout the area. The calculation of water demands for rural domestic needs was based by the County Master Water Plan Update on population estimates, converted into an estimated number of dwelling units, multiplied by a water duty factor. The calculations took into account interior household use and widely variable exterior water needs. As described in the County Master Water Plan Update, rural domestic properties ranged from small lots to 20 acres or more. However, most residences typically used exterior water on no more than one acre around the dwelling, no matter how large the parcel. Because the amount of lawn, orchard, gardens, and stock varied widely from parcel to parcel, the estimated water use ranged from 0.5 AFY to 3 AFY.

Water Well Pumping Tests

There are no public, organized, or centralized sources of data for water well pumping test results in the basin. The only public agency with pumping test records is the County Environmental Health Department database, which contains pumping test records of nine small community water system wells.

The project team had in-house files of 41 water wells in the study area with pumping test data. The large majority of these test results are concentrated in the Highway 101 corridor, specifically in Atascadero, Templeton, and Paso Robles.

The available database for this study was less extensive than the data used by DWR (1979). Pumping test data from 250 wells were used by DWR (1979) with test results from 44 wells presented in the report. As was the case with this study, the majority of the DWR (1979) test results were located along the Highway 101 corridor, however a few more test results were available then in the Creston, Shandon, and Shell Creek areas.

HYDROLOGIC BASE PERIOD

Hydrologic Base Period Definition

The purpose of a hydrologic base period is to define a specific time over which elements of recharge and discharge in a groundwater basin may be compared. This period, when properly selected, will allow investigators to discern long-term basin trends. Some of the analyses that use a hydrologic base period include:

- Water level trends
- Changes to groundwater in storage
- Utilization of basin storage
- Perennial recharge estimates
- Safe yield estimates
- Groundwater modeling

The base period analysis is based on a rainfall year, which in San Luis Obispo County is from July 1 through June 30. For example, the 1981 rainfall year is July 1 1980 through June 30 1981. The rainfall years establish annual precipitation.

The following quote summarizes the main considerations for base period selection:

> *The base period should be representative of long-term hydrologic conditions, encompassing dry, wet, and average years of precipitation. It must be contained within the historical record and should include recent cultural conditions to assist in determining projected basin operations. To minimize the amount of water in transit in the zone of aeration, the beginning and end of the base period should be preceded by comparatively similar rainfall quantities. (DWR, 2000).*

Other considerations for base period selection include data availability, surface water reservoir management, and the historical development of any water supplies imported from outside the basin.

Data Preparation

Precipitation records for 18 stations in the basin were reviewed (Figure 2). Of the 18 stations, 11 stations were selected as best representing an historical record of rainfall in the basin, based on geographic distribution and period of record. Table 1 lists the precipitation stations used in the analysis along with important information for each station:

Graphs showing the cumulative departure from mean precipitation for the above 11 stations were prepared. The departure from mean precipitation is the difference between a specific year precipitation value and the mean precipitation value of the data set. The cumulative departure from mean graphs the sum of these departures over time, beginning with the first year departure and adding each subsequent year departure (cumulative). The cumulative departure value would be similar at the beginning year and ending year of a representative hydrologic base period.

Table 1. Precipitation Stations Used for Base Period Analysis and Selection

Station Number	Station Elevation (ft)	Precipitation Range/Ave (in)	Station Name	T/R-Sec	Year Record Began - Ended
109	620	4.9-27.0 / 13.1	Camp Roberts	24S/11E-35G	1954 – 1994
93	1650	3.8-28.5 / 12.2	McMillan Canyon	25S/15E-21P	1932 – 1998
125	620	4.0-25.5 / 12.0	San Miguel (Sinclair)	26S/12E-17A	1950 – active
10	700	4.8-31.3 / 15.2	Paso Robles	26S/12E-33B	1887 – active
73	1090	3.9-22.9 / 10.6	Shandon (State Div. of Highways)	26S/15E-20G	1938 – active
122	2100	5.0-22.6 / 11.3	Gillis Canyon (Highland Farm)	26S/16E-33F	1948 – 1995
52.1	1070	4.6-27.6 / 12.0	Creston 4.5 NW (Erickson Ranch)	27S/13E-15N	1929 – active
138	1220	3.1-23.8 / 10.1	Camatta Canyon (Canyon Ranch)	27S/15E-35D	1953 – active
65	1500	3.7-20.2 / 8.9	Bitterwater (Standard Oil Company)	27S/18E-24J	1936 – 1998
34	835	6.7-38.8 / 17.8	Atascadero Mutual Water Company	28S/11E-35R	1916 – active
95	1153	12.7-63.3 / 30.9	Santa Margarita (Booster Station)	29S/12E-25K	1943 – active

Note: Records for inactive stations were estimated through rainfall year 2000 by comparison with other stations.

The Paso Robles Station 10 has the longest continuous period of record in the basin and is the reference record (Figure 3). A reference record is needed to establish a reference period over which the cumulative departures for all the stations are calculated. Without a reference period, it is problematical to correlate cumulative departure data between stations. Based on the cumulative departure from mean precipitation at this station, the most appropriate reference period begins with rainfall year 1962 and runs through 2000 (Figure 3).

Mean rainfall and cumulative departure from mean rainfall for the 11 representative basin precipitation stations were prepared using the data from rainfall years 1962 through 2000. Where rainfall data gaps existed in the historical record, estimates were used, using linear regression analysis on data between precipitation stations.

Figure 4 shows a composite cumulative departure curve for the 11 precipitation stations. The cumulative departure from mean precipitation for each year was calculated individually at each station, and then averaged to derive the composite graph. The climatic trends present in the composite cumulative departure curve exhibit cyclic wet and dry periods.

Hydrologic Base Period Selection

A review of the cumulative departure graphs for each of the 11 stations identifies the rainfall year 1997 as the most recent year suitable for ending the hydrologic base period for the groundwater basin. Rainfall totals in subsequent years (1998-2000) are generally too wet, which would result in water-in-transit problems (that is, recharge water still in transit through the unsaturated zone that would not be represented yet as a rise in water levels). The candidate years for beginning the base period include rainfall years 1965, 1972, 1981, and 1987. A review of the differences in cumulative departure for these years is summarized in Table 2.

Table 2. Base Period Analysis (1962-2000 Reference Period)

Station Number	Station Name	Difference In Cumulative Departure Between Base Period Years (Inches)			
		1965-1997	1972-1997	1981-1997	1987-1997
109	Camp Roberts	2.05	3.61	**0.71**	5.59
93	McMillan Canyon	**-3.31**	-5.88	11.23	10.61
125	San Miguel	**0.75**	4.68	3.37	3.38
10	Paso Robles	**-2.79**	-4.50	-5.40	-3.56
73	Shandon	**0.97**	3.12	3.98	3.42
122	Gillis Canyon	0.41	-1.36	**-0.02**	-0.04
52.1	Creston 4.5 NW	3.13	**1.16**	2.20	1.34
138	Camatta Canyon	-4.24	**2.28**	6.03	3.63
65	Bitterwater	4.73	7.33	**-0.37**	1.01
34	Atascadero MWC	1.85	-3.70	**1.34**	-9.93
95	Santa Margarita	-10.87	-20.33	**3.06**	-17.17
Average cumulative departure (absolute)		3.2	5.4	3.5	5.5

Notes: Top base period candidates for each station in **bold**.
Average cumulative departure is the mean of the absolute values.

The most suitable candidates for the hydrologic base period were rainfall years 1965-1997 and 1981-1997. Considering the availability of data, especially water level data and municipal production records, the latter period of 1981-1997 is preferred.

The selected hydrologic base period for the Paso Robles Groundwater Basin study is rainfall years 1981 through 1997 (July 1980 through June 1997; 17 years). Consideration of the Salinas reservoir and Nacimiento reservoir operations do not affect the recommendation. The July 1980 through June 1997 period meets the definition of a hydrologic base period:

- The position of the base period relative to historical wet-dry cycles is appropriate. If a smooth curve is fitted to the precipitation patterns, the base period covers one full cycle, including wet, dry, and average precipitation years (Figure 4).
- The base period ends in 1997, which incorporates recent cultural conditions.
- The rainfall is similar for years leading into the beginning and end of the base period. The average precipitation of the 11 reference stations in 1979 and 1980 is 16.5 inches, and the average for 1996 and 1997 is 15.1 inches.

CHAPTER 2 – GEOLOGY

GENERAL

The Paso Robles Groundwater Basin was first formally defined by the California Department of Water Resources (DWR, 1958). In 1979, the DWR published a detailed investigation of the San Luis Obispo County portion of the basin (DWR, 1979).

The basin boundaries are re-defined in this study (Figures 5 and 6). The basin borders were defined using information obtained from oil well and geothermal well logs, water well logs, geologic mapping, and fault investigations. Six geologic cross sections were prepared correlating the main geologic units using deep well information and geologic mapping. A map of the base of permeable sediments was prepared using these cross sections, along with additional deep well data interspersed within the grid of the cross sections. A geologic map of the basin showing the extent of the basin and the underlying geology is presented on Figure 5. The basin boundary and the locations of the geologic cross sections are presented on Figure 6. A contour map of the base of the permeable sediments is presented as Figure 7, and the geologic cross sections are presented as Figures 8 through 19.

A single subbasin, the Atascadero subbasin, is defined as that portion of the Paso Robles Groundwater Basin west of the Rinconada fault. Between Atascadero and Creston, the Rinconada fault juxtaposes less permeable Monterey Formation rocks with the Paso Robles Formation basin sediments. South of the City of Paso Robles, the Paso Robles Formation is found on both sides of the Rinconada fault, however the fault zone is believed to form a leaky barrier that restricts flow from the Atascadero subbasin to the main part of the Paso Robles basin.

As shown on Figure 6, the western boundary of the Paso Robles Groundwater Basin roughly follows Highway 101 from Santa Margarita northward to Hames Valley. The eastern boundary follows a rough line from Highway 58 in the San Juan Creek area northward to Shandon and Cholame. The basin is downstream of and hydraulically connected by alluvial deposits to the Pozo Groundwater Basin south of the basin, and to the Cholame Groundwater Basin north of the basin. The Paso Robles basin outlet is northwest of and downstream of Bradley, where the Paso Robles basin is hydraulically connected with the Salinas Valley Groundwater Basin (Figure 6).

The stratigraphy in the watershed of the Paso Robles Groundwater Basin includes the water-bearing geologic units that form the basin aquifer, and the non-water bearing geologic units that underlie and are adjacent to the basin sediments. Figure 5 shows the extent of the geologic formations described in the following paragraphs. Descriptions of the water bearing and non-water bearing geologic formations are provided below, including hydrogeologic characterizations of each formation. In addition, the critical structural features within and bounding the groundwater basin are identified.

The main criteria for defining the water-bearing geologic formations in the basin are that they exhibit both sufficient permeability and storage potential for the movement and storage of groundwater such that wells can reliably produce more than 50 gallons per minute (gpm) on a long-term basis. Another criterion is that the groundwater produced from the geologic formation must have generally acceptable quality. DWR (1979) used groundwater conductivity of 3,000 micromhos/centimeter as the maximum limit for basin groundwater quality. Application of these two criteria limits definition of the basin sediments to Quaternary-age alluvial deposits and the Tertiary-age Paso Robles Formation.

The basin boundary generally follows the outcrop contact of these water-bearing geologic units but also follows fault lines, particularly on the eastern edge of the basin (Figures 5 and 6). The bottom of the basin, defined generally as the base of the Paso Robles Formation, is a reflection of the folding, faulting, and erosion that formed the highly variable surface upon which the nonmarine Paso Robles Formation sediments were deposited. The basin boundary and bottom should not be considered as absolute barriers to flow because in most cases the geologic units underlying and adjacent to the basin have limited porosity and permeability.

WATER-BEARING GEOLOGIC FORMATIONS

Alluvium

Alluvial deposits occur beneath the flood plains of the rivers and streams within the basin. These deposits reach a depth of about 100 feet below ground surface (bgs) or less and are typically comprised of coarse sand and gravel. The alluvium is generally coarser than the Paso Robles Formation sediments, with higher permeability that results in well production capability that often exceeds 1,000 gpm. The principal areas of groundwater recharge to the basin occur where the shallow alluvial sand and gravel beds are in direct contact with the Paso Robles Formation.

Paso Robles Formation

The Paso Robles Groundwater Basin is comprised predominantly of Paso Robles Formation sedimentary layers that extend from the ground surface to more than 2,000 feet below sea level in some areas (resulting in basin sediments with a thickness of more than 2,500 feet; best illustrated on Figure 14). Throughout most of the basin, however, the water-bearing sediments have a thickness of 700 to 1,200 feet (with the base of the sediments more or less at sea level; Figure 10).

The Paso Robles Formation is a Plio-Pleistocene, predominantly nonmarine geologic unit comprised of relatively thin, often discontinuous sand and gravel layers interbedded with thicker layers of silt and clay. It was deposited in alluvial fan, flood plain, and lake depositional environments. The formation is typically unconsolidated and generally poorly sorted. It is not usually intensely deformed, except locally near fault zones. The sand and gravel beds within the unit have a high percentage of Monterey shale gravel and generally have moderately lower permeability compared to the shallow, unconsolidated alluvial sand and gravel beds. The formation is typically sufficiently thick such that water wells generally produce several hundred gpm. In the area near Atascadero, the Paso Robles Formation has been folded, exposing the basal gravel beds. With the basal gravel exposed and in direct contact with the shallow alluvium, the Paso Robles Formation is recharged directly from the river alluvium.

NON-WATER BEARING GEOLOGIC FORMATIONS

Underlying the basin sedimentary beds are older geologic formations that typically have lower permeability and/or porosity. In some cases, these older beds yield in excess of 50 gpm flow to wells but they often have poor quality water or are of limited extent, such as are found along a fault fracture zone. The older geologic units that crop out along the basin border are identified on the base of the permeable sediments map (Figure 7) and on the cross sections (Figures 8-19). In general, the geologic units underlying the basin include Tertiary-age consolidated sedimentary beds, Cretaceous-age metamorphic rocks, and granitic rock.

Tertiary-Age Consolidated Sedimentary Formations

The Tertiary-age older consolidated sedimentary formations include the Pancho Rico Formation, an unnamed clastic unit, the Santa Margarita Formation, the Monterey Formation, the Obispo Formation, and the Vaqueros Formation. These units crop out around most of the basin edge and underlie the basin sediments.

The Pancho Rico Formation (Tp) is a Pliocene-age marine deposit found mostly in the northern portion of the study area. In places, it appears to be time-correlative to the Paso Robles Formation, and may be in lateral contact as a facies change. The presence of the Pancho Rico beneath the northern part of the basin is best illustrated in Figures 12 and 13. The increasing thickness of the formation northward is shown on Figures 14 and 15. The unit is predominantly comprised of fine-grained sediments up to 1,400 feet thick that yield low quantities of water in the Gabilan Mesa area north of the Paso Robles basin.

The upper Miocene-age unnamed clastic unit (Tuc) is time-equivalent to the Pancho Rico Formation and is comprised of up to 200 feet of sandy conglomerate beds in the Shandon area (Figures 10 and 11). This unit is cemented and produces limited flow to wells.

The Santa Margarita Formation (Tsm) is an upper Miocene-age marine deposit, consisting of a white, fine-grained sandstone and siltstone with a thickness of up to 1,400 feet (Figures 10, 16, 18, and 19). The unit is found beneath most of the basin. The Santa Margarita Formation crops out in the Santa Margarita area where more than 300 domestic water wells depend on its very limited flow capabilities. It is also a host to a number of springs. South of Templeton, water produced from the Santa Margarita Formation is often of acceptable water quality. However, north of Templeton in the area beneath the City of Paso Robles, the unit becomes progressively more permeable and is the main reservoir for the historical presence of geothermal water. Groundwater in the geothermal areas is often under pressure and artesian flow is a common occurrence, with flow rates at times exceeding 400 gpm. The Santa Margarita Formation aquifer in this area is not considered part of the Paso Robles basin because the produced water quality is usually very poor. The geothermal waters contained in the Santa Margarita Formation in this area are often highly mineralized and characterized by elevated boron concentrations that restrict agricultural uses. North of the study area, the Santa Margarita Formation crops out in the upper portions of the Gabilan Mesa. South of the basin, it is exposed along Highway 58 where springs occasionally issue from the unit.

The Miocene-age Monterey Formation (Tm) consists of interbedded argillaceous and siliceous shale, sandstone, siltstone, and diatomite. The unit is as great as 2,000 feet thick in the study area (Figures 14, 15, 16, 17), and is often highly deformed. It is exposed south and west of the groundwater basin (Figures 8, 10, 14, 18). Water wells completed in the Monterey Formation may be quite productive if a sufficient thickness of highly deformed and brittle siliceous shale is encountered. Springs issue from the Monterey Formation in the Atascadero area and on Cuesta Ridge south of the study area. The Monterey Formation can also be a source for oil as well as water in the area near Hames Valley, downstream of Lake San Antonio, and in upper Indian Valley. Groundwater produced from the Monterey Formation often has high concentrations of hydrogen sulfide, total organic carbon, and manganese. In the Paso Robles area, the Monterey Formation may be a host to geothermal water that has high sulfide concentrations in addition to high boron, iron, manganese, and total dissolved solids.

The lower Miocene-age Obispo Formation (To) is not found adjacent to or underlying the Paso Robles Groundwater Basin sediments but is described here briefly because it is found in the watershed south of the study area. It is a consolidated volcanic tuff bed underlying the Monterey Formation south of Santa Margarita. Wells in the Tassajara Creek area produce more than 100 gpm from the formation, and it is the host of several springs along Cuesta Ridge. Water produced from this unit is generally moderately saline (total dissolved solids concentrations around 1,000 mg/l).

The marine Oligocene-age Vaqueros Formation (Tv) is a highly cemented fossiliferous sandstone that reaches a thickness up to 200 feet. Springs with flows up to 25 gpm are common in canyons on the western and southern sides of the study area (Figure 18). Most water wells tapping this formation produce less than 20 gpm. Generally, the quality of water in this unit is good, though hard due to the calcareous cement within the rock.

Metamorphic and Granitic Rock

The southern and western edges of the basin are bordered by Cretaceous-age metamorphic and granitic rock (Figures 10, 14, 16). The metamorphic rock units include the Franciscan, Toro, and Atascadero formations. The Franciscan Formation consists of discontinuous outcrops of shale, chert, metavolcanics, graywacke, and blue schist, with or without serpentinite. The Franciscan Formation has an undetermined thickness and has low permeability and porosity. Limited volumes of groundwater can be produced from this geologic unit, generally only where the metavolcanics rock has been highly fractured.

The Toro Formation (Kt) is a highly consolidated claystone and shale that does not typically yield significant water to wells. The Atascadero Formation (Ka) is highly consolidated but does have some sandstone beds that yield limited amounts of water to wells. Both the Toro and Atascadero formations are exposed in the hills west of Santa Margarita, Atascadero, and Templeton.

The granitic rock (Kgr) lies east of the Rinconada fault zone, south of Creston, east of Atascadero, and in the area northwest of Paso Robles. The Park Hill area south of Creston and east of Atascadero is well known for the difficulty of finding sufficient groundwater to serve single residences. Where water is found, it is typically low in salinity. The granitic rocks often have a decomposed regolith up to 80 feet in thickness in the valley floor areas that may contain limited amounts of groundwater despite low sediment permeability due to the breakdown of feldspar and iron and magnesium silicates into clays and fine grained sediment. Springs are occasionally found where the rock is fractured, including one spring near Creston known as Iron Spring.

GROUNDWATER BASIN DEFINITION

Structural Boundaries

The lateral extent of the Paso Robles Groundwater Basin is generally defined by the contact of water-bearing unconsolidated aquifer sediments with older geologic units. In some areas, however, the basin boundary is a structural boundary defined by faults (Figures 5 and 6). The Rinconada fault defines the eastern boundary of the Atascadero subbasin and forms the hydraulic barrier between the main part of the basin and the Atascadero subbasin. The entire eastern boundary of the basin is defined by the Red Hill, San Juan, and White Canyon faults (Figures 6, 9, 11, 13, 19).

In the southern part of the Atascadero subbasin, the Rinconada fault juxtaposes the Paso Robles Formation sediments with the Monterey Formation (Figures 6 and 8). The presence of the shale east of the fault forms an effective barrier to groundwater flow between Atascadero and Creston.

Further north, the Rinconada fault zone was exposed in trenches on the Santa Ysabel Ranch (GeoSolutions, 2000). The fault was found to be a barrier to groundwater flow in the Paso Robles Formation as evidenced by differences in water levels at the Santa Ysabel warm water spring and wells drilled at the edge of the terrace above the Salinas River flood plain. Figure 14 illustrates the displacement on the fault in the Santa Ysabel Ranch area, bringing Santa Margarita Formation nearly to the ground surface east of the fault. Dibblee (1976) suggests that vertical displacement along the Rinconada fault exists, but the data conflicts depending on location. In the fault reach along the boundary of the Atascadero subbasin, evidence exists to suggest relative uplift of the northeast block. Dibblee (1976) suggests that the earliest displacement since Miocene time was up on the northeast, then up on the southwest in late Pleistocene time. All evidence indicates that horizontal displacement on the fault is right lateral (Dibblee, 1976; Campion, et al, 1983).

Groundwater flow from the Atascadero subbasin west of the Rinconada fault into the main Paso Robles basin is limited to shallow flow in the alluvial Salinas River deposits because the fault acts as a barrier to flow in the Paso Robles Formation. The Rinconada fault is not considered active because it does not displace Holocene-age deposits, but it is considered potentially active because it displaces the Quaternary-age Paso Robles Formation. North of the study area, however, the Rinconada fault zone and the San Marcos fault zone are considered active and are classified as Alquist-Priolo special studies zones.

East of Shandon, the Red Hill fault displaces the Paso Robles Formation, where exposures can be found in the banks of Cholame Creek along Highway 46 (Figure 11). East of White Canyon, near-vertical bedding of sand and gravel layers of the Paso Robles Formation is uplifted along the White Canyon fault (Figures 13 and 19). Although the fault juxtaposes Paso Robles Formation sediments on both sides of the fault, the uplifting and folding of the sediments on the east side of the fault form a hydraulic boundary that defines the eastern edge of the basin in this area.

Northeast of Cholame and across the White Canyon fault, the Cholame Valley is a separate and hydrologically distinct groundwater basin that overflows into the Paso Robles basin through the Cholame Creek alluvial deposits, much as the Paso Robles basin overflows into the Salinas Valley Groundwater Basin through the Salinas River alluvium. Previous investigations differentiated the Cholame Valley as a groundwater basin distinct from the Paso Robles Groundwater Basin, and bounded by the San Andreas fault zone (DWR, 1958).

Internal Basin Structure

Internally, the Paso Robles Groundwater Basin consists of two deep structural northwest-trending troughs separated by bedrock highs extending from the area east of the Salinas River at Camp Roberts, through the San Miguel Dome, to the Creston anticlinorium in the southern part of the basin (Figure 7). The subsurface expression of the bedrock high is illustrated on Figures 12 and 15, where the underlying consolidated rocks are either very shallow or are exposed at the surface. To the north, this bedrock high is associated with the King City fault, which may trend beneath the Paso Robles basin although there is no surface evidence or expression (Figure 10).

West of the San Miguel dome there is a deep trough that shallows progressively to the south (Figures 12 and 14). South of Paso Robles, the Rinconada fault divides the basin into the Atascadero subbasin and the main part of the Paso Robles Groundwater Basin. As shown on Figures 8 and 16, the basin sediments are generally relatively thin in the Creston area. The Creston area is separated from that part of the groundwater basin underlying Shedd, Shell, Camatta, and San Juan creeks by an anticlinal fold that brings a peninsula of older consolidated rocks to the surface (Figure 8). However, the peninsula of older consolidated rocks does not extend northward far enough to create an effective barrier to flow (Figures 7, 10, and 16). The thickness of basin sediments along the structural high between the San Miguel dome and the Creston anticlinorium reach a thickness as great as 1,200 feet.

CHAPTER 3 – HYDROGEOLOGY AND AQUIFER CHARACTERIZATION

GENERAL

Aquifer characterization includes defining the geometry, boundary conditions, and hydraulic parameters of the major aquifer units, delineating groundwater flow and movement, calculation of basin storage, and calculation of changes in storage over time. The methods of investigation for aquifer characterization consisted of preparing a series of detailed hydrogeologic cross-sections and identifying areas in the basin with similar hydrogeologic characteristics and conditions. A series of water well hydrographs were prepared from which several water level contour maps were prepared and, on the basis of the results of aquifer pumping tests, aquifer parameter tables were prepared for areas across the basin. Finally, the total volume of groundwater in storage was calculated, as well as the change in storage over the base period.

The basin areas identified during this task were used to organize the analysis of hydrogeology, aquifer characteristics, and water levels and groundwater flow and movement. The methods of investigation for hydrogeologic cross-sections, aquifer parameter tables, and water level analyses are discussed below.

Hydrogeologic Cross Sections

To gain an understanding of the major aquifer zones throughout the basin and identify regional groundwater flow dynamics, detailed hydrogeologic cross sections were developed for the basin areas for which there was sufficient data. Previous investigators had noted the difficulty in correlating beds from well to well in the Paso Robles Formation. This difficulty is generally attributed to the changing modes of deposition resulting in complex sedimentary structures including lenticular deposits and frequent lateral variation in aquifer grain sizes. Where electric logs are not available, the difficulty of correlating across any distance increases due to the variability in driller's logging techniques. Nevertheless, prior attempts at lithologic cross-sections of the basin have been made by the Department of Water Resources (DWR, 1979, 1981), and by Coastal Research Institute (CRI, 1993).

The DWR (1979) cross-sections are schematic representations. Individual "aquifer zones" are not correlated zones between wells, but instead depict the structural complexity of the basin with some interpretation of aquifer thickness. An attempt to correlate the "blue clay" horizons between wells in the Paso Robles area was the focus of DWR (1981), although the success of these efforts was limited.

CRI (1993) published sixteen cross-sections that projected sand and gravel stringers horizontally across the basin based on driller's well log descriptions. The cross-sections presented by the CRI (1993) study were more detailed than those in DWR (1979), but correlation of laterally extensive aquifer zones (if any) from these sections proved to be difficult because of the assumed horizontal attitude of discrete beds. Even at the shallow 1^{o} to 3^{o} degree dips on the limbs of synclines and anticlines (Dibblee, 1971, 1973), there is roughly 100 to 300 feet of vertical displacement in the beds per mile of section, which is significant when plotting 10-mile long sections of the basin at an approximate 16:1 vertical scale exaggeration.

The selected hydrogeologic cross-sections prepared for this report incorporate both structural and lithologic interpretations. First, well logs and electric logs were used to identify the discrete sand and gravel intervals at points along the section line. These discrete beds were then combined into potential aquifer zones, based on vertical proximity and thickness.

Hydrogeologic Parameter Tables

Hydrogeologic parameters include estimates of average specific yield for each area and the transmissivity, hydraulic conductivity, and specific capacity of aquifer zones perforated by wells. Because reliable storativity data can only be gained through controlled pumping tests with observation wells, accurate estimates of storativity were available only for the Atascadero subbasin. Average specific yield was estimated by analyzing 10 to 20 of the deepest well completion logs for each area (157 logs were analyzed). Each lithologic interval (discrete bed) was assigned a specific yield by comparison of the formation description with published estimates based on extensive field and laboratory investigations conducted in southern coastal basins by the DWR and modified for the Paso Robles Formation (DWR, 1958). The assigned specific yield was then weighted according to the thickness of each bed and averaged over the entire depth of the well. The compilation of these average specific yields for each well was averaged, in turn, for each area.

The electronic compilation of the thickness of various formation materials by depth was performed in order to: (1) calculate specific yield and change in groundwater storage; and (2) to help identify major production zones and use in a future groundwater flow model to provide initial estimates of transmissivity based on permeable zone thickness and hydraulic conductivity.

Water Well Hydrographs and Water Level Contour Maps

Water level data from the County database were utilized to prepare water level hydrographs and groundwater surface elevation contour maps. Hydrographs were prepared for each study well with sufficient data. Approximately 180 hydrographs were prepared for this analysis.

The water level database was utilized to analyze time-dependent trends in water levels throughout the basin. Water surface elevation data was contoured for the periods of Spring 1980 (beginning of the base period, as described in detail in the next section) and Spring 1997 (end of the base period). In addition, a change in water level map for the base period was prepared.

Groundwater in Storage

By comparing the base of the fresh water surface (represented by the base of the permeable sediments map, Figure 7) with the water level surfaces at the beginning and end of the base period, the total groundwater in storage at the beginning and end of the base period was estimated. The change in storage over the base period was then calculated by taking the difference between these two volumes.

BASIN AREAS

There is a practical value for analytical purposes in dividing the 790-square mile Paso Robles Groundwater Basin into informal areas. A single hydrologically distinct subbasin, the Atascadero subbasin, was earlier defined. The remainder of the basin is hydraulically interconnected by thick sedimentary sections, and thus appropriately defined as a single basin. However, for discussion purposes, the basin was informally divided into several study areas, based on water quality, source of recharge, groundwater movement, and contours on the base of permeable sediments.

Eight areas in the basin (including the Atascadero subbasin) are recognized (Figure 20). (It is important to note that delineation of these areas is for discussion purposes only, and should not be construed to represent formal hydrologic boundaries, planning areas, or some other documented or established division). Detailed hydrogeologic cross-sections were prepared for those areas for which there was sufficient data, which aided in identifying basin boundary conditions, major aquifer production zones, internal structure, and aquifer flow dynamics. The locations of the cross-sections are shown on Figure 21. Descriptions for the boundaries between areas are given below (outflow refers to all groundwater outflow and most surface water/underflow outflow):

1. **Atascadero Subbasin.** The eastern boundary of the subbasin is the Rinconada fault. Because the fault displaces the Paso Robles Formation, the hydraulic connection between the aquifer across the Rinconada fault is sufficiently restricted to warrant the classification of the distinct Atascadero subbasin. Outflow (primarily surface flow and Salinas River underflow) from this subbasin enters the Estrella Area.
2. **Creston.** The Creston area is bounded on the east in part by outcrops of the Santa Margarita Formation exposed from folding along the Creston anticlinorium. The eastern boundary extends along a line parallel to the regional groundwater flow direction from the tip of the Creston anticlinorium to the northern boundary. The northern boundary extends west generally parallel to groundwater level contours and through a series of en echelon structural folds to a point just south of where the Salinas River crosses the Rinconada fault. The Rinconada fault forms a portion of the western boundary of the area and separates it from the Atascadero subbasin. Granitic rock outcrops of the La Panza Range form the southern boundary of the area. Outflow from this area enters the Estrella Area.
3. **San Juan.** The northern boundary is roughly parallel to groundwater level contours extending east from the Creston anticlinorium. Outflow from this area enters the Shandon area.
4. **Estrella.** The northwestern boundary follows the initial groundwater flow direction at the basin edge through a point in the center of the San Miguel dome. All other area boundaries are defined above. Outflow from this area enters the Bradley area.

5. **Shandon.** The southern and southwestern boundaries with San Juan and Creston are described above. The western boundary is a relatively narrow section roughly parallel to the groundwater elevation contours just west of Whitley Gardens, extending from the northeast corner of the Creston area to the base of the canyons north of Whitley Gardens, between which all outflow from the area occurs. The northwestern boundary follows the groundwater flow direction between the western boundary and the edge of the basin. Outflow from this area enters the Estrella area.
6. **North Gabilan.** The southwestern boundary with Bradley and southeastern boundary with South Gabilan are described above. Outflow from this area enters Bradley.
7. **South Gabilan.** The southeastern boundary with Shandon is described above. The southwestern boundary roughly parallels groundwater level contours, skirting the edge of the deep basin trough south of San Miguel. The northwestern boundary follows the groundwater flow direction from the tip of the San Miguel dome to the edge of the basin. Outflow from this area enters the Estrella area.
8. **Bradley.** The southeastern boundary with Estrella is described above. The northeastern boundary runs subparallel to groundwater level contours from the San Miguel dome to the edge of the basin, such that all basin outflow is through the Bradley area.

Atascadero Subbasin

The Atascadero subbasin includes the City of Atascadero and the communities of Templeton and Garden Farms. Highway 101 parallels the main development corridor. The Salinas River is the major hydrologic feature through the subbasin.

The Atascadero subbasin of the Paso Robles Groundwater Basin is defined as that portion of the basin west of the Rinconada fault (Figures 20 and 21). Between Atascadero and Creston, the Rinconada fault juxtaposes less permeable Monterey Formation rocks with the Paso Robles Formation basin sediments. South of the City of Paso Robles, the Paso Robles Formation is found on both sides of the Rinconada fault, however, the fault zone forms a leaky boundary between the Atascadero subbasin and the main part of the Paso Robles Groundwater Basin.

Subbasin sediments consist predominantly of alluvial deposits, including younger and older alluvium and the Paso Robles Formation. Shallow wells up to 100 feet deep in the immediate vicinity of the Salinas River typically tap the younger alluvium and/or shallow Paso Robles Formation aquifer zones. Deep wells reach several hundred feet deep and tap the Paso Robles Formation, although a few of the deeper wells also tap the upper portion of the upper Miocene-age Santa Margarita Formation. Most of the southern portion of the subbasin is underlain by light gray and white sandstone of the Santa Margarita Formation; the northern part of the subbasin, near Templeton, is underlain predominantly by the Monterey Formation. Seashells are reported in some well logs near the base of the Paso Robles Formation, suggesting a near-shore marine depositional environment. Based on inspection of well logs and the base of the permeable sediments map (Figure 7), the deepest part of the subbasin is the area between Templeton and the Rinconada fault. The lithology and structure of the subbasin is shown in detail on Figures 22 and 23.

Highway 101 to Lupine Lane. The younger alluvium and active stream channel deposits along the Salinas River channel directly overlie the Monterey Formation from the northern end of Atascadero throughout the vicinity of Templeton (Figure 22). Paso Robles Formation deposits begin near Templeton Road at Moss Lane and reach a thickness of close to 700 feet. The lithology of this section of the aquifer can be grouped into two finer-grained zones and two coarser-grained zones. The shallower coarser-grained zone is up to 250 feet thick and is partially unsaturated. The deeper coarse-grained zone is approximately 50 feet thick and directly overlies the Santa Margarita Formation. The variation in thickness and lithologic correlation of Paso Robles Formation sediments along the line of section shown in Figure 22 suggests the presence of a broad synclinal structure east of Templeton, between the Salinas River and the Rinconada fault. This synclinal structure is apparently maintained southward as far as the confluence of the Salinas River and Atascadero Creek.

Moss Lane to Garden Farms. Figure 23 shows the gradual rise in the base of permeable sediments between the area east of Templeton (Moss Lane) and the southern edge of Atascadero (San Gabriel Road). The relatively shallow, 250-foot thick coarse-grained production zone in the Moss Lane region (Figure 22) deepens to the south and then flattens out along the top of the Santa Margarita Formation, gradually pinching out due to the rise in the formation contact. An isolated coarse-grained zone is tapped by wells in the Los Palos Road area, at the southernmost extent of the subbasin.

Creston Area

The Creston area is roughly centered on the community of Creston and is bisected by State Highway 41 (Figure 20). Huer Huero Creek flows generally northwesterly through the area and flows into the Salinas River north of Paso Robles. Elevations in the Huer Huero Creek drainage vary from 1,200 feet in the south to 800 feet downstream, in the northern part of the area.

Throughout the Creston area, basin sediments of the Paso Robles Formation are underlain predominantly by Tertiary-age marine sediments (Figures 24, 25, and 26). Along the southern edge of the area, the basin sediments are underlain by and in contact with the granitic rocks that form the basin boundary.

The Pliocene-age Pancho Rico Formation underlies and may in places be intertongued with the Paso Robles Formation in the northern portion of the area (Durham, 1974). The contact between the two units is difficult to identify, but the presence of Pliocene-age marine fossils in the Pancho Rico Formation and electric logs are diagnostic. The lithology of the Pancho Rico varies locally, and may consist of sandstone, conglomerate, mudstone, diatomite, and porcelanite. Electric logs from oil wells drilled in the basin indicate that the Pancho Rico Formation is significantly less permeable than the Paso Robles Formation.

The upper Miocene-age Santa Margarita Formation underlies the Paso Robles Formation in most of the southern and western portions of the Creston area. According to Durham (1974), the contact is conformable in some places within the Paso Robles Groundwater Basin and unconformable in others, although as Hall (1976) notes, the Paso Robles Formation generally rests with an angular unconformity on the Santa Margarita Formation. In the Creston area, deformation of the Paso Robles Formation appears to be generally similar to deformation of beds of the Santa Margarita Formation as evidenced by measurements in surface outcrops and by correlation between oil well logs. The Santa Margarita Formation consists primarily of light gray and white, fine grained sandstone, and is generally calcareous and well cemented. In the Creston area and the Atascadero subbasin, the Santa Margarita Formation has less hydraulic conductivity than the Paso Robles Formation.

In the southwest portion of the Creston area, near Atascadero, the Paso Robles Formation is underlain by the Miocene-age Monterey Formation. The Monterey consists of argillaceous and siliceous shale, interbedded with siltstone and diatomite. These beds are typically highly deformed.

South of the town of Creston, the Paso Robles Formation is underlain by Cretaceous-age granitic rock. Granite is exposed in outcrops south of Creston in the La Panza Range. Wells drilled beneath the Paso Robles Formation may encounter a decomposed granite zone above the unweathered granite. The decomposed granites are typically significantly less permeable because of the breakdown of feldspar, iron, and magnesium silicates into clays and fine-grained sediment.

Alluvial deposits unconformably overlie the Paso Robles Formation beneath the flood plains and older stream terraces of Huer Huero Creek and Cripple Creek. These alluvial deposits reach depths to approximately 60 feet and consist of much coarser and unconsolidated sedimentary layers than are typically found in the Paso Robles Formation. Groundwater recharge to the Creston area occurs where the shallow alluvial deposits are in contact with (overlying) the coarse-grained Paso Robles Formation aquifer.

The basin sediments are relatively flat lying and gently folded with dips typically less than 5 degrees in most of the Creston area, with a few exceptions on the northwest and west. A series of shallow anticlines and synclines lie in an *en echelon* pattern north of the Huerhuero fault (La Panza fault), and northwest of the Creston anticlinorium. On the flanks of these folds, dips in the Paso Robles Formation are up to 10 degrees. On the western border, near Neal Springs Road, some beds of the Paso Robles Formation dip up to 40 degrees.

Depths to the base of the permeable sediments in the area increase from the southeast to the northwest. Thickness of the basin sediments range from approximately 450 to 500 feet near the town of Creston and increase to approximately 1,200 to 1,300 feet in the northern portion of the area along Huer Huero Creek.

To illustrate the typical aquifer characteristics in the Creston area, two hydrogeologic cross-sections were prepared by examining lithologic logs from 32 water wells, and electric logs from four oil wells. Cross Section C–C'-C" extends from just east of the Rinconada fault to a surface outcrop of the Santa Margarita Formation in the Creston anticlinorium (Figures 24 and 25). Cross Section D–D' extends north from an exposure of granite of the La Panza Range through the town of Creston to just north of Highway 41 (Figure 26). Hydrogeologic cross section alignments are shown on Figure 21.

Atascadero to Creston. Northeast of Atascadero, along Highway 41 East, basin sediments terminate against the Monterey Formation, which has been uplifted by the Rinconada fault zone. The Paso Robles Formation in this area gently dips to the northeast at 5 degrees or less (Dibblee, 1971) and tends to flatten out east of the fault. The orientation and dip of these beds is confirmed by correlation between oil wells and, where possible, water wells with distinctive aquifer production zones. Structure shown in the Paso Robles Formation sediments in Figure 24 is supported by surface dip measurements by Dibblee (1971). Domestic water wells that penetrate the Paso Robles Formation east of the Rinconada fault have been drilled to depths exceeding 500 feet, encountering alternating beds of clay, sand, and "shale gravel." A main water-producing zone comprised mostly of sand and gravel was identified as a continuous unit extending from water well 28S/13E-6H to the town of Creston (Figures 24 and 25). This zone is approximately 100 feet thick, approximately 200 feet below ground surface. It apparently thins to the east with increasing interbedded clay.

Locally, the main aquifer zone along this section is highly productive. Inspection of one representative well log shows that sand and gravel beds comprise 83% of the total zone thickness, with an apparent estimated specific yield of 0.17 and production capability exceeding 200 gpm.

Only one domestic well along the trend of the cross section is drilled to depths stratigraphically lower than the main producing zone. Located along the western edge of the basin, well 28S/12E-1P (Figure 24) produces from a zone consisting of 68% sand and gravel with interbedded clay, clayey sand, and gravel. Based on electric logs from two oil wells east of this well, the zone does not appear to extend to the east.

Water levels in this area were measured at approximately 1,100 feet elevation in the Spring of 1980 and approximately 1,120 feet in the Spring of 1997, representing a rise of approximately 20 feet.

Some degree of aquifer confinement is suggested by the presence of multiple clay zones above the main water producing zone and groundwater elevations higher than the main producing zone. Inspection of the logs from several wells along this section indicate that clay-rich beds range from 69% to 96% of the total thickness of the beds above the main aquifer zone.

Creston. Near the town of Creston, approximately 60 feet of alluvial deposits related to Huer Huero Creek overlie the Paso Robles Formation. These deposits consist of highly permeable sand or sand and gravel beds (Figures 25 and 26). A well located south of Creston (28S/13E-36A) and perforated entirely within the shallow alluvial deposits produced 367 gpm during a 24-hour pump test with a specific capacity of 68 gallons per minute per foot of drawdown (gpm/ft) and transmissivity of 186,300 gallons per day per foot of aquifer (gpd/ft).

Domestic wells drilled in the immediate Creston vicinity generally encountered coarser beds of the Paso Robles Formation than wells drilled in the outlying region. The specific yield of the sediments below the alluvium was estimated by examining the lithologic logs for 10 wells, resulting in an average estimated specific yield value of 0.11. For the entire Creston area, the specific yield was determined by examining logs from 47 representative wells, resulting in an estimated specific yield value for the area of 0.09.

The main water-producing zone west of Creston is tilted slightly in response to anticlinal folding north of the Huerhuero (La Panza) fault. The zone becomes shallower beneath the town of Creston (Figure 25). This sand and gravel zone of the basin sediments appears to be in direct contact with the shallow alluvial sand and gravel deposits of the Huer Huero Creek, providing apparent direct recharge to the basin through percolation of stream runoff. Additionally, basin recharge takes place north of Creston where shallow, undifferentiated sand and gravel beds are in contact with alluvial sand and gravel beds (Figure 26).

From the Spring of 1980 to the Spring of 1997, water levels in wells south of Creston fell approximately 1.5 to 2 feet. In the immediate vicinity of the town of Creston, water levels showed no significant change. North of Creston, water levels rose approximately 45 feet during the same period (Figures 24, 25, and 26).

Water levels in the Creston area are typically very shallow, and artesian conditions have occurred in wells that penetrate the deeper zones. A confined sand and gravel zone approximately 360 feet below ground surface is inferred based on lithologic logs and artesian flow or high water levels in wells penetrating this depth. Lithologic logs indicate a series of clay beds present above the inferred zone that confine permeable beds below. In an artesian well penetrating this zone, clay beds with a total thickness of 235 feet were noted in the 358 feet above the inferred zone, and a 33-foot thick clay bed was identified directly above the sand and gravel zone. The source of the artesian pressure to this aquifer is inferred to be the result of inflow from the south where precipitation and runoff at higher elevations percolates into the basin along canyons draining the granitic rocks of the La Panza Range.

East of the Town of Creston. In the area east of the town of Creston (Figure 25), beds of the Paso Robles Formation are slightly folded in a syncline between the bedrock highs of the underlying Santa Margarita Formation sandstone. The axis of the syncline trends northwesterly (Figure 20). Depths to the base of the permeable sediments in this area vary from 150 feet deep approximately one mile east of Creston to 750 feet deep approximately 2½ miles east of Creston. Deepening of the basin continues to increase to the northwest.

Multiple aquifer zones are present with representative specific yields ranging from 0.14 to 0.18 within the zones. Based on driller's logs from two water wells and an electric log from one oil well, basin sediments become finer grained below approximately 450 feet.

During the base period between Spring 1980 and Spring 1997, water level elevations in this area increased by approximately 20 feet. The depth to water below ground surface varies from 50 to 160 feet below ground.

Estrella-Creston Boundary. The boundary between the Estrella area and the Creston area is geologically controlled by the northwesterly extension of the Creston anticlinorium. Older, less permeable beds rise along the anticlinal axis, which turns to the west-northwest, crosses Huer Huero Creek, and extends to the Rinconada fault where it intersects the Salinas River. The presence of less permeable beds, possibly finer grained and/or more highly cemented, is inferred from the geomorphology and from well yields. Immediately upon crossing the anticline north of Creston Road, Huer Huero Creek is pushed westward into a series of meanders, unable to flow in a direct northerly route until reaching a weak zone created by a northwest trending fault that parallels Penman Springs Road (Dibblee, 1971).

Dips on the south side of the anticlinal axis, which plunges to the west, are 6° to 7°, while to the north, the dips are only 1° to 2°. This structure suggests that wells to the northeast of the anticlinal trend penetrate the oldest Paso Robles Formation beds and is an area of lower overall well yields. Dry Creek is the main surface drainage through the area, with a relatively small watershed.

San Juan Area

The San Juan area lies south-southeast of Shandon, and includes rural agricultural land along San Juan Creek, Camatta Canyon, Shell Creek Road, and Shedd Canyon. Well information is relatively limited, with less than a dozen well logs for the entire area. With the exception of some logs in Camatta Canyon, typical lithologic descriptions include interbedded clay with sand and gravel. In Camatta Canyon, sequences of sand and gravel up to several hundred feet thick are reported.

In this area, the Paso Robles Formation is underlain by the Santa Margarita Formation. Along the eastern boundary of the area, the San Juan fault juxtaposes the Santa Margarita Formation against basin sediments.

Estrella Area

The Estrella area includes the City of Paso Robles and the communities of San Miguel, San Lawrence Terrace, Estrella, and Wellsona. Highway 101 is the main north-south corridor, and Highway 46 extends east-west through the heart of the area. Both the Estrella River and the Huer Huero Creek flow into the Salinas River in the Estrella area.

The geologic structure of the area is characterized by relatively flat-lying basin deposits with a series of shallow anticlines and synclines dipping typically less than 5°. Faulting associated with the Rinconada fault zone and the geothermal resource has been mapped in the southwest portion of the area, near Paso Robles. To the north, the area abuts the San Miguel dome, a regional anticlinal structure. The deepest part of the Paso Robles Groundwater Basin, with a basin sediment thickness more than 3,000 feet, occurs southeast of San Miguel (Figures 7 and 14). The central and northern part of the Estrella area is underlain by Pancho Rico Formation. To the west and south, the basin is predominantly underlain by Santa Margarita Formation, with local subcrops of the Monterey Formation near the City of Paso Robles.

A detailed east-west trending hydrogeologic cross section along the Highway 46 corridor shows the basin structure and relationships (Figure 27). The Highway 46 corridor runs from the City of Paso Robles to Whitley Gardens (Estrella area) and continues eastward to the community of Shandon (Figure 21).

Northwest of the City of Paso Robles. Northwest of Paso Robles (in the Mustang Springs Road region), the basin sediments terminate against granitic basement rocks and the Monterey Formation, which have been thrust up along the Rinconada fault zone (Figures 10 and 27). Locally, domestic water wells are up to 400 feet deep. Wells in this region northwest of Paso Robles have been previously incorrectly interpreted as tapping the Santa Margarita Formation (DWR, 1981) and/or the Monterey Formation (Campion et al, 1983).

City of Paso Robles to Whitley Gardens. The City of Paso Robles has historically been the site of hot springs, including several springs on the north side of town. Wells along the Salinas River in Section 21 were historically artesian (flowing at the surface) with water temperatures close to 100^o F. An investigation of the Paso Robles geothermal area concluded that the source of the warm water was deep circulation of meteoric waters along faults, especially along the Rinconada fault (Campion et al, 1983). Campion (1983) suggested that the warmest water was produced from an aquifer interpreted to be the base of the Paso Robles Formation, however it is now understood that those geothermal zones are actually in the underlying Pancho Rico Formation. Therefore, the main geothermal resource is below, not in, the Paso Robles Groundwater Basin sediments. Significant geothermal potential is not restricted to the Pancho Rico Formation, but has also been recognized in deep wells in the area penetrating the Santa Margarita Formation and the Monterey Formation.

Campion et al. (1983) and DWR (1981) suggest that faulting has created the conduit for warm water rising to the ground surface. North of the City of Paso Robles, the Monterey Formation unconformably underlies the Paso Robles Formation and provides a source of geothermal water under artesian pressures (Figure 27). Faulting before deposition of the Paso Robles Formation is inferred to juxtapose the Monterey Formation against the Pancho Rico Formation. A second fault, associated with the Rinconada fault zone, is inferred to break Paso Robles Formation deposits and provide a vertical conduit for upwelling of the warm water to springs along the Salinas River (Figure 27; Dibblee, 1971). Of note is the abrupt change in water level between the area in the Mustang Springs Road area northwest of Paso Robles and the Salinas River, which supports the presence of an inferred fault beneath the hot springs lineament.

Basin sediments cropping out along the east bank of the Salinas River near the City of Paso Robles gently dip to the east and northeast at 3^o to 5^o (Dibblee, 1971). This dip is confirmed by subsurface correlation of aquifer production zones. The main producing zone underlies the Salinas River alluvium, then thins and deepens to the east, becoming the deep aquifer zone east of Huer Huero Creek (Figure 27). This deep aquifer zone continues through Whitley Gardens at an average thickness of 150 feet and an average depth of 700 feet (Figures 27 and 28). The structural orientation of this aquifer zone, rising west of Huer Huero Creek to its subcrop beneath the Salinas River alluvium, is supported by surface measurements of east-dipping Paso Robles Formation beds (Dibblee, 1971). Above and below this aquifer zone are thinner lenticular production zones, with those above the deep zone tapped by domestic wells up to 400 feet deep. The deep aquifer zone is penetrated primarily by deep irrigation wells and municipal supply wells.

San Miguel. San Miguel is at the northern edge of the Estrella area, where the depth to the base of permeable sediments reaches approximately 2,400 feet below sea level, with a saturated thickness of close to 3,000 feet (Figure 7). Water wells in the area are typically less than 600 feet deep. Limited specific capacity data from wells in the region suggest a range of less than 2 gpm/ft to as high as 6 gpm/ft. Wells exhibiting the lower specific capacity values are mostly located west of Highway 101. Well yields in the San Miguel area range from less than 100 gpm to several hundred gpm.

Shandon Area

The Shandon area includes the communities of Whitley Gardens and Shandon. The Highway 46 corridor extends east-west through the area. Cholame Creek, entering the basin from the northeast, and San Juan Creek, flowing northward from the San Juan area, join at Shandon and create the Estrella River.

The geologic structure of the basin sediments in this area is characterized by a broad, shallow syncline with an east-west axis roughly along the Estrella River channel. Flat-lying beds are mapped adjacent to the river; sediments in the hills to the north and south are mapped with dips of 1^{o} to 3^{o} (Dibblee, 1973). Basin sediments in the Shandon area are predominantly underlain by Santa Margarita Formation sandstone, with localized subcrops of the unnamed clastic (conglomerate) unit and the Pancho Rico Formation.

A detailed east-west trending hydrogeologic cross section along the Highway 46 corridor east of Whitley Gardens shows the basin structure and relationships (Figures 21 and 28).

Whitley Gardens to Shandon. Of prominence in this area is the historical presence of numerous flowing wells along the north flank of the Estrella River flood plain and the south side of the river near Whitley Gardens. The artesian pressure in these wells is developed in a relatively shallow production zone from 200 to 400 feet deep, and indicates semi-confined conditions beneath the Estrella River flood plain (Figure 28). This production zone appears to thin and pinch out to the west, and is inferred to be hydraulically disconnected from the shallow, lenticular aquifers to the west based on the lithologic structure and correlation of well logs (Figures 27 and 28).

The source of artesian pressure to the zone is inferred to be from subsurface inflow from the north, where precipitation and runoff at higher elevation percolates into the basin along canyons draining the Cholame Hills. Numerous springs are present in these canyons, typically at elevations close to 1,400 feet above sea level (slightly higher on the east, and lower on the north). Artesian flow in wells north of Shandon has ceased recently, although several wells in the area experienced Spring water levels within 20 feet of ground surface during the 1990's.

Beneath the shallow artesian aquifer zone, at an average depth of 900 feet below ground surface, is the eastern continuation of the main production zone identified from the City of Paso Robles to Whitley Gardens (Figures 27 and 28).

North Gabilan and South Gabilan Areas

The Gabilan Mesa area is a southwestern to southern sloping Pleistocene-age geomorphic surface that rises from the Salinas and Estrella rivers to the watershed boundary ridge of the Cholame Hills. This uplift rises from an elevation of 600 to 1,000 feet along the rivers to elevations of more than 2,000 feet along the ridgeline. This is an area dissected by several south-flowing parallel, 100 to 200-foot deep canyons including (from east to the northwest): Hog and Ranchita canyons, which drain to the Estrella River between Estrella and San Miguel, and Vineyard, Indian Creek, Hare, Portuguese, Powell, and Sargent canyons, which drain to the Salinas River between San Miguel and San Ardo. These canyons are each several miles long and typically less than 500 feet wide. None of the canyons has been extensively developed, with existing development concentrated along the lower reaches of Hog, Ranchita, and Vineyard canyons and Indian Valley.

The water-bearing Paso Robles Formation underlying this area has been folded into a syncline, which is roughly four miles wide and 20 miles long, extending from San Ardo to east of San Miguel. The syncline is bounded by the San Miguel dome near the Salinas River and attendant anticlinal structures and faults along the eastern boundary. This northwest-southeast trending syncline becomes a southern dipping homocline as it reaches the southern boundary of the study area. Bedding surfaces dip to the south in the southern area at dips less than 3^{o}. Along the northernmost edge of the basin near San Ardo, the basin narrows to less than three miles in width with a depth of less than 500 feet.

The Paso Robles Formation in this area reaches a depth up to 1,000 feet along the synclinal axis. Pancho Rico Formation deposits are present beneath the basin sediments. Production zones are comprised of sand and gravel zones in the upper portion with increasing thickness of sand beds in the lower section. Sand and gravel beds are interbedded with clay and comprise less than 25% of the full thickness of the deposits. On the northwestern edge of the syncline, towards San Ardo, the Paso Robles Formation intertongues with the underlying Etchegoin and Pancho Rico formations.

Bradley Area

In the Bradley area (Figures 20 and 29), the Paso Robles Formation has been folded into two predominant northwest-southeast trending synclines, including one in Hames Valley and one along the southwest side of Camp Roberts. The Paso Robles Formation has been folded and uplifted, then eroded by the Salinas River and the Nacimiento and San Antonio rivers, two east-flowing tributaries that join the Salinas River north of Bradley. Alluvial deposits along the stream courses are coarse grained and highly permeable. The Paso Robles Formation in this area generally grades at depth from a coarse sand and gravel to sandy clay. In some locations, such as in Hames Valley, a sand bed up to 200 feet thick that is thought to be the Etchegoin Formation, underlies the Paso Robles Formation. Elsewhere, the Paso Robles Formation is underlain by the Pancho Rico Formation.

Along the northernmost edge of the basin near San Ardo, the basin narrows to less than three miles in width with a depth of less than 500 feet. This natural narrowing and thinning of the basin sediments forms a natural outlet of the Paso Robles Groundwater Basin, where surface and subsurface flow enters the adjacent Salinas Valley Groundwater Basin. A profile of the narrow outlet of the basin is presented on Figure 30. On the eastern side of the basin, the Pancho Rico Formation, consisting of a fine-grained silt and sand facies, is in part age-equivalent with the Paso Robles Formation. The Pancho Rico Formation underlies the basin sediments in this area. The King City fault, shown in Figure 30, is buried where it comes into the Paso Robles basin and extends as far southeast as the San Miguel Dome.

Hames Valley. The Paso Robles Formation in the Hames Valley area has a high percentage (up to 50%) of gravel and sand layers and consequently is highly permeable. Wells produce as much as 4,000 gpm with specific capacities up to 28 gpm/ft in the thickest portion of the syncline, where the Paso Robles Formation reaches a thickness of more than 1,100 feet. Wells located on the flanks of the syncline penetrate basin sediments to depths up to 600 feet and produce several hundred gpm with specific capacities of 3 to 4 gpm/ft. The Saylor fault is inferred along the axis of the syncline, but it apparently does not affect the flow of groundwater nor does it cut the alluvial sediments (Thorup, 1975).

The alluvium and older alluvium in Hames Valley deposited on top of the Paso Robles Formation is up to 200 feet thick (Thorup, 1975). Recent-age alluvial deposits consisting of sand and gravel with occasional interbedded clay comprise less than 100 feet of the total alluvial deposit thickness and probably constitute less than 60 feet of the section. No irrigation wells are completed in the alluvium.

Evidence of confined to semi-confined aquifer conditions exists in the Paso Robles Formation aquifer, based on pumping test data and vertical variation in water quality (Thorup, 1975). Inspection of an electric log for a well in the valley shows a zone of fine-grained sediments from 450 to 600 feet below ground surface, which may act as the confining layer separating the producing zones.

Southern Bradley Region. The southern Bradley area, south of the San Antonio River, is largely within the limits of Camp Roberts. Most of the wells in this area are located along the Nacimiento River valley, although several are also drilled in the San Antonio River valley. Based on inspection of well logs, the basin deposits contain more clay than in Hames Valley, and thinner beds of sand and gravel. There is a thinner section of the very coarse gravel (up to 3-inch diameter) and sand (about 200 to 300 feet thick) which produces up to 1,000 gpm. To the east, the older Paso Robles Formation beds comprised of clay with occasional sand layers crop out at the surface. The overall thickness of the Paso Robles Formation in this area is about 1,000 feet. While these lower zones also produce several hundred gpm, the water quality is poorer and the drawdown is greater.

Northern Salinas River Valley. The Salinas River valley comprises the eastern part of the Bradley area. Underlying the valley are Recent-age Salinas River alluvial deposits and the lower portion of the Paso Robles Formation. To the northeast, east of Bradley, the plunging northwestern end of the San Miguel dome separates the Bradley area from the Gabilan Mesa.

Along the Salinas River valley, the alluvium is generally less than 60 feet thick. However, it typically consists of highly permeable sand and gravel capable of yielding more than 1,000 gpm to wells.

AQUIFER CHARACTERISTICS

Atascadero Subbasin

Pumping test data from wells in the Atascadero subbasin suggest the presence of three aquifer groups with distinctly different hydraulic parameters. These three groups include the shallow younger alluvium along the Salinas River (underflow) and associated tributaries, the Paso Robles Formation deposits directly underlying the younger alluvium, and the Paso Robles Formation deposits along the east side of the subbasin that are not directly connected to the younger alluvium. The aquifer characteristics of each unit is summarized below, and presented in Table 3.

Younger Alluvium (Qa). Water wells penetrating and extracting groundwater from the younger alluvium are located along the full length of the Salinas River. The unit, consisting almost entirely of sand and gravel, is everywhere unconfined with very high transmissivity values. The thickness of the younger alluvium ranges widely, with an estimated maximum thickness of 75 feet. Specific capacity values for wells in the alluvium range from 20 to 60 gpm/ft at production rates as high as 1,000 gpm.

Paso Robles Formation Below Qa (QTp/Qa). In the Atascadero area, the Paso Robles Formation underlies the younger alluvium along the Salinas River channel. Wells in the Paso Robles Formation in hydraulic communication with the overlying younger alluvium tend to have higher transmissivity values than wells that penetrate the portions of the Paso Robles Formation not in contact with the alluvium. Constant discharge tests for three deep wells in Atascadero on the west side of the Salinas River showed production rates up to 1,000 gpm, with an average specific capacity of 15 gpm/ft and storativity of 0.04 to 0.0001 (Table 3).

Paso Robles Formation (QTp). Paso Robles Formation deposits east of the Salinas River comprise the largest portion of the subbasin. Lithology descriptions from driller's logs include sand and gravel with interbedded clays. The upper 300 feet of sediments in this area is characterized by thin (5 feet to 15 feet thick) interbedded brown or yellow clays with sand and "shale gravel." The beds tend to be thicker below 300 feet, with an increasing proportion of sand and gravel.

The results of six controlled pumping tests were reviewed for wells in the Paso Robles Formation, including five wells in the Templeton area and one near Atascadero. None of these wells were in direct hydraulic communication with the shallow younger alluvium. The specific capacity in these wells ranged from 0.9 to 5.7 gpm/ft at pumping rates of 110 to 810 gpm (Table 3). The average hydraulic conductivity of the Paso Robles Formation for the depth intervals tapped by wells in the Atascadero subbasin is estimated at 4 ft/day.

Table 3. Aquifer Parameters, Atascadero Subbasin

Well Location	Test (hours)	Flow (gpm)	Well Depth (ft)	Perf. Int. (ft)	Trans. (gpd/ft)	Q/s (gpm/ft)	Hyd. Cond. (ft/day)	Storativity	Type
28S/12E-5	8	90	55	30	101,106	110	450.6		Qa (Salinas)
27S/12E-29	24	740	60	25	650,000	105	3475.9		Qa (Salinas)
27S/12E-31	20	220	60	20	24,200	27.2	161.8		Qa (creek)
27S/12E-31	24	15	25	10	15,840	7.1	211.8		Qa (creek)
28S/12E-03	72	1300	425	270	45,760	17.6	22.7		QTp/Qa
28S/12E-03	72	1300 (obs)	505	332	45,760	na (obs)	18.4	0.04	QTp/Qa
28S/13E-31a	12	1000	450	300	52,800	11.5	23.5		QTp/Qa
28S/13E-31b	12	950 (obs)	450	300	36,000	na (obs)	16	0.0002	QTp/Qa
28S/13E-31c	24	1000	330	120	22,000	14.5	24.5		QTp/Qa
28S/13E-31d	24	1000 (obs)	320	87	26,400	na (obs)	40.6	0.0001	QTp/Qa
28S/13E-31e	24	1000 (obs)	310	283	--	na (obs)	146.4	0.004	QTp/Qa
28S/12E-03	24	325	370	225	5,400	3	3.2		QTp
28S/12E-11	72	810	600	300	6,198	5.7	2.8		QTp
28S/12E-11	72	810(obs)	350	200	8,250	na (obs)	5.5	0.002	QTp
27S/12E-9	72	475	605	312	6,600	2.3	2.8		QTp
27S/12E-16	24	426	640	380	2,900	2.1	1		QTp
27S/12E-16	24	441	280	115	7,300	4.6	8.5		QTp
27S/12E-20	103	110	290	120	1,700	0.9	1.9		QTp
27S/12E-20	24	150	195	87	7,275	2.8	11.2		QTp
27S/12E-17	50	200	270	170	2,122	1.8	1.7		QTp
Summary:									
Qa (average Salinas)		415	58	28	376000	108	1963		
Qa (average creeks)		118	43	15	20020	17	187		
QTp/Qa (average)		471	399	242	38120	6	42	0.011	
QTp (average)		367	450	212	5305	3	4	0.002	
Specific Yield: Number of wells used to calculate:					20	Average Value:		0.11	

Notes:

Qa – Quaternary Alluvium
QTp – Paso Robles Formation
gpm – Gallons per minute
Hyd. Cond. - Hydraulic conductivity
Trans. – Transmissivity
gpd/ft - Gallons per day per foot
Perf. Int. – Perforated interval
Q/s – Specific capacity
obs – Observation well data
na - Not applicable

Creston Area

Information from controlled constant rate discharge tests in the Creston area indicates two main aquifer groups with distinctive hydraulic parameters: 1) the shallow alluvium along the Huer Huero Creek, and 2) deposits of the Paso Robles Formation. Pumping test data from 15 wells were analyzed for aquifer characteristics, and driller's logs from 47 wells were analyzed to estimate specific yield. None of the pumping tests was suitable to calculate storativity. Table 4 summarizes aquifer parameters for the area.

Table 4. Aquifer Parameters, Creston Area

Well Location	Test (hours)	Flow (gpm)	Well Depth (ft)	Perf. Int. (ft)	Trans. (gpd/ft)	Q/s (gpm/ft)	Hyd. Cond. (ft/day)	Type
28S/13E-36	24	367	70	40	186,300	68	620	Qa
27S/13E-23	8	600	80	19	--	10.9	--	Qa
26S/12E-36	24	400	660	280	8,800	5.1	4.2	QTp
26S/12E-35	18	690	830	370	7,900	4.9	2.9	QTp
27S/14E-18	24	600	740	220	6,100	5.5	3.7	QTp
27S/14E-19	--	1435			--	5.4	--	QTp
27S/14E-4	5	15	360		--	0.8	--	QTp
27S/13E-8	8	100	370		--	6.7	--	QTp
27S/13E-8	24	30	145		--	0.3	--	QTp
27S/13E-9	4	30	360		--	0.3	--	QTp
27S/13E-14	8	600	360		--	10	--	QTp
27S/13E-27	12	500	700		--	3.3	--	QTp
27S/13E-28	8	440	212		--	4.4	--	QTp
27S/13E-28	4	26	440		--	3.3	--	QTp
27S/13E-29	6	110	200		--	15.7	--	QTp
27S/13E-31	4	60	292		--	15	--	QTp
27S/13E-34	4	75	235		--	1	--	QTp
Summary:								
Qa (average)		484	75	30	**10,000**	39	**400**	
QTp (average)		319	369	290	7,800	5.1	3.6	
Specific Yield: Number of wells used to calculate:					47	Average Value:		0.09

Notes:

Qa – Quaternary Alluvium
QTp – Paso Robles Formation
gpm – Gallons per minute
Hyd. Cond. - Hydraulic conductivity

Trans. - Transmissivity
gpd/ft - Gallons per day per foot
Perf. Int. - Perforated interval
Estimates are shown in bold

Q/s – Specific capacity
obs – Observation well data
na - Not applicable

Recent-age alluvium along Huer Huero Creek reaches a maximum depth of 60 feet in the Creston area. The results of a 24-hour pumping test for one well indicated a specific capacity of 68 gpm/ft at a discharge rate of 300 to 400 gpm. The alluvium, consisting predominantly of sand and gravel, is everywhere unconfined and highly permeable.

The results of 15 pumping tests for wells producing from the Paso Robles Formation were reviewed; three of the tests were sufficiently controlled to obtain transmissivity values (Table 4). The average hydraulic conductivity for Paso Robles Formation wells in the Creston area is estimated at 3.6 ft/day, with discharge rates from 300 to 400 gpm and specific capacities averaging 5 gpm/ft. Analysis of 47 well logs in the Creston area suggests an average specific yield of 0.09.

San Juan Area

No aquifer test data were available for wells in the San Juan area except for specific capacity data for wells along Camatta Canyon. Production from these wells is typically more than 1,000 gpm, with some wells capable of pumping more than 2,000 gpm. The discharge rates in Camatta Canyon are typically more than double the yields for wells along San Juan Creek, which are generally about 500 gpm. The specific capacity of deep wells along Camatta Canyon average 26 gpm/ft (from eight wells), with transmissivity values of approximately 35,000 gpd/ft and, assuming 400 feet of saturated aquifer thickness, a hydraulic conductivity of 12 ft/day (Table 5). However, along San Juan Creek where well yields are about one-half the yield found in Camatta Canyon, the hydraulic conductivity of the Paso Robles Formation is about 5 ft/day (Table 5).

Table 5. Aquifer Parameters, San Juan Area

Well Location	Test (hours)	Flow (gpm)	Well Depth (ft)	Perf. Int. (ft)	Trans. (gpd/ft)	Q/s (gpm/ft)	Hyd. Cond. (ft/day)	Type
27S/15E-10	--	1678	--	--	--	29	--	QTp
27S/15E-10	--	2297	--	--	--	49	--	QTp
27S/15E-14	--	569	--	--	--	8	--	QTp
27S/15E-35	--	1246	--	--	--	19	--	QTp
27S/15E-23	--	1190	--	--	--	28	--	QTp
27S/15E-23	--	716	--	--	--	18	--	QTp
27S/15E-35	--	1286	--	--	--	25	--	QTp
27S/15E-35	--	1050	--	--	--	32	--	QTp
Summary:								
QTp (average)		1254	**600**	**400**	**35,000**	26	**12**	
Specific Yield: Number of wells used to calculate:					5	Average Value:		0.10

Notes:

Qa – Quaternary Alluvium
QTp – Paso Robles Formation
gpm – Gallons per minute
Hyd. Cond. - Hydraulic conductivity
Trans. – Transmissivity
gpd/ft - Gallons per day per foot
Perf. Int. – Perforated interval
Estimates are shown in bold
Q/s - Specific capacity
obs – Observation well data
na - Not applicable

Estrella Area

Information from controlled constant discharge pumping tests in the Estrella area is limited to relatively deep wells completed in the Paso Robles Formation. Eleven pumping tests were analyzed for transmissivity, hydraulic conductivity, and one-day specific capacity. Logs for 20 wells were analyzed for specific yield. No storativity data are available. Table 6 presents estimated aquifer parameters for the area.

Table 6. Aquifer Parameters, Estrella Area

Well Location	Test (hours)	Flow (gpm)	Well Depth (ft)	Perf. Int. (ft)	Trans. (gpd/ft)	Q/s (gpm/ft)	Hyd. Cond. (ft/day)	Type
25S/13E-31	12	300	540	240	28,300	14.3	15.8	QTp/Qa
26S/12E-12	24	500	890	425	16,500	16.6	5.2	QTp/Qa
26S/13E-18	12	100	535	--	--	20	--	QTp/Qa
26S/13E-18	12	100	555	--	--	20	--	QTp/Qa
27S/12E-09	72	300	450	170	8,800	4.9	6.9	QTp
26S/13E-16	24	200	820	350	3,100	2.63	1.2	QTp
26S/12E-22	12	220	430	100	900	1.2	1.2	QTp
25S/11E-24	12	150	350	90	800	0.62	1.2	QTp
27S/12E-18	8	140	225	35	4,100	3	15.7	QTp
26S/12E-20	48	115	400	50	7,600	1.0	20	QTp
26S/12E-25	24	500	730	340	5,700	3.6	2.2	QTp
25S/13E-30	24	600	720	260	6,900	7.9	3.5	QTp
26S/13E-7	24	600	825	380	3,200	3	1.1	QTp
26S/13E-7	24	600	990	610	5,000	4.2	1.1	QTp
26S/13E-17	--	290	500	--	--	1.2	--	QTp
26S/13E-17	--	30	380	--	--	0.2	--	QTp
26S/13E-18	12	1000	885	--	--	10	--	QTp
26S/13E-18	5	40	400	--	--	1.3	--	QTp
26S/13E-21	5	30	360	--	--	0.9	--	QTp
26S/13E-22	12	1000	890	--	--	12.5	--	QTp
26S/13E-27	2	33	300	--	--	1.6	--	QTp
26S/13E-28	8	25	410	--	--	0.3	--	QTp
25S/12E-1	72	225	420	--	--	1.9	--	QTp
25S/12E-16	--	760	300	--	--	6	--	QTp
Summary:								
QTp/Qa (average)		250	630	330	22,400	17.7	10.5	
QTp (average)		340	540	240	4,600	3.4	5.4	
Specific Yield: Number of wells used to calculate:					20	Average Value:		

Notes:

Qa – Quaternary Alluvium
QTp – Paso Robles Formation
gpm – Gallons per minute
Hyd. Cond. - Hydraulic conductivity
Trans. – Transmissivity
gpd/ft - Gallons per day per foot
Perf. Int. – Perforated interval
Estimates are shown in bold
Q/s - Specific capacity
obs – Observation well data
na - Not applicable

Younger Alluvium (Qa). Wells penetrating younger alluvium are present along the Salinas and Estrella rivers and the length of Huer Huero Creek. The thickness of the younger alluvium varies locally, reaching a maximum estimated depth of 80 feet near the confluence of the Salinas and Estrella rivers. Short-term (Pacific Gas & Electric Co.) pumping tests in shallow alluvial wells in the area averaged about 900 gpm, with a specific capacity of 66 gpm/ft. The younger alluvium is an unconfined sand and gravel deposit with an estimated transmissivity of 20,000 gpd/ft or more.

Paso Robles Formation Below Qa (QTp/Qa). The overall potential for recharge from stream seepage beneath the younger alluvium into the Paso Robles Formation is very good. Near Paso Robles, the Paso Robles Formation deposits underlie the younger alluvium along the Salinas River channel (Figure 27). Logs of wells located near the confluence of the Salinas and Estrella rivers show a transition from basal cobbles in the younger alluvium directly into typical Paso Robles Formation sediments consisting of interbedded clay, sand, and gravel. The confining clays present beneath the Estrella River along Highway 46 in the Shandon area do not appear to extend into the Estrella area.

Paso Robles Formation (QTp). The results of 24 pumping tests for Paso Robles Formation wells were reviewed (Table 6). Specific capacity values average 3.4 gpm/ft with pumping discharge rates averaging 340 gpm. Note that the specific capacity represents one day of pumping at wells where a transmissivity value is listed. All other specific capacities are for the pump test duration listed. The average hydraulic conductivity of the Paso Robles Formation for the depth intervals tapped by wells in the Estrella area is estimated at 5.4 ft/day.

Shandon Area

Information obtained from wells in the Shandon area is limited to specific capacity data from short-term pumping tests. Table 7 summarizes the data.

Younger Alluvium (Qa). The younger alluvium along the Estrella River in the Shandon area is typically not a host to wells. The alluvium in this area is generally shallow with poor water quality because surface inflow to the Estrella River from Cholame Creek is highly mineralized. Underlying the alluvium throughout the area is 100 to 200 feet of clay, separating the unconfined alluvium from the confined to semi-confined conditions in the Paso Robles Formation.

Paso Robles Formation (QTp). The results of five pumping tests from wells penetrating the Paso Robles Formation are shown in Table 7. The results indicate an average specific capacity of 8.5 gpm/ft with pumping discharge rates of 350 to 900 gpm. The average hydraulic conductivity of the Paso Robles Formation for the depth intervals tapped by wells in the Shandon area is estimated at 6 ft/day.

Table 7. Aquifer Parameters, Shandon Area

Well Location	Test (hours)	Flow (gpm)	Well Depth (ft)	Perf. Int. (ft)	Trans. (gpd/ft)	Q/s (gpm/ft)	Hyd. Cond. (ft/day)	Type
26S/15E-20	24	945	390	340	--	11.8	--	QTp
26S/15E-33	48	800	265	165	--	4	--	QTp
26S/14E-17	--	356	330	180	--	6.1	--	QTp
26S/14E-17	--	900	607	456	--	18	--	QTp
26S/14E-8	--	364	330	100	--	2.4	--	QTp
Summary:								
QTp (average)		673	385	250	**11,000**	8.5	**6**	
Specific Yield: Number of wells used to calculate:					20	Average Value:		0.08

Notes:

Qa – Quaternary Alluvium
QTp – Paso Robles Formation
gpm – Gallons per minute
Hyd. Cond. - Hydraulic conductivity

Trans. - Transmissivity
gpd/ft - Gallons per day per foot
Perf. Int. - Perforated interval
Estimates are shown in bold

Q/s - Specific capacity
obs – Observation well data
na - Not applicable

North Gabilan and South Gabilan Areas

The Gabilan Mesa area is sparsely developed and little aquifer parameter information is available. Wells in Vineyard Canyon and Indian Valley produce at least 1,000 gallons per minute, with specific capacities of about 3 gpm/ft. However, most well records are for domestic wells that produce less than 25 gpm. Typically, the higher producing wells are more than 600 feet deep, whereas the small domestic wells usually penetrate less than 100 feet below the water table.

Adequate pumping test data for the purposes of estimating aquifer parameters are available from only two wells in the area. The test results suggest an aquifer transmissivity of about 5,600 gpd/ft and a hydraulic conductivity of 15 ft/day (Table 8).

Table 8. Aquifer Parameters, North Gabilan and South Gabilan Areas

Well Location	Test (hours)	Flow (gpm)	Well Depth (ft)	Perf. Int. (ft)	Trans. (gpd/ft)	Q/s (gpm/ft)	Hyd. Cond. (ft/day)	Type
24S/12E-27	48	250	180	73	--	2.7	--	QTp
24S/11E-4	8	700	400	27	--	2.9	--	QTp
Summary:								
QTp (average)		475	290	50	**5,600**	2.8	**15**	
Specific Yield: Number of wells used to calculate:					20	Average Value:		0.09

Notes:

Qa – Quaternary Alluvium
QTp – Paso Robles Formation
Gpm – Gallons per minute
Hyd. Cond. - Hydraulic conductivity

Trans. – Transmissivity
gpd/ft - Gallons per day per foot
Perf. Int. – Perforated interval
Estimates are shown in bold

Q/s - Specific capacity
obs – Observation well data
na - Not applicable

Bradley Area

Water wells penetrating the deeper Paso Robles Formation typically have a specific capacity of 3 to 4 gpm/ft, whereas wells pumping from the shallower alluvial sediments generally have a specific capacity of 10 to 15 gpm/ft. Transmissivity values for the deeper Paso Robles Formation aquifer are estimated to be approximately 10,000 gpd/ft. Transmissivity values for the shallow alluvial aquifer are estimated to be approximately 52,000 gpd/ft.

During the drilling of wells at Camp Roberts, wells completed in the aquifer below 500 feet were found to have higher water levels than those in the shallower zones. Based on these data, the aquifer above an elevation of 200 feet in the Camp Roberts area appears to be unconfined, but the lower aquifer below 200 feet elevation is confined.

Data are available for several deep wells in the East Garrison of Camp Roberts. One well, perforated from 238 to 358 feet below ground, produces about 75 gpm with 36 feet of drawdown. Well 24S/11E-23G is 730 feet deep and produced 210 gpm with a specific capacity of 3 gpm/ft. The results of these and other pumping tests of wells in the area indicate confined conditions in the deeper aquifers with transmissivity less than 10,000 gpd/ft (Table 9).

Table 9. Aquifer Parameters, Bradley Area

Well Location	Test (hours)	Flow (gpm)	Well Depth (ft)	Perf. Int. (ft)	Trans. (gpd/ft)	Q/s (gpm/ft)	Hyd. Cond. (ft/day)	Type
24S/11E-6	--	1000	35	17	--	62.5	--	Qa
25S/11E-5	8	140	190	50	52800	13.3	141.2	QTp/Qa
25S/11E-24	12	150	350	90	800	0.62	1.2	QTp
24S/11E-34	24	850	612	100	2805	4.5	3.8	QTp
24S/11E-12	8	700	375	223	--	2.9	--	QTp
24S/10E-3	4	2000	900	540	--	17.4	--	QTp
23S/10E-32	11	435	410	260	--	2.4	--	QTp
24S/10E-4	5	1500	1110	750	--	10.3	--	QTp
23S/10E-33	9	940	650	120	--	6.7	--	QTp
24S/11E-26	--	285	583	329	--	3	--	QTp
24S/11E-26	--	328	615	411	--	5	--	QTp
24N/11E-35	--	95	325	228	--	1	--	QTp
24S/11E-36	--	465	592	427	--	4.8	--	QTp
24S/11E-35	--	600	692	558	--	10.1	--	QTp
24S/11E-23	--	482	710	434	--	5.8	--	QTp
24S/11E-25	--	375	460	315	--	6.5	--	QTp
Summary:								
Qa		1000	35	17	**100,000**	62.5	**400**	
QTp/Qa		140	190	50	52,800	13.3	141	
QTp (average)		647	538	303	**8,000**	5.8	**4**	
Specific Yield: Number of wells used to calculate:					20	Average Value:		0.07

Notes:

Qa – Quaternary Alluvium
QTp – Paso Robles Formation
Gpm – Gallons per minute
Hyd. Cond. – Hydraulic conductivity
Trans. – Transmissivity
gpd/ft – Gallons per day per foot
Perf. Int. – Perforated interval
Estimates are shown in bold
Q/s - Specific capacity
obs – Observation well data
na - Not applicable

WATER LEVELS AND GROUNDWATER MOVEMENT

Water level data from the County database were used to prepare water level hydrographs and groundwater surface elevation contour maps. The locations of wells for which sufficient water level data are available are shown on Figure 31. Hydrographs were prepared for approximately 180 wells (not all are presented in this report).

The water level database was used to analyze time-dependent trends in water levels throughout the basin. Groundwater surface elevation data were contoured for the beginning and end of the base period (Spring 1980 and Spring 1997, respectively; Figures 32 and 33). Based on these two water level contour maps, a change in water surface elevation map was also prepared (Figure 34).

To evaluate groundwater flow patterns and boundary and basin conditions during a critically dry rainfall period, a water level contour map for Fall 1990 was prepared (Figure 35). Additionally, a water level contour map of basin conditions from 1954 was prepared to compare historic conditions with current conditions and evaluate long-term changes (Figure 36).

Limited water level data are available in the northern portion of the basin, particularly that portion of the basin in Monterey County. The Monterey County Water Resources Agency (MCWRA) generally does not monitor any wells south of San Ardo, and San Luis Obispo County does not generally monitor wells north of the County line, with a few exceptions along the Salinas River near Bradley. In order to complete the water level contours in this area of the basin, approximately 10 wells in the northern portion of the basin with one-time water level measurements were used. Because only one-time measurements were available for these wells, the water surface (and hence the volume of groundwater in storage) is held constant in this area from 1980 to 1997.

Groundwater movement is controlled by differences in water elevations or pressure. Water at higher elevation or pressure moves to areas of lower elevation or pressure. As shown on Figures 32 and 33, groundwater elevations in the Paso Robles Groundwater Basin range from approximately 1,500 feet in upland areas to less than 600 feet in the northwestern Bradley area.

Groundwater flow patterns in the basin at the beginning and end of the base period are shown on Figures 32 and 33, respectively. As shown, groundwater moves generally northwesterly from the San Juan area into Shandon and then into the Estrella area. Groundwater flow from Creston is also northerly into the Estrella area. In the northern portion of the basin, groundwater moves southwesterly from the Gabilan Mesa toward Estrella and the Salinas River in the areas near San Miguel and Bradley.

Review of the water level data shows that over the base period there is not a definitive upward or downward water level trend for the basin as a whole, with different water level trends observed in different areas of the basin. The general groundwater flow patterns have not changed significantly over the course of the hydrologic base period. As cultural development has increased along the Highway 46 corridor during the latter part of the base period, the hydraulic gradient east of Paso Robles has steepened. In this area, the historic regional flow patterns are disturbed, with groundwater now moving radially toward localized pumping centers.

Review of the Fall 1990 water level contours (Figure 35) reveals that, while some areas of the basin did display generally lower water levels in the fall of 1990 than in either spring 1980 or 1997, the general directions and patterns of groundwater movement were not significantly different. There did not appear to be any significant depressions or reversals of the regional gradients as a result of the drought conditions of the late 1980's/early 1990's.

Review of the 1954 contours suggests that conditions have not changed appreciably between 1954 and the base period. While water levels were somewhat higher in 1954 in many areas of the basin, the general magnitude of the water levels and the regional groundwater flow patterns have remained relatively consistent in the basin since 1954.

A more detailed description of the observed trends in each area of the basin is presented in the following sections:

Atascadero Subbasin

Water levels in wells in the Atascadero subbasin exhibit both rising and falling trends over the hydrologic base period (Figure 34). Hydrographs of shallow alluvial wells are relatively flat, exhibiting little seasonal fluctuation and rapid recovery from any substantial rainfall. Because the water table is recharged rapidly immediately following any substantial stream runoff, the wells show no long-term decline over the base period, as shown in well 27S/12E-21C01 (Figure 37).

Water levels in deeper Paso Robles Formation wells along the Salinas River corridor often show seasonal fluctuations up to 100 feet or more, as shown in well 28S/12E-10H04 (Figure 37). Despite these wide seasonal fluctuations, recovery back to original Spring levels is generally stable. In the eastern portion of the subbasin, east of the Salinas River, seasonal fluctuations are less pronounced in deep wells and the long term trend is generally stable or gradually increasing water levels east of Templeton (wells 27S/12E-16J01, 27S/12E-33F01, and 27S/12E-22M01; Figures 37 and 38).

Groundwater movement in the subbasin is generally to the north and northwest, parallel to flow in the Salinas River. There have been times in the past when a local pumping depression has resulted in a localized reversal of the groundwater flow direction, but that is a short-term phenomena with local impacts (Fugro, 2000).

Previous studies showed that the hydraulic gradient near the City of Atascadero ranges from as shallow as 0.0007 ft/ft during the late 1980's drought, to as high as 0.002 ft/ft during high rainfall periods (Fugro, 2000). Steeper hydraulic gradients are typical both upstream and downstream of Atascadero, with a typical gradient of 0.01 ft/ft during the Fall of a normal rainfall year.

The relationship of the Atascadero subbasin to the rest of the basin, particularly across the Rinconada fault at the northern end of the subbasin, is of considerable interest. In general, the available water level data from the County database are inconclusive as to whether the Rinconada fault significantly restricts flow in the Paso Robles Formation, as it clearly does in the central and southern portions of the subbasin. Thus, with water level data on both sides of the fault nearing equivalent elevations along the northern end of the subbasin, continuous water level contours have been drawn across the fault. However, there is evidence for restriction of groundwater flow in the existence of hot springs just east of the Santa Ysabel Ranch. The spring, located east of the Rinconada fault at an elevation of 820 feet, results in the flow of warm water with gas bubbles more than 100 feet elevation above the regional water level on the west side of the fault. Additional investigations are warranted in this area to evaluate the nature of the Rinconada fault to groundwater flow.

Creston Area

Water levels in wells in the northern part of the Creston area showed a general decline from the mid-1960's into the early 1990's. From the early 1990's to the present, water levels in most wells in the area have increased markedly, resulting in more than 50 feet of water level rise over the hydrologic base period. Examples of this trend are shown in wells 27S/13E-22Q01 and 27S/13E-27P02 (Figure 39) and 27S/13E-28F01 (Figure 40).

Near the town of Creston, water levels have remained relatively stable for many years. Several wells, particularly along the course of the Huer Huero Creek south of town, have experienced flowing conditions and historic high water levels in recent years (28S/13E-13D01, Figure 40).

Groundwater and surface water flow northward out of the Creston area into the Estrella area primarily along the Huer Huero Creek drainage, and through northwest dipping aquifer production zones. Groundwater flow is generally to the northwest at a regional hydraulic gradient of approximately 0.009 ft/ft.

San Juan Area

Water levels in wells in the San Juan area have shown both rising and falling conditions over the hydrologic base period. Wells exhibiting both the greatest decline and the greatest water level increases can be found in Shedd Creek and Camatta Canyon, indicating the effects of localized heavy agricultural pumping as well as the impacts of significant stream recharge in both canyons. These trends are represented by the hydrograph for well 27S/14E-25A01 in Shedd Creek (Figure 41), which shows a long period of declining water levels from the early 1960's through the mid 1990's, followed by a marked increase to record high levels over the past five years. However, most of the wells in the northern part of Shedd Creek and along Camatta Canyon have not recovered in similar fashion, as shown by the hydrograph of well 27S/14E-11R01 (Figure 41). In the eastern part of the San Juan area, along San Juan Creek, water levels have declined slightly in the southern reach of the creek (well 28S/16E-15D01, Figure 42), and risen slightly along the northern reach (well 27S/16E-07P01, Figure 42).

Groundwater flow in the San Juan area is generally to the north-northwest. The hydraulic gradient steepens at the higher elevations, ranging from 0.006 ft/ft along the border with the Shandon area to a relatively steep 0.01 ft/ft along upper San Juan Creek.

Estrella Area

Water level hydrographs of wells in the Estrella area are dominated by an overall decline in water levels centered along the Highway 46 corridor east of Paso Robles, in the area where Dry Creek flows northwesterly into Paso Robles. Dry Creek flows through an area where well yields are much lower than those generally found in the central part of the basin. This is likely attributable to the presence of older, less permeable sediments associated with uplift along the Creston anticlinorium. These less permeable sediments are also at a greater distance to the major recharge sources of the Huer Huero Creek and the Estrella River. The area of greatest water level decline follows a southeast trend between Huer Huero Creek and the Estrella River, along the same trend as the Creston anticlinorium. Examples of the historically declining water levels are shown in the hydrographs for wells 26S/13E-34B01, -28L03, and -30B02 (Figure 43), where water levels have declined as much as 60 feet during the 1981 to 1997 hydrologic base period. Elsewhere in the area, hydrographs show water levels rising slightly near the old town site of Estrella and along the Salinas River corridor, and declining slightly near San Miguel.

Groundwater flows into the Estrella area from the north and northeast (from the Gabilan Mesa), from the east (from Shandon), and from the south (from the Atascadero subbasin and along the Huer Huero Creek drainage out of the Creston area). The greatest change in hydraulic gradient in the basin during the 1981-1997 hydrologic base period has taken place in the Estrella area. In Spring 1980, flow into the area from adjacent areas was relatively uniform, at approximately 0.003 ft/ft. As of Spring 1997, the hydraulic gradient into the area increased to 0.01 ft/ft. In the center of the Estrella area, the gradient is very flat, with a slight pumping depression over the northeast part of the City of Paso Robles. Surface and subsurface outflow from the area generally follows the Salinas drainage into the Bradley area.

Shandon Area

In general, water levels in the Shandon area have been relatively stable over the past 40 years, although large (30-50 feet) seasonal fluctuations have been observed. Typical water level patterns for the Shandon area are seen in hydrographs for wells 26S/15E-18J01, -21G02, -28Q01, and -20B03 (Figures 44 and 45).

Groundwater flow in the Shandon area moves in a south-southwest direction from the Cholame Hills, west from Shandon, and northwest from the San Juan area. These flows come together in the Estrella River and continue westward into the Estrella area. In the northern part of the area, the hydraulic gradient out of the Cholame Hills is approximately 0.03 ft/ft. The gradient flattens along the Estrella River, where the regional groundwater flow has an approximate gradient of 0.0025 ft/ft.

North Gabilan and South Gabilan Areas

Rising water, where groundwater rises to the surface and flows or ponds on the ground, occurs in both Vineyard Canyon and Indian Valley, upstream of the San Miguel Dome. The rising water surfaces at an elevation of 885 feet in the creek bed in Vineyard Canyon. In Indian Valley, the alluvium is thicker and the canyon is wider than in Vineyard Canyon, so the alluvial deposits transmit and store groundwater without surfacing except during the wettest times of the year. Furthermore, the elevation of the streambed is much lower than in Vineyard Canyon (roughly 700 feet elevation), which increases the gradient and the quantity of groundwater outflow.

One water level hydrograph is available for the Gabilan Mesa area. Well 25S/13E-11E01, near Hog Canyon, shows a steady increase in water levels since the late 1950's (Figure 46).

Groundwater levels in the Gabilan Mesa area generally rise toward the east with the steepest gradients occurring in the southern portion of the area. The groundwater level gradient is flattest along Vineyard Canyon, where there is less than 50 foot elevation change over a distance of approximately 5 miles (less than 0.002 ft/ft). In most of the canyons, the depth to groundwater increases as the ground surface rises. In Ranchita and Vineyard canyons and the adjacent hills, groundwater levels in the Paso Robles Formation are deeper than 300 feet.

Bradley Area

The confluence of the Nacimiento and San Antonio rivers with the Salinas River has a significant impact on groundwater levels in the Bradley area. Groundwater levels in the alluvium reflect this influence with stable historic water levels (Figure 47). Groundwater levels in the deeper Paso Robles Formation underlying the alluvium, however, might be expected to exhibit seasonal fluctuations due to the relatively lower permeability of the aquifers and delayed recharge. The limited data on deep water levels suggest a long-term stability (Figure 47).

The principal groundwater flow direction in Hames Valley is to the southeast, parallel to the axis of the syncline that trends down valley. Irrigation in the valley began in the mid 1970's, resulting in declines of up to 100 feet in the regional water table. These declines have settled over the past 15 years, resulting in stable water levels in the valley.

CHAPTER 4 – WATER QUALITY

GENERAL

A detailed investigation and discussion of the water quality of the Paso Robles Groundwater Basin warrants a focused study that cannot be accomplished within the context of a basin analysis such as this study. However, a general reporting of the various water quality problems in the basin and identification of major water quality trends are an important component of the overall study.

The efforts of this chapter are to describe the water quality of the Paso Robles Groundwater Basin, which for purposes of this study includes the general minerals and selected minor and trace constituents. The scope of the study did not include documentation or investigation of contamination problems from organic chemicals, although it is recognized that these contamination problems are important factors in understanding the useable groundwater supply.

Given the relatively large size of the groundwater basin, the reporting and description of water quality is grouped by basin area (introduced earlier). For each basin area, a description of current groundwater quality is provided and compared with the quality of surface water inflow, drinking water standards, and agricultural irrigation guidelines. Historical water quality data at wells within each area are reviewed to identify any trends and a basin profile for fluoride, arsenic, mercury, selenium, and radioactivity is provided.

Historical water quality data were obtained from several sources, including:

- U.S. Environmental Protection Agency (STORET database)
- California Department of Health Services (GeoTracker database)
- California Department of Water Resources, (DWR 1979; 1981)
- County of San Luis Obispo, electronic database and hardcopy files
- California Regional Water Quality Control Board (CRI, 1993)
- City of Atascadero, Atascadero Mutual Water Company, Templeton Community Services District, and City of Paso Robles

A data review using the above sources was performed to identify those wells with the longest historical data records, establish major trends, and identify target well locations and/or construction criteria for the field sampling program.

Historical data were reviewed and compared with recent data and data collected during this study. Recent drinking water quality data were obtained from 74 locations, including 49 samples collected during this study and 25 laboratory reports from samples collected by well owners within the last three years. Of the 74 recent water quality analyses, the water samples are represented by 66 wells, 5 springs, and 3 surface water locations. Samples were collected from wells tapping stream underflow, shallow aquifers, deep aquifers, and geothermal zones. Representative sample locations were selected for each area in the basin (Figure 48). Selection of sampling locations was based on satisfying as many of the following criteria as possible:

1. Broad areal coverage
2. Wells with historical data, or in close proximity to wells with similar construction with historical data, and
3. Shallow and deep wells in areas where vertical delineation is warranted.

Water quality samples collected from wells during the study were drawn from taps as close to the well as possible, usually at the wellhead. Field temperature and pH were measured for water samples collected from active wells and surface waters. Field pH at wells measured during sampling averaged less than two percent difference from the laboratory reported pH (laboratory pH values are reported here). Well and spring sample locations are reported using the State well identification system (wells without assigned State well numbers are identified with township, range, and section only; spring samples are followed by a parenthetical "S", per convention).

All samples collected during this investigation were analyzed for:

- Carbonate
- Bicarbonate
- Total alkalinity (as CaCO3)
- Chloride
- Electrical conductance (EC)
- Anionic surfactants (MBAS)
- Nitrate (as N)
- Nitrate (as NO3)
- pH
- Sulfate
- Total dissolved solids (TDS)
- Boron
- Calcium
- Hardness
- Sodium adsorption ratio (SAR)
- Copper
- Iron
- Potassium
- Magnesium
- Manganese
- Sodium
- Zinc

The State-certified analytical laboratory performing water quality analyses for this study provided reports in two forms: the standard printed report format, and an electronic version in a spreadsheet format. The standard report rounded the results to two significant figures, while the electronic report, in some cases, included more than two significant figures. Tables and figures prepared for this report utilized the electronic format of the results and may not exactly match the printed reports in Appendix A.

GENERAL DISCUSSION OF WATER QUALITY ISSUES

The report is organized according to the basin areas described earlier. These areas include:

- Atascadero subbasin
- Creston
- San Juan
- Estrella
- Shandon
- Gabilan (North and South combined)
- Bradley

For each area, a discussion is presented of general mineral quality, drinking water suitability, agricultural irrigation suitability, and water quality trends. To allow for a quick review of the water quality of the basin, maps are included with the report showing sample locations (Figure 48), water type (Figure 49), total dissolved solids (Figure 50), sodium concentration (Figure 51), chloride concentration (Figure 52), sulfate concentration (Figure 53), nitrate concentration (Figure 54), total hardness as calcium carbonate (Figure 55), and boron concentration (Figure 56).

General Minerals

Water percolating through the vadose zone reacts with the soil and aquifer sediments, resulting in changing concentrations of dissolved constituents. Dissolved minerals occur mainly in ionic or electrically charged forms. The major ions in groundwater are sodium (Na^{+}), magnesium (Mg^{+2}), calcium (Ca^{+2}), potassium (K^{+}), chloride (Cl^{-}), bicarbonate (HCO3), and sulfate ($SO4^{-2}$). Together, these major ions typically comprise more than 90% of the total dissolved solids of groundwater. The relative dominance of the major ions in water defines the character, or type of water, and is useful in evaluating whether water from separate areas or aquifers may have similar or different sources of origin.

Various systems for graphical presentation and for classifying water type have been developed. Most of these systems (i.e. bar graphs, pie diagrams, Stiff diagrams, and trilinear diagrams) compare the major dissolved ions in terms of milliequivalents per liter (meq/L), rather than the typical reporting standard of milligrams per liter (mg/L). Milliequivalent units are useful because they account for the mass and charge of the ions, which is important in water treatment and agricultural irrigation issues.

To determine the water type, concentrations of the three major cations and the three major anions were converted to milliequivalents. Any cation or anion with at least one third or more of the respective milliequivalent totals becomes part of the water type name. By convention, cations are named first. For example, a water sample with 24% sodium, 30% magnesium, and 46% calcium cations, and 24% chloride, 13% sulfate, and 63% bicarbonate anions would be called a calcium-bicarbonate water. A water sample with 42% sodium, 24% magnesium, and 35% calcium cations, and 23% chloride, 34% sulfate, and 43% bicarbonate anions would be called a sodium-calcium-bicarbonate-sulfate water.

The dominant water type in the Paso Robles Groundwater Basin is calcium-bicarbonate water. Groundwater recharge to the basin from southern drainages, draining the Cretaceous-age granitic rocks and sedimentary beds of the La Panza Range, is typically a calcium-bicarbonate water, which is the predominant water type of the underflow of the Salinas River and Huer Huero, Navajo, Camatta, and Shell creeks. Calcium-bicarbonate waters are characteristic of the Atascadero subbasin, the Creston area, and Camatta Canyon in the San Juan area.

The other principal water type found in the basin is a sodium-bicarbonate water. Sodium-bicarbonate waters are widespread throughout the central part of the basin, and are characteristic of the Estrella and Shandon areas.

Sodium-chloride waters enter the basin from the Cholame Valley and from the Temblor Range east of San Juan Creek. Water entering the basin from the San Juan Creek watershed upstream of Navajo Creek is typically a calcium-sulfate type. To the north, magnesium bicarbonate waters are found in Vineyard, Ranchita, and Hog canyons, and in San Miguel. Groundwater samples in the Bradley area show a variety of water types, as mixtures of calcium and sodium with sulfate, bicarbonate, and chloride. Predominantly calcium-bicarbonate and calcium-magnesium-bicarbonate waters enter the Bradley area from surface inflows on the Salinas, Nacimiento, and San Antonio rivers.

Drinking Water

Drinking water standards are compared to a Maximum Contaminant Level (MCL) established by the California Department of Health Services, Code of Regulations, Title 22, Sections 64435 and 64473. Primary drinking water standards are established for chemical constituents with a potential toxic effect to humans when concentrations are above the MCL. Secondary drinking water standards are established for certain chemical constituents that may cause undesirable water characteristics, but that are not considered threats to human health. Analytes that have no MCL established can be present in drinking water at any level. Table 10 presents Primary and Secondary Drinking Water Standards, established by the Department of Health Services.

Table 10. Drinking Water Standards

Primary Drinking Water Standards Primary standards analytes have potential toxic effects when above the MCL					
Analyte	**MCL**	**Units**	**Analyte**	**MCL**	**Units**
Aluminum	1	mg/L	Nickel	0.1	mg/L
Antimony	0.006	mg/L	Selenium	0.05	mg/L
Arsenic	0.05	mg/L	Silver	0.05	mg/L
Barium	1	mg/L	Thallium	0.002	mg/L
Beryllium	0.004	mg/L	Zinc	5	mg/L
Cadmium	0.005	mg/L	Cyanide	0.2	mg/L
Chromium	0.05	mg/L	Fluoride	2	mg/L
Lead	0.05	mg/L	Nitrate as NO3	45	mg/L
Mercury	0.002	mg/L	Nitrite	1	mg/L

Table 10. Drinking Water Standards (Continued)

Secondary Drinking Water Standards
These aesthetic standards analytes may contribute to undesirable characteristics when over MCL's, but are not threats to human health.

Analyte	MCL	Units	Analyte	MI	Units
Copper	1	mg/L	Color	15	Units
Iron	0.3	mg/L	Odor	3	Units
Manganese	0.05	mg/L	Turbidity	5	Units
MBAS	0.5	mg/L			

Analyte	Recommended MCL	Upper Limit	Short Term	Units
Chloride	250	500	600	mg/L
Sulfate	250	500	600	mg/L
Electrical Conductance	900	1600	2200	umhos/cm
Total Dissolved Solids	500	1000	1500	mg/L

Units are in mg/L = milligrams per liter = ppm = parts per million.

An MCL is established for nine of the constituents analyzed during this study, including one (nitrate) as a primary standard and eight (TDS, EC, chloride, sulfate, iron, manganese, copper, and zinc) as secondary standards. Water quality tests at public supply wells in the basin are available that include many other constituents. Those public system water quality data were reviewed to determine whether some of the other naturally present constituents of local concern to human heath, including fluoride, arsenic, mercury, selenium, and radioactivity, are present in basin waters. A review of the numerous trace metals or organic compounds related to fuels, pesticides, or other commercial products was not part of this study.

Of the 74 water sources analyzed, 23 sample results exceeded at least one MCL. A description of these results and a table showing those constituents exceeding an MCL is described in the sections for each basin area. Laboratory results for the 49 sources sampled in this study are presented in Appendix A.

The most common constituent exceeding an MCL was total dissolved solids, with 14 sources above the standard. Nitrate was exceeded in four samples. The Atascadero subbasin has the fewest number of sources with one or more constituents higher than the drinking water standards (0 out of 12 sources), while Bradley had the highest (5 out of 6 sources).

No fluoride, arsenic, selenium, or uranium radioactivity exceeded the MCL in the samples reviewed from public water purveyor wells across the basin (including current and historical data). One water sample from 1990 in the San Miguel area contained mercury above the MCL, but there have been no mercury detections at that well since. Gross alpha radiation exceeded the MCL in several water samples from the San Miguel and Bradley areas.

Agricultural Irrigation

Irrigation-induced soil salinity is a constant threat to the sustainability of irrigated agriculture. The physical situation and processes that can lead to excess soil salts can be explained as:

1. All irrigation water contains salts; therefore, irrigation continually applies salts to the soil.
2. Crops basically extract pure water, leaving the salts behind.
3. Without action to remove them, salts will build up in the soil to the point that they become a problem.

Salts can cause several types of problems for irrigated agriculture, including:

- **Reduced Crop Yields.** Dissolved salts in the root zone create osmotic forces that are additive to the soil matrix forces and tend to reduce water availability. In addition, excess salts may interfere with chemical reactions and reduce fertilizer uptake. The potential for irrigation water to lead to reduced crop yields is indicated by the electrical conductivity (EC) of the water (expressed as deciSiemens per meter (dS/m) or millimhos per centimeter (mmhos/cm)). The higher the EC, the more likely there will be a problem.
- **Soil Structure Problems.** The potential for soil structure problems depends on the type of soil and the type and balance of salts in the soil. A combination of an expansive clay soil, high levels of sodium salts in relation to calcium and magnesium in the soil, and low-salt water can create soil structure problems. The result is very low infiltration rates and a massive blocky soil that restricts root zone expansion. The common indicator for this type of problem is the sodium absorption ratio (SAR).
- **General Plant Toxicities.** The best known salts with toxic effects are boron and sodium. However, high chloride levels can produce leaf burn if used with sprinklers.

Agricultural Water Quality Thresholds. The most important standards used for judging the suitability of water for irrigation are shown on Table 11.

It is clear from Table 11 that potential problems are related not only to the chemistry of the water but also the crop and means of irrigation. Much research has been done to establish salinity levels where yields can be expected to be affected for various crops. The common measure is termed the "threshold salinity" and is a measure of the salinity of the saturated soil extract (the symbol for which is ECe). Research has also developed estimates of the rate at which yields are impacted if soil salinity rises above the threshold. The relationship between relative yield and soil salinity may be expressed as: Y = 100 - B (ECe - A), where Y = relative yield (%), A = threshold salinity value (dS/m), and B = rate of yield decline per increase in soil salinity (equivalent to the slope of line).

Table 11. Standards for Judging the Suitability of Water for Irrigation

Parameter	Degree of Restriction on Use		
	None	Slight to Moderate	Severe
Salinity (indicated by EC in dS/m)			
< 0.7	--	Suitable for use on all crops	--
0.7 - 3.0	Used on moderately tolerant crops	Used on moderately sensitive crops	Used on sensitive crops
3.0 - 6.0	Used on salt tolerant crops	Used on moderately tolerant or moderately sensitive crops	Used on sensitive or moderately sensitive crops
> 6.0	--	Use only on salt-tolerant crops	--
Water Infiltration/Soil Structure (indicated by a combination of SAR and EC)			
SAR	--	EC of irrigation water	--
0 - 3	> 0.7	0.7 - 0.2	< 0.2
3 - 6	> 1.2	1.2 - 0.3	< 0.3
6 - 12	> 1.9	1.0 - 0.5	< 0.5
12 - 20	> 2.9	2.0 - 1.3	< 1.3
20 - 40	> 5.0	5.0 - 2.9	< 2.9
Specific Toxicities			
Sodium Concentration (ppm) for trees/vines			
Surface irrigation	<70	70 - 200	> 200
Sprinkler irrigation	<70	> 70	--
Chloride Concentration (ppm) for trees/vines			
Surface irrigation	< 140	140-350	> 350
Sprinkler irrigation	< 100	> 100	--
Boron Concentration (ppm) for all crops			
< .5	--	Suitable for all crops	--
0.5 - .75	Most vegetable and field crops	--	Tree and vine crops
.75 - 1.0	Many vegetable and field crops	Sweet potato, wheat, bean, strawberry, artichoke	Tree and vines
1.0 - 2.0	Tomato, alfalfa, sugar beets, and celery	Most vegetable and field crops	Trees and vines, many field and vegetable crops
2.0 - 6.0	Sorghum, cotton, and asparagus	Tomato, alfalfa, sugar beet and vetch	Most other crops

Source: Ayers and Westcott (1985).

Table 12 lists the crop groups for acreages tracked throughout this study, along with their threshold salinities, rate of yield decline, and qualitative rating for salt sensitivity.

Table 12. Threshold Salinity, Yield Decline, and Salt Sensitivity

Crop Group	Threshold Salinity (EC of the saturated soil extract; dS/m)	Rate of Yield Decline (slope)*	Salt Sensitivity Rating
Alfalfa	2.0	7.3	Moderately Sensitive
Deciduous Trees (almond)	1.5	19.0	Sensitive
Field Crops	3.2	12.3	Sensitive to Tolerant
Grains	7.0	6.1	Tolerant
Pasture	3.2	8.9	Moderately Sensitive to Moderately Tolerant
Truck Crops	1.1	12.9	Sensitive
Vineyards	1.5	9.6	Moderately Sensitive

Sources: Ayers (1977), Mass (1996), and Hanson et al. (1999)
Notes: Slope - % relative yield decline per 1 dS/m increase in ECe above threshold salinity value.
Field Crops - average for sugar beet, corn, beans
Grain - average for barley and wheat
Pasture - average for clover, Harding grass, orchard grass, rye grass, vetch
Truck Crops - average for carrot and onion

Comments on specific samples with respect to irrigation suitability are given in each of the basin area discussions. Overall, agricultural irrigation use of basin waters carries no restrictions in 37 of the 74 water samples reviewed. A slight to moderate restriction for irrigation of trees and vines is indicated for 24 of the samples due to potential sodium or chloride ion toxicity. Thirteen samples carry a severe caution for irrigation of trees and vines, including two samples not advised for most other crops due to potential sodium, chloride, or boron toxicity. The Atascadero subbasin had the fewest restrictions for agricultural use (8 out of 12 sources), while the Estrella area had the most (5 out of 17 sources).

Controlling Soil Salinity. Controlling salinity requires maintaining a salt balance in the root zone. That is, the amount of salts being added to the root zone each year must be matched by an equal amount removed. This is done by applying an amount of water in excess of crop needs in order to intentionally create deep percolation. This is termed "leaching" and the amount of water to be applied is indicated by the required "leaching ratio." (Note that this balance can be maintained at any level of soil salinity. Thus, it is assumed that the background soil salinity is acceptable. If the background salinity is not acceptable then reclamation leaching must be applied as well as the annual maintenance leaching.)

There are several equations that have been developed for determining the required leaching ratio. One of the most widely used is:

$$LR = ECi / ((5 * ECe) - ECi)$$

where: LR = required leaching ratio to maintain a salt balance as a decimal

Eci = electrical conductivity of the irrigation water (a measure of salinity) (deciSiemens/meter)

Ece = electrical conductivity of the saturated soil extract (a measure of the salinity of the soil water solution in the rootzone of the crop) (deciSiemens/meter)

Assuming an ECi of 0.75 dS/m and the threshold salinities identified in Table 12, required leaching ratios for the various crop groups are calculated and listed in Table 13.

Table 13. Assumed Threshold Salinities and Required Leaching Ratios

Crop Group	Assumed Threshold Salinity - ECe (dS/m)	Leaching Ratio for Irrigation Water at ECi = .75
Alfalfa	2.0	8%
Deciduous Trees	1.5	11%
Field	3.2	5%
Grains	7.0	2%
Pasture	3.2	5%
Truck (vegetables	2.0	8%
Vineyard	1.1	16%

Leaching requirements can be mostly ignored for calculating required pumping demands (see later section on Agricultural Groundwater Pumpage in Chapter 5). Most growers do not consider leaching as a distinct irrigation requirement (the exception is for vineyards in the eastern part of the basin.) However, as an indication of when water quality might pose a problem for agricultural application, the threshold EC (when leaching ration requirements reach 20%) was calculated for each crop group (Table 14).

Table 14. Estimated Electrical Conductivity of Irrigation Water When the Leaching Ratio Reaches 20%

Crop Group	Assumed Threshold Salinity - ECe (dS/m)	EC of Irrigation Water when Leaching Ratio = 20%
Alfalfa	2.0	1.67
Deciduous Trees	1.5	1.25
Field	3.2	2.67
Grains	7.0	5.83
Pasture	3.2	2.67
Truck (vegetables	2.0	1.67
Vineyard	1.1	.92

For reference, there is a good correlation between electrical conductivity and total dissolved solids at TDS values less than 2,000 mg/L. As shown in Figure 57, the correlation of EC = 0.62 * TDS for water in the Paso Robles Groundwater Basin has a linear regression correlation coefficient (R_2) of 97%.

Low Volume Irrigation. Low volume irrigation typically involves the use of drip or micro-sprinklers, and is common in San Luis Obispo County. Some of the salinity problems discussed above can be mitigated through the use of low-volume irrigation. These types of irrigation systems, however, may be adversely affected by water quality.

One of the most common low-volume irrigation problems is emitter clogging due to lime (calcium carbonate) or iron precipitation. For water pH values over 7.5, and a bicarbonate concentration over 2 milliequivalents (100 mg/L), lime may precipitate and plug the system. To control lime, acidification is commonly used to lower the pH value.

Iron precipitation is possible over a wide pH range (4 - 8.5) and may cause problems when concentrations are at 0.3 mg/L or more (this is also the MCL for iron in drinking water, as iron precipitate may also be a nuisance when deposited on fixtures or laundry). To control iron, aeration and subsequent precipitation in reservoirs is common, although other chemical and filtration methods are also used.

Water Quality Trends

Trends in water quality are evaluated on the basis of changes in water quality over time. Previous water quality studies of the basin include DWR (1979), DWR (1981), and CRI (1993).

The DWR (1979) report contains an extensive set of water quality data. Regarding water quality trends, the following description is provided (DWR, 1979, pg. 35):

> *The groundwater quality for the Paso Robles Basin…was examined to determine whether a clear trend of water quality degradation could be found in any well or area. Few long records were available, but those that are available generally did not show any disconcerting clear trends.*

The report described one well near San Miguel with a possible degrading water quality trend, with two other wells showing improving water quality trends.

The DWR (1981) report included an extensive set of water quality samples, mostly collected between 1978 and 1981. The study examined the effects of nonpoint source discharges from unregulated mineral wells and springs. No analyses of water quality trends over time were included in the report; rather, the study calculated the salt-loading of Salinas River underflow attributable to mineralized flows from wells and springs and to the City of Paso Robles wastewater treatment plant discharges. The 1981 report could be thought of as evaluating a trend in terms of changes in water quality over distance (downstream), rather than temporal trends. The study also attempted to correlate certain water quality characteristics with the presence of blue clayey sediments. The only mineral with any potential association to blue clayey sediments was reported to be sodium.

The CRI (1993) report is the most comprehensive water quality report on the basin to date, and specifically looked for major water quality trends over time. The report summarized its findings as follows:

> *The water quality history in each township, and for individual wells were analyzed to search for signs of progressive changes in Basin chemistry, but no clear trends emerge. Statistically weak increases in chloride, nitrate and boron appear in certain areas. There is no clear evidence that there is increasing degradation of Basin waters.* (Page II)
>
> *The major public suppliers have been keeping detailed records of water quality for decades. A visual inspection of the water quality variations for St. Lawrence Terrace, City of Paso Robles, Templeton Community Services District, and Atascadero Mutual Water Company show no long term trends*. (Page 6-19)

In this current study, distinctions were made if a sufficient trend were established that might result in a change in the potential use of water within 50 years, if the trend were to continue. These trends were defined as and will be referred to here as "major water quality trends." With the possible exception of a single well in San Miguel, the prior investigations did not identify any major water quality trends in the basin.

The results of these efforts identified several water quality deterioration trends in the basin, six of which could be classified as major trends:

1. Increasing concentration of total dissolved solids and chloride in shallow Paso Robles Formation deposits in the central portion of the Atascadero subbasin along the Salinas River;

2. Increasing chloride concentrations in the deep, historically artesian aquifer in the area northeast of Creston;

3. Increasing total dissolved solids and chloride concentrations near San Miguel;

4. Increasing nitrate concentrations in the area north of Highway 46 between the Salinas River and Huer Huero Creek;

5. Increasing nitrate levels in the area south of San Miguel; and,

6. Increasing TDS and chloride concentrations in deeper portions of the aquifer near the confluence of the Salinas and Nacimiento rivers.

Several other minor trends less critical to potential water quality uses were identified, including some trends of improving water quality. Details of water quality trends are discussed below in the discussions of each basin area. Based on the review of the water quality data, three parameters (TDS, chloride, and nitrate) were selected for detailed discussions. TDS provides a good representation of water quality in terms of mineralization, while chloride and nitrates are ions that are highly soluble, providing good indicators of water quality changes due to anthropogenic factors.

GROUNDWATER QUALITY OF THE PASO ROBLES GROUNDWATER BASIN

Atascadero Subbasin

General Minerals. The main source of recharge to the Atascadero subbasin is the percolation of streamflow from the Salinas River, which drains the Cretaceous-age granitic rocks and sedimentary beds of the northwestern La Panza Range. This recharge, typically a calcium and magnesium bicarbonate water, has the greatest influence on water quality in the subbasin. An example of Salinas River water quality is shown in Table 15.

Table 15. Surface Water Quality - Atascadero Subbasin, Salinas River at Highway 58

Water Type	Date	Flow (cfs)	Units	Ca	Mg	Na	K	HCO3	SO4	Cl	TDS
Ca HCO3-SO4	4/10/1962	2000	mg/L	18	7	7.7	2.4	68	32	6	172
			Meq/l	0.9	0.58	0.33	0.06	1.11	0.67	0.17	
Mg-Ca HCO3	2/14/1954	150	mg/L	20	16	8	1.9	98	29	7	211
			Meq/l	1	1.32	0.35	0.05	1.61	0.6	0.2	

Significant inflow from Santa Margarita, Atascadero, and Paso Robles creeks also provides recharge to the subbasin. Santa Margarita Creek (including Trout, Yerba Buena, and upper Santa Margarita creeks) water quality is typically magnesium-calcium-bicarbonate, whereas Atascadero and Paso Robles creek waters are typically calcium-bicarbonate.

A summary of selected water quality results for the Atascadero subbasin is presented in Table 16. A graphical representation of the water quality in the subbasin is shown in Figure 58.

Nine of the twelve samples from the subbasin are predominantly calcium-bicarbonate waters (some with secondary magnesium and/or sulfate), with TDS concentrations between 330 and 720 mg/L and a mean TDS of 500 mg/L. Two of the eleven wells sampled have sodium-dominant cations. One of these, a slightly higher mineralized sodium-calcium-bicarbonate-sulfate water at sample location 27S/12E-22N (approximately two miles northeast of Templeton) suggests that water quality in the hills to the east of the Salinas River may be influenced by local sources of recharge as well as the river. A review of historical water quality data (DWR, 1979) shows similar sodium-calcium-bicarbonate-sulfate water east of Templeton (27S/12E-22M01) in the mid-1960s. East of Atascadero, however, water from a well in the hills (27S/12E-34P01) was a calcium-bicarbonate type, similar to the typical subbasin quality.

A second sodium-bicarbonate water sample came from the Santa Ysabel hot spring (27S/12E-16G01[S]). Water from this spring does not actually represent basin water, but was included because of the possible influence that geothermal waters may have on basin groundwater. The spring water is almost identical in composition to the water from well 27S/12E-09N03, a 650-foot deep well tapping the Monterey Formation along the Salinas River near Highway 46 West. The sodium ion in these geothermal waters is greater than 80% (milliequivalent) of the major cations and, together with higher mineralization, would require a comparatively small ratio of mixing to change the character of subbasin water from calcium to sodium-bicarbonate. It is possible that this mixing may contribute to the sodium dominant groundwater basin water in the hills east of Templeton.

Table 16. Water Quality
Atascadero Subbasin

Sample Description	Water Type	Sample Date	Well Depth	TDS[1] mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 + CO3 mg/l	Cl[1] mg/l	SO4[1] mg/l	NO_3[2] mg/l	Fe[1] mg/l	Mn[1] mg/l	B mg/l	SAR	EC[1] dS/m	PH units
27S/12E-16G01 (S)	Na HCO3	10/17/2001	spring	830	3.7	1.4	302	2.4	461	141	115	< 0.4	< 0.1	< 0.03	1.47	34.7	1.36	8.7
27S/12E-17R02	Ca - HCO3	9/21/1998	245	720	143	51	49	<1	413	126	136	15	< 0.1	< 0.03	NR	0.9	1.27	7.1
27S/12E-22N	Na Ca - HCO3 SO4	10/17/2001		790	91	37	123	3	350	107	217	30	< 0.1	< 0.03	0.36	2.8	1.25	7.5
27S/12E-29H03	Ca Mg - HCO3 SO4	2/14/2000	65	490	86	38	34	1.3	293	42	149	< 2	< 0.1	< 0.02	NR	0.8	0.81	7.4
27S/12E-9M03	Ca Mg - HCO3 SO4	9/12/2000	210	500	91	37	40	< 1	279	46	145	< 1	< 0.1	< 0.02	NR	0.9	0.83	8.0
28S/12E-10A03	Ca HCO3	10/5/1999	500	540	147	11	36	1	310	57	125	12	< 0.1	< 0.02	NR	0.8	0.93	7.2
28S/12E-11K02	Ca Mg - HCO3	2/22/2000	600	480	87	41	36	3	364	58	72	< 2	< 0.1	< 0.02	NR	0.8	0.86	7.0
28S/12E-11N07	Ca Mg -HCO3	4/11/2000	100	540	80	40	46	3	304	57	112	5.0	< 0.1	< 0.02	NR	1.0	0.83	7.0
28S/12E-4J02	Ca HCO3	2/7/2000	86	450	91	24	38	1.4	284	45	102	9.0	< 0.1	< 0.02	NR	0.9	0.76	7.3
28S/12E-14K01	Na Ca - HCO3 Cl	2/7/2000	105	820	120	36	143	1.9	378	208	123	<2.0	<0.1	<0.02	NR	2.9	1.43	7.1
28S/13E-31D	Ca HCO3	6/13/2001	330	430	90	29	28	1.2	320	29	88	4.0	< 0.1	< 0.02	NR	0.7	0.69	7.0
28S/13E-31F02	Ca HCO3	10/5/1999	310	330	66	19	29	2	227	19	83	< 2	< 0.1	< 0.02	NR	0.8	0.62	7.4
Maximum Contaminant Level Concentrations				1000	--	--	--	--	--	500	500	45	0.3	0.05	--	--	1.60	--

MCL = Maximum Contaminant Level of Primary and Secondary analytes
Shaded areas represent concentrations exceeding MCL (No MCL's were exceeded in this table)
mg/l = milligrams per liter
dS/m = deciSiemens per meter
[1] Secondary drinking water standards analyte
[2] Primary drinking water standards analyte

The Monterey Formation groundwater does not appear to be a significant source of sulfate, however, based on the analytical data (SO_4 is less than 20% milliequivalent of the major anions). The Santa Ysabel hot spring is also called Sulphur Spring, but this probably refers to the sulfide presence that is noticeable by odor at very low concentrations. The local Monterey Formation groundwater is also a potential source of boron (1.47 mg/L at the Santa Ysabel hot spring).

The third well with sodium dominant cations is a sodium-calcium-bicarbonate-chloride water. This is a shallow well in the Salinas River valley near Pine Mountain (28S/12E-14K01). Historically (in the 1950's, 60's, and 70's), this well had a calcium-bicarbonate character. The shift in water type has been accompanied by a trend of increasing salinity (see Water Quality Trends section below).

Drinking Water. Water quality data were obtained for 11 wells and one spring in the subbasin. Laboratory reports for samples from the 12 sources indicated that no concentrations of analytes exceeded the MCL. TDS concentrations ranged from a low of 330 mg/L to a high of 820 mg/L. The average TDS concentration in the 12 samples is 580 mg/L.

Agricultural Irrigation. The primary water quality constituents of interest for evaluating agricultural irrigation uses are the sodium adsorption ratio, EC, sodium, boron, chloride, pH, and iron.

Eight of the twelve water samples collected from the Atascadero subbasin show no restriction for use in agricultural irrigation, based on an evaluation of the above parameters. The results of two water samples, one in the hills east of Templeton (27S/12E-22N) and one along the Salinas River valley (28S/12E-14K01) indicate some caution should be used if irrigating trees and vines due to potential sodium ion toxicity. The EC of water at this location, and two others, is above 1.0 dS/m, and if used for vineyard irrigation, seasonal monitoring of root zone soil salinity should be done to identify any developing salinity situation due to the relatively high (20%) leaching ratio requirement. Results from groundwater samples collected at a well along the Salinas River north of Templeton (27S/12E-17R02) also show a slight to moderate degree of restriction for tree and vine irrigation due to potential chloride ion toxicity. The spring sample collected from the Santa Ysabel hot springs has the greatest caution associated with agricultural use, including a severe restriction for irrigation of trees and vines due to potential boron ion toxicity. Two samples from the data set also have pH above 7.5, and may plug low volume irrigation systems with lime deposition if not treated.

Water Quality Trends. Active or recently active wells with the greatest available historical data in the Atascadero subbasin were reviewed. Each of these wells is discussed below (the period of available water quality data is shown in parentheses). Graphs of the individual constituents over time are in Appendix B (note that the graphs in Appendix B are organized in order of township/range and section, and not in the order of introduction in the text).

- **27S/12E-9M02, -9M03 (1970-present)** - Salinas River valley near Hwy 101 and Hwy 46 West. Well is 210 feet deep. Total dissolved solids ranges from 445 to 975 mg/L (currently 500 mg/L at nearby, similarly constructed well 9M03). Chlorides range from 42 to 113 mg/L (currently 46 mg/L at 9M03). Nitrates range from 4 to 20 mg/L (currently 8 mg/L at 9M03). Overall quality at this well is improving over time.
- **27S/12E-17R02 (1970-present)** - East side of Hwy 101 approximately 1.5 miles north of Templeton. The TDS concentration ranges from 585 to 780 mg/L (currently 720 mg/L). Chlorides range from 91 to 130 mg/L (currently 126 mg/L). Nitrates range from 0.5 to 44 mg/L (currently 14 mg/L). Overall quality at this well may be slightly deteriorating over time, although the regression coefficient is low (R2 = 20% or less).
- **28S/12E-10A03 (1973-present)** - Salinas River valley approximately one mile north of Atascadero Creek confluence. Well is 500 feet deep. The TDS concentration ranges from 389 to 595 mg/L (currently 540 mg/L). Chlorides range from 23 to 56.6 mg/L (currently 56.6 mg/L). Nitrates range from 5.3 to 18 mg/L (currently 11 mg/L). Overall quality at this well is slightly deteriorating over time.
- **28S/12E-11N06, N07 (1967-present)** - Salinas River valley at Atascadero Creek confluence. Two wells with similar construction, approximately 100 feet deep. The TDS concentration range from 501 to 719 mg/L (currently 540 mg/L). Chlorides range from 57 to 120 mg/L (currently 57 mg/L). Nitrates range from 1.6 to 18 mg/L (currently 6 mg/L). Overall quality at this location is stable over time.
- **28S/12E-14K01 (1954-present)** - Salinas River valley near Pine Mountain. Well is 105 feet deep. The TDS concentration ranges from 353 to 857 mg/L (currently 820 mg/L). Chlorides range from 34 to 208 mg/L (currently 208 mg/L). Nitrates range from <2 to 13.1 mg/L (currently <2 mg/L). Overall quality at this location is deteriorating over time, and is a major trend at this well (except nitrates).
- **28S/13E-31F02 (1974-present)** - Salinas River valley approximately 1/2 mile downstream of Santa Margarita Creek confluence. The TDS concentration ranges from 317 to 410 mg/L (currently 330 mg/L). Chlorides range from 18 to 26 mg/L (currently 19.4 mg/L). Nitrates range from <2 to 13 mg/L (currently <2 mg/L). Overall quality at this location is improving over time.

Overall, water quality trends in the Atascadero subbasin are variable, with areas of improving quality at the northern and southern parts of the subbasin, and areas of stable to deteriorating quality in the center of the subbasin, based on the above data histories. The most visible trend of water quality deterioration is present at well 28S/12E-14K01, where TDS concentrations have been increasing an average of 10 mg/L per year. This well is relatively shallow (105 feet deep) and is located in the Salinas River valley about one mile downstream of the City of Atascadero wastewater percolation ponds.

Creston Area

General Minerals. The main source of recharge to the subbasin is Huer Huero Creek, with tributaries that drain the Cretaceous granitic rocks and sandstone beds of the northwestern La Panza Range. This recharge is typically a calcium-bicarbonate water with secondary sodium during moderate to low flow. An example of the surface inflow water quality for the Creston area is shown in Table 17.

Table 17. Surface Water Quality - Creston Area, Huer Huero Creek

Water Type	Date	Flow (cfs)	Units	Ca	Mg	Na	K	HCO3	SO4	Cl	TDS
Huer Huero @ Hwy 41 Ca HCO3	12/6/1966	500	mg/L	40	6	7	5	143	9.6	9	224
			meq/l	2	0.49	0.3	0.13	2.34	0.2	0.25	
Middle Branch @ Hwy 58 Ca-Na HCO3	1/31/1967	10-15	mg/L	16	5	15	2	83	8	13	116
			meq/l	0.8	0.41	0.65	0.05	1.36	0.17	0.37	
Middle Branch @ Hwy 58 Ca-Na HCO3	4/10/1954	2	mg/L	27	9.1	24	2.5	114	18.2	29.8	170
			meq/l	1.35	0.75	1.04	0.06	1.87	0.38	0.84	
East Branch @ Hwy 58 Ca-Na HCO3	1/31/1967	5	mg/L	18	5	15	3	78	7	16	158
			meq/l	0.9	0.41	0.65	0.08	1.28	0.15	0.45	
East Branch @ Hwy 58 Mg-Na HCO3	4/10/1954	5	mg/L	4.4	9.1	13.6	2	66.5	0	18.1	83
			meq/l	0.22	0.75	0.59	0.05	1.09	0	0.51	

Ten groundwater samples are used to represent current water quality in the Creston area. Seven of the ten samples are predominantly calcium-bicarbonate waters (some with secondary sodium). Total dissolved solids concentrations (TDS) range from 190 to 540 mg/L, with an average TDS of 310 mg/L. The remaining three samples are of sodium-bicarbonate water, with TDS of 510, 590, and 1620 mg/L. Average TDS for all ten Creston area samples is 490 mg/L.

A summary of selected water quality results for the Creston area is presented in Table 18. A graphical representation of water quality in the area is shown in Figure 59.

In the Creston area, wells extracting groundwater from a relatively shallow depth (<200 feet) generally show increasing mineralization from the southeast to the northwest. Shallow aquifer sample locations farthest upstream along the Middle Branch of the Huer Huero Creek (28S/13E-36A01) and the East Branch of the Huer Huero Creek (28S/14E-18C) have the lowest TDS and relatively soft water. In proximity to the town of Creston (28S/13E-1K01 and 27S/13E-35K), the shallow aquifer water becomes slightly more mineralized and harder. To the northwest, in Section 14 (the old Geneseo School area), the shallow aquifer water is highly mineralized (27S/13E-14P).

Table 18. Water Quality
Creston Area

Sample Description	Water Type	Sample Date	Well Depth	TDS[1] mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 + CO3 mg/l	Cl[1] mg/l	SO4[1] mg/l	NO_3[2] mg/l	Fe[1] mg/l	Mn[1] mg/l	B mg/l	SAR	EC[1] dS/m	PH units
27S/13E-14P	Na Ca - Cl	10/8/2001	85	1620	220	62	280	2.7	386	508	353	25	< 0.1	< 0.03	0.18	4.4	2.6	7
27S/13E-20A	Ca HCO3-Cl	10/8/2001		340	63	24	42	1.5	235	84	18	11	< 0.1	< 0.03	< 0.05	1.2	0.63	7.3
27S/13E-25M	Ca HCO3	10/5/2001	600	540	88	20	56	2.7	244	51	120	22	< 0.1	< 0.03	0.1	1.4	0.7	7.3
27S/13E-35K	Ca HCO3	10/8/2001	100	260	56	22	32	1.7	207	47	34	11	0.5	< 0.03	0.06	0.9	0.53	7.4
27S/13E-5N	Na HCO3	12/17/1999	400	590	48	26	140	1.8	403	100	71	10	0.7	0.2	0.31	4.2	0.96	7.5
28S/13E-1K01	Ca-Na HCO3	10/5/2001	165	290	47	7.3	33	1.8	156	31	28	6.2	< 0.1	< 0.03	0.07	1.2	0.37	7
28S/13E-36A	Ca-Na HCO3	10/5/2001	70	220	28	11	29	0.9	137	29	14	2.0	< 0.1	< 0.03	< 0.05	1.2	0.31	6.8
28S/13E-7K	Ca Cl-HCO3	10/8/2001	150	510	116	34	40	0.7	271	175	8.5	28	< 0.1	< 0.03	< 0.05	0.8	0.99	7.4
28S/14E-18C	Ca-Na HCO3	10/8/2001	200	190	27	4.6	28	2.4	120	25	7.2	3.4	< 0.1	< 0.03	< 0.05	1.3	0.28	7.2
28S/14E-4F	Ca HCO3-Cl	10/8/2001	600	340	80	10	21	1.7	166	65	13	41	< 0.1	< 0.03	< 0.05	0.6	0.55	7.4
Maximum Contaminant Level Concentrations				1000	--	--	--	--	--	500	500	45	0.3	0.05	--	--	1.60	--

MCL = Maximum Contaminant Level of Primary and Secondary analytes
Shaded areas represent concentrations exceeding MCL
mg/l = milligrams per liter
dS/m = deciSiemens per meter
[1] Secondary drinking water standards analyte
[2] Primary drinking water standards analyte

The occurrence of highly mineralized sodium-chloride water in Section 14 is reportedly found throughout the area, according to local residents. The source of the mineralization is not known. Historically, geothermal water sources are documented at depths in excess of 500 feet beneath the area; however, the geothermal water quality is typically sodium-bicarbonate, with TDS less than one-half of that measured in the shallow aquifer wells.

Deeper water, represented by 28S/14E-4F, 27S/13E-25M, 27S/13E-20A, and 27S/13E-5N, has higher mineralization overall than the shallow aquifer water, except for the highly mineralized shallow aquifer water in Section 14. The average shallow aquifer water TDS (excluding Section 14) is 240 mg/L, compared to an average TDS of 450 mg/L in the deeper aquifer.

Geologic structure associated with the Creston anticlinorium may influence the water quality of the deeper aquifer. The anticlinorium is an uplifted area east of Creston, where Santa Margarita Formation sandstones are exposed. Northeast of Creston, the axis of the anticlinorium turns west and plunges, intercepting Huer Huero Creek in the area of the old Geneseo School and pushing the creek westward into a series of meanders. The result of this structure is that older Paso Robles Formation sediments are brought closer to the surface. These older sediments are inferred to be less permeable than younger Paso Robles Formation sediments based on geomorphology and well yields. It is possible that the older sediments may be the source of increased salinity in the deeper aquifer.

Drinking Water. Water quality data in the Creston area were obtained for 10 wells. Samples from three of the wells included constituents exceeding the MCL. Several constituents with concentrations above the MCL were present in the old Geneseo School area sample in Section 14, approximately four miles north of Creston. Iron and manganese concentrations above the MCL were present in a sample from a well near Huer Huero Creek approximately four miles southeast of Paso Robles, and iron concentrations above the MCL were present in an old well located one and one half miles northwest of Creston. With the exception of shallow water in the old Geneseo School area along Huer Huero Creek, water quality for the Creston area is generally good for drinking.

Agricultural Irrigation. Six of the ten water samples collected from the Creston area show no restriction for use in agricultural irrigation, based on the results of the water quality analyses. Shallow aquifer water sampled from a well in the old Geneseo School area carries a severe restriction to irrigation use due to high chloride, and would not be recommended for most crops. Potential plugging of low-volume irrigation systems due to iron precipitate is indicated for water from two locations (27S/13E-35K and 27S/13E-5N). The latter location also carries a caution if used for irrigating trees and vines due to potential sodium ion toxicity, and the SAR and EC values indicate a slight potential for soil permeability problems. The fourth location of caution is in the area of 28S/13E-7K, where a slight to moderate restriction for irrigating trees and vines is applicable due to potential chloride ion toxicity.

Water Quality Trends. Two active wells with available historic data in the Creston area were sampled during this study. Two other wells with a history of water quality that were not sampled are discussed below, with comments on current general water quality in the area.

- **28S/13E-1K01, 2 (1984-present)** - In the town of Creston. There are two wells on site with similar construction (approximately 160 feet deep). The TDS concentration ranges from 287 to 400 mg/L (currently 290 mg/L). Chlorides range from 30.5 to 40 mg/L (currently 30.5 mg/L). Nitrates range from 0.43 to 20 mg/L (currently 6.2 mg/L). Overall quality at this location is stable to slightly improving.
- **28S/13E-36A (1978-present)** - Private well, 70 feet deep, 5 miles south of Creston on Middle Branch of Huer Huero Creek. Only one historical general mineral sample is available (1978). The TDS was reported at 196 mg/L in 1978, and is currently 230 mg/L. Chloride was 20 mg/L in 1978 and is currently 28.5 mg/L. Four data points for nitrates are available, ranging from 2 to 13 mg/L (currently 2 mg/L). Nitrates have improved over time at this location, and there is insufficient data to establish a general mineral trend, nor is one suspected.
- **27S/13E-9P01, 20A, 20R01, 5N (1954-present)** - Historically artesian well along Huer Huero Creek, approximately three miles downstream from Creston Road. The depth of this well is unknown, but other artesian wells in the Creston area typically penetrate deeper aquifer zones. Historically the TDS concentrations range from 395 to 533 mg/L (last measured at 395 mg/L in 1976). Chlorides range from 19 to 25 mg/L (last measured at 19 mg/L in 1976). Nitrates range from 2.8 to 8 mg/L (last measured at 2.8 mg/L in 1976). Overall quality at this location was stable to slightly improving through 1976.

  The well with the most similar water quality is well 27S/13E-20A, an irrigation well (in the deeper aquifer) approximately 1.2 miles south of well 9P01 (described above). TDS in well 27S/13E-20A was 340 mg/L, chloride measured 84 mg/L, and nitrate measured 10 mg/L. Another historically artesian well (27S/13E-20R01), less than one mile south of well 27S/13E-20A, was sampled in 1954 and 1967. TDS of the calcium-magnesium-bicarbonate water measured 340 mg/L, chlorides measured 30 mg/L, and nitrates measured 12 mg/L. These water quality samples suggest that an overall increase in chlorides has taken place in the deeper aquifer northwest of Creston. Another deeper well to the northwest (27S/13E-5N) was sampled in December 1999 and contained 540 mg/L TDS, 100 mg/L chloride, and 10 mg/L nitrate. This analysis supports the conclusion of a local increase in chlorides over time (with a corresponding decrease in bicarbonate anions). Whether or not the interpreted chloride increase constitutes an active trend is unknown. It should be noted that higher chloride concentrations have been measured historically in shallow aquifer wells in the Creston area, including 188 mg/L in well 27S/13E-17Q01 in 1954. This well is 104 feet deep and less than 2,000 feet northwest of well 27S/13E-20A.
- **27S/13E-36R01 (1953-1972)** - This is a shallow well (97 feet deep) less than one mile northeast of Creston. A dozen sampling dates are available. TDS ranges from 300 to 534 mg/L (last measured at 524 mg/L in 1972), chlorides range from 42 to

99 mg/L (last measured at 50 mg/L in 1972), and nitrates range from 3 to 28 mg/L, (last measured at 3 mg/L in 1972). There is a trend of decreasing nitrate concentrations at this well between 1954 and 1972, with other constituents fluctuating but with no recognizable trend. A comparison of water quality for other shallow wells near Creston, including 28S/13E-1K01 (mentioned above) and 27S/13E-35K, indicate that water quality remains within the historic range, with no continuing observable trend.

Overall, water quality trends in the shallow aquifer in the Creston area are stable to slightly improving. However, there is a possible major water quality trend in the deep aquifer. Chloride concentrations in deep, historically artesian aquifer zones to the northwest of town along Creston Road have increased from approximately 20 to 30 mg/L to a concentration of 80 to 100 mg/L since the 1970s. No data in the 1980's or 1990's have been obtained to show the magnitude of the recent trend, but it could be considered major with respect to future irrigation use on salt-sensitive crops.

San Juan Area

General Minerals. Indian, Camatta, Shell, and Navajo creeks all drain the northern La Panza Range, where both Cretaceous rocks (granitics and sandstones) and Tertiary sediments (sandstones and shales) are present. Of these four creeks, only Indian Creek, which drains into Shedd Canyon, captures runoff from mostly Tertiary sediments (Santa Margarita, Monterey, Vaqueros, and Simmler formations) rather than from the Cretaceous granitics and sandstones. San Juan Creek, which drains close to 400 square miles upstream of the Camatta Creek confluence, also receives most of its runoff from Tertiary sedimentary rocks. The surface water quality entering the San Juan area is predominantly calcium-bicarbonate, with various secondary ions. Examples of surface water inflow quality from the creeks entering the San Juan Area are given below in Table 19.

Table 19. Surface Water Quality - San Juan Area, Various Creeks at Highway 58

Water Type	Date	Flow (cfs)	Units	Ca	Mg	Na	K	HCO3	SO4	Cl	TDS
Indian Creek Na-Ca HCO3	1/31/1967	5-7	mg/L	19	7	25	3	90	27	20	171
			meq/l	0.95	0.58	1.09	0.08	1.48	0.56	0.56	
Shell Creek Ca-Na HCO3	1/24/1969	na (high)	mg/L	10	3	9	2	45	11	7	92
			meq/l	0.5	0.25	0.39	0.05	0.74	0.23	0.2	
Shell Creek Na-Ca HCO3	1/31/1967	10	mg/L	13	6	16	2	71	13	12	130
			meq/l	0.65	0.49	0.7	0.05	1.16	0.27	0.34	
Camatta Creek Ca HCO3	1/24/1969	na (high)	mg/L	10	4	3	4	49		3	65
			meq/l	0.5	0.33	0.13	0.1	0.8	0	0.08	
Camatta Creek Ca HCO3	5/11/1967	1	mg/L	22	10	18	2	113	13	19	189
			meq/l	1.1	0.82	0.78	0.05	1.85	0.27	0.54	
Navajo Creek Ca HCO3	1/24/1969	na (high)	mg/L	10	4	6	4	32	14	5	63
			meq/l	0.5	0.33	0.26	0.1	0.52	0.29	0.14	

Table 19. Surface Water Quality - San Juan Area, Various Creeks at Highway 58 (Continued)

Water Type	Date	Flow (cfs)	Units	Ca	Mg	Na	K	HCO3	SO4	Cl	TDS
Navajo Creek Ca-Mg HCO3	5/11/1967	8	mg/L	33	17	18	1	162	27	19	215
			meq/l	1.65	1.4	0.78	0.03	2.66	0.56	0.54	
San Juan Creek Ca HCO3-SO4	2/9/1962	na (high)	mg/L	18	7	11	2	62	44	7	145
			meq/l	0.9	0.58	0.48	0.05	1.02	0.92	0.2	
San Juan Creek Ca SO4-HCO3	5/11/1957	20	mg/L	75	33	52	2	211	205	30	560
			meq/l	3.74	2.71	2.26	0.05	3.46	4.27	0.85	
San Juan Creek Ca-Na SO4	10/21/2001	0.1	mg/L	130	56	121	1.8	314	523	58	968
			meq/l	6.04	4.61	5.66	0.05	5.15	10.9	1.64	

Groundwater quality in the San Juan area is characterized by calcium-bicarbonate water from wells along Camatta, Shell, and Navajo creeks, and various sodium-dominant water from wells along the lower San Juan Valley and in Shedd Canyon.

A summary of selected water quality results for the San Juan area is presented in Table 20. A graphical representation of water quality in the subbasin is shown in Figure 60.

The groundwater type in the various San Juan area drainages roughly mimics surface water quality, with one major exception. In the lower San Juan Valley upstream of Camatta Canyon, both shallow (27S/16E-18H01; 104 feet deep) and deep (27S/15E-12K; 750 feet deep) wells sampled during this study contained sodium-chloride water with elevated TDS.

The source of the sodium-chloride does not come from the San Juan Creek watershed upstream of Highway 58, based on the surface water quality data, and is also not present in the French Camp area (Navajo Creek), which drains into the San Juan Creek valley. However, water quality data from 1961 show a well (27S/16E-35Q01) on the east side of San Juan valley, approximately two miles downstream of the Navajo Creek confluence, with sodium-chloride water (TDS of 2,215 mg/L; sodium of 586 mg/L; chloride of 546 mg/L) (DWR, 1979). Therefore, sodium-chloride waters enter San Juan Creek somewhere between Highway 58 and Long Canyon, and continue downstream in the San Juan Creek valley past the confluence with Camatta Canyon. Below the confluence, sodium-chloride waters persist on the extreme east side of the valley through Shandon.

Wells sampled along Navajo Creek (28S/16E-14N01), Shell Creek (28S/15E-28M01), and Camatta Canyon (28S/15E-14F01 and 28S/16E-35F01) are predominantly calcium-bicarbonate type waters, as would be expected, based on the quality of surface water inflow. A well sampled in Shedd Canyon (27S/14E-24B01) contains sodium-bicarbonate water, consistent with the water flowing in Indian Creek. TDS concentrations in these wells range from 70 to 450 mg/L.

Table 20. Water Quality
San Juan Area

Sample Description	Water Type	Sample Date	Well Depth	TDS[1] mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 + CO3 mg/l	Cl[1] mg/l	SO4[1] mg/l	NO_3[2] mg/l	Fe[1] mg/l	Mn[1] mg/l	B mg/l	SAR	EC[1] dS/m	PH units
27S/14E-24B01	Na HCO3	10/2/2001		310	29	3.5	66	2.2	195	20	42	12	< 0.1	< 0.03	0.26	3.1	0.43	7.5
27S/15E-12K	Na Cl-SO4	5/22/2001	750	1700	102	30	435	4.0	256	390	500	23	0.71	0.02	1.94	9.7	2.61	7.5
27S/15E-2P	Na-Ca HCO3-SO4	5/22/2001	700	490	62	5.0	76	4.0	146	69	117	5.9	0.06	< 0.01	0.26	2.5	0.7	7.7
27S/15E-35F01	Ca HCO3	10/6/2001		170	44	5.4	23	1.8	137	17	30	10	< 0.1	< 0.03	< 0.05	0.9	0.33	7.6
27S/16E-18H01	Na Cl-SO4	10/2/2001	104	2170	163	44	551	4.0	259	699	722	56	< 0.1	< 0.03	2.29	10	3.15	7.2
28S/15E-14F02	Ca HCO3	10/6/2001		160	22	6.2	16	1.3	82	13	24	8.4	0.1	< 0.03	< 0.05	0.8	0.22	6.9
28S/15E-26M01	Ca HCO3-SO4	10/6/2001		570	80	23	60	4.3	234	41	166	< 0.4	2.5	0.223	0.14	1.5	0.74	7.1
28S/16E-14N01	Ca HCO3	10/2/2001	375	450	83	21	41	1.7	232	46	112	26	2.6	0.032	0.08	1.1	0.65	7.3
San Juan Ck. @ Hwy 58	Ca SO4	10/17/2001	surface	970	130	56	121	1.8	314	58	523	< 0.4	< 0.1	0.145	0.19	2.3	1.46	7.7
Maximum Contaminant Level Concentrations				1000	--	--	--	--	--	500	500	45	0.3	0.05	--	--	1.60	--

MCL = Maximum Contaminant Level of Primary and Secondary analytes
Shaded areas represent concentrations exceeding MCL
mg/l = milligrams per liter
dS/m = deciSiemens per meter
[1] Secondary drinking water standards analyte
[2] Primary drinking water standards analyte

Drinking Water. Water quality samples were obtained from eight water wells in the San Juan area, plus a surface water sample from San Juan Creek at Highway 58. Samples from four of the wells and from San Juan Creek contained constituents exceeding the MCL. Several constituents in excess of the MCL were present in a sample from a well located near San Juan Creek upstream of the Camatta Canyon confluence, including a nitrate concentration of 56 mg/L (MCL of 45 mg/L). Based on the eight wells sampled, water from wells located near San Juan Creek is typically poorer quality than most other wells in the Shandon area. TDS concentrations ranged from a low of 70 mg/L in a well sample from Camatta Canyon, to a high of 2,170 mg/L in a well sample obtained near San Juan Creek. The average TDS concentration in samples from the nine sources in the San Juan area is 740 mg/L.

Agricultural Irrigation. Six of the nine groundwater samples collected from the San Juan area show no restriction for use in sprinkler or surface agricultural irrigation. Severe restrictions for trees and vine irrigation are indicated for the two samples of sodium-chloride groundwater in the lower San Juan Creek valley, upstream of Camatta Canyon, due to high sodium, chloride, and boron. The surface water in San Juan Creek at Highway 58 carries a slight to moderate restriction for tree and vine irrigation due to potential sodium ion toxicity. Potential plugging of low-volume irrigation systems due to iron or lime precipitate is indicated for all the samples except one from Camatta Canyon, and the surface water in San Juan Creek. The EC of the San Juan Creek water and all other sodium-chloride waters in the area are above 1.0 dS/m. Monitoring for potential salinity problems should be conducted on crops irrigated with these waters if used for vineyard irrigation, due to the relatively high (20%) leaching ratio requirement.

Water Quality Trends. Two active wells with available historical data in the San Juan area were sampled. One other well with a history of water quality that was not sampled in this study is discussed below, with comments on general water quality in the area.

- **28S/16E-14N01 (1954-present)** - French Camp (Navajo Creek). The depth of this well is unknown, but is assumed to be a least a few hundred feet based on information on a nearby well with similar capacity. Historically, the TDS concentrations range from 288 to 563 mg/L (currently 450 mg/L). Chlorides range from 21 to 66 mg/L (currently 46 mg/L). Nitrates range from 7 to 26 mg/L (currently 26 mg/L). A review of these water quality parameters plotted over time indicates no clear trend, although nitrate concentrations are higher than previously recorded and may be indicative of a rising trend.
- **27S/15E-35F01 (1954-present)** - Camatta Canyon. The depth of this well is unknown, but is assumed to be several hundred feet, based on information on nearby wells with similar capacity. Historically, the TDS concentrations range from 167 to 217 mg/L (currently 170 mg/L). Chlorides range from 16 to 19 mg/L (currently 17 mg/L). Nitrates range from 3 to 10 mg/L (currently 10 mg/L). This well exhibits a clear trend of decreasing TDS. Chloride concentration levels are stable, while nitrates show a trend of increasing concentrations over time. This trend of increasing nitrates, at an average increase of 0.1 mg/L per year, is not considered a major trend.

- **27S/15E-13A01 (1954-1967)** - Lower San Juan Creek. The depth of this windmill well is unknown, but exceeds 100 feet (based on pumping water level data). The well is located on the west side of the San Juan Creek valley approximately two miles upstream from the Camatta Canyon confluence. The well water is of a sodium-chloride-sulfate type. TDS ranges from 2,378 to 3,408 mg/L (last measured at 2,881 mg/L in 1967), chlorides range from 567 to 890 mg/L (last measured at 785 mg/L in 1967), and nitrates range from 2 to 47 mg/L (last measured at 27.5 mg/L in 1967).

  Historically, a major trend of increasing nitrates developed at this well through 1964, at which time the maximum value of 47 mg/L was reached. A decline in nitrate concentrations followed in 1965 and 1967. This well is located between two other sodium-chloride-sulfate wells sampled during this study. The shallower of these wells (27S/16E-18H01) has a TDS concentration of 2,170 mg/L, chlorides of 699 mg/L, and nitrates of 56 mg/L. The nearby deeper well (27S/16E-12K) has a TDS of 1,700 mg/L, chlorides of 390 mg/L, and nitrates of 23 mg/L. Assuming that well 13A01 is a shallow well, the trend of increasing nitrates appears to have continued locally since 1967 at a rate of approximately one (1) mg/L per year. This would normally be a major trend, except that the potential use of this shallow aquifer for drinking water is severely restricted because of the high mineralization.

Overall, the water quality trends in the San Juan area are stable, with the exception of nitrate levels. There appears to be a trend of increasing nitrates in the shallow aquifer zones in the lower San Juan Creek valley above the Camatta Canyon confluence. The quality of this particular water, however, is already highly mineralized and of limited use.

Shandon Area

General Minerals. The Shandon area receives surface water inflow primarily from Cholame Creek on the east, San Juan Creek and Shedd Canyon from the south, and several smaller canyons to the north (McMillan, Shimmin, and Pine canyons). The quality of surface water entering Shandon from Cholame varies widely based on discharge, and is typically a sodium-bicarbonate to sodium-chloride type water. One surface water sample from San Juan Creek at the Highway 41 bridge was collected in 1953 (at low flow) and is a sodium-bicarbonate-sulfate type water.

As noted earlier in the discussion of the San Juan area, water quality is highly mineralized in the San Juan Creek valley between Long Canyon and Camatta Canyon. Downstream of the Camatta Canyon confluence, the sodium-chloride waters of the San Juan valley are blended with surface flow and underflow from Camatta Canyon. There are areas in Camatta Canyon where there is no incised stream channel, indicating that most surface water inflow to Camatta Canyon from the La Panza Range percolates before reaching San Juan Creek.

As discussed earlier, there is a relatively shallow (200 to 400 feet deep) confined aquifer beneath the Estrella River valley with historical artesian flowing conditions. The confining clays appear to be laterally extensive and restrict the deep percolation of surface water in the Estrella River. The location of historically artesian wells along Highway 46 on the north side of the river at heights close to 35 feet above the river bed, together with the broad syncline paralleling the river valley mapped by Dibblee (1973), suggest there is significant subsurface inflow from the north flank of the syncline. This northern area extends essentially to the watershed boundary in the Cholame Hills.

Examples of available surface water inflow quality for the Shandon Area are listed in Table 21.

Table 21. Surface Water Quality - Shandon Area

Source ID/Water Type	Date	Flow (cfs)	Units	Ca	Mg	Na	K	HCO3	SO4	Cl	TDS
Cholame Ck. @ Stream gage Na HCO3-SO4	1/7/1965	15	mg/L	33	26	74	7	187	123	57	440
			meq/l	1.65	2.14	3.22	0.18	3.06	2.56	1.61	
Cholame Ck. @ Stream gage Na Cl	2/14/1975	5	mg/L	71	89	340	6.6	247	319	534	1573
			meq/l	3.54	7.32	14.79	0.17	4.05	6.64	15.06	
Cholame Ck. @ Bitterwater Na Cl-SO4	10/4/2000	Ponded	mg/L	127	119	469	5.2	451	740	550	2380
			meq/l	6.34	9.79	20.4	0.13	7.39	15.41	15.52	
San Juan Creek @ Hwy 41 Na-Ca HCO3-SO4	1/11/1953	0.5		104	37	173	4.7	418	278	110	848
			meq/l	5.19	3.04	7.53	0.12	6.85	5.79	3.1	

Nine water samples were used to represent current groundwater water quality in the San Juan area. The area includes predominantly calcium-sodium-bicarbonate type water, with chloride and sulfate anions dominant on the east side of the area. In addition, two springs were sampled in one of the northern canyons, and samples of surface water in Cholame Creek and the Estrella River were collected.

A summary of selected water quality results for the Shandon area is presented in Table 22. A graphical representation of water quality in the area is shown in Figure 61.

There are two wells along the Estrella River valley with high sodium concentrations (26S/14E-14R and 26S/14E-21M01). The water quality of these wells is very similar in mineral composition to the water sample taken from a well in Shedd Canyon (27S/14E-24B01), suggesting that a component of recharge to aquifers beneath the Estrella River valley also comes from the southern flank of the broad syncline referred to earlier.

Cation and anion comparisons suggest water quality in the town of Shandon is a mixture of subsurface inflow from both the north and the south, with no noticeable influence from the highly mineralized waters that are found immediately to the east (i.e. at 26S/15E-21G). In fact, groundwater in the vicinity of Shandon has the lowest mineralization in the area, with a sharp increase to the east against the hills, and a gradual increase to the west, toward Whitley Gardens.

Table 22. Water Quality
Shandon Area

Sample Description	Water Type	Sample Date	Well Depth	TDS[1] mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 + CO3 mg/l	Cl[1] mg/l	SO4[1] mg/l	NO_3[2] mg/l	Fe[1] mg/l	Mn[1] mg/l	B mg/l	SAR	EC[1] dS/m	PH units
25S/15E-31K (S)	Ca-Mg HCO3	10/11/2001	spring	550	70	37	62	1.2	245	93	92	41	< 0.1	< 0.03	0.35	1.5	0.83	7.1
25S/15E-31Q	Ca-Na HCO3	10/11/2001	700	460	63	18	63	3.2	195	45	105	17	0.1	< 0.03	0.41	1.8	0.65	7.2
26S/14E-14R	Na HCO3	10/4/2001	715	460	36	6.5	121	2.9	251	48	78	7.8	< 0.1	< 0.03	0.63	4.9	0.67	7.7
26S/14E-18J01	Na HCO3	10/2/2001	440	460	39	25	89	2.8	256	64	103	10	< 0.1	< 0.03	0.49	2.8	0.73	7.4
26S/14E-21MO1	Na HCO3	10/4/2001		440	26	7.6	119	2.7	272	31	65	5.6	< 0.1	< 0.03	0.53	5.3	0.61	7.8
26S/15E-6N (S)	Ca-Mg SO4	10/11/2001	spring	3160	339	217	237	3.9	251	240	2010	54	< 0.1	< 0.03	1.31	2.5	3.48	7.0
26S/15E-20B03	Ca-Na HCO3	5/21/2001	400	350	60	4.6	37	NR	159	50	57	14	0.01	< 0.02	NR	1.2	0.5	7.7
26S/15E-21G	Na-Ca Cl-SO4	10/11/2001		1610	176	31	323	5.4	223	451	584	13	0.6	< 0.03	1.26	6.0	2.73	7.2
26S/15E-28Q02	Ca-Na SO4	10/11/2001		1070	167	22	123	3.3	176	182	410	8.3	< 0.1	< 0.03	0.48	2.4	1.5	7.3
26S/15E-31K	Ca HCO3	10/17/2001		270	55	4.7	26	2.0	144	33	14	35	< 0.1	< 0.03	0.08	0.9	0.44	7.6
26S/15E-33C01	Ca Cl	10/2/2001	500	330	87	6.3	36	2.7	120	95	79	8.8	< 0.1	< 0.03	0.11	1.0	0.57	7.3
Cholame Creek	Na Cl-SO4	10/4/2001	surface	2380	127	119	469	5.2	451	550	740	< 0.4	< 0.1	< 0.03	2.97	7.3	2.98	7.6
Estrella River	Na-Mg HCO3	10/4/2001	surface	670	40	52	130	4.5	388	130	77	< 0.4	< 0.1	0.03	0.68	3.2	0.99	8.6
Maximum Contaminant Level Concentrations				1000	--	--	--	--	--	500	500	45	0.3	0.05	--	--	1.60	--

MCL = Maximum Contaminant Level of Primary and Secondary analytes
Shaded areas represent concentrations exceeding MCL
mg/l = milligrams per liter
dS/m = deciSiemens per meter
[1] Secondary drinking water standards analyte
[2] Primary drinking water standards analyte

The reason for the relatively sudden transition from high TDS, sodium-chloride-sulfate water along the hills east of Shandon to calcium-sodium-bicarbonate water in town is not certain, but is not interpreted as a shallow versus deep aquifer issue (both shallow and deep sodium-chloride waters are east of Shandon).

There is a relatively narrow zone where water quality appears to be a mixture of the highly mineralized waters from the east with the lower TDS water from Shandon. Well 26S/15E-21E01, which is 410 feet deep, is located on the east side of the town of Shandon. Water sampled from this well in the 1970's and 1980's was of a calcium-chloride character with TDS ranging from 438 to 725 mg/L. Other wells with transitional water quality sampled in this study include 26S/15E-28Q02 (TDS 1,000 mg/L, calcium-sodium-sulfate water) and 26S/15E-33C01 (330 mg/L TDS, calcium-chloride water). One (presumably deeper) irrigation well (26S/15E-21P01) located southeast of Shandon produced calcium-sodium-bicarbonate water with 376 mg/L TDS in 1957, but by 1974 was producing sodium-calcium-sulfate-chloride water with 756 mg/L TDS.

Water from a spring approximately one mile north of the McMillan Canyon confluence (26S/15E-6N[S]) has particularly high mineralization with sulfate concentrations close to 2,000 mg/L. One possible explanation for the high sulfate water quality would be the presence of gypsum and/or anhydrite deposits. These deposits contain calcium sulfate, and can produce high sulfate waters. Agricultural runoff could also be an explanation, although this does not appear likely since the only irrigation in the area is more than a mile up-canyon, with no evidence of shallow water between the two areas. Water flowing from an abandoned oil well or test hole could also carry high-sulfate concentrations, although the nearest known oil well is approximately one mile to the east in McMillan Canyon.

One final note on general mineral quality in Shandon is the similarity between surface water collected from the Estrella River at Whitley Gardens, and the water collected from a nearby 440-foot deep well (26S/14E-18J01). This does not necessarily imply that there is recharge from the Estrella River into the shallow artesian aquifer at Whitley Gardens, however. During the late fall, before seasonal rains, the Estrella River near Whitley Gardens is a gaining stream, and the surface flow sample collected likely includes irrigation return water pumped out of the artesian and deeper aquifers.

Drinking Water. Groundwater from two of the wells sampled in this study, water from one of the springs, and surface water from Cholame Creek all contained constituents exceeding the MCL. The two wells with concentrations exceeding the MCL are located east and southeast of Shandon, and contained high TDS and EC (one also contained high sulfate and iron). The lower Bud Canyon spring and the surface water in Cholame Creek also contained non-potable water. TDS concentrations ranged from a low of 270 mg/L in a well southwest of Shandon, to a high of 3,160 mg/L in a non-drinking water spring located northwest of Shandon. The average TDS concentration in samples from the nine wells and one drinking water spring in the Shandon area is 600 mg/L.

Agricultural Irrigation. Five of the thirteen water samples collected from the Shandon area show no restriction for use in sprinkler or surface agricultural irrigation. These sources include groundwater and a spring source from Bud Canyon, and groundwater in Shandon and southwest of Shandon along Highway 41. A slight caution for trees and vines irrigation due to potential sodium ion toxicity is indicated for irrigation with water collected from three wells tapping the shallow artesian aquifer and deeper zones along the Estrella River valley, as well as from surface water collected from the Estrella River. Plugging of low-volume irrigation systems due to lime precipitate may also occur due to the slightly elevated pH. A moderate degree of restriction for irrigation of trees and vines is indicated for water in the transitional quality zone (between Shandon and the east hills) due to potential sodium and chloride ion toxicity. Three water samples, one on the far east side of Shandon, one of spring water in Bud Canyon, and one of surface water in Cholame Creek, carry severe restriction for irrigating trees, vines, and many field and vegetable crops due to potential ion toxicity from sodium, chloride, and boron.

Water Quality Trends. Four active wells with available historical data in the Shandon area were sampled during this study. Other wells with a history of water quality that were not recently sampled are also discussed below, with comments on general water quality in the area today.

- **26S/15E-28Q02 (1964-2001)** - Lower San Juan Creek two miles upstream of Shandon. Depth of well unknown. Historically, the TDS concentrations range from 1,070 to 3,868 mg/L (currently 1,070 mg/L). Chlorides range from 182 to 663 mg/L (currently 182 mg/L). Nitrates range from 0 to 14 mg/L (currently 8 mg/L). This well exhibits a water quality trend of decreasing TDS and chloride, which has greatly improved the potential use of this water. Nitrates were measured at 14 mg/L in 1964, and then not detected the following year. If the first year data point is removed, nitrates would show a trend of slightly increasing concentrations over time beginning in 1965, although the average rate of change is very low (+0.2 mg/L per year).
- **26S/15E-20B03 (1985-2001)** - In Shandon. Depth 400 feet. Historically, the TDS concentrations range from 200 to 350 mg/L (currently 350 mg/L). Chlorides range from 21 to 51 mg/L (currently 50 mg/L). Nitrates range from 9 to 24 mg/L (currently 14 mg/L). This well exhibits a trend of increasing TDS (+6.25 mg/L per year) and chloride (+1.5 mg/L per year) concentrations. These are clear trends of increasing mineralization, but are not classified as major trends as it would require more than 50 years at the current rate to affect the potential uses of the water. Nitrate concentrations have risen slightly overall but do not show a clear trend.
- **26S/15E-20N01, 20L01 (1954-1986)** - West side of Shandon. Depth of wells are not known (both are irrigation). Historically, the TDS concentrations range from 220 to 380 mg/L (last measured at 240 mg/L in 1986). Chlorides range from 12 to 34 mg/L (last measured at 16 mg/L in 1986). Nitrates range from 10 to 45 mg/L (last measured at 13 mg/L in 1986). Together, these wells do not exhibit any clear trend through 1986. The nearest well with recent water quality data is at well 20B03 (see above), with current TDS, chloride, and nitrate concentrations of 350 mg/L, 50 mg/L,

and 14 mg/L, respectively. Based on the nearby data, chloride has increased significantly, while the other two parameters are within the historical range.

- **26S/15E-21G02, 21G (1974-2001)** - East of Shandon against hills. Well 21G02 is 575 feet deep. During this study, a nearby well (21G) was sampled to gain a representation of the current local water quality. The depth of well 21G is not known. Historically, the TDS concentrations at 21G02 range from 1,582 to 1,710 mg/L (currently measured at 1,610 mg/L). Chlorides range from 378 to 418 mg/L (currently 451 mg/L). Nitrates range from 12 to 14 mg/L (currently 13 mg/L). Together, these wells exhibit a trend of increasing chloride concentrations. This would be a major trend of increasing chloride except that the water is already impacted by high mineralization. Nitrate concentrations have been stable, while TDS concentrations do not show a clear trend.
- **26S/14E-18J01 (1967-2001)** - In Whitley Gardens. Well is 440 feet deep. Historically, the TDS concentrations range from 472 to 525 mg/L (currently 460 mg/L). Chlorides range from 35 to 64 mg/L (currently 64 mg/L). Nitrates range from 0 to 13 mg/L (currently 10 mg/L). Despite chloride and nitrate concentrations near the historical maximum, there is no clear trend at this well due to historical fluctuations. The TDS concentration has been relatively stable.
- **26S/14E-14R01, 14R (1967, 2001)** - South of Highway 46 approximately three miles west of Shandon. The depth of the original well 14R01 is unknown. A nearby 715-foot deep replacement well was sampled during this study (well 14R). The older well has one historical data point from June 1967, when TDS, chloride, and nitrate measured 260 mg/L, 32 mg/L, and 0 mg/L, respectively. When sampled in October 2001, these constituents were measured in the new well at 464 mg/L, 47 mg/L, and 8 mg/L, respectively. Based on these two data points, there has been an increase in all three parameters, although the older well may not tap the deeper aquifer. Water quality in 1967 at 14R01 is similar to the shallow aquifer water near Shandon, while the quality from deep well 14R in 2001 is similar to well 21M01 below (both 1967 and 2001 results).
- **26S/14E-21M01 (1967, 2001)** - North side of Estrella River. The depth of the well is unknown (irrigation). This well has one historical data point from June 1967, when TDS, chloride, and nitrate measured 420 mg/L, 31 mg/L, and 3.5 mg/L, respectively. When sampled in October 2001, these constituents were measured at 436 mg/L, 31 mg/L, and 6 mg/L, respectively. There has been no change in water quality, based on these two data points. The 1967 water sampled exhibited the same sodium-bicarbonate character as the recent sample.
- **26S/14E-35D01 (1954-1972)** - Lower Shedd Canyon. Depth of well not known (irrigation). Historically, the TDS concentrations range from 260 to 329 mg/L (last measured at 278 mg/L in 1972). Chlorides range from 37 to 61 mg/L (last measured at 48 mg/L in 1972). Nitrates range from 6 to 27 mg/L (last measured at 18 mg/L in 1972). The data do not exhibit a clear trend through 1972, although chlorides were generally rising. The closest available recent water quality is from wells two miles away in the Estrella River valley (see 26S/14E-20M01 and 14R, above). These wells

have a higher TDS than the lower Shedd Canyon well, but this does not establish a trend.

Overall, water quality trends in the Shandon area suggest increasing chloride and TDS concentrations in the shallow pressure aquifer near the town of Shandon, with variable trends, including some improvement in quality elsewhere.

Estrella Area

General Minerals. The Estrella area receives surface water inflow primarily from the Estrella River on the east, Huer Huero Creek on the southeast, and the Salinas River on the southwest. The most common water type entering the Estrella from the major drainages is calcium-bicarbonate. An example of the surface water inflow quality is shown on Table 23.

Table 23. Surface Water Quality - Estrella Area

Source ID/Water Type	Date	Flow (cfs)	Units	Ca	Mg	Na	K	HCO3	SO4	Cl	TDS
Estrella @ Hwy 46 Ca HCO3-SO4	4/10/1962	2000	mg/L	18	7	7.7	2.4	68	32	6	172
			meq/l	0.9	0.58	0.33	0.06	1.11	0.67	0.17	
Estrella @ Hwy 46 Mg-Ca HCO3	2/14/1954	150	mg/L	20	16	8	1.9	98	29	7	211
			meq/l	1	1.32	0.35	0.05	1.61	0.6	0.2	
Estrella @ Hwy 46 Na-Mg HCO3	10/4/2001	0.2	mg/L	40	52	130	4.5	388	77	130	665
			meq/l	2	4.28	5.66	0.12	6.36	1.6	3.67	
Huer Huero @ Hwy 41 Ca HCO3	12/6/1966	500	mg/L	40	6	7	5	143	9.6	9	224
			meq/l	2	0.49	0.3	0.13	2.34	0.2	0.25	
Huer Huero @ Hwy 46 Ca HCO3	4/25/1967	175	mg/L	33	7	21	3	130	18	22	214
			meq/l	1.65	0.58	0.91	0.08	2.13	0.37	0.62	
Salinas @ Paso Robles Ca HCO3	2/6/1958	1500	mg/L	45	17	20	0.4	180	49	18	270
			meq/l	2.25	1.4	0.87	0.01	2.95	1.02	0.51	
Salinas @ Paso Robles Ca HCO3	3/13/1968	500	mg/L	84	29	55	3	286	137	46	553
			meq/l	4.19	2.39	2.39	0.08	4.69	2.85	1.3	
Salinas @ Paso Robles Ca HCO3	4/2/1965	25	mg/L	71	34	56	1	263	110	39	458
			meq/l	3.54	2.8	1.57	0.03	4.31	2.29	1.1	

Note: Salinas @ Paso Robles location is at 13th Street Bridge.

Sixteen water samples and one spring sample are used to represent current water quality in the Estrella area. Groundwater in the area is predominantly sodium-bicarbonate, which differs from the predominantly calcium-bicarbonate surface water inflow. Therefore, other factors contribute to groundwater recharge and water quality in the Estrella area besides surface water inflow. A summary of selected water quality results for the Estrella area is presented in Table 24. A graphical representation of water quality in the area is shown in Figure 62.

Table 24. Water Quality
Estrella Area

Sample Description	Water Type	Sample Date	Well Depth	TDS[1] mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 + CO3 mg/l	Cl[1] mg/l	SO4[1] mg/l	NO_3[2] mg/l	Fe[1] mg/l	Mn[1] mg/l	B mg/l	SAR	EC[1] dS/m	PH units
25S/13E-21N	Mg HCO3	10/15/2001	300	360	33	33	49	2.1	279	41	23	11	< 0.1	< 0.03	0.29	1.5	0.59	7.4
25S/12E-27F	Na HCO3	10/16/2001	750	410	28	21	82	1.4	256	46	60	17	< 0.1	< 0.03	0.48	2.9	0.66	7.7
25S/12E-27R	Na HCO3-SO4	10/16/2001		830	60	54	145	3.2	312	168	240	8.1	< 0.1	< 0.03	0.89	3.3	1.34	7.4
25S/12E-33Q	Na HCO3-Cl	10/16/2001	80	1270	116	71	218	4.0	488	262	342	21	< 0.1	< 0.03	0.78	4.0	1.88	7.0
25S/12E-21G01	Mg HCO3	5/12/1999	400	830	72	69	96	NR	366	120	180	30	0.1	< 0.005	NR	1.9	1.29	7.2
26S/12E-20A01 (S)	Na Cl	10/17/2001	spring	1560	124	29	357	4.7	259	564	375	< 0.4	< 0.1	< 0.03	5.21	7.6	2.55	7.2
26S/12E-22J01	Na-Ca HCO3	9/26/2000	775	530	62	6.0	128	2.0	279	70	107	19	< 0.1	< 0.02	NR	4.2	0.92	8.0
26S/12E-24D03	Na HCO3	8/3/1999	1075	530	31	12	146	2.7	307	48	134	< 2	< 0.1	< 0.02	NR	5.6	0.93	7.4
26S/12E-25C	Na HCO3	1/14/2000	760	490	21	10	140	2.0	293	32	100	< 0.4	0.0	0.048	NR	6.3	0.75	8.1
26S/12E-29B	Na Cl	10/19/2001	400	1260	116	21	355	4.3	195	572	308	< 0.4	0.2	< 0.03	5.66	8.1	2.38	7.2
26S/12E-4K	Ca-Mg HCO3-Cl	10/19/2001		590	77	46	77	2.2	317	153	113	10	< 0.1	< 0.03	0.30	1.8	1.12	7.4
26S/13E-15F	Na-Mg HCO3	6/20/2000	820	380	41	29	60	1.9	256	52	46	4.5	< 0.1	< 0.03	0.31	1.8	0.65	7.9
26S/13E-18K01	Na HCO3	9/26/2000	885	370	43	22	68	2.0	256	70	26	< 1	< 0.1	< 0.02	NR	2.1	0.69	8.0
26S/13E-19P	Ca-Mg HCO3	10/4/2001	580	360	47	27	37	1.5	229	61	11	20	< 0.1	< 0.03	0.13	1.1	0.56	7.6
26S/13E-28K	Na HCO3	10/4/2001		350	28	20	66	1.7	261	38	26	< 0.4	0.9	< 0.03	0.39	2.4	0.52	7.8
26S/13E-5E	Mg Cl-SO4	10/4/2001	490	1000	93	81	115	2.7	277	223	272	14	< 0.1	< 0.03	0.59	2.1	1.42	7.8
27S/12E-2E01	Na HCO3	9/19/2000	600	420	41	25	87	2.0	351	61	31	< 1	< 0.1	< 0.02	NR	2.6	0.78	7
Maximum Contaminant Level Concentrations				1000	--	--	--	--	--	500	500	45	0.3	0.05	--	--	1.60	--

MCL = Maximum Contaminant Level of Primary and Secondary analytes
Shaded areas represent concentrations exceeding MCL
mg/l = milligrams per liter
dS/m = deciSiemens per meter
[1] Secondary drinking water standards analyte
[2] Primary drinking water standards analyte

The potential for influence on water quality due to subsurface inflow from surrounding, hydraulically upgradient areas can be evaluated through a review of the sodium cation percentages using trilinear diagrams. Figure 62 is a trilinear diagram of water quality for the Estrella area. Note that there are no samples for the Estrella area that are above 40% calcium (cation milliequivalents).

For samples from the Atascadero subbasin (Figure 58), almost all the samples contain greater than 40% calcium. Therefore, subsurface underflow from the Atascadero subbasin is not a candidate for the source of increased sodium to the Estrella area. This is also predicated by the Rinconada fault, which apparently reduces subsurface inflow below the Salinas River alluvium.

Similarly, almost all the samples of groundwater from the Creston area are greater than 40% calcium (Figure 59). Therefore, subsurface underflow from the Creston area is apparently not the source of increased sodium to the Estrella area. The western extension of the Creston anticlinorium brings older, less permeable sediments closer to the surface and restricts subsurface inflow from Creston.

Magnesium cations dominate in the South Gabilan, and the appearance of magnesium bicarbonate waters in San Miguel and along the Estrella indicate that there is significant subsurface inflow to the Estrella area from the South Gabilan area, although this inflow would not be considered a source of higher sodium cation percentages.

The Shandon area water quality is sodium cation dominant. Groundwater flow is toward the Estrella area and, therefore, significant subsurface inflow is interpreted to enter the Estrella area from the east, carrying sodium-bicarbonate waters.

A possible influence on water quality in the Estrella area is from geothermal waters, which are of sodium-chloride composition in the vicinity of Paso Robles (26S/12E-20A01[S]). The trilinear plot (Figure 62) shows a correlation between the geothermal resource water and water collected from the east side of Paso Robles, in the Mustang Springs area (26S/12E-29B). It may be inferred, from both the water quality and from information on structure and water levels, that groundwater west of the historical hot springs alignment in the Estrella area is mostly derived from the deeper circulating waters of the geothermal resource and is hydraulically isolated from the main basin. The sodium-chloride waters are also characterized by high boron levels.

The degree to which deep sodium-chloride waters, whether geothermal or not, is influencing water quality in the Estrella area has been evaluated qualitatively using the water quality data. Overall, there is no increase in concentrations of TDS, sodium, or chloride with increased well depth. In fact, the only apparent correlation is the reverse (lower mineralization with depth), although this trend may be biased by the grouping of deep wells in an area of better water quality. Nevertheless, no significant influence on water quality from geothermal waters in basin sediments east of Paso Robles is found.

TDS concentrations range from a low of 350 mg/L in a well sample obtained east of Paso Robles, to a high of 1,560 mg/L in the spring sample. The average TDS concentration in samples from the 16 wells in the Estrella area is 624 mg/L.

Drinking Water. Samples from three wells and one spring contained dissolved constituents exceeding the MCL (Table 26). Samples from the spring (Mud Bath hot spring) and from one nearby well northwest of Paso Robles exhibited TDS, chloride, and EC in excess of the MCL. Chloride and EC concentrations above the MCL were also present in a sample from a shallower well near the Salinas River north of Paso Robles. Based on laboratory results from the 17 sources, and with the exception of two wells (high iron in one well east of Paso Robles and a high TDS in a 500-foot deep well near the Estrella River), water quality is of generally good quality east of the Salinas River.

Agricultural Irrigation. Five of the 17 water samples collected from the Estrella area show no restriction for use in sprinkler or surface agricultural irrigation. These sources include groundwater from a well near the base of Hog Canyon, and from wells in the area of groundwater decline between Highway 46 and Union Road. There is, however, a potential for lime deposition and plugging of low-volume irrigation due to pH values between 7.7 and 8.0 together with bicarbonate concentrations over 100 mg/L.

Groundwater from nine of the 16 wells sampled in the Estrella area carry a slight to moderate level of restriction for trees and vines irrigation due to potential sodium ion toxicity. Five of the wells sampled also carry slight to moderate restriction due to potential chloride ion toxicity.

Groundwater from one shallow well along the Estrella River near its confluence with the Salinas River (25S/12E-33Q) carries a severe restriction for trees and vines irrigation due to potential sodium ion toxicity. The well northwest of Paso Robles and the nearby hot spring carry severe restrictions due to not only sodium, but also chloride and boron ion toxicity.

Water Quality Trends. Water quality from six locations in the Estrella area with available historical data was reviewed in this study. The data are presented below.

- **25S/12E-16N01 (1953-2001)** - In San Miguel. Well is 300 feet deep. Historically, the TDS concentrations range from 398 to 832 mg/L (currently 630 mg/L). Chlorides range from 42 to 107 mg/L (currently 88 mg/L). Nitrates range from 2 to 25 mg/L (currently 14 mg/L). The TDS concentration has increased 5 mg/L per year on average over the last 48 years, while chloride concentrations have increased an average of 0.5 mg/L per year. These trends may be considered major trends. Nitrate concentrations have fluctuated but have shown no clear trend over time.
- **25S/12E-21G01 (1969-2001)** - In San Lawrence Terrace. Well is 400 feet deep. Historically, the TDS concentrations range from 565 to 1,545 mg/L (last measured at 830 mg/L in 1999). Chlorides range from 83 to 199 mg/L (last measured at 120 mg/L in 1999). Nitrates range from 18 to 66 mg/L (last measured at 49 mg/L). The TDS, chloride, and nitrate concentrations in groundwater have increased on average over

time, although the statistical correlations are poor (R^2 less than 20%). Rather than exhibiting a slow changing trend, water quality at this well exhibits wide fluctuations, especially in nitrate concentrations since 1997. The magnitude of the nitrate fluctuations has increased over time and may suggest a major trend of deteriorating water quality.

- **26S/12E-22J01 (1977-2001)** - Approximately 1.5 miles east of Hwy 101 along Hwy 46. Well is 775 feet deep. Historically, the TDS concentrations range from 393 to 648 mg/L (last reported at 531 mg/L in 2000). Chlorides range from 45 to 86 mg/L (last reported at 70 mg/L in 2000). Nitrates range from <0.4 to 41 mg/L (last reported at 41 mg/L in 2000). The chloride concentrations in groundwater have been relatively stable since 1986, and show no current trend of change over time. TDS has decreased over the same period. The most significant water quality trend at this well is nitrates, which have increased an average of 1.3 mg/L per year since 1977. If this rate continues, the average nitrate concentration in groundwater from this well will begin exceeding drinking water standards within 10 years.
- **26S/13E-15F01 (1992-2001)** - Near Highway 46 and Geneseo Rd. Well 1,050 feet deep. Historically, the TDS concentrations range from 410 to 440 mg/, chlorides range from 37 to 49 mg/L, and nitrates range from 2.1 to 3.4 mg/L. As indicated by the range of concentrations, water quality has been relatively consistent at this well. A second 820-foot deep well (26S/13E-15F), located within a few hundred feet of 15F01, has similar water quality. There are no identifiable trends at this location.
- **27S/12E-02E01 (1967-2001)** - Sherwood Park, Paso Robles. Well is 600 feet deep. Historically, the TDS concentrations range from 379 to 570 mg/L (last reported at 424 mg/L in 2000). Chlorides range from 47 to 67 mg/L (last reported at 61 mg/L in 2000). Nitrates range from 3.8 to 18 mg/L (last reported at 4 mg/L in 2000). The chloride and TDS concentrations in groundwater have been relatively stable, and show no current trend of change over time. Nitrates have decreased on average over time. There is no clear trend in water quality over time at this location.
- **27S/12E-28J01, L02, K (1954-2001)** - Near Union Road and Branch Road. Well 28J01 is 440 feet deep, well 28L02 is 440 feet deep, and the depth of well 28K is unknown. All three wells are within a half-mile of each other. Historically, the TDS concentrations range from 290 to 419 mg/L (currently 350 mg/L at well 28K). Chlorides range from 38 to 53 mg/L (currently 38 mg/L at well 28K). Nitrates range from <0.1 to 5.6 mg/L (currently <0.1 mg/L at well 28K). Groundwater quality has been relatively stable at these wells, with no clear trend of change over time.

Water quality trends in the Estrella area indicate potential major trends of increasing TDS and chloride near San Miguel and of increasing nitrates along the Highway 46 corridor between the Salinas and Huer Huero rivers. Elsewhere, water quality is generally stable.

Gabilan Area

General Minerals. The Gabilan area receives no surface water inflow from streams that originate from other parts of the basin. Several streams originate in the area, or in the watershed upstream of the Gabilan area, thereby providing surface water flow across the Gabilan area during certain times of the year. Six groundwater samples and one spring water sample are used to represent current groundwater water quality in the Gabilan Area. Groundwater in the area is predominantly a calcium-magnesium-bicarbonate type. A summary of selected water quality results for the Gabilan area is presented in Table 25. A graphical representation of water quality in the Gabilan area is shown in Figure 63.

Drinking Water. Samples from two wells contained dissolved constituents exceeding the MCL. A sample from one well located in Indian Valley contained concentrations of TDS, sulfate, and EC in excess of the MCL (Table 25). A high nitrate concentration of 71 mg/L was also present in a sample from a well located in upper Ranchita Canyon. Nitrate concentrations were relatively high, but generally not exceeding the MCL, in samples from wells in Powell Canyon, Portuguese Canyon, Indian Valley, and Vineyard Canyon. TDS concentrations range from a low of 370 mg/L in a well sample from Portuguese Canyon to a high of 1,320 mg/L in a well sample from Indian Valley. The average TDS concentration in samples from the seven sources in the Gabilan area is 700 mg/L.

Agricultural Irrigation. Five of the seven water samples collected from the Gabilan area show no restriction for use in sprinkler or surface agricultural irrigation (including low volume systems), based on the water quality results from sources between Portuguese Canyon and Hog Canyon. Groundwater from two wells sampled in the Gabilan area (Powell Canyon and Indian Valley) carry a slight to moderate level of restriction for trees and vines irrigation due to potential sodium and chloride ion toxicity. The EC of these two samples, and of one other in Vineyard Canyon, is above 1.0 dS/m, and if used for vineyard irrigation, monitoring should be done to identify developing salinity problems due to the relatively high (20%) leaching ratio requirement. There is also a potential for lime deposition and plugging of low volume irrigation systems at one of the sites due to a pH value of 7.7, together with bicarbonate concentrations over 100 mg/L in the Powell Canyon source.

Water Quality Trends. Only one location with multiple historical water quality samples is available for the Gabilan area (24S/12E-17L01, L02). Two other locations that were sampled in this study had a single historical water quality sampling date, in addition to the current water quality analysis results.

- **24S/12E-17L01, 17L02, 17L (1954-2001)** - Indian Valley, four miles from Hwy 101. The depths of these wells are not known. All three wells are in the same 40-acre area. Historically, the TDS concentrations range from 968 to 1,082 mg/L during the 1950's and 1960's, with current TDS of 1,320 mg/L at well 17L. Chlorides range from 32 to 47 mg/L prior to 1965, and are currently 120 mg/L at well 17L. Nitrates range from 4 to 8.1 mg/L prior to 1965, and are currently 34 mg/L at well 17L. Groundwater quality was relatively stable in this area through at least 1965, but has since significantly increased in mineralization. There are insufficient data in the gap between 1965 and present to identify whether the water quality change remains a current trend or not.

Table 25. Water Quality
Gabilan Area

Sample Description	Water Type	Sample Date	Well Depth	TDS[1] mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 + CO3 mg/l	Cl[1] mg/l	SO4[1] mg/l	NO_3[2] mg/l	Fe[1] mg/l	Mn[1] mg/l	B mg/l	SAR	EC[1] dS/m	PH units
23S/11E-11E	Ca Cl	10/19/2001		870	123	55	76	4.4	279	209	204	39	0.1	< 0.03	0.2	1.5	1.42	7.7
23S/11E-33A	Ca HCO3	10/11/2001		370	48	20	36	1.7	215	57	8.9	44	< 0.1	< 0.03	0.11	1.1	0.57	7.4
24S/12E-17L	Ca-Mg SO4	10/11/2001		1320	142	81	132	4.7	279	120	648	34	< 0.1	< 0.03	0.44	2.2	1.99	7.2
24S/12E-27E	Ca-Mg HCO3-SO4	10/15/2001	450	900	136	66	39	2.9	393	55	256	34	< 0.1	< 0.03	0.22	0.7	1.21	6.9
24S/12E-33H (S)	Mg HCO3	10/15/2001	spring	450	44	47	37	2.5	303	35	50	23	< 0.1	< 0.03	0.18	0.9	0.69	7.4
24S/13E-23K	Mg-Ca HCO3-SO4	10/16/2001	540	630	85	58	29	2.1	309	38	165	71	< 0.1	< 0.03	0.19	0.6	0.94	7.5
25S/13E-22F	Mg-Na HCO3	10/15/2001	350	380	31	37	58	2.3	295	44	29	11	< 0.1	< 0.03	0.37	1.7	0.63	7.5
Maximum Contaminant Level Concentrations				1000	--	--	--	--	--	500	500	45	0.3	0.05	--	--	1.60	--

MCL = Maximum Contaminant Level of Primary and Secondary analytes
Shaded areas represent concentrations exceeding MCL
mg/l = milligrams per liter
dS/m = deciSiemens per meter
[1] Secondary drinking water standards analyte
[2] Primary drinking water standards analyte

- **24S/12E-27M01, 27E (1954, 2001)** - About 5 miles north of San Miguel in Vineyard Canyon. The depth of well 27M01 is not known. Well 27E is 450 feet deep. These wells are within a half-mile of each other. In June 1954, the TDS, chloride, and nitrate concentrations in groundwater at this location measured 433 mg/L, 32 mg/L, and 34 mg/L, respectively. Currently, these same parameters were measured at 900 mg/L TDS, 55 mg/L chloride, and 34 mg/L nitrate. TDS has increased significantly at this location.
- **24S/12E-33H01, 33H spring (1953, 2001)** - About four miles north of San Miguel in Vineyard Canyon. The depths of these wells are not known. In October 1953, the TDS, chloride, and nitrate concentrations in groundwater at this location measured 513 mg/L, 32 mg/L, and 16.4 mg/L, respectively. Currently, these same parameters were measured in a nearby spring at 450 mg/L TDS, 35 mg/L chloride, and 23 mg/L nitrate. There has been no significant change in water quality between 1954 and 2001 at this location, based on the three constituents reviewed.

There is insufficient information to evaluate water quality trends in the Gabilan area. The available data suggest an increase in groundwater mineralization has taken place in two of the main drainages (Indian Valley and Vineyard Canyon).

Bradley Area

General Minerals. The Bradley area receives surface water inflow from the Salinas River on the south, and the Nacimiento and San Antonio rivers on the west. The most common water type entering the Estrella from the major drainages is calcium-bicarbonate, with magnesium the secondary cation in most cases. An example of the surface water inflow quality is shown on Table 26.

Table 26. Surface Water Quality - Bradley Area

Source ID/Water Type	Date	Flow (cfs)	Units	Ca	Mg	Na	K	HCO3	SO4	Cl	TDS
Salinas @ San Miguel Ca HCO3	03/17/54	353	mg/L	50	11	16	3.1	168	49	27	300
			meq/l	2.5	0.9	0.7	0.08	2.75	1.02	0.76	
Salinas @ San Miguel Na HCO3	03/26/54	20	mg/L	78	39	127	3.5	342	180	113	767
			meq/l	3.89	3.21	5.52	0.09	5.61	3.75	3.19	
Nacimiento @ San Miguel Ca-Mg HCO3	03/13/68	1000	mg/L	30	15	10	1	134	37	6	202
			meq/l	1.5	1.23	0.44	0.03	2.2	0.77	0.17	
Nacimiento @ San Miguel Ca-Mg HCO3	05/07/68	200	mg/L	30	15	10	1	135	36	7	168
			meq/l	1.5	1.23	0.44	0.03	2.21	0.75	0.2	
Nacimiento @ San Miguel Ca-Mg HCO3	11/18/74	2	mg/L	27	13	11	1	123	34	6.5	163
			meq/l	1.35	1.07	0.48	0.03	2.02	0.71	0.18	
San Antonio @ G19 Bridge Ca HCO3	02/06/58	500	mg/L	32	9.1	9.2	1.4	109	34	10	198
			meq/l	1.6	0.75	0.4	0.04	1.79	0.71	0.28	

Six water samples are used to represent current groundwater water quality in the Bradley area. Groundwater quality in the area is variable, with no dominant type. Calcium-bicarbonate, which is the primary surface water inflow quality, is represented by only one groundwater sample, a shallow well in the town of Bradley with a TDS of 400 mg/L. The remaining samples include sodium-chloride, sodium-bicarbonate-chloride, and sodium-sulfate-bicarbonate waters from deeper wells along the Nacimiento River valley, a calcium-sulfate water from Hames Valley, and a calcium-sodium-sulfate water from a well on the east side of the Salinas River. A summary of selected water quality results for the Bradley area is presented in Table 27. A graphical representation of water quality in the Bradley area is shown in Figure 64.

As mentioned above, with the exception of the sample from a 120-foot deep well in Bradley, water quality in the area is not consistent with the surface water inflow quality, both in type and degree of mineralization. There are apparent significant sources of dissolved sodium, chloride, and sulfate ions in the area. Descriptions of aquifer characteristics and geologic structure (in Chapters 2 and 3) indicate that the Bradley area is comprised of two predominant northwest-southeast trending synclines, one in Hames Valley and one along the southwest side of Camp Roberts. Wells tapping older, less permeable Paso Robles Formation deposits contain higher mineralized waters. In the Hames Valley, marginal quality water is reported from the marine Etchegoin Formation sands, which underlie the Paso Robles Formation and may influence water quality in deep wells and wells on the margins of the valley (Thorup, 1975). Older deposits are also brought closer to the surface adjacent to the San Miguel Dome, which continues in the subsurface through the confluence of the Nacimiento and Salinas Rivers (Figure 29).

Water quality in the Bradley area, despite having a relatively large amount of low salinity surface inflows, is apparently controlled by the geologic structure that brings older, less permeable deposits closer to the surface. These older beds have higher salinity and provide sources of dissolved sodium, chloride, and sulfate ions to the aquifers. TDS concentrations range from a low of 400 mg/L in a well sample from the town of Bradley to a high of 1,280 mg/L in a well sample obtained southeast of Bradley. The average TDS concentration in samples from the six wells is approximately 900 mg/L.

Drinking Water. Samples from five of the six sampled wells contained dissolved constituents exceeding the MCL (Table 27). Several constituents above MCL were present in samples from three wells (up to 500 feet deep) located southeast of Bradley in the Salinas River valley area. An iron concentration above MCL was present in a sample from a deep irrigation well located in Hames Valley, and a nitrate concentration above MCL was present in a sample from a well located in the town of Bradley. The one well containing no analytes above MCL is a 340-foot deep well located south of the Nacimiento River. Wells near the confluence of the Nacimiento and the Salinas River exhibited the poorest overall water quality in the area.

Table 27. Water Quality
Bradley Area

Sample Description	Water Type	Sample Date	Well Depth	TDS[1] mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO3 + CO3 mg/l	Cl[1] mg/l	SO4[1] mg/l	NO_3[2] mg/l	Fe[1] mg/l	Mn[1] mg/l	B mg/l	SAR	EC[1] dS/m	PH units
24S/10E-4A	Ca SO4	10/11/2001	1100	730	118	35	50	3.2	204	47	348	< 0.4	0.5	0.067	0.18	1.1	1.12	7.5
24S/11E-24Q01	Ca Na - SO4	3/23/1999		1150	208	50	190	4.9	256	40	704	0.8	0.4	< 0.005	NR	3.1	NR	8.1
24S/11E-26L01	Na – SO4 HCO3	3/23/1999	204	1280	153	36	303	NR	299	90	344	1.8	0.4	0.09	NR	5.7	NR	8.4
24S/11E-34K02	Na - HCO3 Cl	3/23/1999	340	780	21	8.9	312	2.0	372	150	94	NR	0.2	0.04	NR	14.5	NR	8.3
24S/11E-35E01	Na Cl	3/23/1999	500	1040	21	6.6	529	2.0	335	400	257	NR	0.1	NR	NR	25.7	NR	8.7
24S/11E-8B	Ca HCO3	10/11/2001	120	400	60	23	36	1.5	207	58	30	55	< 0.1	< 0.03	0.12	1.0	0.63	7.4
Maximum Contaminant Level Concentrations				1000	--	--	--	--	--	500	500	45	0.3	0.05	--	--	1.60	--

MCL = Maximum Contaminant Level of Primary and Secondary analytes
Shaded areas represent concentrations exceeding MCL
mg/l = milligrams per liter
dS/m = deciSiemens per meter
[1] Secondary drinking water standards analyte
[2] Primary drinking water standards analyte

Agricultural Irrigation. Two of the six groundwater samples collected from the Bradley area show no restriction for use in sprinkler or surface agricultural irrigation (sources in the town of Bradley and in the Hames Valley). Groundwater from a shallow (204 feet deep) well east of the Salinas River near the confluence of the Nacimiento and Salinas rivers carries a moderate level of restriction for trees and vines irrigation due to potential sodium ion toxicity. The remaining three Bradley area water samples, all located along the Nacimiento River valley, have a severe restriction for trees and vines irrigation due to potential sodium ion toxicity (including one with chloride ion toxicity).

There is also a potential for lime deposition and plugging of low volume irrigation systems at four of the sites due to a pH value greater than 8, together with bicarbonate concentrations over 100 mg/L. Three samples also carry a caution for low volume irrigation system plugging due to iron concentrations in excess of 0.3 mg/L.

Water Quality Trends. Three wells with more than one historical water quality sample and a recent sampling event are available for the Bradley area. These wells are evaluated for water quality trends below.

- **24S/11E-35E01 (1954-1999)** - This well is 500 feet deep, located between the Nacimiento and Salinas rivers, approximately 1.5 miles south of the confluence. Historically, TDS concentrations range from 762 to 1,100 mg/L (last reported at 1,037 mg/L in 1999). Chlorides range from 93 to 400 mg/L (last reported at 400 mg/L in 1999). Nitrates range from 1.3 to 4.6 mg/L (last reported at 4.6 mg/L in 1999). The chloride and TDS concentrations in groundwater have been increasing on average over time, although the apparent doubling of chloride concentrations between 1996 and 1999 may be an anomaly.

  TDS has increased almost 7 mg/L per year since the 1950's, and has already exceeded drinking water standards. Chloride has reached 400 mg/L (which severely restricts irrigation use), although the most recent data point does not correlate with the historic trend of 2 mg/L increase per year between 1954 and 1996. These indications of increased mineralization over time are considered a major water quality trend that has already affected the use of water from this well for drinking and irrigation. Nitrates are also at the historic high, but show no clear trend due to fluctuations.

- **24S/11E-26C01 (1975-1999)** - The well is 204 feet deep, located on the west bank of Nacimiento River at the confluence with the Salinas River. Historically, the TDS concentrations range from 1,281 to 1,400 mg/L (last reported at 1,281 mg/L in 1999). Chlorides range from 80 to 101 mg/L (last reported at 90 mg/L in 1999). Nitrates range from 0 to 1.8 mg/L (last reported at 0 mg/L in 1999). Chloride concentrations have been decreasing over time at a rate of 0.6 mg/L per year. Nitrates and TDS have been relatively stable.

- **24S/11E-14Q01 (1985-1999)** - Well depth is unknown. Well is located on east side of Salinas River near confluence with Nacimiento River. Historically, the TDS concentrations range from 840 to 1,200 mg/L (last reported at 1,151 mg/L in 1999).

Chlorides range from 40 to 51 mg/L (last reported at 51 mg/L in 1999). Nitrates range from 0.8 to 23 mg/L (last reported at 0.8 mg/L in 1999). Chloride concentrations have been relatively stable over time, while TDS has increased and nitrates have decreased. These changes, however, are dominated by a large increase in TDS between the 1995 and 1996 sampling events (from 850 mg/L in 1995, to 1,200 mg/L in 1996) and a large decrease in nitrates between the 1985 and 1995 sampling events. These single event changes do not constitute long-term trends.

As with the Gabilan area, there is little historical data with which to evaluate trends. The available information shows one potential major trend of increasing TDS and chloride concentrations in a deeper well at the confluence of the Salinas and Nacimiento rivers.

Other Constituents of Interest

There are a wide variety of minor and trace constituents in groundwater sampled during the study. Some of the common minor constituents such as nitrate, potassium, boron, iron, and manganese were part of the analyses included in the discussions above. Others not included, but of potential local interest, are discussed below.

The majority of natural trace constituents are metals, but may include nonmetals such as arsenic, selenium, bromine, and iodine. The scope of this study does not include a detailed review of trace constituents; however, the presence of fluoride, arsenic, mercury, and selenium was screened in the databases. In addition, radioactivity as gross alpha and uranium was screened. The results of these water quality screens are presented in Tables 28 through 33.

Table 28. Fluoride Concentrations

Area	Atascadero	Creston	Shandon	San Juan	Estrella	Bradley
Total sources	52	11	34	8	91	22
Total samples	143	39	120	31	289	59
Maximum (mg/L)	1.4	1.7	1.3	1.2	5.8	1
Number of wells with history of no detection	0	0	1	0	0	3
Number of samples with no detection	4	2	5	0	4	6
Mean detection (mg/L)	0.32	0.43	0.41	0.48	0.56	0.41
Median detection (mg/L)	0.3	0.3	0.4	0.4	0.4	0.4

Note: Fluoride MCL is 2 mg/L

Dissolved fluoride concentrations are present throughout the groundwater basin, typically at levels below 0.5 mg/L (Table 28). Fluoride concentrations in groundwater exceeded the MCL of 2 mg/L in 10 samples collected from sources along the Salinas River near the Huer Huero Creek confluence.

Dissolved arsenic concentrations are present in most areas of the basin, typically at levels below 10 µg/l (Table 29). Arsenic concentrations in groundwater did not exceed the MCL for drinking water in any of the samples tested.

Table 29. Arsenic Concentrations

Area	Atascadero	Creston	Shandon	Estrella	Bradley
Total sources	12	1	2	10	5
Total samples	42	1	21	72	12
Maximum (µg/l)	15	10	3.7	19	20
Number of wells with history of no detection	4	0	0	1	0
Number of samples with no detection	33	0	9	32	3
Mean detection (µg/l)	5.7	--	2.9	5.9	9.5
Median detection (µg/l)	4.4	--	2.8	4.4	7

Note: Arsenic MCL is 50 µg/l

Groundwater throughout most of the basin does not contain dissolved mercury in reportable levels (Table 30). Mercury concentrations in groundwater exceeded the MCL for drinking water in one 1990 sample from a well near San Miguel; however, this well has not contained detectable mercury concentrations in groundwater over the last 10 years (seven tests, last in 2000).

Table 30. Mercury Concentrations

Area	Atascadero	Shandon	Estrella	Bradley
Total sources	12	2	10	2
Total samples	43	21	71	2
Maximum (µg/l)	--	1	2.07	--
Number of wells with history of no detection	12	0	8	2
Number of samples with no detection	43	19	65	2
Mean detection (µg/l)	--	0.73	0.98	--
Median detection (µg/l)	--	1	1	--

Note: Mercury MCL is 2 µg/l

Dissolved selenium concentrations are present in some areas of the basin (Table 31). Selenium concentrations in groundwater did not exceed the MCL for drinking water in any of the samples tested.

Table 31. Selenium Concentrations

Area	Atascadero	Creston	Shandon	Estrella	Bradley
Total sources	12	1	2	10	5
Total samples	43	1	21	72	14
Maximum (µg/l)	34.1	2	2.3	8	25
Number of wells with history of no detection	8	0	0	4	0
Number of samples with no detection	33	0	17	50	4
Mean detection (µg/l)	16.4	--	1.8	4.1	13.4
Median detection (µg/l)	15	--	1.8	3.5	12

Note: Selenium MCL is 50 µg/l

Gross Alpha radioactivity is present in most areas of the basin (Table 32). Gross Alpha particle count activity in groundwater exceeded the MCL for drinking water in the Estrella and Bradley areas. All of the groundwater sources with excessive gross alpha particle counts are located along the Salinas River valley between the Estrella River confluence and the Nacimiento River confluence. The source of the excessive Gross Alpha is presumed to be natural, but has not been unidentified.

Table 32. Gross Alpha Radiation

Area	Atascadero	Shandon	Estrella	Bradley
Total sources	12	2	11	4
Total samples	56	2	118	10
Maximum (pCi/L)	11	3	31	23
Number of wells with history of no detection	1	0	0	0
Number of samples with no detection	15	0	4	0
Mean detection (pCi/L)	2	3	20	2
Median detection (pCi/L)	2	--	9	8

Note: Gross Alpha MCL is 15 pCi/L

Uranium radioactivity is present in most areas of the basin (Table 33). Uranium particle count activity in groundwater exceeded the MCL for drinking water in four samples collected from the same source near San Lawrence beginning in 1998.

Table 33. Uranium Radiation

Area	Atascadero	Estrella	Bradley
Total sources	6	8	3
Total samples	8	77	6
Maximum (pCi/L)	9	21	16
Number of wells with history of no detection	1	0	0
Number of samples with no detection	1	0	0
Mean detection (pCi/L)	5	12	10
Median detection (pCi/L)	5	13	8

Note: Uranium particle count MCL is 20 pCi/L.

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CHAPTER 5 – HYDROLOGIC BUDGET

GENERAL

The methodology used to perform the water balance for the Paso Robles Groundwater Basin entailed an analysis of each component of water supply use and disposal (or discharge) for each year of the base period. Given the availability of data and uncertainties in accuracy in calculating the magnitude of each of these components, the annual totals were in turn compared to the annual changes of groundwater in storage within the basin, as determined by the specific yield method.

A hydrologic budget (or water balance) is simply a quantitative statement of the balance of the total water gains and losses from the basin for a given period of time. The major components of the budget or balance evaluated for the Paso Robles basin can be expressed by the following relationship.

$$Sb_I + P + S_I + PR + WW + W_I = Sb_o + Q + EP + W_E \pm \Delta S$$

where:
- Sb_I = Subsurface Inflow
- P = Percolation of Precipitation
- S_I = Streambed Percolation
- PR = Percolation of Irrigation Return Water
- WW = Percolation of Wastewater Discharge
- W_I = Imported Water
- Sb_o = Subsurface Outflow
- Q = Gross Groundwater Pumpage
- EP = Extraction by Phreatophytes
- W_E = Exported Water
- ΔS = Change in Groundwater Storage

These relationships are graphically illustrated on Figure 65.

The hydrogeologic base period for the study encompasses the years from 1981 through 1997 (17 years). Selection of this base period was sensitive to the issues of historic wet-dry cycles, approximation of average precipitation conditions throughout the basin given its size and relief, and avoidance of significant volumes of water in transit to the zone of saturation at either the beginning or end of the base period. In any water balance study, there are assumptions in estimating the seasonal volumes of recharge or discharge. The assumptions used in calculating the magnitude of the seasonal amounts of recharge and discharge are explicitly stated. In some cases, there were slight variations in the time periods used for the entry of the annual totals of inflow and outflow, depending on how data sets were available (i.e., water year

v. calendar year). As appropriate, all values were adjusted slightly to generate a common water year (October to September) time period.

COMPONENTS OF INFLOW

Subsurface Inflow (Sb_I)

Subsurface inflow is the flow of groundwater from the surrounding "non-water bearing bedrock" into the basin sediments. Because the permeability of surrounding bedrock units are often significantly less than basin sediments, the volume of subsurface inflow is often inappropriately ignored. In an investigation of the Carpinteria and Goleta basins in southern California, Evenson et al. (1962; p. 9) stated that "additional replenishment, above that estimated by previous investigators, probably occurred through a lowering of the water table and the consequent steepening of groundwater gradients out of the consolidated rocks that border the edges of the Carpinteria and Goleta basins." Feth (1964) compared Evenson's results with discrepancies in the hydrologic budget for other groundwater basins in the Western Cordillera and found that, on the basis of imbalances in the hydrologic equation, water quality data, and evidence of groundwater in various consolidated rocks provided by man-made tunnels, it is generally unrealistic to ignore the factor of subsurface underflow from consolidated non-water-bearing rocks into alluvial basins. Studies conducted by the DWR (Bulletin Nos. 104 [1962] and 104-2 [1966]) similarly concluded that such components of recharge cannot be ignored.

Depending on the availability of data, the volume of subsurface inflow to the Paso Robles basin can be estimated using several interrelated methods:

1. Total precipitation less surface runoff and consumptive use.
2. Natural water loss and recoverable water from mountain basins (the so-called Crippen method).
3. Base flow recession curves.
4. Comparison of tunnel inflow volume and Darcy's law.

Each method of analysis essentially limits the amount of water that can theoretically be available as a source of recharge to the groundwater basin. The range of values obtained can be compared and an estimate of recharge entered in the hydrologic equation. Annual amounts can also be adjusted based on a simple regression from the average of precipitation in a given year to the base period average.

Unfortunately, data on average volumes of runoff, precipitation, and consumptive use of native vegetation in the watershed areas tributary to the Paso Robles basin are subject to considerable uncertainty and interpretation. Application of methods 1, 2, and 3 above would likely yield misleading and potentially conflicting results, particularly given the size of the Paso Robles basin watershed. Efforts in assessing the magnitude of the annual amount of subsurface inflow focused on methodology number 4 above. It should be recognized that the results obtained are considered a gross approximation due to a lack of specific data on hydraulic gradients, saturated cross-sectional area, and conductivity values in bedrock formations at the basin boundaries.

The quantity of subsurface inflow was computed by the slope area method using Darcy's Law in which the rate of discharge through a given cross section of saturated material is proportional to the hydraulic gradient. This equation can be expressed as follows:

$$Q = PIA$$

in which:
- Q = amount of flow in gallons per day
- P = coefficient of permeability in gallons per day per square foot
- I = hydraulic gradient in feet per foot
- A = saturated area in square feet

It is important to note that a key variable in the calculation of the subsurface inflow component is the coefficient of permeability (hydraulic conductivity), which in the case of the bedrock units surrounding the Paso Robles Groundwater Basin varies over three orders of magnitude. Although it is recognized that the hydraulic characteristics of the bedrock units vary considerably, for purposes of this analysis the geologic units can be divided into several general categories including the Monterey Formation, Pancho Rico Formation, Paso Robles Formation, Santa Margarita Formation, and granite. A tabulation of the approximate linear reaches of these units surrounding the basin is provided in Table 34. The location of the reaches is shown on Figure 66.

Table 34. Annual Subsurface Inflow

Reach	Formation	Length (feet)	Average Hydraulic Gradient (feet/foot)	Average Saturated Thickness[1] (feet)	Saturated Area ($feet^2 \times 10^6$)	Assumed Hydraulic Conductivity (gpd/ft^2)	Average Annual Inflow Across Reach (afy)
			(I)		(A)	(P)	(Q)
1	Granite	36,110	0.02	500	18.1	0.1	40
2	Monterey	48,421	0.02	500	24.2	0.01	5
3	Pancho Rico	13,401	0.02	500	6.7	1	150
4	Monterey	152,548	0.03	500	76.3	0.01	26
5	Monterey	110,439	0.03	500	55.2	0.01	19
6	Pancho Rico	198,712	0.03	500	99.4	1	3,339
7	Paso Robles, across fault	103,810	0.02	500	51.9	0.01	12
8	Unnamed clastic unit, across fault	24,770	0.02	500	12.4	0.01	3
9	Paso Robles, across fault	16,341	0.02	500	8.2	0.01	2

Table 34. Annual Subsurface Inflow (Continued)

Reach	Formation	Length (feet)	Average Hydraulic Gradient (feet/foot)	Average Saturated Thickness[1] (feet)	Saturated Area ($feet^2 \times 10^6$)	Assumed Hydraulic Conductivity (gpd/ft^2)	Average Annual Inflow Across Reach (afy)
			(I)		(A)	(P)	(Q)
10	Santa Margarita, across fault	67,008	0.03	500	33.5	0.01	11
11	Granite	129,718	0.02	500	64.9	0.1	145
12	Santa Margarita	253,037	0.02	500	126.5	1	2,834
13	Granite	128,990	0.02	500	64.5	0.1	145
14	Monterey[2]	19,999	0.03	500	10.0	0.01	3
15	Granite[2]	40,998	0.02	500	20.5	0.1	46
16	Santa Margarita[2]	62,488	0.02	500	31.2	1	700
17	Monterey[2]	51,047	0.01	500	25.5	0.01	3
	Total:	**1,457,837**					**7,483, say 7,500**

Note: 1. Assumed to be 500 feet. Taken from geologic cross sections in Task 2 Interim Report.
2. Atascadero subbasin boundary.

The hydraulic gradient for each reach was assumed to mimic surface topography. The gradient for each reach was calculated in ArcView GIS using several methods. The slope of a specific area was calculated and converted to foot rise per foot run. The slope was then determined by calculating the maximum rate of change from each elevation grid cell to its neighbors. The individual reaches were then buffered 1,000 feet on the outside of the basin. The mean slope of each of these reach polygons was calculated and is summarized on Table 34. Although determined to three significant figures, these were adjusted on the table and range from about 0.01 to 0.03 ft/ft. Although the gradients are somewhat high, they are believed to be a reasonable approximation to groundwater gradients in the bedrock units. Studies of subsurface inflow in Santa Barbara County for the Santa Ynez Mountains used an average gradient of 0.04, or about 200 feet per mile (Geotechnical Consultants, Inc., 1975).

The average saturated thickness at the various boundaries was taken at 500 feet based on the geologic and hydrogeologic cross sections described earlier. Hydraulic conductivity values were chosen at between 0.01 and 1 gallon per day per square foot (gpd/ft^2) based on aquifer properties data from Chapter 3 and published literature. The permeability values chosen greatly influence the results of the analysis and deserve some discussion. Wells in the bedrock units surrounding the basin typically display specific capacities of one (1) gallon per minute per foot (gpm/ft) of drawdown or less, with corresponding transmissivity values of less than 1,000 gpd/ft. Flow across the basin boundary is predominantly via highly conductive, but random and discontinuous, fractures. Comparison of typical nomograms that relate transmissivity to permeability (e.g., U.S. Department of Interior *Ground Water Manual*, 1977; Freeze and Cherry, 1979) would suggest permeability values no greater than about 0.1 gpd/ft^2 for granite units, 0.01 gpd/ft^2 for the Monterey Formation, and perhaps as high as 1 gpd/ft^2 for the Pancho Rico, Santa Margarita, and the Paso Robles formations. Because the White Canyon, Red Hill, and San Juan faults that form the eastern boundary of the basin are thought to act as barriers (or at least leaky barriers) to groundwater flow, permeability values across those fault are assumed to be 0.01 gpd/ft^2, regardless of the geologic unit juxtaposing the fault.

The calculated volume of average annual underflow by reach (unadjusted from annual precipitation) is shown on Table 34. The rate of subsurface inflow to the Paso Robles basin from the surrounding hill and mountain area undoubtedly varies considerably from year to year depending upon precipitation (intensity, frequency and duration, seasonal totals, etc.) and groundwater level gradients. There are no available published or unpublished tunnel inflow data for the hill and mountain areas surrounding the Paso Robles basin, for geologic units that border the basin sediments. The nature of groundwater discharge, however, can be seen in the response of the Tecolote Tunnel in Santa Barbara County to precipitation. As discussed by Rantz (1962), there is almost an immediate response between precipitation and tunnel discharge. Rantz (1962) further observed that a certain amount of deep percolation from rainfall occurred as evidenced by the continued tunnel discharge for some time after a precipitation event. Similar conditions were noted by Thomasson (1951, p. 39) in the Mission Tunnel, which transports water through the Santa Ynez Mountains to the City of Santa Barbara. Rantz (1962) concluded that although quantitative studies of the rainfall-discharge are not possible, antecedent or "carry-over" effects of precipitation from year to year are quite evident.

Based on the above method of analysis, a contribution of about 7,500 acre-feet per year (afy) over the base period is considered reasonable as an estimate of subsurface inflow to the Paso Robles Groundwater Basin. The inflow value was subsequently adjusted according to annual variations in precipitation (as a percentage of the rainfall in any particular year versus annual average rainfall) and is provided on Table 35. Contrary to discussions by Evenson et al. (1962), the lowering of water table elevations in basins in Santa Barbara County during periods of drought is not considered to be the moving force behind hill and mountain recharge. Rather, as is demonstrated qualitatively by the tunnel inflows in the Santa Barbara area, seasonal variations in precipitation are considered to be the controlling factor. Subsurface underflow would correspondingly increase during wet years and be reduced significantly during dry years. Although individual years may be in error (and indeed the "carry-over" effect must be significant after periods of heavy precipitation, perhaps for as much as two years), the long-term estimates are considered reasonably correct.

Subsurface inflow into the Atascadero subbasin was estimated using the same methodology. Table 35 provides adjusted inflow volumes for each year of the base period. Average quantities of inflow are about 800 afy.

Table 35. Estimate of Adjusted Annual Subsurface Inflow

(in acre-feet per year)

Year	Paso Robles Basin		Atascadero Subbasin	
	Rainfall (in)	Subsurface Inflow (afy)	Rainfall (in)	Subsurface Inflow (afy)
1981	10.20	5,563	14.25	568
1982	13.95	7,727	20.17	776
1983	22.96	12,720	38.84	1,278
1984	9.14	5,066	13.72	509
1985	8.24	4,568	13.10	459
1986	15.40	8,532	23.85	857
1987	8.41	4,661	9.26	468
1988	13.56	7,513	17.59	755
1989	7.27	4,031	10.74	405
1990	9.10	5,044	10.19	507
1991	13.49	7,476	17.71	751
1992	14.87	8,239	20.80	828
1993	21.07	11,677	28.68	1,173
1994	8.11	4,493	8.27	451
1995	26.90	14,906	31.15	1,498
1996	12.33	6,834	19.14	687
1997	14.56	8,069	22.69	811
Average:		**7,483, say 7,500**		**752, say 800**

Percolation of Precipitation (P)

The volume of precipitation that percolates vertically downward into a groundwater basin aquifer can vary considerably, depending mostly upon the type of soil, density of vegetation, the quantity, intensity, and duration of rainfall, the vertical permeability of the soil, and topography. Much of the infiltrating rainfall is held in the root zone because at the beginning of each rainy season there is generally an initial deficiency of soil moisture. During the summer months, the capillary soil moisture is more or less completely depleted from the soil within the root zone by the processes of evaporation and transpiration. No deep percolation of rainfall can occur until the initial fall soil moisture deficiency is exceeded. Many years may pass before any rainfall penetrates beyond the root zone of native vegetation. In irrigated soils, because of the artificial application of water, the initial fall moisture content is greater and less annual rainfall is required to meet the soil moisture deficiency. Once the soil moisture deficiency within the root zone has been satisfied, the excess precipitation will percolate downward until it eventually reaches the water table.

There are two primary considerations in calculating the volume of precipitation that percolates beyond the root zone and contributes to groundwater in storage: first, the determination of deep percolation of rainfall in inches for various vegetative covers, and second, the determination of the total area of the various covers for which inches of percolation is determined (see Tables 45 and 46 for tabulations of various land covers). The total volume of percolation in acre-feet (af) is then calculated (i.e., inches of percolation x acreage). Note that these calculations cover the 505,000 acre area of the basin, and are not applied to the area of the watershed.

The precise field measurement of the amount of total rainfall that percolates below the root zone and reaches the main water body requires special equipment, is time consuming, and, to be of value, must be continued over several years and under a variety of conditions. In order to estimate the amount of rainfall that percolates to the Paso Robles basin, it was necessary to rely upon measurements made by Blaney (1933) in Ventura County. The Blaney (1933) investigation has become the standard reference for calculation of deep percolation of rainfall. Although conditions in the Paso Robles basin are not exactly the same as in Ventura County, it is believed that they are sufficiently similar for the estimates to be valid.

Blaney (1933) empirically tabulated the amount of rainfall that percolated beyond the root zone, depending upon the type of vegetation and amount of precipitation. Blaney's values of deep percolation (in inches) versus rainfall were plotted for land covers similar to those in the Paso Robles basin, and best-fit curves drawn through these points. Values of percolation of rainfall corresponding to rainfall and vegetative cover types in the Paso Robles basin were picked from these curves.

Blaney developed curves for most of the land cover types found in the Paso Robles basin (Figure 67). Land use categories for which specific Blaney data were not available include: urban/rural, suburban, and vineyards. For the urban/rural and suburban areas, Blaney's curve for grass and weeds was utilized. While the actual land use is very different, the grass and weeds curve was considered reasonable because the amount of deep percolation occurring on grass and weeds is the most limited of all the Blaney curves, due primarily to the large initial soil moisture deficiencies. Due to the presence of impervious surfaces in the urban/rural and suburban areas where no percolation can occur and much of the rainfall runs off, a relatively limited amount of deep percolation is expected to occur in these areas. The Blaney curve for deciduous land covers was utilized for the vineyard areas in the Paso Robles basin. Again, it is acknowledged that the actual land use is somewhat different; however, the curve for deciduous crops reflected better the deep percolation conditions on vineyards, primarily due to the similarly deep rooting depths, as compared to, for example, truck crops with relatively shallow rooting depths.

As discussed above, Blaney's curves are utilized to determine the inches of percolation during each rainfall year for the various land covers. This is the first part of the calculation. The available land use data allow only for the determination of gross acreages of the various land covers within the Paso Robles basin for each year of the base period, but not the spatial distribution of the various types within the basin. As a result, annual precipitation for each year of the base period was determined by taking the average value of annual precipitation from seven precipitation stations distributed geographically throughout the basin. The stations were selected to best represent wet, average, and dry conditions within the basin (i.e., west to east and north to south).

The amount of precipitation that infiltrated as deep percolation for each of the land covers in the Paso Robles basin is shown below in Table 36, as is the total volume of deep percolation for each year of the base period and the average for the 17-year period.

Based on the data presented in Table 36, it is evident that significant deep percolation only occurs in the wettest years (particularly on non-irrigated native lands), which is to be expected given the soil moisture discussion above. As shown in Table 36, deep percolation is estimated to have occurred on native lands only during the three wettest years during the period (1983, 1993, and 1995), years when the average annual precipitation exceeded 20 inches. On irrigated lands, some additional deep percolation occurred in years when the average annual precipitation exceeded approximately 12 inches. In years when the average annual rainfall is less than approximately 12 inches, no deep percolation occurred. Based on the estimates presented above, more than 90 percent of all the deep percolation during the 17-year base period occurred during the three wettest years.

Table 36. Deep Percolation by Precipitation, Paso Robles Groundwater Basin

Rain-fall Year	Rain-fall (in)	Deep Percolation (acre-feet)											
		Native	Alfalfa	Pas-ture	Grain	Field	Truck	Urban/ Rural	Vine-yard	Decid-uous	Idle	Subur-ban	Total
1981	10.20	0	204	0	0	124	0	0	2	7	0	0	337
1982	13.95	467	2,082	198	2,761	364	62	50	87	102	0	53	6,226
1983	22.96	102,660	9,294	1,593	94,771	1,607	292	2,902	2,816	2,965	2,608	1,472	222,982
1984	9.14	0	129	0	0	78	0	0	1	1	0	0	209
1985	8.24	0	84	0	0	51	1	0	0	0	0	0	136
1986	15.40	2,264	2,264	522	10,511	449	99	166	657	520	0	136	17,588
1987	8.41	0	0	0	0	0	0	0	0	0	0	0	0
1988	13.56	0	823	0	952	202	52	0	73	21	0	0	2,123
1989	7.27	0	0	0	0	0	0	0	0	0	0	0	0
1990	9.10	0	0	0	0	0	0	0	0	0	0	0	0
1991	13.49	0	447	0	607	165	50	0	103	13	0	0	1,385
1992	14.87	1,733	766	177	2,093	269	85	82	667	307	0	42	6,221
1993	21.07	83,063	2,204	834	29,486	736	244	2,459	4,257	1,791	447	275	125,796
1994	8.11	0	0	0	0	0	0	0	0	0	0	0	0
1995	26.90	263,227	3,600	2,543	54,678	1,076	393	8,250	8,449	2,989	735	495	346,436
1996	12.33	597	190	44	736	53	21	27	202	0	0	9	1,879
1997	14.56	3,495	721	235	532	191	78	157	653	195	0	48	6,305
												Total:	**737,623**
												17-year Average:	**43,400**

Of interest is that 1986 was the fourth wettest year during the base period, with about 15.4 inches of rainfall averaged over the entire basin. The hydrographs for many wells in the basin indicate a significant addition of groundwater in storage (refer forward to Table 68). Closer inspection of the deep percolation calculations reveal that in 1986 the average rainfall of 15.4 inches was just below that required to obtain deep percolation on the natural grass/weeds, but there was some deep percolation on irrigated lands. For that year, based on the Blaney curves, there was no deep percolation on the native grass/weeds category, which is the largest single land use category in the basin. Also, for 1986 (as well as other years), the rainfall totals for the seven stations used were averaged and ranged from 11 to more than 23 inches (averaging 15.4). Assuming the Blaney curves are accurate, some deep percolation may have actually occurred in the northern/western portions of the basin where the rainfall was greater than 18 inches, but by using the average rainfall value, the amount of deep percolation is likely underestimated for that year by the method used. Such uncertainties are to be expected and for 1986, deep percolation of rainfall is conservatively stated.

Some compensation for this uncertainty is achieved by assigning specific rainfall data to the Atascadero subbasin for calculation of rainfall percolation in that area. Because the Atascadero subbasin is located on the western edge of the Paso Robles basin where rainfall is greatest, area-specific rainfall data was used in the area of the subbasin, which increases total percolation values for the basin as a whole.

Based on the estimates presented above, the average annual recharge to the basin during the base period from deep percolation of rainfall is estimated to be approximately 43,400 afy. This represents a significant percentage (approximately 46 percent) of the overall inflow water budget. It is important to note that the DWR (1979) study essentially discounted deep percolation of precipitation as a component of recharge in the Paso Robles basin, based on the assumption that because average annual evapotranspiration is greater that the average annual precipitation, no deep percolation occurs. This is certainly true in most years, but as shown above, deep percolation of rainfall is expected to occur on an episodic basis during years of excessive rainfall.

Deep percolation by precipitation into the Atascadero subbasin was estimated using the same methodology described above (using area-specific rainfall data). Table 37 shows the estimated annual volumes of recharge by precipitation for each year of the base period, with an average percolation inflow of approximately 3,900 afy. Similar to the deep percolation by precipitation estimates for the whole basin, significant recharge occurred in years 1983, 1993, and 1995, although years 1982, 1986, and 1992 also resulted in deep percolation above the 17-year average.

Table 37. Deep Percolation by Precipitation, Atascadero Subbasin

Rain-fall Year	Rain-fall (in.)	Deep Percolation (acre-feet)											
		Native	Alfalfa	Pasture	Grain	Field	Truck	Urban/ Rural	Vine-yard	Decid-uous	Idle	Sub-urban	Total
1981	14.25	0	204	0	0	124	0	0	2	7	0	0	336
1982	20.17	467	600	198	2,761	364	0	50	32	66	0	53	4,592
1983	38.84	3,327	1,152	1,158	6,874	700	0	319	114	148	0	317	14,135
1984	13.72	0	129	0	0	78	0	0	1	1	0	0	209
1985	13.10	0	84	0	0	51	1	0	0	0	0	0	135
1986	23.85	2,264	593	522	3,649	360	8	166	143	71	0	136	7,912
1987	9.26	0	0	0	0	0	0	0	0	0	0	0	0
1988	17.59	0	227	0	952	138	8	0	73	21	0	0	1,419
1989	10.74	0	0	0	0	0	0	0	0	0	0	0	0
1990	10.19	0	0	0	0	0	0	0	0	0	0	0	0
1991	17.71	0	132	0	607	80	13	0	103	13	0	0	949
1992	20.80	1,733	149	177	1,169	90	23	82	198	17	0	42	3,679
1993	28.68	7,198	178	685	2,521	108	46	338	437	23	0	159	11,693
1994	8.27	0	0	0	0	0	0	0	0	0	0	0	0
1995	31.15	9,660	0	790	2,987	0	65	452	603	0	0	174	14,730
1996	19.14	597	0	44	736	0	27	27	202	0	0	9	1,644
1997	22.69	3,495	0	235	1,096	0	44	157	352	0	0	48	5,527
												Total:	**66,859**
												17-Year Average:	**3,900**

Streambed Percolation (S_l)

Groundwater recharge from deep percolation of streamflow takes place in the narrow stream and alluvial valleys overlying the basin sediments. Recharge from streamflow percolation is a major component of the hydrologic budget because water is present as stream underflow, and therefore available for recharge, for extended periods of time. The amount of recharge from this component of inflow varies annually with the quantity and duration of runoff.

Information on streamflow for the main rivers and creeks in the Paso Robles Groundwater Basin is very limited. There are only four stream gages in the basin for which sufficient data exist for analyses of this type: Salinas River at the City of Paso Robles, Estrella River at Estrella, Huer Huero Creek downstream of Creston, and the Salinas River downstream of Bradley.

Methodology. To determine basin recharge by streamflow percolation, up- and downstream gage data is generally compared with the difference attributed to percolation of streamflow. On a gross scale, this can be done by totaling the flow from the upstream gages and reservoir releases and comparing it to the downstream gage at Bradley. While this gives a good idea of the overall balance of the surface water inflows and outflows, it is not accurate enough to use in determining the percolation of streamflow because there are insufficient numbers of gages in the basin.

Percolation of streamflow rapidly recharges the alluvial aquifers, which must be saturated before streamflow can progress down the channel. This shallow groundwater (underflow) then percolates into the underlying basin sediments (Paso Robles Formation). The permeability of the Paso Robles Formation is lower than the alluvial sediments (as discussed earlier), so advance of the percolated waters is slowed. The volume of percolating water depends on the available storage capacity of the alluvial aquifer and the rate at which the underflow can percolate into the underlying basin sediments.

The available storage capacity of the alluvial aquifers was estimated by measuring the width of the alluvial channels, determining the depth of the alluvial deposits from water well logs, determining the range of water level fluctuations within the alluvial deposits, assigning specific yield values for the alluvial deposits, and measuring the length of the alluvial valley. The amount of water recharging the alluvial aquifer was based on the local stream gage flow data or was based on simulated flows derived from these data. If streamflow was low, the alluvial aquifers did not become fully replenished and the percolated streamflow would be the same as the total streamflow.

Percolation of streamflow into the Paso Robles Formation was estimated for each year of the base period using a correlation of streamflow to the change in water levels at representative deep wells along the reach of the stream. The minimum flows that cause a change in water level from October of one year to April of the next year are interpreted to be the amount of stream recharge, with the excess flowing downstream to the next reach. When a water level depression forms adjacent to a stream, there is a gradient toward the depression from the stream valley. The amount of water percolating from the alluvium toward the depression is also attributed to streamflow percolation. This quantity of water is estimated using the Darcy flow equation.

Annual streamflow recharge is controlled by the volume of runoff, which varies dramatically from one year to the next. Annual streamflow from the main uncontrolled tributaries to the Salinas River and the amount of releases from the main reservoirs in the watershed are critical to understanding the recharge potential for each year. During low flow periods, all of the runoff is assumed to recharge the basin. During high flow periods, significant flow continues downstream as runoff. Where the streams are dammed, the reservoir releases control the high runoff events and maintain year-round flows that maximize recharge. This is a major consideration in understanding groundwater recharge in the Nacimiento River and San Antonio River areas.

Flow duration is reflected in the quantity of flow for the uncontrolled stream systems. The analytical method selected for determining recharge from the uncontrolled streams does not require this information but it is considered when evaluating the results of the analysis.

In summary, preparation of annual estimates of recharge from deep percolation of streamflow requires findings related to annual streamflow quantities for specific stream reaches, storage capacity of the alluvial aquifer along each reach of the stream, and deep water level data before and after each runoff season. To estimate stream recharge, annual duration of flow estimates and percolation conditions are considered.

Description of Streams. Streams that carry runoff within the watershed of the Paso Robles Groundwater Basin, along with the associated watershed area are provided in Table 38 and shown on Figure 68. Some areas drain directly to the Salinas River and these also are included in the table of drainage areas. The Paso Robles Groundwater Basin watershed can be separated into four main stream systems: the southern Salinas River area (which includes the Atascadero subbasin), the eastern tributaries, the middle Salinas River reach, and the northern tributaries. Each of these stream system subsets includes watershed areas that drain into the basin and watershed areas within the basin.

The southern Salinas River area upstream of the Paso Robles gage drains an area of 390 square miles. The main tributaries to the Salinas River in this area include: the Salinas River upstream of the confluence with Santa Margarita Creek, Santa Margarita Creek, Paloma Creek, Atascadero Creek, Graves Creek, and Paso Robles Creek (which includes Jack Creek and Santa Rita Creek). The watersheds of these streams are nearly entirely outside the Atascadero subbasin.

Table 38. Watershed Areas of the Paso Robles Groundwater Basin

Drainage	Watershed Area (square miles)	
	Subtotal	Total
Salinas River, north of confluence of San Antonio and Nacimiento Rivers		100
Powell Canyon Area	52	
Hames Creek	48	
Salinas River near Bradley (Station 11150500)		2,535
San Antonio Reservoir Dam Release	323	
San Antonio River below the dam	22	
Eastern Bradley Area	50	
Nacimiento River below Nacimiento Dam near Bradley (Station 11149400)	329	
Nacimiento River below dam	38	
Big Sandy Creek	75	
Vineyard Canyon	51	
Western San Miguel Area	8	
Estrella River		940
Estrella River (Station 11148500), including Lowes Canyon	208	
Northeast Paso Robles Area	12	
Cholame Creek near Shandon (Station 11147800)	227	
San Juan Creek	443	
Shedd Canyon	20	
Wood Canyon	6	
San Marcos Creek		28

Table 38. Watershed Areas of the Paso Robles Groundwater Basin (Continued)

Drainage	Watershed Area (square miles)	
	Subtotal	Total
Huer Huero Creek		161
Huer Huero Creek (Station 11147600)	111	
Lower Huer Huero Creek	37	
Dry Creek	23	
Salinas River at Paso Robles (Station 11147500)		390
Western Paso Robles Area	45	
Paso Robles Creek	86	
Graves Creek	14	
Atascadero Creek	20	
Atascadero/Templeton Area	21	
Atascadero East Area	16	
Santa Margarita Creek	35	
Salinas River near Santa Margarita (Station 11145500) + ungaged portion	153	

East of the Salinas River and entering the Salinas River downstream of Paso Robles, the Huer Huero Creek and the Estrella River drain the central and eastern portions of the Paso Robles basin. Huer Huero Creek flows into the Salinas River downstream of Paso Robles, but is gaged upstream of this confluence, closer to Creston. This gage is useful for evaluating surface water recharge in the upper portion of Huer Huero Creek near Creston and the downstream portion near Paso Robles.

The Estrella River forms where Cholame Creek enters the groundwater basin and joins with San Juan Creek. San Juan Creek drains 244 square miles of watershed area, only a small part of which is inside the basin. Stream gage data for the Estrella River system are available at two locations: one on Cholame Creek near Cholame and one on the Estrella River near Estrella. The Estrella River gage data are the most useful for evaluating stream percolation in the Estrella River portion of the groundwater basin, but evaluation of stream percolation in the San Juan Creek/Shedd Canyon area requires streamflow simulation.

Salinas River flow downstream of the Paso Robles gage and upstream of the confluence with the Nacimiento River is influenced by all of the flow from the major tributaries entering the river. However, the main source of flow for recharge flows downriver from the upper Salinas River area.

The northern Salinas River flow is derived from the Nacimiento River, San Antonio River, Vineyard Creek, and Big Sandy Creek. Streamflow from the Nacimiento and San Antonio rivers are controlled by reservoir releases. Groundwater recharge is continuous along the San Antonio and Nacimiento rivers and in the Salinas River downstream of its confluence with the Nacimiento River. This continuous source of recharge has significant influence on the basin north of the Monterey County line. Because flow is year-round at more than 2,000 afy, estimates of streamflow percolation assume that the basin refills in this location every year. The eastern canyon areas in the Gabilan Mesa are separated from the Salinas River by the San Miguel Dome and apparently do not benefit from Salinas River recharge.

Description of Surface Water Flow. Most precipitation in the area occurs between November and May, mostly in the mountainous regions along the west side of the study area. Annual precipitation in the headwater areas of the Salinas River can reach 30 inches or more. In contrast, annual precipitation east of Paso Robles and Atascadero is generally between 10 and 13 inches. As a result, more than 90 percent of the total streamflow is produced in the western hills, from the Salinas River upstream of Paso Robles, from the Nacimiento River, and from the San Antonio River, even though the watershed area is roughly one-half the watershed area of the entire basin. Figure 68 illustrates the average annual streamflow of the major tributaries to the Salinas River and the watershed areas for each.

Annual runoff quantities for each area in the basin were calculated. Table 39 lists actual annual flow for streams with gage data, and Table 40 presents the simulated annual flow and days of flow for those areas where no stream gages exist.

Table 39. Measured Streamflow for Gaged Streams

(in acre-feet per year)

Water Year	San Antonio River (Reservoir releases plus estimate of lower reach)	Nacimiento River (Gage Sta. 11149500 plus estimate of lower reach)	Salinas River at Paso Robles (Gage Sta. 11147500)	Estrella River (Gage Sta. 11148500 plus estimate of lower reach)	Huer Huero Creek (Gage Sta. 11147600 plus estimate of lower reach)	Salinas River at Bradley (Gage Sta. 11150500)
1981	38,738	179,126	35,755	460	49	253,163
1982	65,303	136,381	95,420	2,274	610	315,085
1983	277,285	780,472	394,500	56,685	16,715	1,510,259
1984	85,894	195,831	32,055	2,637	485	321,887
1985	20,371	162,245	8,963	202	4	210,789
1986	88,277	143,380	127,841	7,562	2,098	401,578
1987	74,231	126,569	4,008	230	5	189,427
1988	49,715	160,573	7,175	445	9	213,511
1989	145,343	70,034	4,682	0	0	222,487
1990	2,174	2,525	262	216	5	6,943
1991	21,896	82,161	29,577	19,630	5,836	168,207
1992	16,887	115,697	56,874	9,885	2,828	207,612
1993	15,895	267,503	204,972	26,272	7,648	568,434
1994	83,466	153,557	5,431	0	0	251,735
1995	26,418	183,451	273,989	68,827	20,456	758,423
1996	35,920	296,886	96,050	3,704	928	448,141
1997	149,066	438,606	205,279	59,209	17,591	852,861
Average Annual Flow	70,404	205,588	93,108	15,190	4,427	405,914
% of Total Flow:	17	49	24	7	2	100
% of Total Drainage Area:	14	14	15	38	6	100

Table 40. Simulated Streamflow Estimates

Water Year	San Juan Creek (Shedd, Wood, and San Juan creeks)		Estrella River (Cholame Creek and Estrella River)		Huer Huero Creek (at Gage Station)		Lower Huer Huero Creek		Salinas River (from Paso Robles to Nacimiento River)		Salinas River (from Nacimiento River to northern edge basin)	
	Annual Flow (afy)	Days of Flow	Annual Flow (afy)	Days of Flow	Annual Flow (afy)	Days of Flow	Annual Flow (afy)	Days of Flow	Annual Flow (afy)	Days of Flow	Annual Flow (afy)	Days of Flow
1981	71	59	460	59	16	10	10	8	28	112	217,903	365
1982	356	28	363	28	82	30	48	30	132	161	201,841	365
1983	8,867	142	9,047	142	2,042	182	1,201	182	3,283	232	1,061,661	365
1984	412	146	421	146	95	91	56	91	153	203	281,907	366
1985	32	17	32	17	7	2	4	1	12	152	182,629	365
1986	1,183	68	1,207	68	272	59	160	59	438	128	232,178	365
1987	36	31	37	31	8	2	5	2	13	84	200,816	365
1988	70	57	71	57	16	8	9	8	26	126	210,319	366
1989	0	0	0	0	0	0	0	0	0	123	215,377	365
1990	34	4	34	4	8	2	5	2	13	29	4,714	365
1991	3,071	47	3,133	47	707	19	416	19	1,137	54	105,410	365
1992	1,546	64	1,578	64	356	25	209	25	572	97	133,265	366
1993	4,110	121	4,193	121	946	110	557	110	1,521	174	285,207	365
1994	0	0	0	0	0	0	0	0	0	97	237,023	365
1995	10,767	158	10,985	158	2,479	86	1,458	86	3,986	217	214,608	365
1996	579	103	591	103	133	9	78	9	214	161	333,061	366
1997	9,262	131	9,450	131	2,133	130	1,254	130	3,429	183	591,749	365

Percolation of Streamflow Analysis. Water level measurements from representative wells were selected in each stream reach and averaged to provide a change in water level for each recharge period. The selected wells are all screened in the Paso Robles Formation.

San Juan Creek/Shedd Creek. The San Juan Creek/Shedd Creek valleys receive groundwater recharge whenever the streams are flowing. Streamflow in these valleys take place less than 70 days most years but may flow as long as six months during heavy rainfall years. Flow rates vary from no flow in water years ending September 1989 and 1994, to nearly 11,000 af in water year ending September 1995 (flow in water year ending September 1998, not shown on Table 40, was about 42,000 af). The available storage capacity of the alluvial aquifers of Shedd, Camatta and San Juan creek valleys are estimated to be about 1,700 af, 3,000 af, and 4,200 af, respectively, for a total available storage capacity of 8,900 af. As streamflow fills the alluvium, a portion of the water percolates into the Paso Robles Formation as basin recharge. This amount depends on groundwater availability and on available aquifer storage capacity. The monitored water level rise in the selected wells, one each in Shedd, Camatta, and San Juan creeks, were averaged and ranged from a decline of 10 feet to a rise of 11 feet. The rising groundwater levels were observed during winters when streamflow was greater than 1,000 af. The average surface water percolation and groundwater recharge in this area is estimated at 2,280 afy.

Estrella River. The Estrella River alluvium from Cholame Creek to the confluence of the Salinas River is estimated to have an available groundwater storage capacity of 1,472 af. The Estrella River alluvium consists of clay-rich sediments with an estimated specific yield of 15 percent. Water level fluctuations appear to have a narrower range in the Estrella River alluvium than in the alluvial deposits of the steeper tributary valleys, which was estimated at 5 feet. The alluvial deposits were estimated to be about 600 feet wide with a length of 28 miles. Surface water inflow to this reach of the Estrella River ranges from no flow in water years ending September 1989 and 1994, to more than 42,000 af in 1998. Recharge to the groundwater basin in this reach is slightly less than the San Juan Creek/Shedd Creek valleys, with an average annual percolation of streamflow of 1,975 afy.

Huer Huero Creek - Creston. The Huer Huero Creek reach from the southern boundary of the basin to the stream gage location is 29,000 feet long. The alluvial deposits along this reach have a width of about 1,000 feet and an average thickness of 50 feet. Water level fluctuations in the alluvium average about 20 feet. Assuming a specific yield of 0.17, the alluvial deposits have an available groundwater storage capacity of 2,260 feet. During the study period, streamflow duration was short-lived except during very high rainfall years. Streamflow varied from no flow during two years, to 9,600 af in water year ending September 1998. Groundwater recharge from percolation of Huer Huero Creek water in the proximity of Creston averaged 530 afy.

Huer Huero Creek - Paso Robles. The Huer Huero Creek from the Creston gaging station to its confluence with the Salinas River has a reach of 35,000 feet, an average width of 300 feet, and an average alluvial depth of about 20 feet. Water level fluctuations in deep wells along the reach appear to be about 20 feet. Given a specific yield of 0.17, the alluvium has an available water storage capacity of 820 af. A portion of the alluvial water percolates into the basin during recharge periods, depending on available storage capacity. This is estimated to amount to as much as 550 af, but is typically less than 50 af. The percolation of streamflow in this reach during the study period was estimated to average about 290 afy.

Salinas River - Atascadero Subbasin. The Salinas River within the Atascadero subbasin receives runoff from several tributaries within its 390 square mile watershed. Flow along the uppermost reaches is controlled by Salinas Reservoir releases. The reservoir is operated for water supply purposes and diverts water to the City of San Luis Obispo, outside the watershed. Significant inflow from Paso Robles Creek and Santa Margarita Creek increase flow of the Salinas River through the Atascadero subbasin. Groundwater recharge from percolation of streamflow is known to occur near Atascadero with lesser recharge occurring in the Templeton area, downstream of the confluence of the Salinas River with Graves and Paso Robles creeks. The alluvial deposits have an available groundwater storage capacity of about 7,700 afy. Once the alluvial deposits are saturated, additional recharge occurs as a result of the deep percolation of alluvial water into the Paso Robles Formation. Deep percolation of streamflow along this reach ranges from 300 afy to as much as 19,000 afy. The average total annual percolation of streamflow in this reach is about 10,500 af.

Salinas River - Paso Robles to Nacimiento River. From Paso Robles to the confluence with the Nacimiento River, the Salinas River flows on average about 150 days of the year. This reach of the river is host to several highly productive alluvial agricultural wells. The alluvial deposits are highly permeable with a specific yield as high as 0.20. Water level fluctuations in the alluvial aquifer can be relatively extreme during droughts, but generally fall within a 15-foot range. Given a reach of 80,000 feet and width of 1,400 feet, this stream valley alluvium has an available groundwater capacity of 8,260 af. There are no years without any streamflow within this reach. Annual streamflow has been as low as 262 afy, but typically exceeds 5,000 af with high streamflow years reaching nearly 400,000 af. The recharge estimate for deep percolation of streamflow averages about 24,000 afy. Additional recharge may be occurring as a result of the pumping of the alluvial wells, which increases available storage capacity, but this cannot be assessed without further information on the pumping quantities from the shallow wells.

Northern Salinas River and Tributaries. Water stored in the Nacimiento and San Antonio reservoirs are released for water conservation and downstream aquifer recharge purposes. As a result, flow is year-round in these tributaries to the Salinas River and in the Salinas River. Flow from these reservoirs is much greater than the flow in the Salinas River upstream and there is continuous percolation of streamflow where the basin has available storage.

Groundwater demand is relatively low in the Nacimiento River valley from the dam to the Salinas River. The groundwater level contour maps for the basin (Chapter 3) suggest that streamflow percolation recharges the area along the river valley and does not flow toward the south. Groundwater level hydrographs for the Bradley area are very flat and show a stable water level. Due to the lack of available groundwater storage capacity in this area, there is minimal groundwater recharge from percolating surface water above that which offsets phreatophyte losses and the relatively minor pumpage by Camp Roberts. Additional recharge from percolation of streamflow could occur with increased storage capacity.. Average annual percolation of streamflow in this reach of the Nacimiento River is estimated at about 15 afy.

Reservoir releases in the San Antonio River have extended the periods of streamflow and, similar to the Nacimiento River, recharge has been sufficient to offset the predominantly agricultural pumpage. Since the dam was constructed, the number of no flow days per year has decreased. From water year ending 1991 to the present, there has been continual flow in the San Antonio River downstream of the dam. Some groundwater level data from Hames Valley in the 1990's show that groundwater levels are as deep as 470 feet elevation. The San Antonio River flows along a northerly sloping channel that drops from about elevation 560 feet to about elevation 500 feet at the Salinas River. Therefore, there is a gradient towards a groundwater trough in Hames Valley. Assuming a gradient of 60 feet of decline over a 15,000 feet distance from San Antonio River to the depression area, with a cross sectional flow width of 8,000 feet and a transmissivity of 8,000 gpd/ft, the flow from the San Antonio River would be about 300 afy.

Groundwater pumpage in the San Antonio River valley increased from about 500 afy in 1979 to 2,000 afy in 1988, where it has remained relatively constant. Assuming that this pumpage created storage capacity to receive recharge from the percolation of San Antonio River water, the percolation of streamflow in this area increased from about 500 afy in water year ending 1981 to 2,000 afy in 1988, remaining constant to water year 1997. Combining the estimate for recharge to the Hames Valley area and the San Antonio River area, the total average percolation of San Antonio River streamflow ranges between 800 afy to 2,300 afy. This is a small percentage of the total flow in this river, except in water year ending 1990 when the total discharge from the reservoir was 2,172 afy. For this one year, the percolation of streamflow from San Antonio River is reduced to the total release from the dam.

The eastern side of the Salinas River in this reach is characterized by several west-flowing canyons that dissect the Gabilan Mesa. Percolation of streamflow in the streams within these canyons can be expected to occur because the alluvial deposits are very coarse and the topographic gradient of the valley floor and the alluvial deposits is fairly steep (the steep stream grade results in more rapid runoff and deposition of coarser materials in the stream channel, which contributes to higher percolation rates along the portions of the stream channel with steeper gradients). The two main alluvial valley reaches (Indian Valley and Vineyard Canyon) have a composite length of 40,000 feet, an average width of 500 feet, average storage capacity of 30 feet, and a specific yield of 0.17, with about 2,350 af of available storage. Simulated flow in these canyons generally is less than the amount of available storage in the alluvium, so the entire flow can be expected to percolate into the underlying basin sediments. Only in water years ending 1995 and 1997 was streamflow greater than the storage capacity of the streams. In these years, the percolated streamflow is limited to this estimated storage capacity.

Because the Gabilan Mesa area is separated from the Salinas River by the San Miguel Dome structural trend, these areas receive minimal recharge contribution from the Salinas River. Rising water is observed in the Vineyard Canyon stream channel where the permeable aquifers rise to the surface on the north slope of the San Miguel Dome. This rising water, similar to many springs in the basin, percolates back into the basin before it reaches the Salinas River.

Summary of Streamflow Recharge. Percolation of streamflow in the Paso Robles Groundwater Basin ranges widely. Runoff characteristics on the west side of the basin result in much more streamflow and allows for greater recharge than the eastern watershed areas. Streamflow is seasonal except where upstream reservoirs regulate flow, such as on the Nacimiento and San Antonio rivers. Percolation of streamflow is dependent on aquifer storage capacity in the alluvium and the Paso Robles Formation basin sediments.

Overall, percolation of streamflow is much greater along the Salinas River corridor than in the eastern and central areas of the basin. The total average percolation of streamflow in the eastern and central basin areas is approximately 5,000 afy, while the total average percolation of streamflow along the Salinas River corridor is about 37,000 afy (Table 41).

Table 41. Percolation of Streamflow Estimates

(in acre-feet per year)

Water Year	San Juan Creek/ Shedd Creek	Estrella River	Huer Huero Creek Creston	Huer Huero Creek Paso Robles	Salinas River Atascadero Subbasin	Salinas River Paso Robles to Nacimiento	Northern Salinas River Area	Total (rounded)
1981	71	460	16	10	11,713	8,264	1,265	21,800
1982	356	363	82	48	13,713	25,264	1,385	41,200
1983	8,867	8,472	2,042	860	19,213	46,264	3,075	88,800
1984	412	421	95	56	11,713	8,264	1,829	22,800
1985	32	32	7	4	8,963	8,963	1,873	19,900
1986	1,183	1,207	272	160	16,000	31,264	2,350	52,400
1987	36	37	8	5	4,008	4,008	2,175	10,300
1988	70	71	16	9	7,175	7,175	2,335	16,900
1989	0	0	0	0	4,682	4,682	2,315	11,700
1990	34	34	8	5	262	262	2,182	2,800
1991	3,071	3,133	707	416	12,913	29,577	3,188	53,000
1992	1,546	1,578	356	209	11,713	56,874	2,753	75,000
1993	4,110	4,193	946	557	16,013	98,264	3,534	127,600
1994	0	0	0	0	5,431	5,431	2,315	13,200
1995	9,144	10,985	2,263	60	11,713	36,264	4,746	75,200
1996	579	591	133	898	11,713	22,264	2,477	38,700
1997	9,262	2,000	2,133	850	11,713	9,064	4,746	39,800
Average (rounded)	**2,300**	**2,000**	**500**	**200**	**10,500**	**23,700**	**2,600**	**41,800**

Percolation of Irrigation Return Water (PR)

Percolation of irrigation return water in the Paso Robles basin is a function of both irrigation efficiency and required leaching of the soils, and is dependent on a variety of factors including crop type, climate factors, irrigation management practices, and soil types. For this analysis, the volume of irrigation return water that percolates back into the basin as recharge (inflow) is calculated as Gross Required Pumping minus Total Consumptive Use multiplied by an average deep percolation ratio (Table 42). (Gross Required Pumping and Total Consumptive Use are defined and calculated in the section on "Agricultural Groundwater Pumpage," Tables 58 and 59).

Gross required pumpage for the irrigated acreages in the basin by crop type is calculated for each year of the base period. It is an estimate of applied water taking into account net crop water use, effective rainfall, losses due to conveyance and frost control, irrigation efficiency and required leaching for salinity control. The term "irrigation efficiency" accounts for required applications in excess of net consumptive use due to system design, maintenance, and scheduling (frequency and duration of irrigations). Leaching of the soil is necessary and, depending on irrigation water quality and soil type, will range from 0 percent to as high as 16 percent (see the sections on "Leaching Ratios (LR) and Irrigation Efficiency (IE) in

"Agricultural Groundwater Pumpage.") Thus, irrigation losses due to irrigation efficiency are normally considered distinct from losses due to required leaching (percolation of water below the root zone) to maintain a salt balance in the root zone. The combination of these two factors creates the average deep percolation ratio applied in Table 42. This deep percolation of irrigation return water is, then, a theoretical component of recharge back to the groundwater basin.

Table 42. Annual Volumes of Irrigation Return Flow, Paso Robles Groundwater Basin

(in acre-feet, rounded)

Year	Gross Required Pumping	Total Consumptive Use	Irrigation Losses	Irrigation Return Flows
1980	66,593	41,439	25,154	3,000
1981	114,860	81,107	33,753	4,100
1982	98,692	76,341	22,351	2,700
1983	87,512	74,748	12,764	1,500
1984	111,802	75,394	36,408	4,400
1985	102,970	70,560	32,410	3,900
1986	82,936	65,707	17,229	2,100
1987	88,503	63,304	25,199	3,000
1988	78,318	60,229	18,089	2,200
1989	79,815	58,211	21,604	2,600
1990	79,781	56,064	23,717	2,900
1991	67,348	51,372	15,976	1,900
1992	63,755	50,523	13,232	1,600
1993	56,780	46,810	9,970	1,200
1994	56,864	45,019	11,845	1,400
1995	49,775	41,105	8,670	1,000
1996	49,591	40,993	8,598	1,000
1997	50,768	41,730	9,038	1,100

Depending on land use group and type of irrigation (sprinkler vs. drip), the deep percolation ratio (percolation below the root zone) can range from about 2 to 17 percent. For drip irrigation, deep percolation likely ranges from 10 to 16 percent of the applied water. For sprinkler irrigation, deep percolation may range from about 8 to 17 percent. For purposes of estimating deep percolation for the entire Paso Robles Groundwater Basin, an average of 12 percent was used.

The estimated volume of irrigation return water to the basin for each year of the base period is presented in Table 42. Amounts range from 1,032 afy to 4,370 afy. The calculated volumes have declined steadily over the base period due to changes in irrigated crop types over the 17-year period.

Irrigation return flows into the Atascadero subbasin were calculated using the same methodology. Table 43 shows the annual volumes of irrigation return flow for the subbasin for the base period. Amounts vary from 4 to 533 afy. The volumes show a steady decline over the base period as irrigation practices and crop patterns have changed.

Table 43. Annual Volumes of Irrigation Return Flow, Atascadero Subbasin
(in acre-feet, rounded)

Year	Gross Required Pumping	Total Consumptive Use	Irrigation Losses	Irrigation Return Flows
1980	10,302	6,486	3,816	500
1981	16,377	11,934	4,443	500
1982	13,363	10,911	2,452	300
1983	11,980	10,377	1,603	200
1984	14,454	10,106	4,348	500
1985	12,917	9,188	3,729	500
1986	10,277	8,298	1,979	200
1987	10,770	7,739	3,031	400
1988	9,126	7,033	2,093	300
1989	8,610	6,458	2,152	300
1990	8,126	5,850	2,276	300
1991	6,500	4,968	1,532	200
1992	5,611	4,466	1,145	100
1993	4,624	3,694	930	100
1994	3,885	3,071	814	100
1995	2,780	2,292	488	100
1996	2,472	2,132	340	0
1997	1,023	992	31	0

Percolation of Wastewater Discharge (WW)

Wastewater discharge from municipal wastewater treatment plants is a component of basin inflow that is not accounted for in the other components of this study. During the base period of this study, municipal wastewater treatment plants operated by the City of Paso Robles and the City of Atascadero discharged treated wastewater effluent to the Salinas River, either by direct discharge or through percolation ponds. Both plants are located adjacent to the Salinas River. Atascadero discharges treated effluent to the river alluvium via percolation ponds. At one time, the City of Paso Robles discharged treated effluent to the alluvium via percolation ponds; more recently, permits were obtained to discharge directly to the river. The plant operated by the City of Atascadero serves most of the community of Atascadero; historically, the Paso Robles plant treated and discharged wastewater from Paso Robles and most of Templeton. In late 2001, the Templeton Community Services District began operating a wastewater treatment plant that discharges effluent into the Salinas River via percolation ponds, however that contribution volume is accounted for in historic Paso Robles treatment plant records. Future investigations will have to take into account the added contribution of TCSD.

Wastewater percolates into the Paso Robles basin at the City of Paso Robles plant on the north side of the City, just north of Highway 46 East. Discharge records show an average discharge (combined cities of Paso Robles and Atascadero) of 3,272 afy over the base period, with a range of 2,258 af to 3,993 af (Table 44). As shown in Table 44, however, the discharge contribution is steadily increasing throughout the base period, and is becoming an increasingly important component of basin inflow (coincidentally, of course, with increasing municipal pumpage). It is important to note that the inflow contribution of wastewater discharge by municipal purveyors is distinct from the inflow contribution of streamflow percolation, even though the wastewater discharge is directly into the stream system.

Wastewater percolates into the Atascadero subbasin at the City of Atascadero wastewater treatment plant percolation ponds located adjacent to Chalk Mountain golf course. Factoring out evaporation losses from the ponds and the approximately 300 afy supplied to the golf course for reclaimed irrigation use, the wastewater return flow to the Salinas River averaged 998 afy over the base period from 1981 through 1997, with a range of 733 af to 1185 af (Table 44). The recharged water percolates into the river alluvium, forming a recharge mound in the alluvium and a shallow water level plane for some distance downstream.

Table 44. Percolation of Wastewater Discharge

(in acre feet)

Year	Paso Robles Groundwater Basin	Atascadero Subbasin
1981	2,300	800
1982	2,300	700
1983	2,600	700
1984	2,800	900
1985	2,900	1,000
1986	3,200	1,000
1987	3,200	1,100
1988	3,400	1,200
1989	3,500	1,200
1990	3,400	1,100
1991	3,500	900
1992	3,600	1,000
1993	3,800	1,100
1994	3,500	900
1995	4,000	1,200
1996	3,900	1,100
1997	3,900	1,100
Average	3,300	1,000
High	3,993	1,186
Low	2,258	734

Imported Water (W_I)

There has been no importation of water to the Paso Robles Groundwater Basin over the base period. Accordingly, for purposes of the water balance, this component of supply (either to the basin as a whole, or as water entering the zone of saturation by direct injection or surface spreading activities) is zero.

COMPONENTS OF OUTFLOW

Subsurface Outflow (Sb_O)

Paso Robles Groundwater Basin. Groundwater outflow from the Paso Robles Groundwater Basin is comprised of flow within the alluvial deposits and flow in the Paso Robles Formation aquifer. Subsurface outflow from the basin is assumed to take place only at the "outlet" of the basin, in the northwest corner of the basin near San Ardo where the Salinas River flows into the Salinas Valley Groundwater Basin. Subsurface outflow is not thought to occur along the boundary of the basin except for the outlet because water levels in the bordering consolidated rocks are everywhere higher than water levels in the basin.

Similar to the calculation of subsurface inflow, the quantity of subsurface outflow was computed using Darcy's Law in which the rate of discharge through a given cross section of saturated material is proportional to the hydraulic gradient.

This equation is expressed as:

$$Q = PIA$$

in which: Q = amount of flow in gallons per day
P = coefficient of permeability in gallons per day per square foot
I = hydraulic gradient in feet per foot
A = saturated area in square feet

The hydraulic parameters for the alluvium and the Paso Robles Formation were defined earlier. The cross sectional width through which groundwater flows out of the basin is about 1,000 feet in the alluvium and about 15,000 feet in the Paso Robles Formation. Transmissivity of the alluvial aquifer is estimated to be about 52,000 gpd/ft, with an estimated transmissivity of the Paso Robles Formation at 10,000 gpd/ft. The groundwater gradient in these aquifer zones is not well defined, however the underflow flows at a similar gradient to the Salinas River, which is about one foot per 800-foot distance. The groundwater gradient in the Paso Robles Formation flows sub-parallel to the outflow section, but the portion of the flow that flows through the outflow section is at a gradient of about one foot in a distance of 300 feet. Given these parameters, the annual outflow from the alluvium is estimated to be about 75 afy, with about 560 afy outflow through the Paso Robles Formation.

The groundwater levels in the alluvial aquifer are very stable over time because of the moderating effect of the Nacimiento and San Antonio river recharge. Therefore, outflow is considered constant in the alluvium. The groundwater level gradient in the Paso Robles Formation, as shown on the groundwater level elevation maps (Chapter 3), have also maintained a similar pattern from one year to the next. As a result, the total outflow of groundwater from the basin sediments is assumed to relatively constant from one year to the next, and is estimated to be about 635 afy, rounded to 600 afy.

Atascadero Subbasin to the Main Basin. Groundwater in the Atascadero subbasin flows toward the main basin across the Rinconada fault. The fault displaces the Paso Robles Formation and evidence may exist to suggest restricted groundwater flow across the fault. There may be some flow within the Paso Robles Formation in the proximity of the Salinas River, however. The fault does not displace the alluvial deposits and does not restrict flow in the alluvium.

Groundwater flow across the Rinconada fault varies as the groundwater gradient varies. The flow direction is generally to the north from Templeton to Paso Robles. A review of water level data from wells on both sides of the fault show that the gradient has varied from near level to as much as 0.002.

The area of subsurface outflow from the Atascadero subbasin to the main basin has a width of about 5,000 feet and a composite transmissivity of 38,120 gpd/ft. With an average gradient of $7x10^{-4}$ ft/ft, average subsurface outflow from the Atascadero subbasin to the main basin is 150 afy, say 200 afy. During years 1982 and 1990, the subsurface flow was twice the average, and in 1991 the subsurface flow was 3.5 times the average.

For purposes of the hydrologic budget, it is appropriate to take an average subsurface outflow value for each year of the base period because of the limited water level data on each side of the Rinconada fault, and because of the relatively small volume of outflow. For all years except 1982, 1990, and 1991, an average value of 200 afy was used. As explained above, subsurface flow was twice the average in 1982 and 1990 (300 afy) and 3.5 times the average in 1991 (500 afy).

Gross Groundwater Pumpage (Q)

The groundwater pumpage component of the water balance accounts for approximately 95% of the annual basin outflow. The pumpage component consists of the combination of agricultural pumpage and municipal, community, and rural domestic pumpage. Each element of the groundwater pumpage component is discussed in detail in the following sections.

Agricultural Groundwater Pumpage (Computation of Agricultural Water Applications and Consumptive Use). This section explains the method used to estimate gross pumping for agricultural irrigation water demand and the consumptive losses from irrigated crops. Important terms used in the following discussion are:

- **Gross Pumping –** this is the amount of groundwater pumped for application on irrigated crops.
- **System Returns –** a portion of the gross pumping that returns to the hydrologic system through percolation. For example, "conveyance efficiency" is a measure of how much water reaches its intended destination while being conveyed through a pipeline or open channel. Some of the conveyance losses will be system returns, such as percolation through the ditch bank. Others will be consumptive use, such as evaporation of water during conveyance.
- **Consumptive Use –** consumptive uses are water lost to the hydrologic system. Consumptive uses are usually less than the gross pumping because a portion of the inefficiencies inherent in irrigation are system returns.
- **Irrigation Losses, Conveyance Losses –** these terms are used to represent water that does not reach its intended destination. Irrigation water is intended to be stored in the root zone, available for crop use. Irrigation losses include surface runoff or immediate evaporation during the irrigation, or percolation of water below the root zone just after the irrigation. Conveyance losses include evaporation from the exposed surface of the conveyance facility (an open ditch or a reservoir), evaporation of spills or leaks from the facility, or percolation of spills or leaks. The important factor for both irrigation and conveyance losses is that some of the losses may become consumptive use and some may become system returns.
- **Leaching –** deep percolation that will carry excess salts below the crop root zone. Leaching may occur due to intentional over-irrigation, or it may occur as a result of normal rainfall or normal irrigation activities (since there are inherent inefficiencies with any irrigation system).
- **Leaching ratio –** a theoretical measure of how much leaching is required to maintain a salt balance in the root zone, that is, the amount of salts is neither increasing nor decreasing with time under irrigation. The required leaching identified by the leaching ratio may be satisfied by intentional over-irrigation or it may occur due to normal rainfall or the inherent inefficiencies in the irrigation system (combination of hardware and management).

Basic Methodology. Equations [1], [2], and [3] were used to develop estimates of both gross pumping for and consumptive use of agricultural irrigation water in the Paso Robles Groundwater Basin.

The annual gross pumping requirements for irrigated crops can be estimated using equation [1]:

$$AF/yr = \sum CL + (Ac * (ETcyr - PPTeff) / ((1 - LR) * IE)) \qquad \text{[Equation 1]}$$

where:	$\sum$	=	a summation of all crops for the year
	AF/yr	=	required annual gross pumping for irrigation in acre-feet
	CL	=	conveyance system losses in acre-feet
	Ac	=	crop acreage
	Etcyr	=	annual net crop water use in acre-feet/acre (evapotranspiration)
	PPTeff	=	annual effective rainfall (rainfall that infiltrates and is stored for subsequent use by the crop) in acre-feet/acre
	LR	=	required leaching ratio to maintain a salt balance as a decimal
	IE	=	irrigation efficiency as a decimal (an indicator of irrigation losses)

Also, for any one crop:

$$ETcyr = \sum Kc * ETr \qquad \text{[Equation 2]}$$

where:	$\sum$	=	a summation throughout the year
	Etcyr	=	annual net crop water use in acre-feet/acre
	Kc	=	crop coefficient relating crop water use to a reference water use
	Etr	=	reference water use (evapotranspiration)

Also, for any given cropping situation:

$$LR = ECi / ((5 * ECe) - ECi) \qquad \text{[Equation 3]}$$

where:	LR	=	required leaching ratio to maintain a salt balance as a decimal
	Eci	=	electrical conductivity of the irrigation water (a measure of salinity) (deciSiemens/meter)
	Ece	=	electrical conductivity of the saturated soil extract (a measure of the salinity of the soil water solution in the root zone of the crop) (deciSiemens/meter)

Note: ECi is assumed to be known -- usually an ECe sufficient to prevent yield declines is assumed.

Gross Pumping Versus Consumptive Use. An important factor in the development of the hydrologic balance is an understanding of consumptive use versus required gross pumping for irrigation applications. Consumptive use (water lost to the hydrologic system) is usually different from the required gross pumping. Estimating actual consumptive use involves an identification of the types of irrigation and conveyance inefficiencies and the destinations of these losses. That is, does the water pumped in excess of crop water needs return to a usable body of water within the basin, or outside the basin -- or does it return to an unusable water body such as a saline lake?

The important factor is that irrigation "losses" on one farm may be used on another farm, or on the same farm on a different field, or on the same field at a later time. Examples of these situations are when deep percolation returns to a groundwater basin for later re-pumping (however, note the potential impacts on groundwater quality), or when surface runoff is intercepted for storage or for immediate re-use.

There are essentially no aboveground irrigation return flows in the Paso Robles basin. That is, no water runs off irrigated fields into a creek or river for use on a downstream farm or field, or for transport out of the basin.

Assuming that excessive pumping returns to the groundwater for subsequent re-pumping, consumptive uses by irrigated agriculture in the basin include only:

- Crop evapotranspiration,
- Immediate evaporation from the soil surface during or just after irrigations or rainfall, or after frost control events,
- Immediate evaporation from the soil surface due to leaks in conveyance systems or from flush water from micro-irrigation filters, and
- Evaporation from water surfaces in reservoirs.

The calculations for equation [1] were done on an October through September basis. This allowed for a more accurate accounting of off-season rainfall (rainfall that occurs when no crop is planted or permanent crops are dormant) stored in the root zone for seasonal water use as well as matching up with California Department of Water Resources ("DWR") water years.

Conveyance Losses (CL). Conveyance losses include evaporative losses from reservoirs and canals, evapotranspiration by phreatophytes along canals, leaks in pipelines, and seepage from reservoirs and canals.

The vast majority of irrigation systems in the basin are either high-pressure impact sprinkler or some form of micro-irrigation. Conveyance losses in these systems occur mainly from leaking pipeline joints or filter flush water for micro-irrigation systems. Losses also occur in reservoirs used for frost control and micro-irrigation system. This includes free water surface evaporative losses for the number of days that water is in the reservoirs and seepage from those reservoirs that are unlined.

However, as previously noted, conveyance losses due to percolation theoretically stay in the basin. Consumptive use due to conveyance losses are due to evaporation, either from a wet soil surface (caused by leaks in above or below-ground pipelines or filter flush) or a reservoir surface. These estimates assume a one (1) percent conveyance loss, that is, 1% of the gross pumping will not reach the irrigation or frost control system. However, only half of this (0.5 percent of total pumping) is consumptively used.

Acreages (Ac). Acreages of the different crops grown in the basin were aggregated by standard DWR land use groups. The major groupings used for this project include:

- Truck crops – designation "T"
- Field crops – designation "F"
- Deciduous trees – designation "D"
- Citrus – designation "C"
- Vineyards – designation "V"
- Small grains and grain hay - designation "G"
- Pasture – designation "P" – alfalfa (designation "P1") was specifically identified within this grouping due to the economic importance of the crop
- Native Vegetation – designated "NV" (with subgroups Barren, Riparian, and Wetland)
- Urban – designated "S"
- Rural – designated "R"
- Suburban – designated "S"

Estimating the acreages for these groups for the years 1981 through 1997 was a three-step process:

1. Four DWR land use studies were analyzed to identify actual acreages for the various land uses for two years each in San Luis Obispo and Monterey counties. These were 1984 and 1995 for San Luis Obispo County and 1989 and 1997 for Monterey County. DWR (Southern Division) supplied data for San Luis Obispo County and DWR (San Joaquin Division) supplied data for Monterey County. Analyses proceeded on a map basis to identify acreage inside and outside the defined basin boundaries.

2. The results from these analyses were then transferred to a spreadsheet and the acreages for each year for each land use group estimated by direct projection of trend.

   As an example, alfalfa acreage in San Luis Obispo County was 1,000 acres in 1984 and 2,100 acres in 1995, 11 years later. The alfalfa acreage for the 10 intervening years would be estimated by adding 100 acres each year. The 100 acres is derived by dividing the difference in acreage between 1995 and 1984 by the 11 intervening years. Thus:

   Additional acreage/year = (Acreage in 1995 – Acreage in 1984) / 11
   = (2100 – 1000) / 11
   = 100

   Thus, alfalfa acreage for 1985 would be estimated as 1,100 acres (1,000 acres in 1984 + 100), alfalfa acreage for 1986 would be estimated as 1,200 acres (1,100 acres in 1985 + 100), and so on.

3. Since trends can be misleading, Agricultural Commissioner Office (ACO) Annual Crop Reports from 1980 through 1998 and personal conversations with experts in the area (including Assistant Agricultural Commissioners in both San Luis Obispo and Monterey counties) were used to adjust the indicated acreages as needed. Table 45 indicates total cropped acres for various land uses overlying the basin as reported by the ACO.

   Grain acreage is an example of correcting the trend. Land use studies indicate approximately 163,000 acres of small grains in the basin in 1984 and 64,000 in 1995. However, examination of the ACO data and conversations with ACO and the Farm Service Agency of the Natural Resources Conservation Service indicate that the Conservation Reserve Program became popular in the period 1986 through 1989. It is obvious that there was a large drop in the grain acreage through this period. The apparent trend in grain acreage was modified according to percentage changes as indicated by ACO data.

Table 45. Total Acreages for Various Crops

Year	Small Grains	Alfalfa	Pasture	Vineyard	Almonds & Walnuts	Total Acreages for Crops
1980	165,661	12,123	6,000	3,957	9,121	196,862
1981	174,291	11,780	5,800	4,374	9,013	205,258
1982	166,300	10,619	5,500	4,500	9,007	195,926
1983	142,515	9,619	5,750	4,977	8,932	171,793
1984	141,365	9,345	5,900	5,477	8,754	170,841
1985	157,165	7,245	5,800	5,480	8,954	184,644
1986	160,255	6,775	5,600	6,084	9,003	187,717
1987	128,722	5,263	5,600	6,459	8,054	154,098
1988	122,000	5,100	5,600	7,255	7,873	147,828
1989	93,500	5,000	5,600	7,649	7,744	119,493
1990	73,275	4,200	5,600	8,150	7,372	98,597
1991	63,465	3,480	5,600	8,100	6,269	86,914
1992	66,184	3,850	5,600	8,327	5,569	89,530
1993	68,565	3,700	5,500	8,676	5,290	91,731
1994	66,640	3,800	5,400	9,080	5,100	90,020
1995	65,510	3,750	5,250	9,380	4,900	88,790
1996	67,750	3,600	5,200	9,905	2,700	89,155
1997	47,740	3,900	4,900	11,128	2,560	70,228

The resulting estimates of total acreages overlying the Paso Robles Groundwater Basin for each major group for the years 1980 through 1997 are seen in Table 46. Estimates of irrigated acreage overlying the Paso Robles Groundwater Basin are seen in Table 47.

Table 46. Estimated Acreages of Various Land Uses Overlying the Paso Robles Basin

	Suburban	Urban/Rural	Idle	Deciduous	Vineyard	Truck	Field	Grain	Pasture	Alfalfa	All Native	Totals
1980	5,038	7,159	9,188	6,122	4,156	384	2,481	163,154	4,631	14,381	288,308	**505,000**
1981	4,753	7,521	8,595	5,983	4,576	384	2,357	163,154	4,596	13,656	289,424	**505,000**
1982	4,467	7,883	8,002	5,844	4,997	384	2,234	163,154	4,561	12,932	290,540	**505,000**
1983	4,182	8,246	7,410	5,705	5,417	384	2,111	163,514	4,527	12,208	291,657	**505,000**
1984	3,896	8,608	6,828	5,567	5,838	384	1,988	163,063	4,492	11,483	292,854	**505,000**
1985	3,611	8,970	6,309	5,428	6,259	384	1,865	158,966	4,457	10,135	298,617	**505,000**
1986	3,325	9,332	5,791	5,289	6,679	384	1,742	154,869	4,422	8,766	304,381	**505,000**
1987	3,040	9,695	5,272	5,151	7,100	384	1,618	125,358	4,387	7,438	335,558	**505,000**
1988	2,754	10,057	4,753	5,012	7,520	384	1,495	119,390	4,353	6,089	343,193	**505,000**
1989	2,469	10,419	4,234	4,873	7,941	384	1,372	92,438	4,318	4,740	371,811	**505,000**
1990	2,183	10,781	3,716	4,735	8,521	384	1,318	74,335	4,245	3,392	391,390	**505,000**
1991	1,898	11,144	3,197	4,596	9,101	384	1,265	65,729	4,172	3,417	400,098	**505,000**
1992	1,612	11,506	2,678	4,457	9,682	384	1,211	65,408	4,099	3,441	400,521	**505,000**
1993	1,327	11,868	2,160	4,318	10,262	384	1,158	65,086	4,027	3,466	400,944	**505,000**
1994	1,041	12,230	1,641	4,180	10,842	384	1,104	64,765	3,954	3,491	401,368	**505,000**
1995	756	12,593	1,122	4,041	11,423	384	1,051	64,443	3,881	3,516	401,791	**505,000**
1996	471	12,955	897	3,902	12,003	384	997	64,122	3,808	3,540	401,921	**505,000**
1997	185	13,317	971	3,764	12,583	384	944	47,232	3,735	3,565	418,320	**505,000**

The following points are made concerning Tables 46 and 47:

- The acreages for 1984 and 1995 are from California DWR land use studies. The acreages for the other years from 1980 through 1997 were developed through conversations with ACO and NRCS personnel, local growers, and ACO crop reports.
- The increase in irrigated Grain acres in Table 46 most likely represents grain hay.
- There was a steady decline in irrigated crop acreage (60 – 70% from 1980 to 1991) except for Vineyards. Note especially the major decline in Alfalfa acreage.
- The vegetable acreage (Truck Crops) is constant at 384 acres (the average of the 1984 and 1995 reports) since no discernable trend from the DWR data or ACO could be discerned, and represents a minor portion of the acreage total.
- Reduction of Field Crop acreage is in part due to loss of the sugar beet industry in early 1980's. This may also reflect a conversion of good growing ground into vineyards.
- The loss of Pasture and Alfalfa are probably due to the economics of those particular crops plus the improving economics of premium wine grapes. Again, the best fields were probably converted to vineyards.

Table 47. Estimated Irrigated Acreages of Various Land Uses Overlying the Paso Robles Basin

	Deciduous	Vineyard	Truck	Field	Grain	Pasture	Alfalfa	Total
1980	882	4,156	384	2,694	506	4,417	14,381	**27,420**
1981	839	4,577	384	2,518	513	4,397	13,656	**26,884**
1982	801	4,997	384	2,341	520	4,378	12,932	**26,353**
1983	769	5,418	384	2,165	527	4,358	12,208	**25,829**
1984	735	5,838	384	1,988	581	4,339	11,483	**25,348**
1985	701	6,258	384	1,865	640	4,149	10,759	**24,756**
1986	669	6,679	384	1,742	698	3,964	10,035	**24,171**
1987	635	7,099	384	1,619	756	3,773	9,311	**23,577**
1988	603	7,520	384	1,496	814	3,584	8,585	**22,986**
1989	569	7,941	384	1,373	873	3,396	7,861	**22,397**
1990	537	8,521	384	1,318	930	3,209	7,138	**22,037**
1991	503	9,102	384	1,264	989	3,021	6,414	**21,677**
1992	471	9,682	384	1,211	1,047	2,832	5,688	**21,315**
1993	437	10,262	384	1,158	1,105	2,641	4,964	**20,951**
1994	405	10,843	384	1,104	1,163	2,456	4,240	**20,595**
1995	371	11,423	384	1,051	1,222	2,266	3,516	**20,233**
1996	333	12,003	384	1,053	1,281	2,077	2,923	**20,054**
1997	312	12,583	384	1,123	1,339	1,891	2,541	**20,173**

- Note also the ability of the wine grape to justify micro-irrigation. Micro-irrigation is particularly adapted to vineyard agronomic systems due to the ability to control both irrigation and fertilizer applications. Micro is normally the most likely irrigation system to be efficient, which would have been an important consideration in the years of the 1987-1992 drought.

Reference Evapotranspiration (ETr). DWR has recently developed a statewide ETo map (ETo is one type of reference evapotranspiration, specifically the evapotranspiration of a well-watered, lush pasture). Dr. Rick Snyder of the University of California, Davis (an author of the map) has indicated that considerable statistical analysis was performed to ensure that the areas delineated are sufficiently accurate for long-range water-use studies. However, he also stated that they are unclear as to actual ETo in much of San Luis Obispo County due to lack of data from calibrated weather stations. Daily values of ETo are tabulated on a monthly basis for ETo Zone 10 (Creston/Shandon) and ETo Zone 16 (Salinas River corridor). Figure 69 is a close-up of the portion of the map covering the basin. Average daily reference evapotranspiration for Climate Zones 10 and 16 are provided in Table 48.

Table 48. Average Daily Reference Evapotranspiration (ETo)
(in inches)

Climate Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10	.03	.06	.10	.15	.19	.24	.26	.23	.17	.10	.05	.03
16	.05	.09	.13	.19	.25	.29	.30	.27	.21	.14	.08	.05

It is seen that ETo Zone 10 (the Creston/Shandon area) is considered "cooler" than ETo Zone 16 (the Salinas River corridor). Since this is obviously not the case, the DWR information was not considered sufficiently accurate for use in this study.

The first phase of the update to the San Luis Obispo County Master Water Plan was conducted by EDAW (1998). Estimates of required pumping for agriculture throughout the County were developed within that document and have been generally accepted in the agricultural community. Those numbers are accordingly used in this analysis.

Table 49 lists the average monthly reference evapotranspiration for the Paso Robles and San Miguel climates as identified by EDAW (1998). Only the Paso Robles climate was used in this project due to the very close nature of the two assumed climates.

Table 49. Average Monthly Reference Evapotranspiration (ETo)
(in inches)

Climate Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Paso Robles	1.6	2.0	3.2	4.3	5.5	6.3	7.3	6.7	5.1	3.7	2.1	1.4	49.2
San Miguel	1.6	2.0	3.2	4.3	5.3	6.4	7.4	6.8	5.1	3.7	2.1	1.4	49.3

An attempt was made to identify a surrogate for correction of average reference ET for any given year. Again, it is noted that there is a lack of calibrated weather stations in the area, especially for the base period. Thus, the ratio of average monthly temperature to long term average monthly temperature at the Paso Robles Airport was used. An example set of calculations is seen in Table 50.

Table 50. Example of ETc Adjustment Calculations

Row		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Long Term Average Monthly Temperature – F	46.70	50.03	52.57	56.80	62.73	68.88	73.60	73.35	69.63	62.16	52.63	46.53
2	1995 Average Monthly Temperature – F	50.65	53.71	53.9	55.23	59.84	66.78	72.35	72.82	70.08	62.92	57.55	50.15
3	Average Monthly ETc – inches	1.60	2.00	3.20	4.30	5.50	6.30	7.30	6.70	5.10	3.70	2.10	1.40
4	Adjusted Monthly ETc Used for 1995 Calculations- inches	1.74	2.15	3.28	4.18	5.25	6.11	7.18	6.65	5.13	3.75	2.30	1.51

Note: Row 4 = Row 3 * Row 2 / Row 1

Crop Coefficients (Kc). A commonly used objective method of estimating crop water use (or crop evapotranspiration) was introduced by equation [2]. In equation [2], the reference evapotranspiration is multiplied by some "crop coefficient" to estimate the crop evapotranspiration. Thus, the crop coefficient is an empirically-determined relationship between reference evapotranspiration and any particular crop.

As noted above, crop coefficients from EDAW (1998) were used as a base model for these calculations. However, there were some minor changes and extensions to those coefficients. Table 51 lists the base crop coefficients used in this analysis.

Table 51. Crop Coefficients (Kc) for Irrigated Land Use Groups

Land Use	Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
P1	Alfalfa	0	0	0.9	0.9	0.9	0.9	1	1	1	1	0	0
P	Pasture	1	1	1	1	1	1	1	1	1	1	1	1
D	Deciduous	0	0	0.6	0.7	0.8	0.9	1	1	0.9	0.8	0	0
T	Vegetables	0	0	0.3	0.5	0.9	0.9	0.9	0	0	0	0	0
V	Vineyard	0	0	0	0.2	0.6	0.7	0.6	0.5	0.3	0.1	0	0
G	Grains	0.5	0.75	0.8	0.6	0.4	0	0	0	0	0	0.1	0.3
F	Field Crops	0	0	0.15	0.35	0.6	0.8	0.8	0.8	0.6	0.2	0	0

Changes and extensions to the EDAW (1998) crop coefficients included:

1. EDAW (1998) used 0 for the April crop coefficient for vineyards (land use group V). A value of 0.2 was assumed for this investigation.
2. EDAW (1998) assumed two crops per year for the vegetable acreage (land use group T) because the majority of vegetable acreage in San Luis Obispo County as a whole is in the coastal areas. Only one, Spring crop, has been assumed in the basin for this study.
3. Because estimates of acreages of vineyard for individual years were used, the development of vineyard acreage could be tracked. That is, as vineyard acreage increased it could be estimated how much acreage was in various stages of development. Four stages of development were used: 1) first year, 2) second year, 3) third year, and 4) mature vineyards. Table 52 indicates the percentage of mature vineyard ET assumed for each growth stage. Also, in any year past 1984, five percent of the mature acreage was reassigned as "first year" to account for replants.

Table 52. Assumed Percentage of Normal Crop Water Use During Vineyard Development

Stage of Vineyard Development	1st Year	2nd Year	3rd Year	Mature
Assumed Percent of Normal ETc	20%	60%	80%	100%

4. There are at least two major groups of canopy management/irrigation management for vineyards in use in the basin. One utilizes a normal canopy and full irrigation for table grapes and some varieties of wine grape. The other utilizes a much smaller canopy with intentional water stress in order to produce a higher quality wine grape. The latter management technique has gained favor (or at least publicly acknowledged favor) in the past 5 to 10 years. A correction was made to a certain percentage of the third year and mature vineyard acreages for the stressed condition. This was done by reducing normal ET by 30 percent. Table 53 indicates the progressive implementation of this correction throughout the hydrologic period.

Table 53. Assumed Percentage of Normal and Stressed Vineyard Acreage

	Period			
	1980-1985	1986-1990	1991-1995	1996-1997
Assumed Percent of Acreage with Normal ETc	100	85	70	65
Assumed Percent of Acreage with 30 Percent Reduction in ETc	0	15	30	35

5. Wet soil evaporation occurs after each rainfall or irrigation. Wet soil evaporation is the immediate evaporation of water from the soil surface. Models used by the industry for irrigation scheduling account for this in different ways. For this study, wet soil evapotranspiration was combined with net crop evapotranspiration. Micro-irrigation is the major form of irrigation for Deciduous and Vineyards, with sprinklers on all other irrigated crops. Although micro-irrigation wets a small portion of the soil surface, it is wet quite frequently. Conversely, sprinklers wet the total field surface but on an infrequent basis. For this analysis, net crop evapotranspiration, after accounting for effective rainfall was increased 5 percent for Deciduous and Vineyards and 10 percent for all other crops to account for wet soil evapotranspiration after an irrigation.

Effective Rainfall (PPTeff). Effective rainfall (PPTeff) is defined as that part of total rainfall satisfying the crop evapotranspiration requirements or stored in soil (Hanson, et al, 1999). Note that the word "stored" implies that this portion of effective rainfall can be used for later crop evapotranspiration.

The following excerpt from Hanson, et al (1999) is instructive and repeated here:

> *Effective rainfall is that part of total rainfall satisfying the crop evapotranspiration requirements or stored in soil. Effective rainfall depends on amount of total rainfall, soil moisture depletion at the time of the rainfall, frequency of occurrence of rainfall, timing of rainfall with respect to the growing season, and absence or presence of growing crops.*

Estimating effective rainfall can be difficult. High-intensity rainfall may result in much surface runoff resulting in little effectiveness. Small amounts of rainfall on dry soil with little vegetation may be lost to evaporation.

Guidelines on effective rainfall have been established by the Natural Resources Conservation Service (USDA), formerly the Soil Conservation Service. These guidelines…provide a method for calculating effective rainfall if monthly mean rainfall and average monthly crop evapotranspiration are known. This procedure is appropriate for use during the growing season.

Most areas in California experience substantial rainfall only during the winter and early spring. Rainfall during the growing season usually is negligible. Thus, effective rainfall in these areas is the amount stored in soil during periods of rainfall minus evaporation and drainage from the soil below the root zone between time of the rainfall and start of the crop-growing season.

Much uncertainty exists in estimating effective rainfall under these conditions. The California Department of Water Resources studied effective rainfall at 10 locations in the San Joaquin Valley between 1983 and 1987. A variety of relationships between cumulative rainfall and cumulative changes in soil moisture content were found…

Based on this study, the average effective rainfall was found to be about 50 percent of total rainfall during the winter months. However, the range of values was 16 to 79 percent reflecting time and site-specific nature of effective rainfall. The best method to determine stored soil moisture from rainfall in the soil profile is to measure soil moisture contents at the start of the growing season.

From the above quote, it must be recognized that any estimates of effective rainfall for a study of this sort are extremely gross. Estimating effective rainfall for this project was performed as follows:

1. Acreages were identified by quadrangle map with zones of equal rainfall identified as aggregates of one or more quadrangles. One or more key precipitation recording stations (Figure 2) were then assigned to the group. The rainfalls at these assigned stations were averaged for each year of the study for each grouping. Five such aggregate groups were identified:
   a. Quadrangle maps 4929, 4930, 4931, 5029, 5030, 5031, and 5032 – this group is essentially the Monterey County portion of the basin. Precipitation stations at Camp Roberts (number 109) and San Miguel (number 125) were averaged for this group.
   b. Quadrangle maps 5235, 5335, 5435, 5034, 5134, 5234, 5334, 5033, 5133, and 5233 - this group represents the eastern San Luis Obispo County portion of the basin. Precipitation stations at Shandon (number 73), Camatta Canyon (number

138), McMillan Canyon (number 93), and Creston (number 52) were averaged for this group.

c. Quadrangle maps 5132, 5232, 5332, and 5333 – this group represents the western-center of the basin and includes the Estrella and Creston areas. Precipitation stations at Paso Robles (number 10), Creston (number 52), and Atascadero (number 34) were averaged for this group

d. Quadrangle maps 5130 and 5131- these represent the northern Salinas River area. Precipitation stations at Camp Roberts (number 109) and Paso Robles (number 10) were averaged for this group.

e. Quadrangle maps 5132, and 5133 – these represent the southern Salinas River and Santa Margarita areas. Precipitation stations at Atascadero (number 34), Paso Robles (number 10), and Santa Margarita (number 60) were averaged for this area.

2. Effective rainfall was then estimated separately for in-season and off-season periods for each of the crop groups. For the off-season period, 35 percent of monthly gross rainfall was assumed effective, up to a maximum value. This maximum value would represent approximately 60 percent of the available water holding capacity of the effective root zone (that depth of soil where the crop is going to extract water). The level of 60 percent dryness was assumed to model the status of the effective root zone at the end of the previous season. Table 54 lists the assumed maximum amount of effective rainfall in the off season for the various crop groups.

   Root zones were estimated as per Hanson, et al (1999). An examination of the General Soil Map contained in the Soil Survey for Paso Robles shows a wide range of soils used for agriculture in the basin. The main soil complexes in the irrigated areas of the basin are seen to be Nacimiento-Ayar, Nacimiento-Los Oso-Balcom, Arbuckle-Positas-San Ysidro, and Pico-San Emigdio-Serento. A review of the General Soil Map suggests that 0.15 inches/inch Available Water Holding Capacity is a reasonable estimate for the entire basin as a whole.

Table 54. Assumed Maximum Stored Rainfall from Off-Season Storm Events

Land Use Group	Assumed Root Zone (feet)	60% of Available Water-Holding Capacity in the Root Zone (inches)
Truck (vegetables)	2.0	2.16
Field	3.0	3.24
Grains	3.0	3.24
Pasture	2.5	2.70
Alfalfa	5.0	5.40
Deciduous	4.0	4.32
Vineyard	3.0	3.24

3. Effective rainfall in-season was then estimated using the relationships listed in Table 55 between gross rainfall, crop water use, and resulting effective rainfall. The information in Table 55 is taken from the Natural Resources Conservation Service National Engineering Handbook, Chapter 2 (NEH-2).

   As an example of using Table 55, if the gross monthly rainfall was 2.5 inches and the monthly crop ETc was 3.0 inches, then the estimated effective rainfall would be 1.65 inches.

Table 55. Average Monthly Effective Rainfall

Monthly ETc (inches)	Gross Monthly Rainfall (inches)																
	0	**.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**	**5.5**	**6.0**	**6.5**	**7.0**	**7.5**	**8.0**
0.0	0.00	0.28	0.59	0.87	1.14	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39
1.0	0.00	0.30	0.63	0.93	1.21	1.47	1.73	1.98	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23
2.0	0.00	0.32	0.66	0.98	1.27	1.56	1.83	2.10	2.36	2.61	2.86	3.10	3.10	3.10	3.10	3.10	3.10
3.0	0.00	0.34	0.70	1.03	1.35	1.65	1.94	2.22	2.49	2.76	3.02	3.28	3.53	3.79	4.03	4.03	4.03
4.0	0.00	0.36	0.74	1.09	1.43	1.74	2.05	2.35	2.63	2.92	3.20	3.47	3.74	4.00	4.26	4.52	4.78
5.0	0.00	0.38	0.78	1.16	1.51	1.84	2.17	2.48	2.79	3.00	3.38	3.67	3.95	4.23	4.51	4.78	5.05
6.0	0.00	0.40	0.83	1.22	1.59	1.95	2.29	2.62	2.95	3.26	3.57	3.88	4.18	4.48	4.77	5.06	5.34
7.0	0.00	0.42	0.88	1.29	1.69	2.06	2.42	2.77	3.12	3.45	3.78	4.10	4.42	4.73	5.04	5.35	5.65
8.0	0.00	0.45	0.93	1.37	1.78	2.18	2.56	2.93	3.29	3.65	4.00	4.34	4.67	5.00	5.33	5.65	5.97
9.0	0.00	0.47	0.98	1.45	1.88	2.30	2.71	3.10	3.48	3.86	4.23	4.50	4.94	5.29	5.64	5.98	6.32
10.0	0.00	0.50	1.00	1.50	1.99	2.44	2.86	3.28	3.68	4.08	4.47	4.85	5.23	5.60	5.96	6.32	6.68

Leaching Ratios (LR). Leaching is deep percolation required to maintain a salt balance in the root zone. The leaching ratio is an indicator of how much leaching must occur for any combination of crop and irrigation water quality.

As noted in the explanation for equation [3], normally an ECe (a measure of salinity in the root zone) is chosen to ensure full crop yields. This is generally termed the threshold ECe. Table 56 lists the assumed threshold ECes for the different crop groups. These numbers were developed using data from tables contained in NEH-2 of ECe for various crops.

Past studies indicate high variability in measured water quality in the Paso Robles basin (CRI, 1993). Additional data gathered in this study reinforce this variability. However, for the most part, irrigation water quality is generally in the range of 400 to 600 mg/L TDS or less. This would result in required leaching ratios in the range indicated by Table 56.

As did EDAW (1998), this study assumes that natural rainfall and excessive irrigations will account for required leaching for most of the crop groups in most of the basin. However, indications are that some areas of the eastern part of the basin have significantly poorer water quality than the basin as a whole.

Table 56. Assumed Threshold Salinities (ECe)

Land Use Group	Assumed Threshold Salinity ECe (dS/m)	Leaching Ratio for Irrigation Water at ECi = .75 (percent)
Truck (vegetables)	2.0	8
Field	3.0	5
Grains	7.0	2
Pasture	3.2	5
Alfalfa	2.0	8
Deciduous	1.5	11
Vineyard	1.1	16

Table 57 is a list of annual rainfall for the aggregate quadrangle group representing the eastern (Shandon/Camatta Canyon/San Juan Creek) part of the basin. There is obviously a wide variability in annual rainfall. The majority of this rain will occur in winter months, when there is no crop water use. Thus, any water infiltrated above the assumed storage capacity will go into deep percolation and be helpful in fulfilling leaching requirements. However, a 5 percent leaching ratio is used for vineyards in the quadrangle group representing the eastern portion of the basin (quadrangle maps 5235, 5335, 5435, 5034, 5134, 5234, 5334, 5033, 5133, and 5233) due to the poorer water quality in this area.

Table 57. Estimated Annual Rainfall for the Eastern Portion of the Basin

(inches)

Year	Annual Rainfall
1981	10.52
1982	17.72
1983	22.07
1984	5.71
1985	5.89
1986	11.71
1987	13.49
1988	8.98
1989	5.68
1990	4.77
1991	14.82
1992	15.03
1993	15.58
1994	10.25
1995	20.35
1996	16.38
1997	10.55

Irrigation Efficiency (IE). "Irrigation efficiency" is an ambiguous term that has both spatial and temporal implications. In terms of spatial boundaries, the question is whether the measurement is for a field, for a farm, for an irrigation district, or for a basin. It also depends on whether the measurement is for one irrigation, for a season, or for a hydrologic period. There are also a number of other direct factors including irrigation system design, system maintenance, and system management. For this study, it is assumed that the measure of irrigation efficiency is the season average for an individual field.

Another aspect of estimating IE for determining agricultural water demand is the base time period involved (1981 through 1997). This period encompasses one of the most important droughts in the State's history. This has been a period of generally increasing awareness of the need for improved water resources management. Thus, the models used to estimate both required pumping and consumptive use attempt to account for this.

Table 58 lists the irrigation efficiencies assumed for the different crop groups for four different time periods. These estimates are based on field experience, conversations with irrigation system designers who have worked extensively in the area, and published estimates.

Table 58. Assumed Irrigation Efficiencies
(percent)

Land Use Group	Period			
	1980-1985	1986-1990	1991-1995	1996-1997
Field Crops	63	65	68	72
Truck Crops	63	65	67	70
Grains	63	65	68	72
Irrigated Pasture	63	65	67	70
Alfalfa	63	65	68	72
Vineyards	63	68	72	75
Deciduous	63	68	72	75

Frost Control. Groundwater pumping for frost control can be a significant factor. EDAW (1998) estimated that 0.5 acre-feet/acre per year was applied on average. This factor was applied to the entire acreage. Conversations with UC Extension and ACO personnel, as well as personal observations in the field, indicate that approximately 50 percent of the vineyard acreage has frost control systems in place. Thus, while the 0.5 acre-feet/acre factor is retained, it is applied against only one-half of the vineyard acreage. However, 0.5 acre-feet/acre is the amount of water applied for frost control. Consumptive use of this water would only be for immediate and subsequent wet-soil evaporation. EDAW (1998) estimated 11 nights of frost control on average. For this study, the following was assumed in order to estimate consumptive use of frost control water:

- It was assumed that the 11 nights of frost control would be split so that seven nights occurred in March and four in April.

- It was assumed that there would be an additional three days of wet soil evaporation in March and two days in April.
- Thus, it was assumed that 10 days of evaporation occurred in March and six days in April, all at the rate of the corrected, reference evapotranspiration for those months.

As an example, the corrected monthly reference evapotranspiration for 1995 (using temperature at the Paso Robles Airport) is 3.28 inches for March and 4.18 inches for April. This equates to 0.11 inches/day in March and 0.14 inches/day in April. Thus, consumptive use equal to 10 days at 0.11 inches/day and six days at 0.14 inches/day is added to the consumptive use on half of the vineyard acreage in 1995.

Results of the Computations. Table 59 tabulates the results of the computations using equation [1] and the data and methodology identified above, while Table 60 provides the results for the Atascadero subbasin using the same methodology. Note that the Atascadero subbasin is included in the totals for the whole basin.

Explanations for some of the columns include:

a. Columns 2 through 9 are the total and detail of irrigated acreage in the basin (or the Atascadero subbasin) for each year.
b. Column 10 is the total consumptive use of water to the irrigated crops and is equal to crop evapotranspiration, immediate evaporation during and just after irrigations or frost control events, and evaporation of conveyance system losses.
c. Column 11 is gross rainfall across the basin (or Atascadero subbasin).
d. Column 12 is that portion of gross rainfall that falls during the growing season and used for crop evapotranspiration.
e. Column 13 is that portion of gross rainfall that falls in the off-season, stored in the root zone, and later used for crop evapotranspiration.
f. Column 14 is the total consumptive use after accounting for effective rainfall. Note that this column will not equal Column 10 – (Column 12 + Column 13) because of the method for accounting for evaporation losses during frost control.
g. Column 15 is the gross pumping required to satisfy the consumptive uses in Column 14.

From the analysis, the following comments can be made:

- The Gross Required Pumping (column 15) has been relatively stable, along with Total Consumptive Use (column 14) from about 1991 to the end of the base period. There has been a slight increase in Alfalfa acreage, increases in irrigated Grain acreage, and continued increases in Vineyard acreage offsetting losses in irrigated Pasture and Deciduous Trees.

Table 59. Irrigated Acreage and Water Use Calculations, Paso Robles Groundwater Basin

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Year	Total Irrigated Acres (acres)	Vineyard Acres (acres)	Pasture Acres (acres)	Alfalfa Acres (acres)	Field Crop Acres (acres)	Truck Crop Acres (acres)	Deciduous Tree Acres (acres)	Grain Acres (acres)	Total Consumptive Use (acre-feet)	Gross Rain (acre-feet)	Effective Rain In Season (acre-feet)	Effective Rain Off Season (acre-feet)	Consumptive Use Effective Rain (acre-feet)	Gross Required Pumping (acre-feet)
1980	27,420	4,156	4,417	14,381	2,694	384	882	506	41,439	387	0	1	41,439	66,593
1981	26,884	4,577	4,397	13,656	2,518	384	839	513	81,107	21,987	5,994	3,444	71,668	114,860
1982	26,353	4,997	4,378	12,932	2,341	384	801	520	76,341	31,656	10,750	4,088	61,504	98,692
1983	25,829	5,418	4,358	12,208	2,165	384	769	527	74,748	53,847	11,731	8,590	54,426	87,512
1984	25,348	5,838	4,339	11,483	1,988	384	735	581	75,394	15,814	2,017	3,752	69,624	111,802
1985	24,757	6,259	4,149	10,759	1,865	384	701	640	70,560	16,476	3,029	3,487	64,040	102,970
1986	24,170	6,679	3,964	10,035	1,741	384	669	698	65,707	30,848	6,974	5,352	53,395	82,936
1987	23,576	7,098	3,773	9,311	1,619	384	635	756	63,304	15,266	3,514	2,786	57,000	88,503
1988	22,986	7,520	3,584	8,585	1,496	384	603	814	60,229	25,740	4,431	5,463	50,354	78,318
1989	22,398	7,942	3,396	7,861	1,373	384	569	873	58,211	16,680	3,836	3,074	51,324	79,815
1990	22,039	8,523	3,209	7,138	1,318	384	537	930	56,064	12,010	2,324	2,466	51,283	79,781
1991	21,679	9,104	3,021	6,414	1,264	384	503	989	51,372	23,562	3,210	3,125	45,041	67,348
1992	21,317	9,684	2,832	5,688	1,211	384	471	1,047	50,523	25,292	3,015	4,913	42,598	63,755
1993	20,952	10,262	2,641	4,964	1,159	384	437	1,105	46,810	37,501	2,998	5,974	37,843	56,780
1994	20,596	10,844	2,456	4,240	1,104	384	405	1,163	45,019	17,136	4,230	3,002	37,882	56,864
1995	20,232	11,422	2,266	3,516	1,051	384	371	1,222	41,105	43,120	3,470	4,597	33,067	49,775
1996	20,055	12,004	2,077	2,923	1,053	384	333	1,281	40,993	20,008	2,586	4,002	34,438	49,591
1997	20,172	12,582	1,891	2,541	1,123	384	312	1,339	41,730	25,040	167	6,275	35,291	50,768

Note:
1. 1980 only covers July-September.
2. 1997 only covers October through June.
3. Calculations done on basis of October to September.
4. Column 14 may not exactly equal Column 10 – (Column 12 + Column 13) due to how frost control is handled for vineyards.

Table 60. Irrigated Acreage and Water Use Calculations, Atascadero Subbasin

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Year	Total Irrigated Acres (acres)	Vineyard Acres (acres)	Pasture Acres (acres)	Alfalfa Acres (acres)	Field Crop Acres (acres)	Truck Crop Acres (acres)	Deciduous Tree Acres (acres)	Grain Acres (acres)	Total Consumptive Use (acre-feet)	Gross Rain (acre-feet)	Effective Rain In Season (acre-feet)	Effective Rain Off Season (acre-feet)	Consumptive Use - Effective Rain (acre-feet)	Gross Required Pumping (acre-feet)
1980	3,940	7	1,820	1,203	731	0	179	0	6,486	85	0	0	6,486	10,302
1981	3,747	48	1,727	1,123	682	0	167	0	11,934	3,946	943	680	10,311	16,377
1982	3,553	89	1,634	1,042	633	0	155	0	10,911	5,541	1,681	817	8,413	13,363
1983	3,361	129	1,542	962	585	0	143	0	10,377	9,267	1,615	1,219	7,542	11,980
1984	3,168	170	1,449	882	536	0	131	0	10,106	2,658	237	771	9,098	14,454
1985	2,980	211	1,356	802	487	5	119	0	9,188	2,783	322	736	8,131	12,917
1986	2,791	250	1,264	722	439	9	107	0	8,298	5,033	700	917	6,685	10,277
1987	2,602	291	1,171	641	390	14	95	0	7,739	1,804	346	384	7,010	10,770
1988	2,414	333	1,078	561	341	18	83	0	7,033	3,158	373	720	5,940	9,126
1989	2,227	374	986	481	292	23	71	0	6,458	2,006	368	482	5,608	8,610
1990	2,040	415	893	401	244	27	60	0	5,850	1,480	167	389	5,297	8,126
1991	1,851	454	801	321	195	32	48	0	4,968	2,400	291	270	4,405	6,500
1992	1,662	495	708	241	146	36	36	0	4,466	2,441	164	499	3,801	5,611
1993	1,472	535	615	160	97	41	24	0	3,694	3,245	155	397	3,143	4,624
1994	1,285	576	523	80	49	45	12	0	3,071	1,120	176	259	2,644	3,885
1995	1,097	617	430	0	0	50	0	0	2,292	2,738	161	232	1,900	2,780
1996	1,051	659	337	0	0	55	0	0	2,132	1,443	93	274	1,768	2,472
1997	1,002	698	245	0	0	59	0	0	992	1,658	0	259	731	1,023

Note:
1. 1980 only covers July-September.
2. 1997 only covers October through June.
3. Calculations done on basis of October to September.
4. Column 14 may not exactly equal Column 10 – (Column 12 + Column 13) due to how frost control is handled for vineyards.

- Vineyards use much less water than alfalfa or irrigated pasture as a crop, plus most vineyards use drip irrigation. Irrigated grains are a low water user due to their growing season (short and many times over-winter).
- The vegetable acreage (Truck Crops, column 7) is held constant at 384 acres (the average of the 1984 and 1995 reports) because the DWR data and ACO showed no discernable trend in vegetable acreage. This acreage is of minor impact anyway.
- The years of heaviest pumping (column 15) occurred in years with low rainfall (Gross Rainfall, column 11) and substantial acreages of alfalfa and pasture (1981, 1982, 1984, and 1985).
- Gross required pumping (column 15) has declined substantially. This is due to the substantial reductions in alfalfa and pasture acreage. There has been a significant increase in the vineyard acreage. However, this crop has a much lower seasonal net evapotranspiration than alfalfa or pasture and also is generally irrigated with micro-irrigation systems, normally considered the most efficient of irritation system types.

Municipal, Community, and Rural Domestic Groundwater Pumpage

Basic Methodology. Total municipal and industrial (M&I) groundwater demand in the Paso Robles basin is estimated for three main categories: Urban, Rural Domestic, and Small Commercial and Community Water Systems. Data used to estimate the water demand included information from several sources, including metered water use from each of the municipal purveyors, demand estimates from the San Luis Obispo County Master Water Plan Update (EDAW, 1998), historical population data from the County Planning and Building Department and the California Department of Finance, and historical records and estimates provided by individual water users.

Urban Demand. Urban demand, which comprises 55 to 60 percent of the total M&I demand, is the demand on groundwater occurring in incorporated cities and unincorporated communities of the basin served by a municipal water purveyor. All other water demands of the unincorporated areas in the study area are compiled under Rural Domestic demand and/or Small Commercial and Community Water Systems, and are described further below.

Urban demand was assessed for the hydrologic base period by compiling actual metered production records provided by the municipal water purveyors. Monthly production records were obtained from the major municipal water purveyors in the study area (Atascadero Mutual Water Company (AMWC), the City of Paso Robles, Templeton Community Services District (TCSD), and San Miguel (WW-1)). The periods of record of production data obtained for Paso Robles and Templeton CSD began in 1982, but pumping data for the first year of the base period for these two systems were available from the County Engineering Department database.

It is important to note that the metered or estimated production records for several County Service Areas or small community systems (Shandon, Garden Farms, Green River, etc.) are not included in the Urban demand dataset. Groundwater demand for these systems is included in the Rural Domestic demand, and will be described in more detail below. Table 61 presents production records of the major municipal water purveyors during the base period.

Table 61. Urban Demand, Paso Robles Groundwater Basin
(acre-feet per year)

Year	Atascadero MWC	Templeton CSD	Atascadero Subbasin (subtotal)	City of Paso Robles	San Miguel (WW 1)	Basin Total
	(col. 1)	(col. 2)	(1 + 2)	(col. 4)	(col. 5)	(1 + 2 + 4 + 5)
1981	4,221.5	312.3	4,534	3,323.1	164.0	8,021
1982	3,676.4	296.7	3,973	2,994.1	209.8	7,177
1983	3,863.1	284.9	4,148	3,170.2	175.9	7,494
1984	4,946.0	366.0	5,312	3,833.4	221.5	9,367
1985	4,783.5	422.9	5,206	4,057.6	184.7	9,449
1986	5,305.0	480.0	5,785	3,857.5	255.0	9,898
1987	5,815.2	628.6	6,444	4,044.3	247.0	10,735
1988	5,991.7	723.1	6,715	4,123.9	229.9	11,069
1989	5,978.6	781.2	6,760	4,481.2	217.5	11,459
1990	5,386.7	881.2	6,268	4,617.5	226.0	11,111
1991	4,656.4	897.7	5,554	4,599.7	230.1	10,384
1992	5,182.4	947.2	6,130	4,777.7	246.3	11,154
1993	5,333.3	927.3	6,261	4,737.0	230.3	11,228
1994	5,574.7	956.7	6,531	5,074.4	221.5	11,827
1995	5,107.3	885.1	5,992	4,921.4	251.0	11,165
1996	5,905.1	1,041.9	6,947	5,606.4	239.8	12,793
1997	6,317.4	1,126.0	7,443	5,843.6	225.9	13,513

Rural Domestic Demand. Rural domestic demand is defined as water use required by the remaining community areas in the basin that fall outside the categories of incorporated cities served by the five major water purveyors or those small water systems in outlying areas that do not show up in population surveys (such as small commercial systems). The majority of the rural domestic demand is from rural residential developments ("ranchettes"). No agricultural demand is included in the rural domestic demand compilation.

Calculation of the rural water demand was patterned on the procedures used in the County Master Water Plan Update (EDAW, 1998). Rural population estimates from the County Planning Department and the California Department of Finance were coupled with estimated dwelling units to approximate water demand. To obtain the number of dwelling units, rural population numbers for a given year were divided by the 2.92 population-per-dwelling unit factor (pop/du) used in the County Master Water Plan Update (EDAW, 1998). The estimated number of dwelling units in the rural areas was then multiplied by a net "water duty" factor to obtain an estimate of the total water use during that year. Historical population data were obtained from the County Planning and Building Department.

The water duty factor, which was established in the County Master Water Plan Update, is an estimate of the volume of water used annually by a single dwelling unit or "ranchette." The net water duty (1.7 afy per dwelling unit) was then multiplied by the number of dwelling units in the study area to obtain a total Rural Domestic demand for that year. The assumptions used in the County Master Water Plan Update (EDAW, 1998) for developing Rural Domestic Demand were used for this study. Table 62 presents the Rural Domestic demand estimate for the basin.

Table 62. Rural Domestic Demand, Paso Robles Groundwater Basin

Year	Rural Population	POP/DU	Dwelling Units	Water Duty Factor (af/DU)	Demand (afy, rounded)
1981	8,050	2.92	2,757	1.7	4,700
1982	8,715	2.92	2,985	1.7	5,100
1983	9,370	2.92	3,209	1.7	5,500
1984	10,025	2.92	3,433	1.7	5,800
1985	10,680	2.92	3,658	1.7	6,200
1986	11,350	2.92	3,887	1.7	6,600
1987	12,226	2.92	4,187	1.7	7,100
1988	12,670	2.92	4,339	1.7	7,400
1989	13,057	2.92	4,472	1.7	7,600
1990	14,418	2.92	4,938	1.7	8,400
1991	14,468	2.92	4,955	1.7	8,400
1992	14,502	2.92	4,967	1.7	8,400
1993	14,706	2.92	5,036	1.7	8,600
1994	15,023	2.92	5,145	1.7	8,700
1995	15,511	2.92	5,312	1.7	9,000
1996	15,787	2.92	5,407	1.7	9,200
1997	16,215	2.92	5,553	1.7	9,400

Small Commercial and Community Water Systems. Several small community water systems throughout the basin provide groundwater supply to small residential communities, mutual water companies, and commercial users. Data obtained from the San Luis Obispo County Environmental Health Department files indicate that approximately 36 small community and commercial water systems pump groundwater from the basin. However, most of these smaller systems supply water to residential connections and have therefore been accounted for in this study in the Rural Domestic demand population estimates. The small community water systems included in the Rural Domestic demand estimates include:

- Almira Park MWC
- Shandon (CSA 16-1)
- Garden Farms MWC
- Green River MWC
- Adelaide Estates MWC
- Bow Valley Aquiland Water Supply
- Mustang Mobile Village
- Babe Ruth Trailer Park
- Los Robles MHP
- McNamara WC
- Mustang Springs MWC
- Durand MWC
- Town Creek Water Supply
- Rancho Colina MHP
- Rinconada Trailer Park

Twenty small commercial systems supply water to small facilities or other commercial establishments and are not accounted for in the rural domestic or rural population estimates. These systems include facilities like the Atascadero State Hospital, golf courses, and other small establishments that do not show up in population estimates. These small commercial systems include:

- Atascadero State Hospital
- El Paso de Robles Youth Authority
- Arciero Winery
- Camp Emmanuel
- Camp Roberts
- Creston Elementary School
- Philips Elementary School
- Shandon Rest Stop
- Creston Country Store
- Hunter Ranch Golf Course
- Links Golf Course
- Loading Chute
- Long Branch Saloon
- Pete Johnston Chevrolet
- Pleasant Valley Elementary School
- San Paso Truck & Auto
- Camp Wantala
- Christmas Cove Co.
- Wine World
- Atascadero Lake

Water demand estimates for these small commercial systems were obtained through interviews with system operators/owners, metered records (where available), engineer's water demand estimates at the time of permitting, and estimates of irrigation demands. The water demand estimates of small commercial systems are provided in Table 63.

Total Demand. Total municipal and industrial (M&I) water demand estimates in the Paso Robles Groundwater Basin were calculated in three main categories: Urban, Rural Domestic, and Small Community and Commercial Systems. Table 64 presents the total M&I demand for the Paso Robles basin during the base period. Similarly, Table 65 itemizes total demand (municipal and industrial, rural domestic, and small commercial systems) for the Atascadero subbasin.

Table 63. Small Commercial Water System Demand

Year	Small Commercial Water System Demand (afy, rounded)
1981	700
1982	700
1983	800
1984	800
1985	800
1986	800
1987	800
1988	800
1989	800
1990	700
1991	700
1992	700
1993	1,100
1994	1,100
1995	1,500
1996	1,400
1997	1,400

Table 64. Total Municipal, Community, and Rural Domestic Demand, Paso Robles Groundwater Basin

Year	Urban Demand (afy)	Rural Demand (afy)	Small Commercial Systems (afy)	Total Demand (afy)
1981	8,021	4,700	700	13,400
1982	7,177	5,100	700	13,000
1983	7,494	5,500	800	13,700
1984	9,367	5,800	800	16,000
1985	9,449	6,200	800	16,500
1986	9,898	6,600	800	17,300
1987	10,735	7,100	800	18,600
1988	11,069	7,400	800	19,200
1989	11,459	7,600	800	19,900
1990	11,111	8,400	700	20,200
1991	10,384	8,400	700	19,500
1992	11,154	8,400	700	20,300
1993	11,228	8,600	1,100	20,900
1994	11,827	8,700	1,100	21,700
1995	11,165	9,000	1,500	21,600
1996	12,793	9,200	1,400	23,400
1997	13,513	9,400	1,400	24,400

Table 65. Total Municipal, Community, and Rural Domestic Demand, Atascadero Subbasin

Year	Urban Demand (afy)	Rural Demand (afy)	Small Commercial Systems (afy)	Total Demand (afy)
1981	4,534	1,100	300	6,000
1982	3,973	1,100	300	5,400
1983	4,148	1,200	400	5,700
1984	5,312	1,200	400	7,000
1985	5,206	1,300	400	6,800
1986	5,785	1,300	400	7,500
1987	6,444	1,400	400	8,200
1988	6,715	1,400	300	8,500
1989	6,760	1,500	400	8,600
1990	6,268	1,600	300	8,200
1991	5,554	1,600	200	7,400
1992	6,130	1,600	200	8,000
1993	6,261	1,600	200	8,100
1994	6,531	1,700	200	8,400
1995	5,992	1,700	300	8,000
1996	6,947	1,800	300	9,000
1997	7,443	1,800	300	9,500

Consumptive Use by Phreatophytes (EP)

Consumptive use by phreatophytes was determined by mapping acreage of riparian vegetation and applying a unit water use factor (in afy per acre) based on data contained in USGS Water Supply Paper 1423 (1958). Vegetative types and density of growth in the riparian corridor of the Paso Robles basin are only generally known. Groundwater consumed by phreatophytes is dependent on many factors including species, vegetative density, climate (sunlight, wind, temperature, humidity), soil, and depth to and quality of groundwater.

Riparian vegetation GIS data for the Paso Robles basin was obtained from the California Department of Forestry (CDF), Fire and Resource Assessment Program. The data are raster based with a 25-meter pixel resolution, and the original projection was Albers with units as meters. Riparian vegetation was mapped as part of a project to inventory state-wide hardwood rangelands below elevation 5,000 feet. The coverage was completed in 1991 by Pacific Meridian Resources under contract with CDF, and is based on a project completed by Dr. Norm Pillsbury, Cal Poly, San Luis Obispo, in 1981. Riparian vegetation was delineated through a supervised classification of Landsat™ imagery obtained in midsummer of 1989 and 1990. Supervised image classification requires the analyst to delineate areas of similar vegetation characteristics that can be differentiated on an image.

Computer software was used to search an image for pixels spectrally similar to the specified areas. The riparian vegetation coverage classifies vegetation types within a 375-meter buffer zone around perennial streams. Perennial streams were obtained from USGS Digital Line Graphs for the region. The project defined riparian vegetation as areas of greater than 10 percent crown closure with greater than 50 percent non-conifer vegetation within the 375-meter buffer zone. Field checks of the accuracy of the classification were conducted by Pacific Meridian Resources. The coverage was also compared with newer aerial imagery and corrected where differences were apparent. The coverage identifies 30,678 pixels (4,738 acres) in the basin as riparian vegetation. An example of GIS images of the Paso Robles basin showing the locations of riparian (phreatophytes) vegetation is provided in Figure 70.

Measurements of consumptive use by phreatophytes in the Paso Robles basin do not exist. Conversations with Mr. Jim Patterson (Water Conservation Director for AMWC) suggest that while the riparian and phreatophyte acreage calculated using the CDF imagery may be reasonably accurate, a distinction exists between riparian habitat and properly-defined phreatophytes. Riparian vegetative demand refers to evapotranspiration along the stream bed or stream corridor; phreatophytes send their roots directly into the groundwater table. Thus, phreatophyte consumption is much greater than typical riparian habitat demand.

From the literature, phreatophyte unit consumptive use values range from 0.5 to 1.2 af/acre. Because some of the calculated CDF acreages included riparian habitat, a phreatophyte consumptive use value of 0.8 afy per acre was assumed for the approximate 4,700 acres mapped (1989 and 1990 coverage). Water use by phreatophytes was undoubtedly less during the drought of the late 1980's-early 1990's and, accordingly, the annual estimate was adjusted based on average precipitation in the basin. The results are provided in Table 66, adjusted based on variations in seasonal phreatophytes.

Average annual consumptive use by phreatophytes in the Paso Robles basin for the base period was about 3,800 afy (Table 66) or about 4 percent of the total extractions from the zone of saturation. Included in this amount is local rising water, which occurs in the basin as a result of geologic barriers to flow (e.g., springs along stream systems that cross the San Miguel Dome) as wells as locally in the Salinas River.

For the Atascadero subbasin, the same general methodology was employed. Riparian vegetation in the Atascadero subbasin contained 1,433 cells, which translates to about 221 acres (Figure 71). Applying an annual water demand of 0.8 acre-feet/acre results in an average annual consumptive use value of 177 af (Table 66). These values were subsequently adjusted based on variations in rainfall for the precipitation station closest to Atascadero.

Exported Water (W_E)

Water impounded by Salinas Dam has been exported from the watershed above the Paso Robles basin to the City of San Luis Obispo, under certain entitlements, since 1944. Quantities of exported water are generally known and are tabulated for the base period on Table 67. The average annual exports are in the range of 4,380 afy over the base period.

Table 66. Phreatophyte Extraction

(acre-feet per year)

Year	Rainfall (in)	Paso Robles Groundwater Basin	Atascadero Subbasin
1981	10.20	2,800	100
1982	13.95	3,900	200
1983	22.96	6,400	300
1984	9.14	2,500	100
1985	8.24	2,300	100
1986	15.40	4,300	200
1987	8.41	2,300	100
1988	13.56	3,800	200
1989	7.27	2,000	100
1990	9.10	2,500	100
1991	13.49	3,800	200
1992	14.87	4,100	200
1993	21.07	5,900	300
1994	8.11	2,300	100
1995	26.90	7,500	400
1996	12.33	3,400	200
1997	14.56	4,100	200
17-Year Average:		3,800	200
High		7,500	400
Low		2,000	100

Note: Precipitation values shown are an average of values from several precipitation stations across the basin.

Table 67. Exported Water to City of San Luis Obispo

(acre-feet)

Water Year	Exported Water to the City of San Luis Obispo
1981	6,640
1982	6,280
1983	5,180
1984	7,270
1985	6,550
1986	6,760
1987	6,800
1988	5,540
1989	2,580
1990	1,670
1991	490
1992	1,990
1993	3,690
1994	2,980
1995	570
1996	3,880
1997	5,540
Average	4,400
Maximum	7,270
Minimum	490

Notes: Each year extends from July through June.
Source: Woodward-Clyde Consultants (1997)

To the extent that any exported water volume could be a component of recharge to the Paso Robles basin, it needs to be considered in the overall water balance. However, as will be explained below, it is not appropriate to include the water used by San Luis Obispo out of Salinas Reservoir as a component to the Paso Robles basin water balance equation. It should be noted that the amount of exported water is not a simple 1:1 loss to the watershed system in that the benefit to the groundwater basin is dependent on a complicated relationship of the watershed water balance equation, release schedules from the dam, the volume and duration of water released to the stream system, and losses within the reach of the stream prior recharge (i.e., consumptive use in the stream system). The reservoir must be operated in accordance with the State Water Resources Control Board mandate of the "live stream" concept, which requires that water cannot be diverted to storage in the reservoir until a visible stream is flowing from Salinas Dam to the confluence of the Salinas and Nacimiento rivers. The purpose of the live stream concept is to protect downstream water users and provides for recharge of the Atascadero subbasin and Paso Robles Groundwater Basin before adding water to storage in the reservoir.

For the seven spill years between 1973 and 1986, about half of all outflow from the river went to groundwater recharge in the reach between the dam and Paso Robles. The average of the outflows was approximately 14,000 afy, while the amount of exported water was about 3,000 afy (for that time period). It could be argued that about one-half of the 3,000 afy of exported water could benefit the Atascadero subbasin and Paso Robles basin, or about 1,500 afy. Where this 1,500 afy would ultimately recharge the aquifer is not known, given the uncertainties of streamflow conditions at the time and the possibility of rejected recharge. Arguably, this amount of water is accommodated in the estimates of streamflow recharge calculated elsewhere.

For purposes of estimating the perennial yield of the basin, it is not appropriate to incorporate the exported water component into the water balance equation. The water exported from the Salinas Dam reservoir to the City of San Luis Obispo is an export volume from the watershed, but should not be considered an outflow component from the groundwater basin. Because the water never reaches the basin as an inflow volume, the exported water is not an outflow component of the water balance equation for the base period.

ANNUAL CHANGE OF GROUNDWATER IN STORAGE USING THE CHANGE IN STORAGE METHOD

Groundwater in Storage

The volume of groundwater in storage in a basin controls the ability of the basin to tolerate periods of drought and/or extractions more than the annual recharge rate. Areas with large volumes of groundwater in storage can maintain extraction rates that exceed the average annual recharge rates for multiple years without significant impacts. Areas with limited groundwater in storage, on the other hand, can experience water supply shortages relatively rapidly.

The total groundwater in storage is the volume of water existing within void spaces of the water-bearing materials. The amount of this void space that holds retrievable water is commonly known as specific yield or the coefficient of storage. Considering the basin in its entirety, particularly over long periods of time, the change in storage likely represents a dewatering/rewetting of the aquifer, which is best represented by an average specific yield value. Specific yield is the ratio of the volume of water that a saturated sediment will yield by gravity drainage in proportion to the total volume of the sediments. The ratio is dimensionless and is expressed in percent. Previous investigators, most notably DWR (1979), estimated the specific yield of the Paso Robles Formation by assigning specific yield values to the various lithologic units described on driller's logs and the developing a weighted average for specific yield of the formation as a whole. The weighted average specific yield values calculated by DWR ranged from 6% to 13%, averaging 9%.

Specific Yield Calculations

In order to verify and refine the DWR estimates of specific yield, the specific yield value for water-bearing sediments of each area was estimated by analyzing a total of 157 driller's logs, including the deepest available logs. For each well, a specific yield value was assigned to the lithologic description on the log, based on the empirical studies conducted by DWR (1958). The thickness of the intervals was then multiplied by the respective assigned specific yield value, then divided by the total drilled formation thickness to obtain a weighted average of specific yield for each well. The mean value of the specific yield for logs in each area was then calculated. The results of the specific yield analysis are presented in Table 68.

Table 68. Results of Specific Yield Analyses, Paso Robles Groundwater Basin

Subbasin/Area	Specific Yield
Atascadero subbasin	11 %
Creston	9 %
San Juan	10 %
Estrella	8 %
Shandon	9 %
North Gabilan and South Gabilan	9 %
Bradley	7 %
Basin Average	**9 %**

As shown, the specific yield values estimated here range from 7% to 11%, with an average basin specific yield of 9%. This compares well with the 9% specific yield value used basin-wide by DWR (1975).

Groundwater Storage and Change in Storage Calculations

The change in amount of groundwater in storage depends on the annual water supply surplus or deficiency as expressed in the general water balance equation. This equation evaluates occurrence of both surface and subsurface water as they relate to water supply, use, and disposal during the base period. An additional method of determining the annual change of groundwater in storage involves use of the specific yield method. In the next section, the results obtained by these two methods are compared. In the future, these can also be verified by mathematical modeling of the basin, if desired.

The water level contour maps described earlier and shown on Figures 32 through 35 were prepared by plotting water level data on the base map and manually contouring the water surfaces. Manual contouring is a preferred method of generating water level contours that make sense hydrogeologically where data may be spatially limited, as is the case in some areas of the Paso Robles basin.

The annual storage calculations performed here for the hydrologic budget were prepared in a slightly different manner by using an automated contouring program to generate the annual groundwater surfaces. The automated contouring program is better than manual contouring of accurately accounting for the relatively small incremental changes in water level at the observation wells from one year to the next. Several combinations of automated gridding and contouring techniques were performed until the generated contours most closely approximated the general groundwater patterns developed on Figures 32, 33, and 35. The same combination of gridding and contouring and the exact same wells were utilized to generate a water level contour map for every year of the base period.

GIS was utilized to calculate the volume of saturated materials between the water level contour surfaces and the base of the fresh water surface for each year of the base period. These volumes were combined with the specific yield estimates to quantify the amount of groundwater in storage each year. The difference between the groundwater in volume from one year to the next is the annual change in groundwater storage. The calculated annual total groundwater in storage and change in storage values are presented in Tables 69 and 70.

As shown, the total average estimated groundwater in storage for the basin was 30,534,000 af. This estimate of groundwater in storage is comparable to the DWR (1979) estimate of approximately 26,520,000 af (also assuming a basin-wide specific yield of 9%). The greater volume shown here is accounted for largely by the re-definition in this study of the northern basin boundary. DWR (1975) limited the study area to the county line, whereas the current study is based on a larger basin area with geologically controlled boundaries.

Table 69. Annual Groundwater in Storage, Paso Robles Groundwater Basin

(in acre-feet)

Year (Spring)	Groundwater in Storage	Annual Change in Storage
1980	30,504,766	--
1981	30,545,003	40,200
1982	30,520,527	(24,500)
1983	30,705,027	184,500
1984	30,529,851	(175,200)
1985	30,413,260	(116,600)
1986	30,663,053	249,800
1987	30,595,180	(67,900)
1988	30,388,460	(206,700)
1989	30,382,429	(6,000)
1990	30,337,412	(45,000)
1991	30,522,404	185,000
1992	30,607,191	84,800
1993	30,644,905	37,700
1994	30,438,568	(206,300)
1995	30,644,173	205,600
1996	30,632,520	(11,700)
1997	30,517,138	(115,400)
Total:	--	12,400
17-year Average:	30,534,000	700

Table 70. Annual Groundwater in Storage, Atascadero Subbasin

(in acre-feet)

Year (Spring)	Groundwater in Storage	Annual Change in Storage
1980	513,626	--
1981	513,677	100
1982	514,337	700
1983	522,291	8,000
1984	521,461	(800)
1985	516,712	(4,700)
1986	517,372	700
1987	543,050	25,700
1988	542,401	(600)
1989	502,465	(39,900)
1990	490,944	(11,500)
1991	490,743	(200)
1992	504,705	14,000
1993	508,405	3,700
1994	498,627	(9,800)
1995	510,973	12,300
1996	516,681	5,700
1997	516,681	(500)
Total:	--	2,600
17-year Average:	513,600	200

By the specific yield method of calculating perennial yield, approximately 12,400 af more groundwater was in storage in the Paso Robles Groundwater Basin in 1997 compared to 1980, an approximate 0.04% increase in total groundwater in storage during the base period. Over the time of the base period, this averages out to about 700 afy increase in storage. This relatively small percentage might be viewed as an indication of stable basin-wide conditions, however, as will be discussed in more detail later, decreasing storage in the 1980's has been balanced by increased water in storage throughout the 1990's. Furthermore, as discussed above, not all areas of the basin have observed the same trends in water levels and change in storage. Clearly, some areas have experienced significantly increasing groundwater in storage. For example, the Creston area has experienced an increase in the volume of groundwater in storage of approximately 25,000 af (a 1.25% increase; data not shown). Some areas, on the other hand, have observed declines in water levels/storage throughout the base period, most notably in the Estrella area where a decline of approximately 78,000 af (an approximate 0.88% decrease) has been observed over the past 20 years.

In the Atascadero subbasin, total groundwater in storage averaged about 513,590 af. By the specific yield method of calculating perennial yield, approximately 2,600 af more groundwater was in storage in the subbasin in 1997 compared to 1980, an approximate 0.5% increase in total groundwater in storage during the base period. This averages out to about 200 afy increase in storage.

Groundwater in storage calculations are based on three parameters: specific yield, water level contours, and basin boundaries. Each of these parameters has been developed using standard technical methods, but are not free of error. Some of the inherent errors introduced into data measurement or interpretation would tend to cancel out during the storage calculations. For example, the average specific yield for different parts of the basin was derived from an analysis of well logs, and shows a basin-wide variation of 0.07 to 0.11 (Table 68). A basic assumption was made that the discrete depth interval within a basin area that was filled or dewatered between 1980 and 1997 has a specific yield that matches the specific yield of the entire basin area. Deviations would tend cancel out, as some would be higher and others lower, but there remains some uncertainty as to the true specific yield. A misrepresentation of 0.01 (1 percent) in specific yield would, in the case of the Paso Robles Groundwater Basin, result in a total groundwater in storage error of close to 300,000 acre-feet. This error, however, would be minimized during a change-in-storage calculation, except for that portion representing the actual difference in storage. In other words, if the change in storage is estimated at 12,372 acre-feet, and the true specific yield is misrepresented by 0.01 (1 percent), then the change-in-storage error would be less than 150 acre-feet.

There are also uncertainties in the water level contours and in the interpretation of water level data. The influence of a particular data point on the regional piezometric surface is based in large part on the density of available data points. If more data points were available in certain areas, the contours could change. A groundwater high or depression that is not contoured (because there are no available data points) will only introduce error if it is present either at the beginning or ending of the period being compared (i.e. is not present both at the beginning and ending of the comparison period). The principal data gaps are in areas of relatively low water supply development, however, where one would not expect large losses or increases in storage to develop in these areas over the selected base period. In fact, the largest losses and increases are in areas with good data control.

Error in delineating basin boundaries will affect the total groundwater storage calculation, but will not affect change-in-storage calculations. Given the relatively high degree of confidence with which the basin boundaries have been defined, it would appear unlikely for a gross error to exist, especially due to the tendency for these types of errors to cancel out. This would, however, be a larger source of error in the total storage calculations.

In summary, the figures for total groundwater in storage are subject to the most influence from errors introduced by data and data interpretation. The change-in-storage calculations, however, are less susceptible to error, especially in the areas of more complete data coverage (the Atascadero, Estrella, Creston, and Shandon areas).

WATER BALANCE RESULTS OF THE INVENTORY METHOD OF THE WATER BALANCE EQUATION

Using the inventory method of summing all the inflow and outflow components in the water balance equation, the sum of all the components of outflow from the Paso Robles basin exceeded the sum of all the components of inflow during the 17-year base period. This resulted in an average deficit of about 2,700 afy during the base period and a corresponding decrease of groundwater in storage. Table 71 presents the annual amounts of each component of the water balance equation for the Paso Robles Groundwater Basin as computed by the inventory method. Changes in the amount of groundwater in storage as calculated by the specific yield method are also presented for comparison. By this method, there was a slight annual increase in the amount of groundwater in storage (about 700 afy).

The annual amounts of changes in storage by the two methods differed, and these differences can be graphically presented as cumulative variations. Such deviations are not unexpected for several reasons: in any particular season, the amount of water entering the zone of saturation is not always equal to the amount of water originating as deep percolation and subsurface inflow. Moreover, any inaccuracies in the estimated annual component of water supply, use, and disposal may cause appreciable variations in the amount of change of groundwater in storage. These differences, however, appear to be minimal since the accumulated amounts derived from each method follow annual totals reasonably well, and the summations of both methods for the entire base period are nearly equal (-2,700 afy vs. 700 afy). As previously discussed, the biggest difference between the two methods is illustrated by comparison to two change in storage values for 1986, which likely occurred due to the inherent limitations in the calculations for percolation of precipitation (which used the standard reference Blaney curve). Although rainfall for that year was slightly above normal (and perhaps considerably so in parts of the basin where precipitation station data are lacking), it is likely that the inventory method under-accounts for recharge for this year. Balancing the water balance equation can be accomplished by adjusting values of individual components of inflow and outflow (e.g., subsurface inflow) to achieve a better match. However, no such adjustments have been made at this time.

Table 71. Estimated Annual Deep Percolation, Extractions, and Change in Storage, Paso Robles Groundwater Basin

(in thousands of acre-feet)

Year	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9		Col. 10	Col. 11	Col. 12	Col. 13
	Subsurface Inflow	Percolation of Precipitation	Streambed Percolation	Percolation of Irrigation Water	Percolation of Wastewater Discharge	Total Inflow	Subsurface Outflow	Groundwater Pumpage		Total Extraction	Extraction by Phreatophytes	Total Outflow	Inventory Method	Specific Yield Method
								Gross Agr.	M&I					
	IN	IN	IN	IN	IN	(1+2+3+4+5)	OUT	OUT	OUT		OUT	(7+8+9+10)	(6-11)	
1981	5.6	0.3	21.8	4.1	2.3	34.0	0.6	114.9	13.5	126.1	2.9	131.9	-97.9	40.2
1982	7.7	6.2	41.2	2.7	2.3	60.1	0.6	98.9	13.0	109.6	3.9	116.5	-56.4	-24.5
1983	12.7	223.0	88.8	1.5	2.6	328.6	0.6	87.5	13.7	98.6	6.4	108.3	220.3	184.5
1984	5.1	0.2	22.8	4.4	2.7	35.2	0.6	111.8	16.0	125.1	2.6	131.0	-95.8	-175.2
1985	4.6	0.1	19.9	3.9	2.9	31.4	0.6	103.0	16.5	116.6	2.3	122.5	-91.0	-116.6
1986	8.5	17.6	52.4	2.1	3.2	83.8	0.6	82.9	17.3	97.0	4.3	105.2	-21.4	249.8
1987	4.7	0.0	10.3	3.0	3.2	21.2	0.6	88.5	18.6	103.9	2.4	110.1	-88.9	-67.9
1988	7.5	2.1	16.9	2.2	3.4	32.1	0.6	78.3	19.2	94.1	3.8	101.9	-69.8	-206.7
1989	4.0	0.0	11.7	2.6	3.5	21.8	0.6	79.8	19.9	96.2	2.0	102.4	-80.6	-6.0
1990	5.0	0.0	2.8	2.8	3.4	14.1	0.6	79.8	20.2	96.6	2.6	103.2	-89.1	-45.0
1991	7.5	1.4	53.0	1.9	3.5	67.2	0.6	67.3	19.5	83.3	3.8	91.2	-24.0	185.0
1992	8.2	6.2	75.0	1.6	3.6	94.6	0.6	63.8	20.3	80.5	4.2	88.9	5.7	84.8
1993	11.7	125.8	127.6	1.2	3.8	270.1	0.6	56.8	20.9	73.9	5.9	84.3	185.8	37.7
1994	4.5	0.0	13.2	1.4	3.5	22.7	0.6	56.9	21.7	75.1	2.3	81.5	-58.9	-206.3
1995	14.9	346.4	75.2	1.0	4.0	441.6	0.6	49.8	21.6	67.4	7.6	79.6	362.0	205.6
1996	6.8	1.9	38.7	1.0	3.9	52.3	0.6	49.6	23.4	69.1	3.5	77.1	-24.8	-11.7
1997	8.1	6.3	39.8	1.1	3.9	59.2	0.6	50.8	24.4	71.3	4.1	79.9	-20.7	-115.4
17-Year Average:	7.5	43.4	41.8	2.3	3.3	98.2	0.6	77.7	18.8	93.2	3.8	100.9	-2.7	0.7
High	14.9	346.4	127.6	4.4	4.0	441.6	0.6	114.9	24.4	126.1	7.6	131.9	362.0	249.8
Low	4.0	0.0	2.8	1.0	2.3	14.1	0.6	49.6	13.0	67.4	2.0	77.1	-97.9	-206.7
Percentage of Total	8%	44%	43%	2%	3%	100%	1%	77%	19%	92%	4%	100%		

Inspection of Figure 72 reveals that water supply deficiencies were apparent during the late 1980's. Surpluses, however, occurred during the early 1980's (1983) and mid-1990's (1993 and 1995). During these periods, annual surpluses in excess of 100,000 af occurred. The periods of water supply surplus and deficiency are generally consistent with the annual and cyclic pattern of precipitation during the base period. Notable in the annual components of inflow to the basin (Table 71) is the episodic, event-driven nature of deep percolation by precipitation vs. the more uniform recharge occurring by streambed infiltration within the Salinas River corridor. The components of subsurface inflow, irrigation return inflows, extraction by phreatophytes, and subsurface outflow are all relatively minor but seasonally constant and constitute less than 10 percent of the total inflows and outflows.

A similar tabulation of all the components of inflow and outflow by the inventory method and comparison with the specific yield method is presented for the Atascadero subbasin in Table 72. As calculated by the inventory method, outflow from the subbasin equaled inflow over the 17-year base period, with no change in storage. Calculation of change in storage by the specific yield method, however, resulted in a slight increase of about 200 afy in groundwater in storage in the subbasin over the base period. As would be expected, inflow to the subbasin as percolation from the Salinas River was the predominant recharge mechanism (64% of the inflow component). Agricultural demand decreased from about 16,000 afy at the beginning of the base period to about 1,000 afy by 1997. Municipal and industrial demand (delivered water) showed a corresponding increase. Figure 73 shows periods of surplus and deficiency over the base period, with a similar apparent divergence (albeit slighter than that seen in the Paso Robles basin) in recharge by deep percolation of precipitation occurring for 1986 based on the limitations of use of the Blaney curve.

Perennial Yield

The perennial yield of a groundwater basin may be defined as the rate in which water can be pumped from wells year after year without decreasing the groundwater in storage. Many definitions of perennial yield tie the acceptable level of extractions to a negative economic impact. However, for the purposes of this study, the perennial yield is tied more closely to the rate of replenishment or recharge to the basin that will not result in diminished storage. The Paso Robles Groundwater Basin has a very large amount of groundwater in storage that can be used as carryover storage during years when there is little to no recharge. The drought of the late 1980's is an example.

The perennial yield estimate of the basin (and Atascadero subbasin) is not an exact calculation. The difficulty in calculating an exact perennial yield figure relates to the inherent uncertainties in the estimates of recharge and discharge. Also contributing to the difficulty is the lack of historical and current data on change of groundwater in storage in large and remote portions of the basin. Despite these limitations, there are several methods available to estimate the perennial yield under the conditions of water supply and use that prevailed during the 17-year base period.

Table 72. Estimated Annual Deep Percolation, Extractions, and Change in Storage, Atascadero Subbasin

(in thousands of acre-feet)

Year	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13
								Groundwater Pumpage					
	Subsurface Inflow	Percolation of Precipitation	Streambed Percolation	Percolation of Irrigation Water	Percolation of Wastewater Discharge	Total Inflow	Subsurface Outflow	Gross Agr.	M & I	Extraction by Phreatophytes	Total Outflow	Inventory Method	Specific Yield Method
	IN	IN	IN	IN	IN	(1+2+3+4+5)	OUT	OUT	OUT	OUT	(7+8+9+10)	(6-11)	
1981	0.6	0.3	11.7	0.5	0.8	13.9	0.15	16.4	5.9	0.1	22.6	-8.7	0.0
1982	0.8	4.6	13.7	0.3	0.7	20.1	0.30	13.4	5.4	0.2	19.3	0.8	0.7
1983	1.3	14.1	19.2	0.2	0.7	35.6	0.15	12.0	5.7	0.3	18.1	17.4	8.0
1984	0.5	0.2	11.7	0.5	0.9	13.8	0.15	14.5	7.0	0.1	21.7	-7.9	-0.8
1985	0.5	0.1	9.0	0.4	1.0	11.0	0.15	12.9	6.8	0.1	20.0	-9.0	-4.7
1986	0.9	7.9	16.0	0.2	1.0	26.0	0.15	10.3	7.5	0.2	18.1	7.9	0.7
1987	0.5	0.0	4.0	0.4	1.1	6.0	0.15	10.8	8.2	0.1	19.2	-13.3	25.7
1988	0.8	1.4	7.2	0.3	1.2	10.9	0.15	9.1	8.5	0.2	17.9	-7.1	-0.6
1989	0.4	0.0	4.7	0.3	1.2	6.6	0.15	8.6	8.6	0.1	17.5	-10.9	-39.9
1990	0.5	0.0	0.3	0.3	1.1	2.2	0.30	8.1	8.2	0.1	16.7	-14.5	-11.5
1991	0.8	0.9	12.9	0.2	0.9	15.8	0.53	6.5	7.4	0.2	14.6	1.2	-0.2
1992	0.8	3.7	11.7	0.1	1.0	17.3	0.15	5.6	8.0	0.2	13.9	3.3	14.0
1993	1.2	11.7	16.0	0.1	1.1	30.1	0.15	4.6	8.1	0.3	13.2	16.9	3.7
1994	0.5	0.0	5.4	0.1	0.9	6.9	0.15	3.9	8.4	0.1	12.6	-5.7	-9.8
1995	1.5	14.7	11.7	0.1	1.2	29.2	0.15	2.8	8.0	0.4	11.4	17.8	12.3
1996	0.7	1.6	11.7	0.0	1.1	15.2	0.15	2.5	9.0	0.2	11.8	3.4	5.7
1997	0.8	5.4	11.7	0.0	1.1	19.0	0.15	1.0	9.5	0.2	10.9	8.1	-0.5
17-Year Average:	0.8	3.9	10.5	0.2	1.0	16.4	0.2	8.4	7.7	0.2	16.4	0.0	0.2
High	1.5	14.7	19.2	0.5	1.2	35.6	0.5	16.4	9.5	0.4	22.6	17.8	25.7
Low	0.4	0.0	0.3	0.0	0.7	2.2	0.2	1.0	5.4	0.1	10.9	-14.5	-39.9
Percentage of Total	5%	24%	64%	1%	6%	100%	1%	51%	47%	1%	100%		

This first approach is that the perennial yield is equal to the long-term recharge less the long-term discharge. Although there are considerable assumptions used in the methodology used to estimate each component in the hydrologic equation and it is apparent that recharge to the basin by deep percolation of rainfall is considerably episodic, the data suggest a perennial yield of the Paso Robles Groundwater Basin of approximately 95,500 afy. Discharge from the basin exceeded recharge by some 2,700 afy over the base period, resulting in a "basin-wide" decline in water levels. Imbalances of pumping demand resulting from land use changes over the base period are apparent, which created pronounced lowering of water levels in some parts of the basin.

For the Atascadero subbasin, a perennial yield of approximately 16,400 afy is indicated by calculation of long-term recharge less the long-term discharge. As mentioned, recharge to the subbasin is dominated by streambed percolation from the Salinas River. Over the base period, M&I demand has replaced agricultural demand to now constitute approximately 91% of basin pumpage. Storage in the Atascadero subbasin is relatively small; however, the subbasin is rapidly recharged by surface flow within the Salinas River, which, for the most part, is perennial.

A second method to estimate the perennial yield of the Paso Robles Groundwater Basin is to compute the average annual total net discharge over a period when the net change of groundwater in storage was zero and when recharge was about equal to the long-term average. This method, the so-called "practical rate of withdrawal" is a useful method so long as the coefficient of correlation between annual pumpage and storage changes is sufficiently robust and the calculated inflow and outflow values are relatively accurate.

For this study, it is believed that a high degree of accuracy in the estimates of annual groundwater extractions exists. Annual storage change estimates are also believed to be reasonably accurate, but are clearly somewhat erratic due to the bias of significant recharge occurring in only a few years of the base period and the distribution of water level data. As shown on Figure 74, the intercept of zero storage change occurs at an annual pumpage value of about 93,500 af (inventory method) and 94,600 afy (specific yield method), implying that net annual groundwater extractions at this approximate amount would produce no change of groundwater in storage. Several variations of this plot were made by excluding several years with unusually large annual storage changes (1983, 1986, 1994), which lead to a statistically higher coefficient of correlation, but generally the same result.

Comparison of the three methods of calculating perennial yield show agreement of the numbers:

- 95,500 afy (long-term recharge less long-term discharge)
- 93,500 afy (zero change in inventory method storage at net pumpage)
- 94,600 afy (zero change in specific yield method storage at net pumpage)

Based on these results, a perennial yield value of 94,000 afy for the Paso Robles Groundwater Basin is appropriate. Selecting a number near the lower end of the range (and to the nearest 1,000 af) is warranted because of the inherent uncertainty in calculating some of the components.

For the Atascadero subbasin, similar plots (Figure 75) were constructed using both the inventory and specific yield methods. Acknowledging the relatively poor coefficient of correlation, both methods indicate a practical rate of withdrawal of about 15,900 to 16,600 afy, which compares well with the perennial yield estimate of 16,400 afy indicated by the inventory method.

Comparison of the three methods of calculating perennial yield for the subbasin also shows agreement of the numbers:

- 16,400 afy (long-term recharge less long-term discharge)
- 15,900 afy (zero change in inventory method storage at net pumpage)
- 16,600 afy (zero change in specific yield method storage at net pumpage)

Based on these results, a perennial yield value of 16,500 afy for the Atascadero subbasin is appropriate. A perennial yield value at the upper end of the range of calculated values is selected because of the significant role that Salinas River streambed percolation plays in the recharge of the subbasin, which may take into account any rejected recharge in the underflow that might not otherwise have been accounted for in the water balance equation (and a value to the nearest 500 af may also be appropriate because of the slightly greater certainty of the figures).

The "practical rate of withdrawal" can be viewed as an operational yield of the basin, which reflects the condition of water supply, use, and disposal over the base period. However, it should not be interpreted as the safe yield of the basin because, as is clearly evident in the land use data over the base period, changing cultural conditions can and will affect the manner and amounts of annual recharge and discharge. The implication of management alternatives that can be used to refine and possibly increase the perennial yield of the Paso Robles Groundwater Basin are discussed in Chapter 6 of this report. That discussion expands on the merits of proceeding with the Phase II computer flow model of the basin and strategies for expanding the collection of much needed hydrologic data for the area to support the assumptions used in the water balance.

Basin Conditions (Year 2000)

To gain a view of current basin conditions (through year 2000) in comparison with the previous discussion of perennial yield, the groundwater pumpage figures compiled in the water balance equation were updated. Current pumpage demands for urban (municipal), small community services, rural domestic, and gross agricultural pumpage are presented in Table 73.

Table 73. Pumpage Demands (Year 2000)

(acre feet)

Type	Paso Robles Groundwater Basin (af)			Atascadero Subbasin (af)		
	Gross Pumping	Irrigation Return Water	Total Net Pumping	Gross Pumping	Irrigation Return Water	Total Net Pumping
Municipal	--	--	14,629	--	--	7,889
Rural Domestic	--	--	9,993	--	--	1,867
Small Community Services	--	--	1,465	--	--	306
Agriculture	57,698	1,147	56,551	1,035	10	1,025
Total (Year 2000)			**82,638, say 82,600**			**11,087, say 11,100**

In the year 2000, pumpage in the Paso Robles Groundwater Basin was approximately 82,600 af, compared with the perennial yield estimate of 94,000 afy. Similarly, Atascadero subbasin pumpage in the year 2000 was approximately 11,100 af, compared with an estimated perennial yield of 16,500 afy. However, a note of caution is urged, and a discussion of recent pumpage history of the basin is warranted before applying too much significance to these statements.

Total net groundwater pumpage varies from year to year, depending on the agricultural demand fluctuations, which in turn is dependent on Gross Rainfall (see section Agricultural Demand, Chapter 5). Gross Rainfall in 2000 was 110% of average, indicating that the 2000 total pumpage figures shown in Table 73 are likely slightly below "average" conditions. With an average rainfall, the total pumpage figures for both the Paso Robles basin and the Atascadero subbasin would likely have been slightly greater.

Paso Robles Groundwater Basin. Total net groundwater pumpage in the basin declined steadily from 1984 through 1998 (Table 74, Figure 76). If the past two years (1999, 2000) are an indication of a trend, then it appears that groundwater pumpage may again be increasing. Pumpage in 2000 was higher than at any previous time since 1992. It should also be pointed out that pumpage exceeded the perennial yield from the start of the base period in 1980 through 1990. It has only been in the last decade that pumpage has been less than the perennial yield.

As is evident from inspection of Figure 76, total basin pumpage has mirrored the agricultural use trend. Agricultural pumpage has declined since 1980 for several reasons, primary among them being the reduction in irrigated alfalfa and pasture acreage. From a high in 1980 of 18,800 acres under irrigation with alfalfa and pasture, current irrigated alfalfa and pasture acreage is approximately 5,100 acres. Although much of that retired alfalfa and pasture acreage has been converted to vineyards (from a low of 4,156 acres in 1980 to 20,133 acres in 2000), required pumping did not increase accordingly because the demand factor for vineyards is substantially less than alfalfa and pasture. Additionally, the vineyard growers are implementing increasingly efficient irrigation practices.

Table 74. Total Net Pumpage History, Paso Robles Groundwater Basin
(acre feet per year)

Year	Gross Pumping (col. 1)	Irrigation Return (col. 2)	M&I (col. 3)	Total Net Pumping ([1-2]+3) (rounded)
1981	114,860	4,050	13,447	124,300
1982	98,692	2,682	12,990	109,000
1983	87,512	1,532	13,748	99,700
1984	111,802	4,369	16,046	123,500
1985	102,970	3,889	16,452	115,500
1986	82,936	2,067	17,291	98,200
1987	88,503	3,024	18,639	104,100
1988	78,318	2,171	19,218	95,400
1989	79,815	2,592	19,862	97,100
1990	79,781	2,846	20,222	97,200
1991	67,348	1,917	19,476	84,900
1992	63,755	1,588	20,260	82,400
1993	56,780	1,196	20,879	76,500
1994	56,864	1,421	21,659	77,100
1995	49,775	1,040	21,648	70,400
1996	49,591	1,032	23,410	72,000
1997	50,768	1,085	24,397	74,100
1998	50,059	1,152	24,960	73,900
1999	53,678	1,255	25,523	77,900
2000	57,698	1,147	26,087	82,600

Domestic demand (municipal, small community systems, and rural domestic) has increased at a steady rate since 1980 (Figure 76), and there appears to be no reason that that trend will not continue into the future.

Currently, agricultural pumpage comprises 69% of total basin pumpage. Depending on new trends or pressures in the agricultural industry, it is conceivable that basin pumpage could approach or exceed the perennial yield in the near future (five to twenty years). Possibly supporting this inference is that, by the year 2000, approximately 6,000 acres of vineyards in the first or second year of development had been planted. Thus, required pumping could increase substantially past the year 2000 as these vineyards mature and more vineyards are planted. A counteracting factor, however, is that these acreages will be operated under increasingly efficient irrigation systems and probably utilize deficit irrigation practices and minimal canopy management. Also, it is becoming more and more of a concern in the vineyard industry that there is an over planting of certain grape varietals, and it is unlikely that the large expansion of vineyard acreage seen from the mid to late 1990's to the present will be repeated.

The San Luis Obispo County Master Water Plan Update (EDAW, 1998) indicated a 1997 water demand of 76,260 af for the area covering the Paso Robles Groundwater Basin. This value compares well with the 82,600 af in year 2000 calculated by this study, particularly considering the growth of vineyard plantings in the intervening three years. The Master Water Plan Update projects future water demands for the area, based on urban area buildout and estimated agricultural industry trends, to be 120,620 afy by the year 2020. Acknowledging that the planning areas delineated in the Master Water Plan Update do not correspond exactly with the extent of the Paso Robles basin, it is still suggestive that future water demands may soon exceed the 94,000 afy perennial yield of the basin.

Atascadero Subbasin. The groundwater pumpage history of the Atascadero subbasin has similar trends to the Paso Robles basin (Table 75, Figure 77). Total pumpage declined steadily from the start of the base period in 1980 until 1997, when pumpage started to increase again. Total pumpage exceeded the perennial yield of the subbasin throughout the 1980's, and has been less than the perennial yield throughout the 1990's.

Table 75. Total Net Pumpage History, Atascadero Subbasin
(acre feet per year)

Year	Gross Pumping (col. 1)	Irrigation Return (col. 2)	M&I (col. 3)	Total Net Pumping ([1-2]+3) (rounded)
1981	16,377	533	5,914	21,800
1982	13,363	294	5,407	18,500
1983	11,980	192	5,693	17,500
1984	14,454	522	6,951	20,900
1985	12,917	447	6,839	19,300
1986	10,277	237	7,473	17,500
1987	10,770	364	8,193	18,600
1988	9,126	251	8,495	17,400
1989	8,610	258	8,604	17,000
1990	8,126	273	8,163	16,000
1991	6,500	184	7,408	13,700
1992	5,611	137	7,981	13,500
1993	4,624	112	8,129	12,600
1994	3,885	98	8,439	12,200
1995	2,780	59	8,022	10,700
1996	2,472	41	8,981	11,400
1997	1,023	4	9,530	10,500
1998	1,027	4	9,707	10,700
1999	1,031	17	9,884	10,900
2000	1,035	10	10,062	11,100

Agricultural pumpage in the Atascadero subbasin is rapidly and dramatically declining. From a high in 1980 of 3,900 irrigated acres, current irrigated acreage is less than 1,000 acres. As is the case with the Paso Robles basin, alfalfa and pasture acreage has steadily declined, being replaced only in part with new vineyard plantings. In a departure from similarities with the whole basin, domestic (M&I) pumpage in the Atascadero subbasin comprises 91% of total pumpage in the subbasin.

Comparison of the current demand and perennial yield of the Atascadero subbasin with the project buildout numbers of the County Master Water Plan Update (EDAW, 1998) are more problematic than it was with the Paso Robles basin. The Master Water Plan Update divided the region into Water Planning Areas, which do not necessarily correspond with the geologic boundaries of basins and subbasins. Although strict comparisons are not possible, it can be seen from the Master Water Plan Update that 2020 projected water demands in the Atascadero subbasin will be in the range of 16,000 to 20,000 afy, compared to the perennial yield value of 16,500 afy.

Comparison to Previous Investigations

The DWR (1979) analysis is the only previous comprehensive water balance investigation of the Paso Robles Groundwater Basin. Because some of the conclusions of this current study differ from those offered by DWR, a brief comparison of the two studies is warranted.

DWR calculated the volume of groundwater in storage in a similar manner as was done in this study, with comparable results, given the difference in the size of the study area. DWR's study area was limited to that portion of the basin contained in San Luis Obispo County, rather than extending the study area into Monterey County to encompass the entire groundwater basin. Thus, the size of the basin studied by DWR was 640 square miles with 26.5 million acre feet in storage, vs. 790 square miles with 30.5 million acre feet. Both studies used a similar specific yield value of 9%. Another factor in the greater volume proffered in this study is that, through the benefit of some deep oil well data, the thickness of the basin is several hundred deeper in places than suggested by DWR.

The DWR year 2000 projected water demands of 87,100 afy were close to the 82,600 afy numbers estimated for 2000 in this study.

Primary among the differences is the dissimilarity of the 94,000 afy "perennial yield" of this study vs. DWR's 47,000 afy "estimated annual recharge." The reason for this difference is discussed below.

Over the period from 1965 to 1975, DWR calculated a net annual reduction in storage of 30,300 afy (vs. a relatively stable basin over the base period of 1981 through 1997), which resulted in portions of the basin experiencing declining water levels and portions of the basin experiencing rising water levels (similar to the conditions found today). DWR noted, however, that the study did not study the basin over a true base period and the conclusion was not a true hydrologic balance. Nevertheless, the conclusions suggested that during that time period, outflow exceeded inflow.

The most important reason that the "perennial yield" values differed so greatly was the consideration of percolation of precipitation as an inflow component of the water balance equation. Because the estimated "average seasonal unit value of consumptive use" for vegetation was 11.1 inches per year compared to the "calculated long-term annual precipitation" of 12.2 inches per year, DWR concluded that any amount of rainfall available for percolation was negligible. This study agreed that percolation of precipitation was nil in most years of the base period but, based on empirical data showing significant deep percolation of rainfall during rainfall years greater than 18 inches, the average percolation of precipitation over the base period was 43,400 afy. This volume alone constitutes 94% of the difference in the two values of perennial yield.

A comparison of the inflow components of the two studies is shown below, in Table 76.

Table 76. Comparison of Inflow Components of the Water Balance Equation, DWR (1979) vs. Current Study

(in acre feet per year)

	DWR (1979)	Current Study
Subsurface Inflow	7,300	7,500
Percolation of Precipitation	0	43,400
Streambed Percolation	19,000	41,800
Percolation of Irrigation Water	16,000	2,300
Percolation of Wastewater Discharge	4,700	3,300
Total	**47,000**	**98,300**

Note: The inflow component total for current study does not equal perennial yield. Perennial yield equals inflow minus outflow +/- change in storage, as explained earlier.

CHAPTER 6 – RECOMMENDATIONS

PHASE II GROUNDWATER MODEL

Model Purpose/Objectives

It is recommended that a basin-wide numerical groundwater flow model be developed for the Paso Robles Groundwater Basin. The model will serve as a tool for quantitative evaluation of existing and future hydraulic conditions across the basin, including changing groundwater level elevations, well yields, natural and artificial recharge, and associated effects on surface water-groundwater interaction. Specifically, the objectives of the model include:

- Refining uncertain components of the hydrologic budget for the basin;
- Refining estimates of perennial yield for the basin;
- Evaluating water quality trends in response to hydraulic changes across the basin;
- Evaluating potential impacts on groundwater levels and perennial yield as a result of continued and varied basin operations and hydraulic conditions; and
- Defining operational options for comprehensive and/or localized management of groundwater use across the basin.

Model Development

The groundwater model should encompass the entire project study area defined in this study and include the hydraulic interaction between surface water and groundwater. Specific components of the model required include groundwater flow, hydrologic budget, and water quality.

To represent these components, it is recommended that the groundwater flow model be based on the US Geological Survey's (USGS) MODFLOW model (McDonald and Harbaugh, 1988). MODFLOW is a modular, three-dimensional, finite difference groundwater flow model used widely for evaluation and management of groundwater resources (van der Heijde et al., 1985). To evaluate water quality, use of the US Environmental Protection Agency's (USEPA) MT3D model (Zheng, 1990) in conjunction with the USGS MODFLOW code is recommended. MT3D is used widely in conjunction with MODFLOW in order to evaluate changes in groundwater quality in response to hydraulic conditions represented by MODFLOW.

The model domain should reflect the entire study area and associated Atascadero subbasin, with variable grid discretization based on known locations of groundwater pumping and recharge centers across the basin. The temporal component of the model should correspond to the base period defined in this study. Data reflecting aquifer geometry, hydrogeologic parameters, well pumpage, recharge, and groundwater quality, as summarized in this study, should be incorporated into the model.

Once these data have been incorporated into the groundwater flow model, the model should be calibrated with respect to historically observed conditions across the basin. Specifically, calibration targets such as average groundwater level elevations throughout the base period, annual groundwater level elevations throughout the base period, and the hydrologic budget for the basin should serve as targets for steady-state and transient calibrations.

Model Application

A series of basin-operation scenarios should be developed and simulated using the calibrated model. For each scenario, groundwater level declines, water quality impacts, and estimates of perennial yield may be defined for the specific hydrologic conditions simulated. The initial scenario, representing a baseline condition, should reflect a transient simulation with known pumping, recharge, and climatological conditions throughout the base period. Additional scenarios should build on the Baseline Scenario, reflecting changes to one or more hydrologic components of the basin. The list of potential scenarios may include:

- Simulation of historical conditions throughout the base period (i.e. Baseline Scenario);
- Simulation of water level and water level impacts based on anticipated water demands at "build-out";
- Simulation of water level and/or water quality impacts associated with brief extreme drought (mid-1970s drought);
- Simulation of water level and/or water quality impacts associated with sustained severe drought (late 1980s-early 1990s drought)
- Simulation of water level and/or water quality impacts associated with increased vineyards and more agricultural pumping
- Simulation of water level and/or water quality impacts associated with increased municipal pumping (same wastewater disposal as Baseline Scenario)
- Simulation of water level and/or water quality impacts associated with continued pumping (i.e. same as Baseline Scenario), but no municipal wastewater returns (RWQCB stops discharge of wastewater to groundwater or streams)
- Simulation of water level and/or water quality impacts associated with Nacimiento Water Project (e.g. decreased municipal pumping) but wastewater returns are the same;
- Simulation of water level and/or water quality impacts associated with City of Atascadero water reuse plan, including changes in wastewater reuse;
- Simulation of water level and/or water quality impacts associated with water conservation, both urban and agricultural;

- Simulation of water level and/or water quality impacts associated with various pumping patterns; (e.g., the City of Paso Robles, TCSD, or AMWC alter pumping amounts from various wells/wellfields to optimize use of storage);
- Simulation of water level and/or water quality impacts associated with possible artificial recharge scenarios, (e.g., changes in Salinas Dam operations, increasing recharge along the Salinas River, Estrella River, or Huer Huero Creek using in-channel check dams or releasing raw surplus water from Nacimiento);
- Simulation of water quality impacts associated with accidental release of chemical contamination in open recharge pits or rivers within the basin;

In addition, the model may be used to develop specific operational scenarios (i.e. pumping and recharge) in order to address any undesirable trends in water quality and water levels resulting from the above scenarios.

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CHAPTER 7 – REFERENCES

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Herman Schwartz, Continental Vineyards

Scott Williams, J Lohr Winery

Mary Bianchi, UC Extension

Kris O'Connor, Central Coast Vineyard Team

Robert Hopkins, Deputy ACO, San Luis Obispo Ca

Henry Gonzales, ACO office, Monterey County

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GLOSSARY OF TERMS

Acre Foot -- a unit for measuring the volume of water and is equal to the quantity of water required to cover one acre to a depth of one foot; a total of 325,858 gallons or 43,560 cubic feet.

Alluvium -- a general term for deposits of clay, sand, gravel, or other particulate material that has been deposited by a stream or other body of running water in a streambed.

Anticline -- a fold that is convex upward; in simple anticlines, the beds are oppositely inclined.

Anticlinorium -- a series of anticlines and synclines so arranged structurally that together they form a general arch or anticline.

Aquiclude -- a formation that, although porous and capable of absorbing water slowly, will not transmit water fast enough to furnish an appreciable supply for a well or spring. Aquicludes are characterized by very low values of "leakage," so that they transmit only minor inter-aquifer flow and have very low rates of yield from compressible storage. Therefore, they often constitute boundaries of aquifer flow systems.

Aquifer -- a geologic formation(s) that is water bearing. A geological formation or structure that stores and/or transmits water, such as to wells and springs. Use of the term is usually restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply for people's uses.

Aquifer (semi-confined) -- an aquifer confined by a low-permeability layer that permits water to slowly flow through it.

Aquifer Test -- a test whereby drawdown and recovery levels are monitored in a well during and after pumping from which the hydraulic characteristics or aquifer parameters of transmissivity and storativity can be calculated.

Aquitard -- a saturated, but poorly permeable bed that impedes groundwater movement and does not yield water freely to wells, but which may transmit appreciable water to or from adjacent aquifers and, where sufficiently thick, may constitute an important groundwater storage unit.

Artesian -- an adjective applied to groundwater, or things connected with groundwater, such as a well or basin, where water is under pressure and will rise to a higher elevation if afforded an opportunity to do so.

Artificial recharge -- any process by which man fosters the transfer of surface water into the groundwater system.

Base Flow -- that part of stream discharge from groundwater seeping into the stream.

Basin -- a hydrogeologic unit consisting of an area underlain by permeable materials that are capable of storing or furnishing a significant water supply; the basin includes both the surface area and the permeable materials beneath it.

Bedrock -- the solid rock beneath the soil and superficial rock. A general term for solid rock that lies beneath soil, loose sediments, or other unconsolidated material.

Cone of depression -- a cone-like depression of the water table or other piezometric surface that has the shape of an inverted cone and is formed near a well by withdrawal of water. The surface area included in the cone is known as the area of influence of the well.

Confined groundwater -- groundwater under pressure whose upper surface is the bottom of an impermeable bed or a bed of distinctly lower permeability than the material in which the confined water occurs. Confined groundwater moves under the control of the difference in head between the intake and discharge areas of the water body.

Conformable – when beds or strata lying upon one another in unbroken and parallel order, and this arrangement shows that no disturbance or denudation has taken place at the locality while their deposition was going on, they are said to be conformable. But if one set of beds rests upon the eroded or the upturned edges of another, showing a change of conditions or a break between the formations of the two sets of rocks, they are said to be unconformable.

Contact -- the plane or surface where two different kinds of rocks come together.

Deep percolation -- the moisture which penetrates below the depths from which it may be used by plants; it represents that part of the water absorbed which exceeds the field capacity of the soil within the depth of root development. In this report, deep percolation is water, which moves downward from the surface of the ground and reaches the water table.

Dip -- the angle at which a bed or other planar feature is inclined from the horizontal.

Drainage basin (area) -- an area whose runoff is more or less separate from the runoff for adjacent areas, so that it can be considered a distinct hydrogeologic unit or area.

Drainage divide -- the boundary line, along a topographic ridge or along a subsurface geologic formation, separating two adjacent drainage basins (areas).

Drawdown -- a lowering of the ground-water surface caused by pumping.

Driller's log -- a record of the types of earth materials encountered at various depths during the drilling of a well and as recorded by the drilling contractor or his crew.

En echelon – parallel structural features that are offset like the edges of shingles on a roof when viewed from the side.

Evapotranspiration -- the sum of evaporation and transpiration.

Groundwater -- (1) water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturate zone is called the water table. (2) Water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust.

Homocline – a group of inclined beds of the same dip. A structural condition in which the beds dip uniformly in one direction.

Hydraulic conductivity -- describes mathematically the rate at which water can move through a permeable medium.

Hydrograph -- a graphic plot of changes in the flow of water or in elevation of water level against time.

Hydrologic budget -- an accounting of the inflow, outflow, and storage in a basin.

Hydrologic equation -- the water inventory equation: Inflow = [Outflow + Change-in-Storage], which balances the hydrologic budget and expresses the basic principle that during a given time interval the total inflow to an area must equal the total outflow plus the net change in storage.

Incidental recharge -- groundwater recharge (infiltration) that occurs as a result of human activities unrelated to a recharge project, for example, irrigation and water diversion (unlined canals).

Infiltration -- flow of water from the land surface into the subsurface.

Interference -- a change in the water level of one well caused by the pumping at another well. The condition occurring when the area of influence of a water well comes into contact with or overlaps that of a neighboring well, as when two wells are pumping from the same aquifer or are located near each other.

Isohyet -- a line on the surface of the earth as represented on a map connecting all points of equal precipitation.

Overdraft -- any withdrawal of groundwater more than the safe yield.

Perched water -- water in a relatively small body supported above the main groundwater table.

Percolating groundwater -- underground waters whose course and boundaries are incapable of determination. Waters, which pass through the ground beneath the earth's surface without a definite channel.

Perennial yield -- the amount of usable water of a groundwater basin that can be withdrawn and consumed economically each year for an indefinite period of time. It cannot exceed the sum of the natural recharge, artificial recharge, and incidental recharge, without causing depletion of the basin.

Period -- a specified division or portion of time.

Period, average -- an arithmetical average relating to a period other than a mean period.

Period, base -- a period chosen for detailed hydrologic analysis because prevailing conditions of water supply and climate are approximately equivalent to mean conditions, and because adequate data for such hydrologic analysis are available.

Period, mean -- a period chosen to represent conditions of water supply and climate over a longer series of years.

Period, seasonal -- any 12-month period other than the calendar year. In this study, the runoff year is October 1 through September 30, and the rainfall year is July 1 through June 30.

Permeability -- the capacity of soil, sediment, or porous rock to transmit water.

Phreatophyte -- a plant that habitually obtains its water supply from the zone of saturation, either directly or through the capillary fringe.

Precipitation -- the total measurable supply of water received directly from clouds as rain, snow, hail, and sleet; usually expressed as depth in a day, month, or year, and designated as daily, monthly, or annual precipitation.

Pumping level -- the level as measured from ground surface at which water stands in a well when pumping is in progress.

Radius of influence -- the radial distance from the center of a well bore to the point where there is no lowering of the water table (the edge of its cone of depression).

Recharge -- the downward movement of water through soil to groundwater.

Recovery -- the amount of rising of the water level in a well above the pumping level once the pumping has been terminated.

Return flow -- (1) that part of a diverted flow that is not consumptively used and returned to its original source or another body of water. (2) (Irrigation) Drainage water from irrigated farmlands that re-enters the water system to be used further downstream.

Runoff -- that part of the precipitation or irrigation water that appears in uncontrolled surface streams, rivers, drains, or sewers. Runoff may be classified according to speed of appearance after rainfall as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or groundwater runoff.

Safe yield -- the rate at which water can be pumped from wells year after year without decreasing groundwater in storage to the point where pumping lift would become economically unfeasible or where water of poor quality would begin to intrude into the reservoir. The amount of naturally occurring groundwater that can be economically and legally withdrawn from a basin on a sustained basis without producing an undesired result.

> *"It should be apparent that safe yield cannot exceed the long-time mean annual water supply to the basin. Withdrawals exceeding this supply must come from storage within the aquifer. Such a permanent depletion is often referred to as mining of groundwater because of its analogy to mining of ores and petroleum. In most basins, the quantity of water in storage is many times the annual recharge or draft; therefore, in any one year, the draft can exceed the recharge without causing permanent depletion. But on a long-term basis, when a series of wet and dry years would tend to average out, the draft becomes an overdraft if the mean supply is exceeded" (adapted from Todd, 1959).*

Specific capacity -- an expression of the productivity of a well, obtained by dividing the rate of discharge of water from the well by the drawdown of the water level in the well.

Specific yield -- as applied to water bearing materials, it is the ratio of the volume of water drained by the force of gravity from a saturated material over a reasonably long period of time, expressed as a percentage of the total volume of the saturated material.

Static (or standing) level -- the distance from ground surface to the water level in a nonpumping well, outside the area of influence of any adjacent pumping well.

Storativity – coefficient of storage. The volume of water released from storage in each vertical column of the aquifer having a base of 1-foot square when the water table or other piezometric surface declines 1 foot. This is approximately equal to the specific yield for non-artesian aquifers.

Subbasin -- a portion of a basin that can be subdivided for hydrologic study purposes. Hydraulically, a sub-basin is interdependent on the basin as a whole, but is locally independent of pumping depressions and recharge effects.

Surface water -- water that is on the Earth's surface, such as in a stream, river, lake, or reservoir.

Syncline -- a fold in rocks in which the strata dip inward from both sides toward the axis.

Transmissivity -- the rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient.

Transpiration -- process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface, such as leaf pores.

Unconfined groundwater -- groundwater in an aquifer whose upper water surface (water table) is at atmospheric pressure.

Unconformable – not succeeding the underlying strata in immediate order of age and in parallel position.

Underflow -- subsurface flow of groundwater associated with a river or stream that occurs as sub-horizontal flow, roughly parallel to and within the near-surface deposits underlying and directly adjacent to the course of the river and/or its tributaries.

Unsaturated zone -- the zone immediately below the land surface where the pores contain both water and air, but are not totally saturated with water. These zones differ from an aquifer, where the pores are saturated with water.

Vadose zone -- see unsaturated zone.

Water balance --a measure of the amount of water entering and the amount of water leaving a system. Also, see hydrologic budget and hydrologic equation.

Watershed -- the topographic divide separating one drainage basin from another.

Water table -- the top of the water surface in the saturated part of an aquifer.

Withdrawal -- water removed from a groundwater or surface water source for use.

STUDY AREA LOCATION MAP
Paso Robles Groundwater Basin

FIGURE 1

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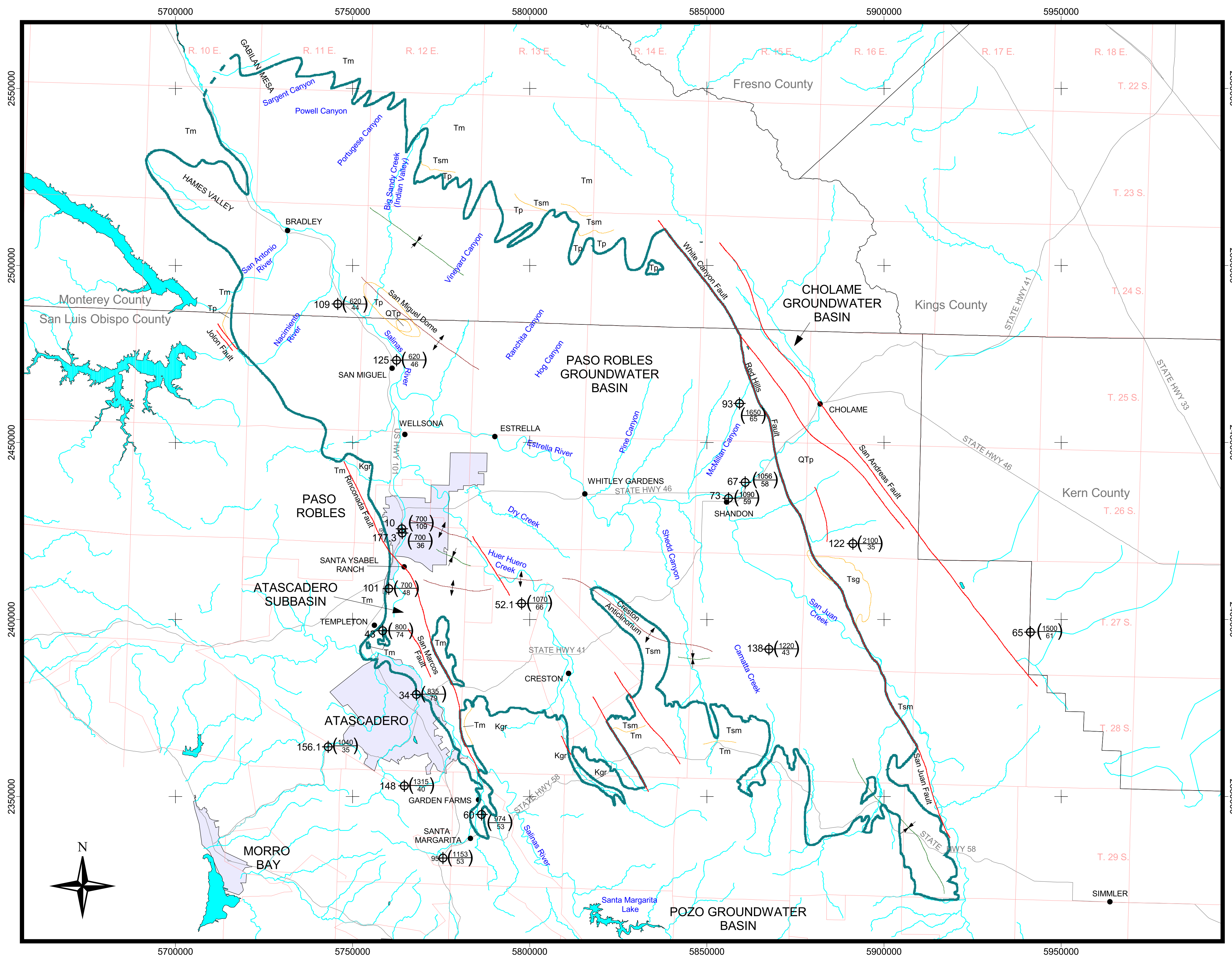


Legend

Precipitation Station Number

Station Elevation in feet

109 ⌖ (620/44)

Number of years of record

- City
- Basin Outline
- Fault
- Anticline
- Syncline
- Streams
- Highways
- County Line
- Township and Range Grid

Geologic Units

Paso Robles Groundwater Basin Sediments	Qa	Alluvium
	Qoa	Older Alluvium
	Qls	Landslide
	QTp	Paso Robles Formation
Other Geologic Units	Tp	Pancho Rico Formation
	Tsm	Santa Margarita Sandstone
	Tm	Monterey Shale
	Tv	Vaqueros Formation
	Ts	Simmler Formation
	Tsg	unnamed (maroon) conglomerate
	Kgr	granite rocks

Notes:
1. Geologic units shown on base map around basin boundary are for reference only. For a geologic map of the basin see Figure 5.
2. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

30000 0 30000 Feet

Location of Precipitation Recording Stations

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

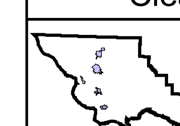
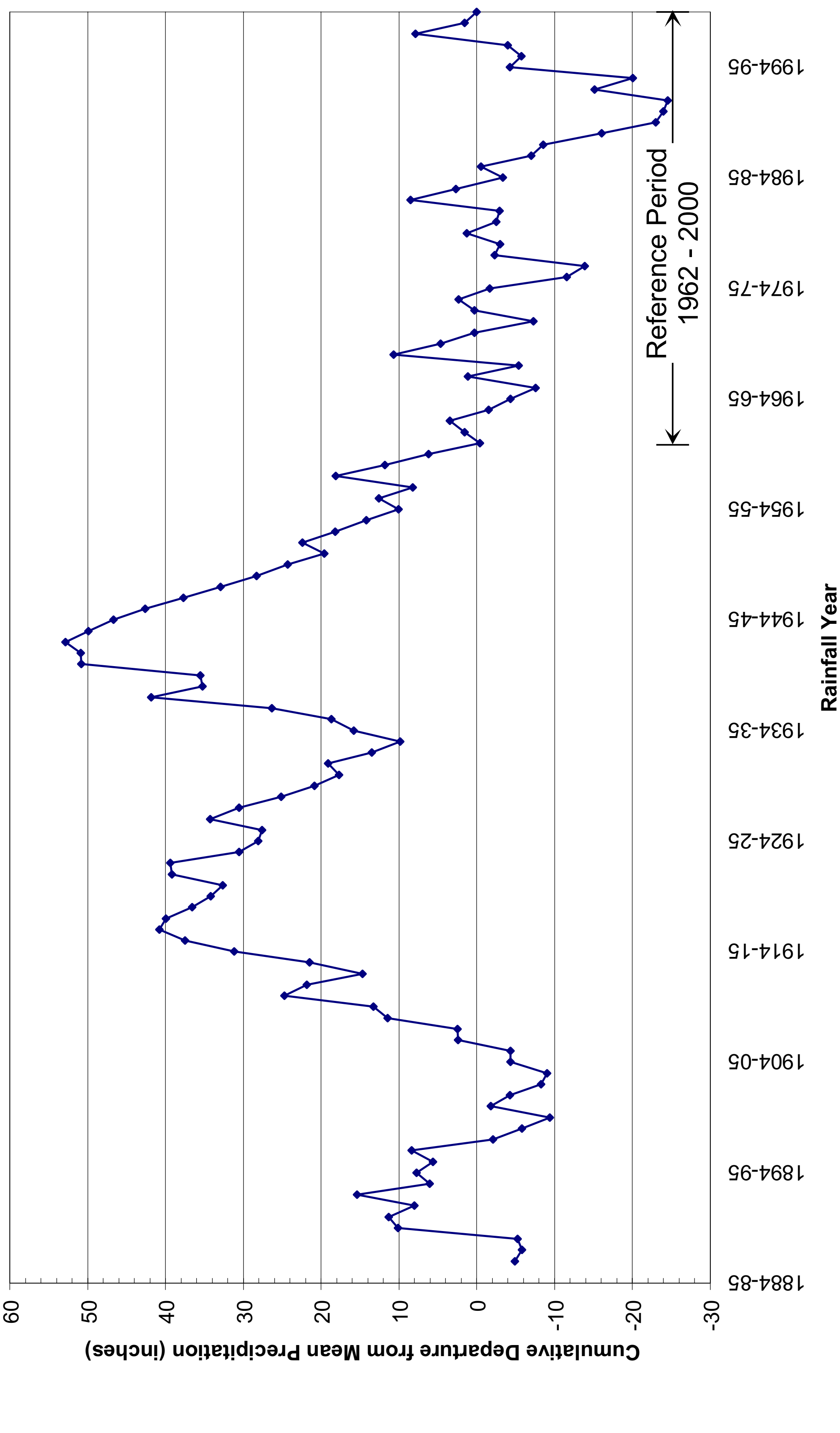


Figure 2



AVERAGE CUMULATIVE DEPARTURE CURVE
Annual Precipitation at Paso Robles Station 10
Complete Historical Record 1886-87 through 1999-2000
Paso Robles Groundwater Basin Study

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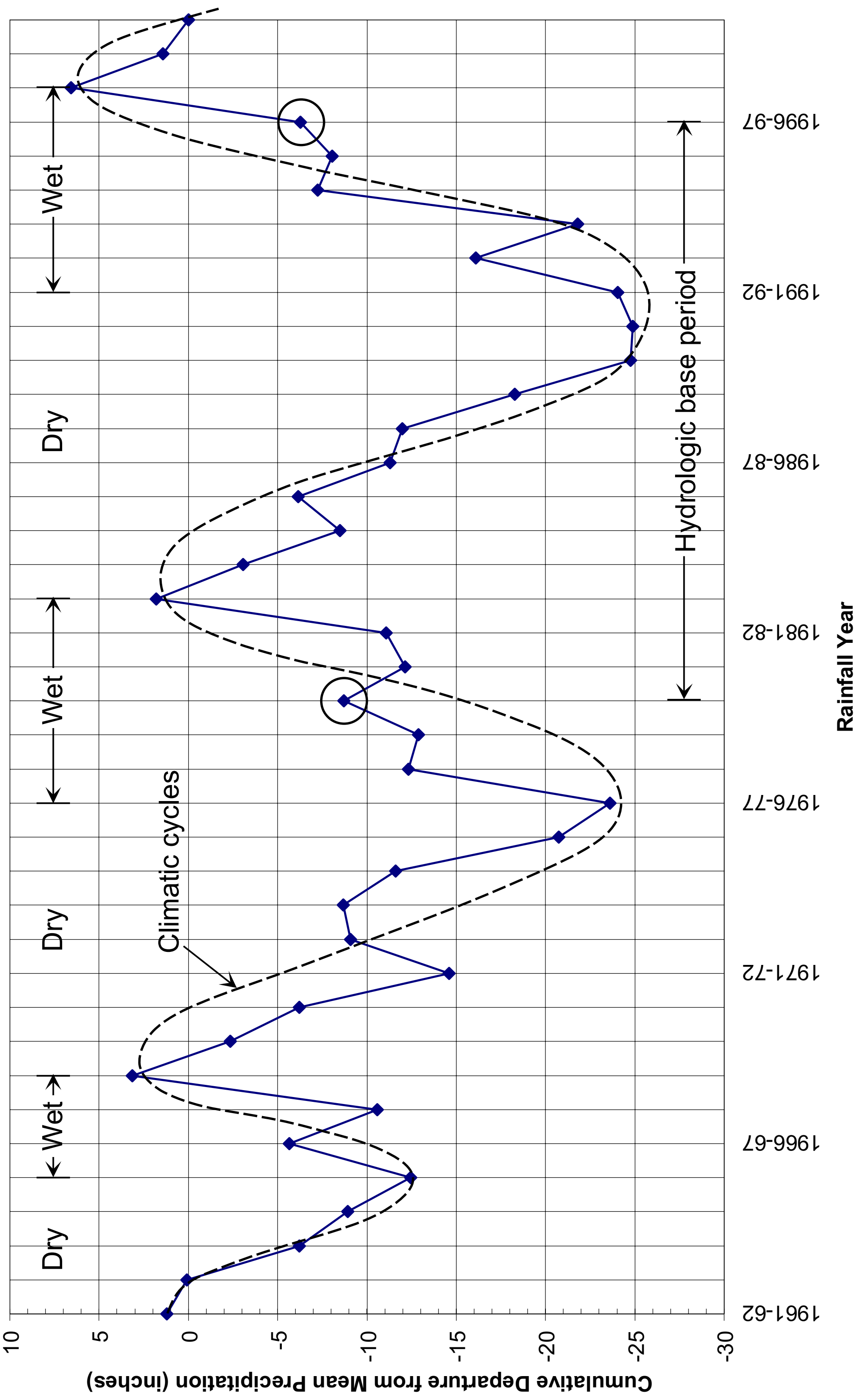
FIGURE 3



AVERAGE CUMULATIVE DEPARTURE CURVE
Annual Precipitation at 11 Stations
Reference Period 1961-62 through 1999-2000
Paso Robles Groundwater Basin Study

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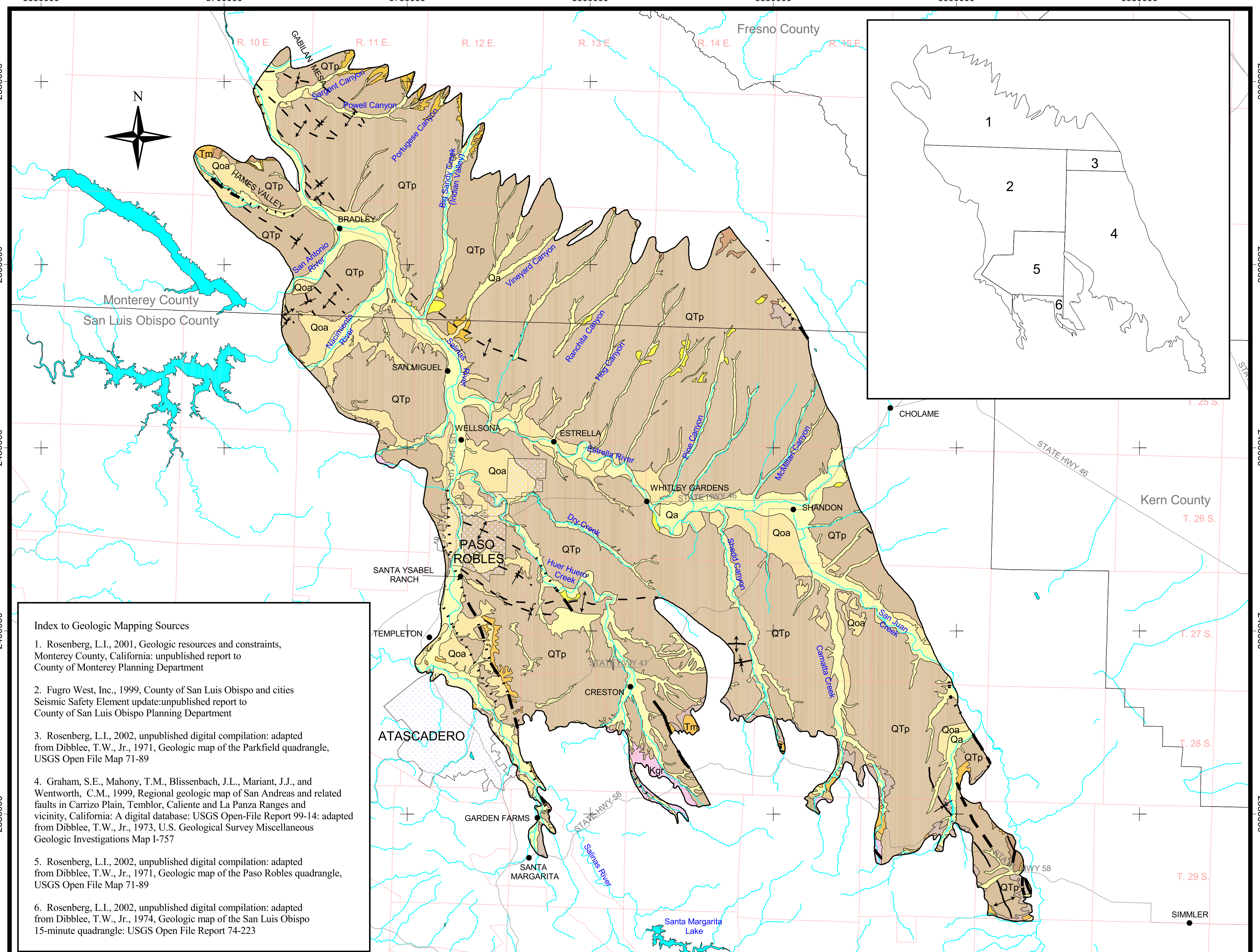

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3. Rosenberg, L.I., 2002, unpublished digital compilation: adapted from Dibblee, T.W., Jr., 1971, Geologic map of the Parkfield quadrangle, USGS Open File Map 71-89

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6. Rosenberg, L.I., 2002, unpublished digital compilation: adapted from Dibblee, T.W., Jr., 1974, Geologic map of the San Luis Obispo 15-minute quadrangle: USGS Open File Report 74-223

Legend

Geologic Units

Paso Robles Groundwater Basin Sediments

Qa	Quaternary alluvium, undifferentiated (Holocene)
Qoa	Older alluvium, undifferentiated (Pleistocene)
Qls	Landslide deposits (Holocene-Pleistocene)
QTp	Paso Robles Formation, undifferentiated (Pliocene-Pleistocene)

Other Geologic Units

Tuc	Unnamed clastic sedimentary unit (probably Pliocene)
Tp	Pancho Rico Formation, undifferentiated (late Miocene to early Pliocene)
Tsm	Santa Margarita Sandstone (late Miocene)
Tbs	Branch Canyon Sandstone (middle to late Miocene)
Tm	Monterey Shale, undifferentiated (middle Miocene)
Tv	Vaqueros Formation, undifferentiated (Oligocene)
Ts	Simmler Formation, undifferentiated (Oligocene?)
Tsg	unnamed conglomerate (Oligocene or Miocene)
Kgr	Granitic rocks (Cretaceous)

Fault, certain
Fault, approximately located
Fault, concealed
Anticline, certain
Anticline, approximately located
Syncline, certain
Syncline, approximately located
Streams
Highways
County Line
Township and Range Grid

Note:
1. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

30000 0 30000 Feet

Geologic Map of the Paso Robles Groundwater Basin

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 5

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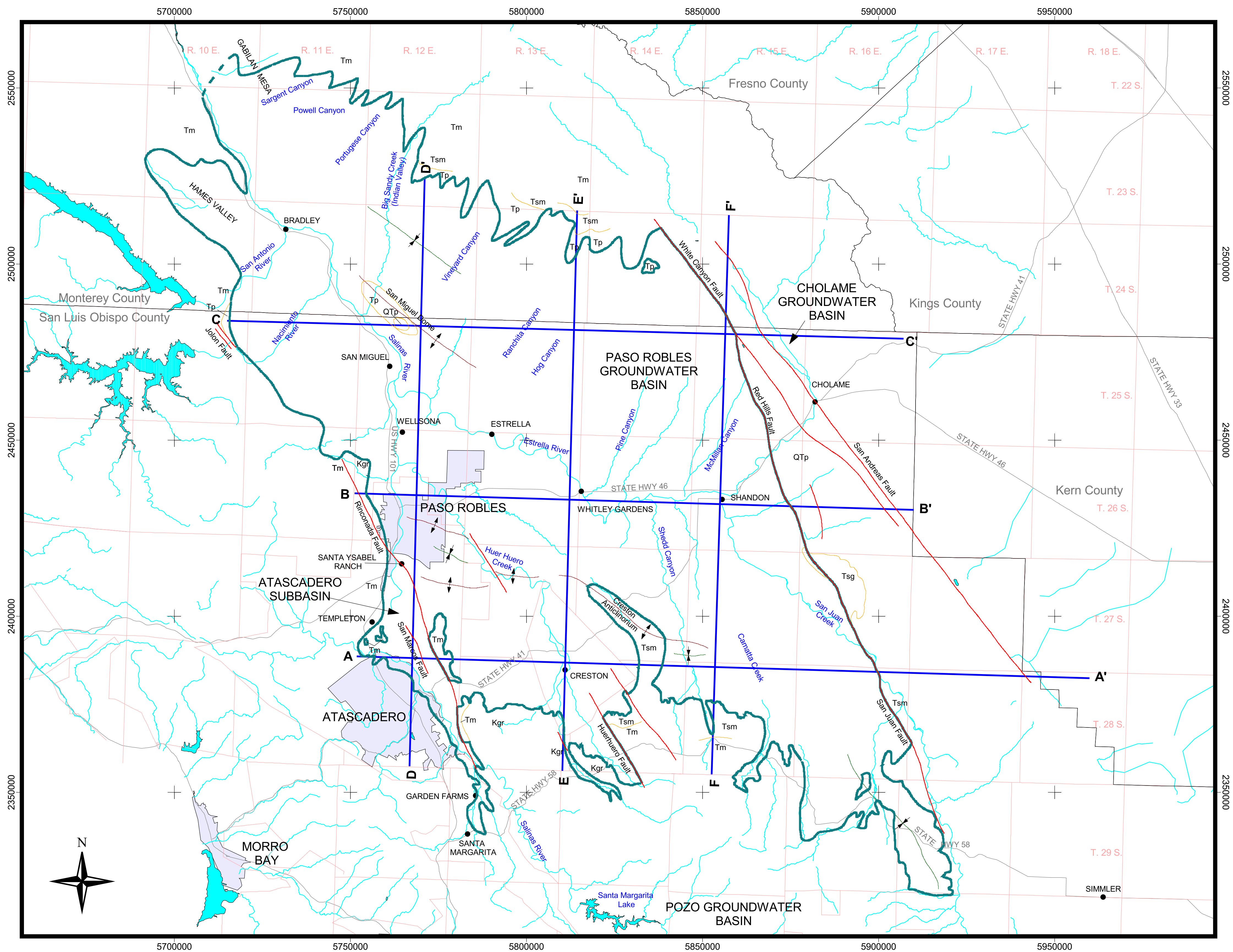

Legend

- City
- Cross Section Line
- Basin Outline
- Fault
- Anticline
- Syncline
- Streams
- Highways
- County Line
- Township and Range Grid

Geologic Units

Paso Robles Groundwater Basin Sediments	Qa	Alluvium
	Qoa	Older Alluvium
	Qls	Landslide
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Other Geologic Units	Tp	Pancho Rico Formation
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	Tm	Monterey Shale
	Tv	Vaqueros Formation
	Ts	Simmler Formation
	Tsg	unnamed (maroon) conglomerate
	Kgr	granite rocks

Notes:
1. Geologic units shown on base map around basin boundary are for reference only. For a geologic map of the basin see Figure 5.
2. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

30000 0 30000 Feet

Basin Boundary Map and Geologic Cross Section Location Map

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

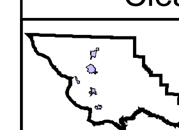

FIGURE 6

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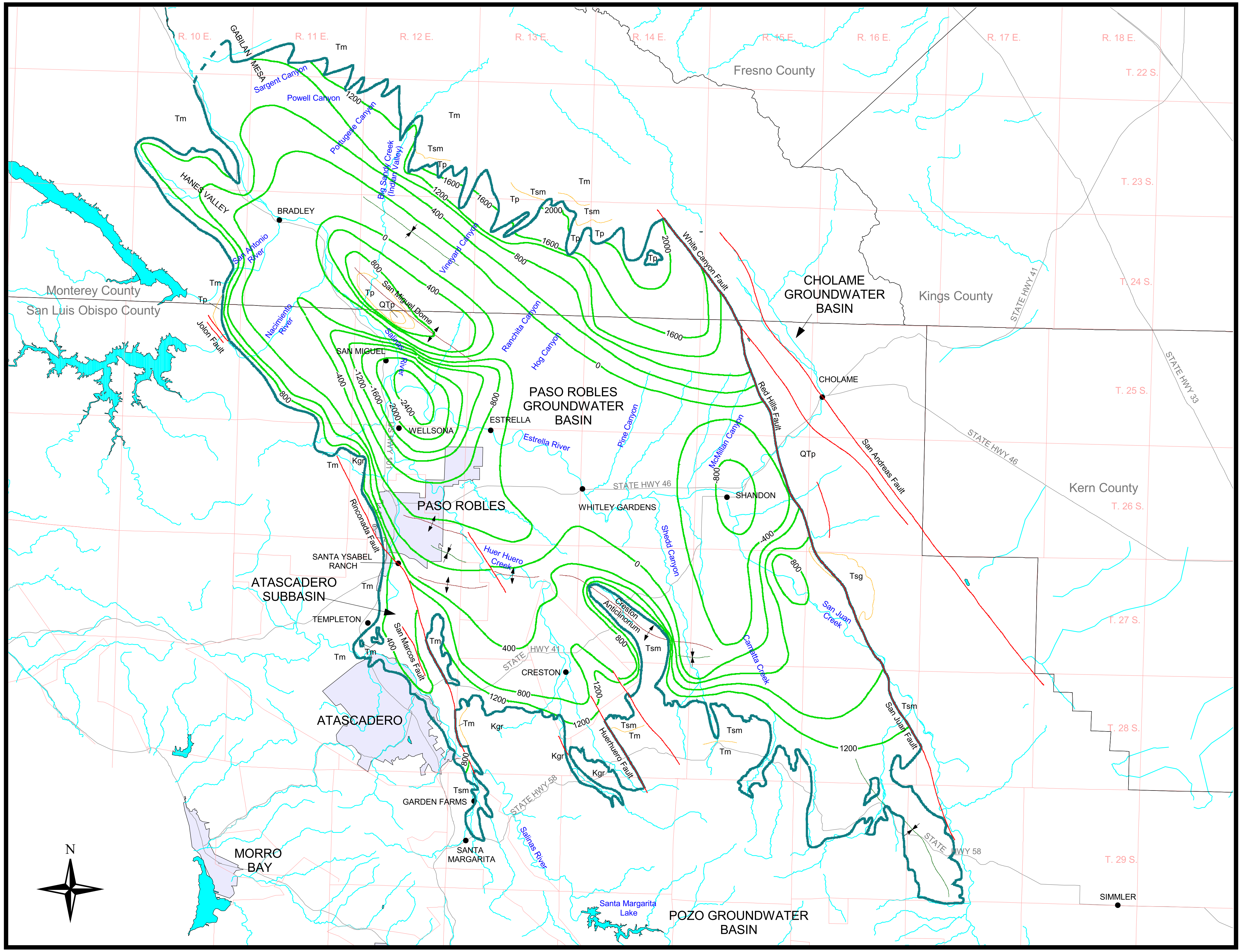

Legend

- City
- Elevation Contours on Base of Paso Robles Formation Contour interval = 400 feet
- Basin Outline
- Fault
- Anticline
- Syncline
- Streams
- Highways
- County Line
- Township and Range Grid

Geologic Units

Paso Robles Groundwater Basin Sediments	Qa	Alluvium
	Qoa	Older Alluvium
	Qls	Landslide
	QTp	Paso Robles Formation
Other Geologic Units	Tp	Pancho Rico Formation
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	Tsg	unnamed (maroon) conglomerate
	Kgr	granite rocks

Notes:
1. Geologic units shown on base map around basin boundary are for reference only. For a geologic map of the basin see Figure 5.
2. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

30000 0 30000 Feet

Base of Permeable Sediments Map

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

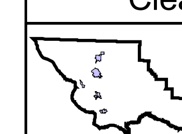
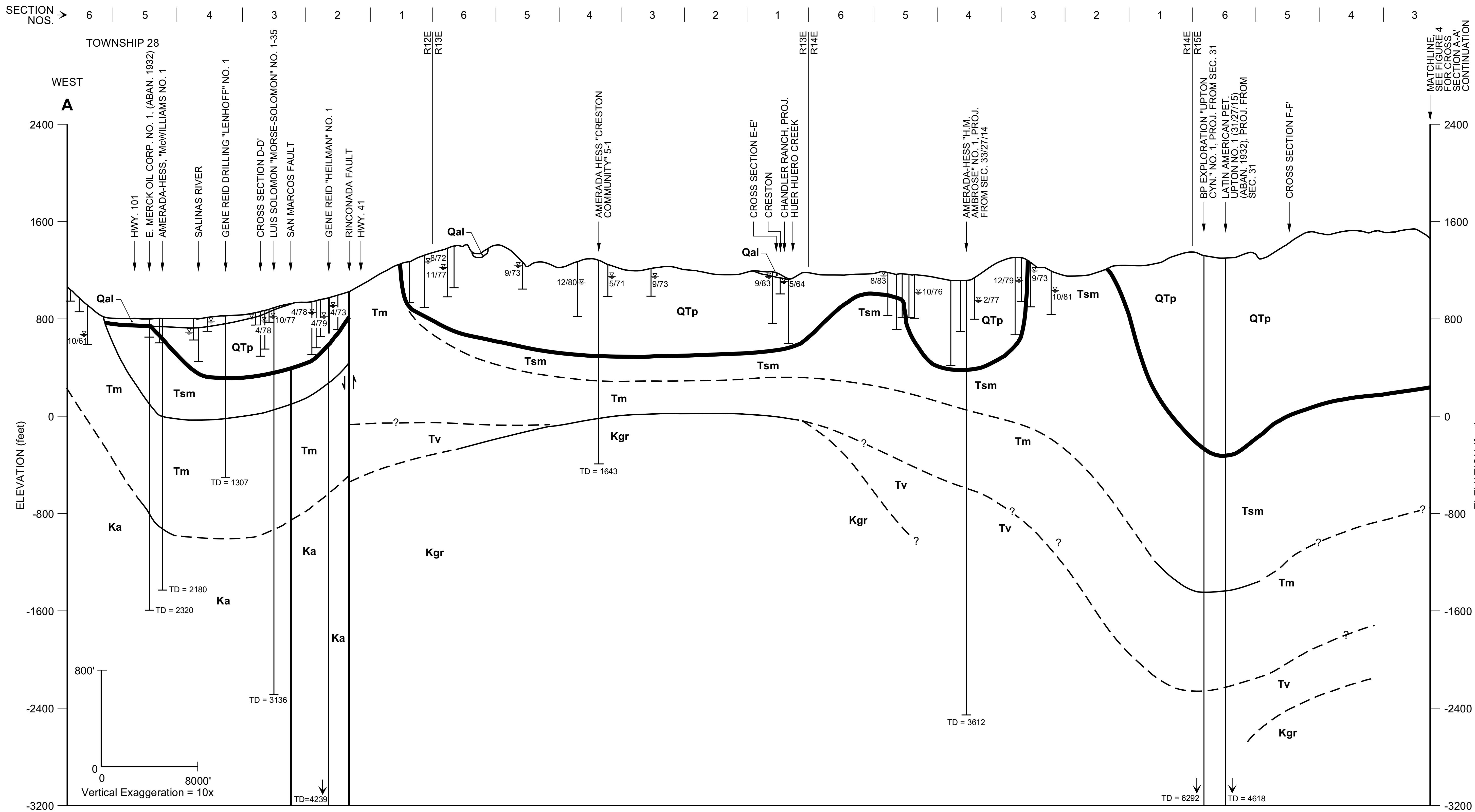


FIGURE 7



LEGEND

Qal	Alluvium	Tsm	Santa Margarita Formation	Kgr	Quartz Diorite or Granodiorite
QTp	Paso Robles Formation	Tm	Monterey Formation	Ka	Atascadero Formation
Tp	Pancho Rico Formation	Tv	Vaqueros Formation		

Fault, arrows show relative movement

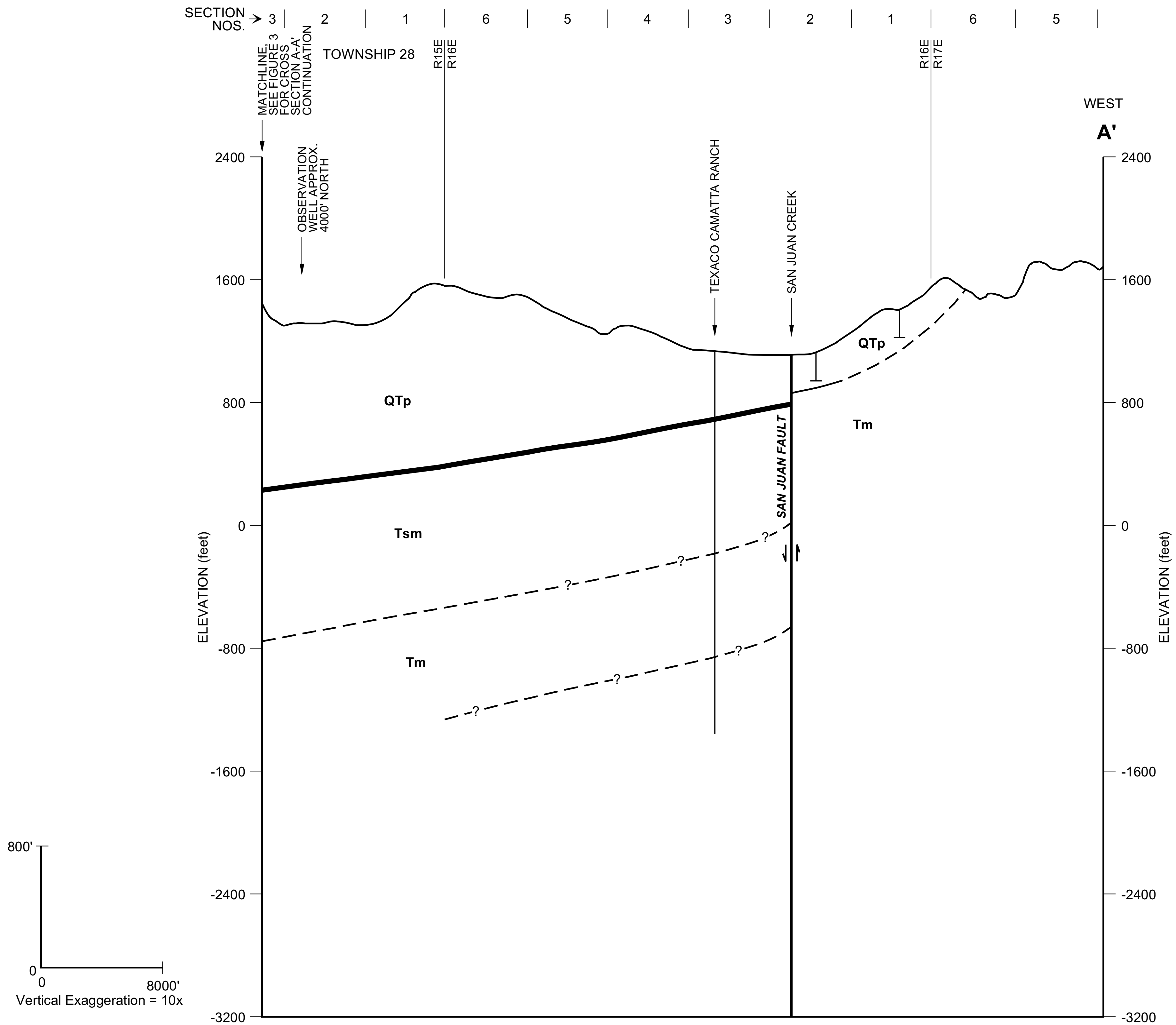
Water level with date noted

Base of permeable sediments

GEOLOGIC CROSS-SECTION A-A'
Paso Robles Groundwater
Basin Study

FIGURE 8

98711137sec1.dsf.p1



LEGEND

Qal	Alluvium	**Tsm**	Santa Margarita Formation	**Kgr**	Quartz Diorite or Granodiorite
QTp	Paso Robles Formation	**Tm**	Monterey Formation	**Ka**	Atascadero Formation
Tp	Pancho Rico Formation	**Tv**	Vaqueros Formation		

Fault, arrows show relative movement

Water level with date noted

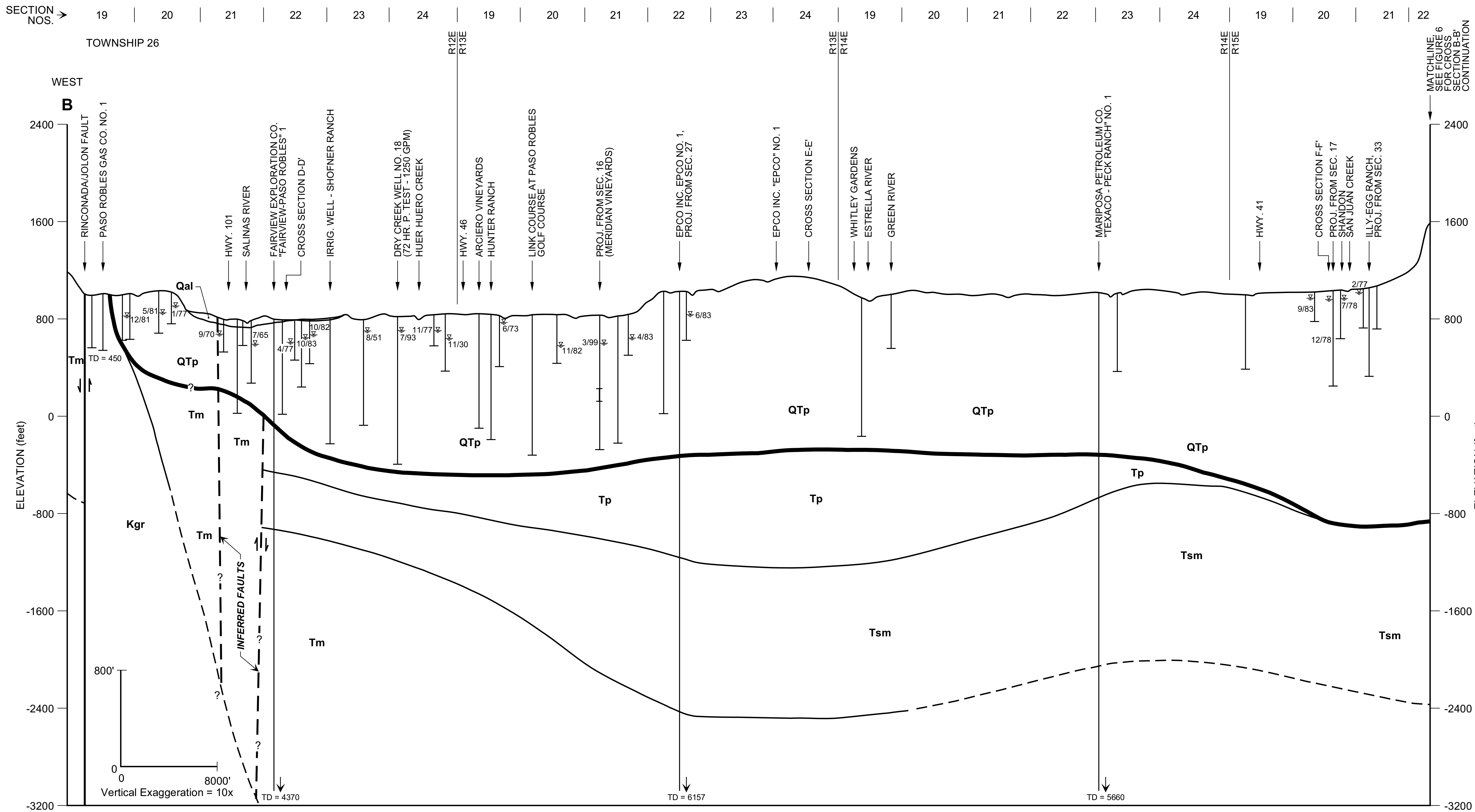
Base of permeable sediments

GEOLOGIC CROSS-SECTION A-A'
(Continued)
Paso Robles Groundwater
Basin Study

FIGURE 9

9871l1137sec1.dsf,p2

FUGRO



LEGEND

Qal	Alluvium
QTp	Paso Robles Formation
Tp	Pancho Rico Formation
Tsm	Santa Margarita Formation
Tm	Monterey Formation
Tv	Vaqueros Formation
Kgr	Quartz Diorite or Granodiorite
Ka	Atascadero Formation

Fault, arrows show relative movement

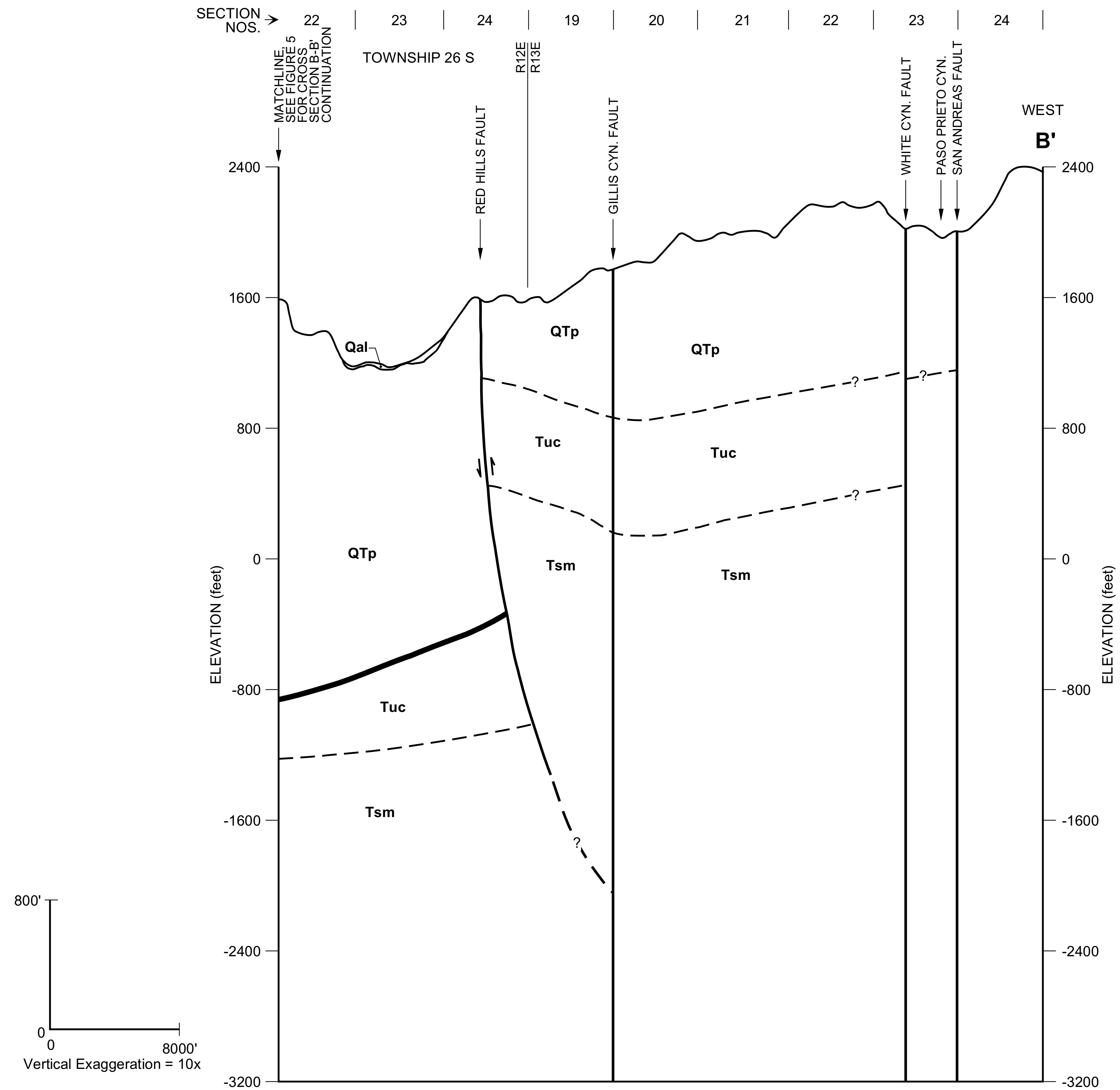
Water level with date noted

Base of permeable sediments

98711137sec1.dsf.p3

GEOLOGIC CROSS-SECTION B-B'
Paso Robles Groundwater
Basin Study

FIGURE 10

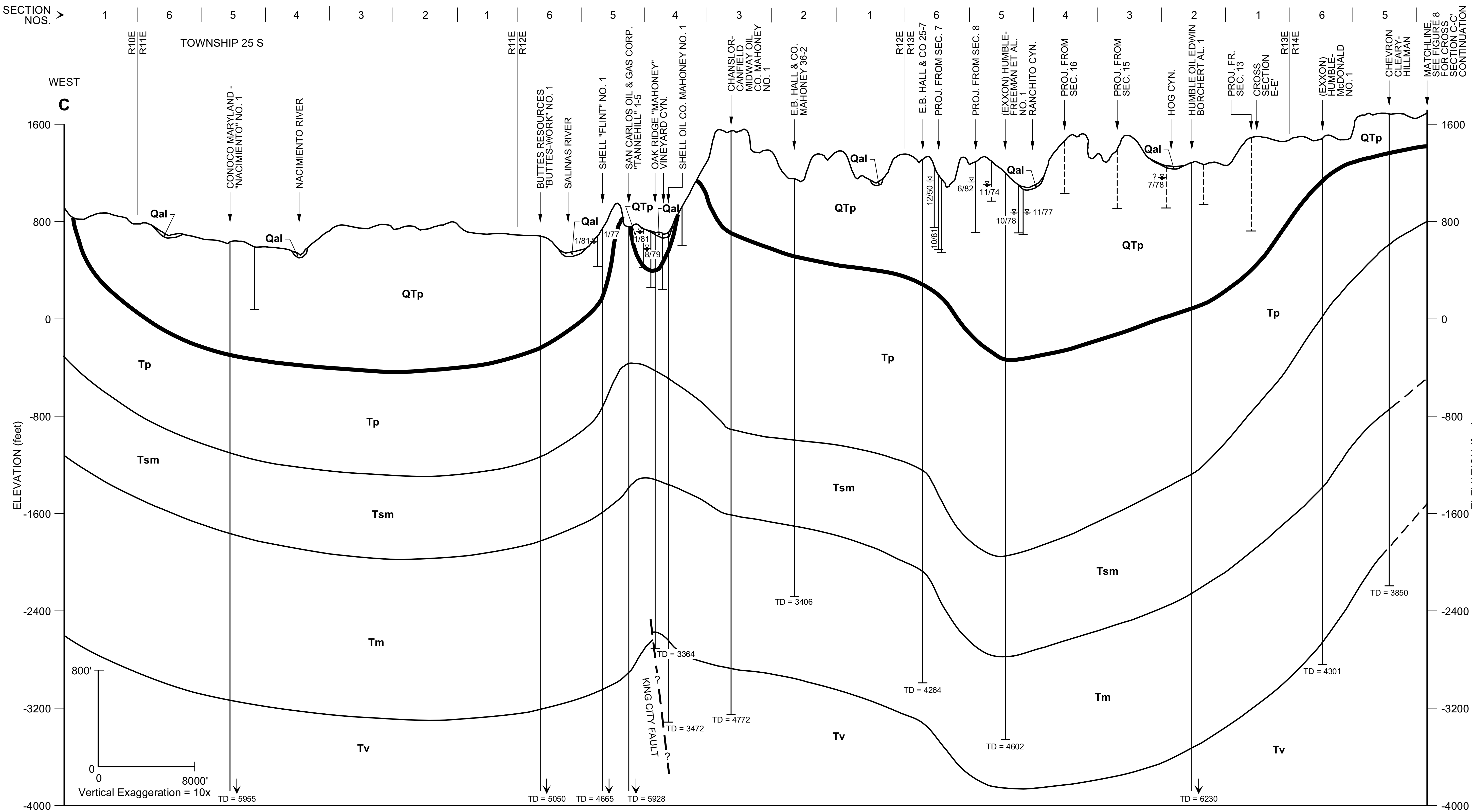


LEGEND

Qal	Alluvium	**Tuc**	Unnamed Clastic Unit	**Tv**	Vaqueros Formation		Fault, arrows show relative movement
QTp	Paso Robles Formation	**Tsm**	Santa Margarita Formation	**Kgr**	Quartz Diorite or Granodiorite		Water level with date noted
Tp	Pancho Rico Formation	**Tm**	Monterey Formation	**Ka**	Atascadero Formation		Base of permeable sediments

GEOLOGIC CROSS-SECTION B-B'
(Continued)
Paso Robles Groundwater
Basin Study

FIGURE 11



LEGEND

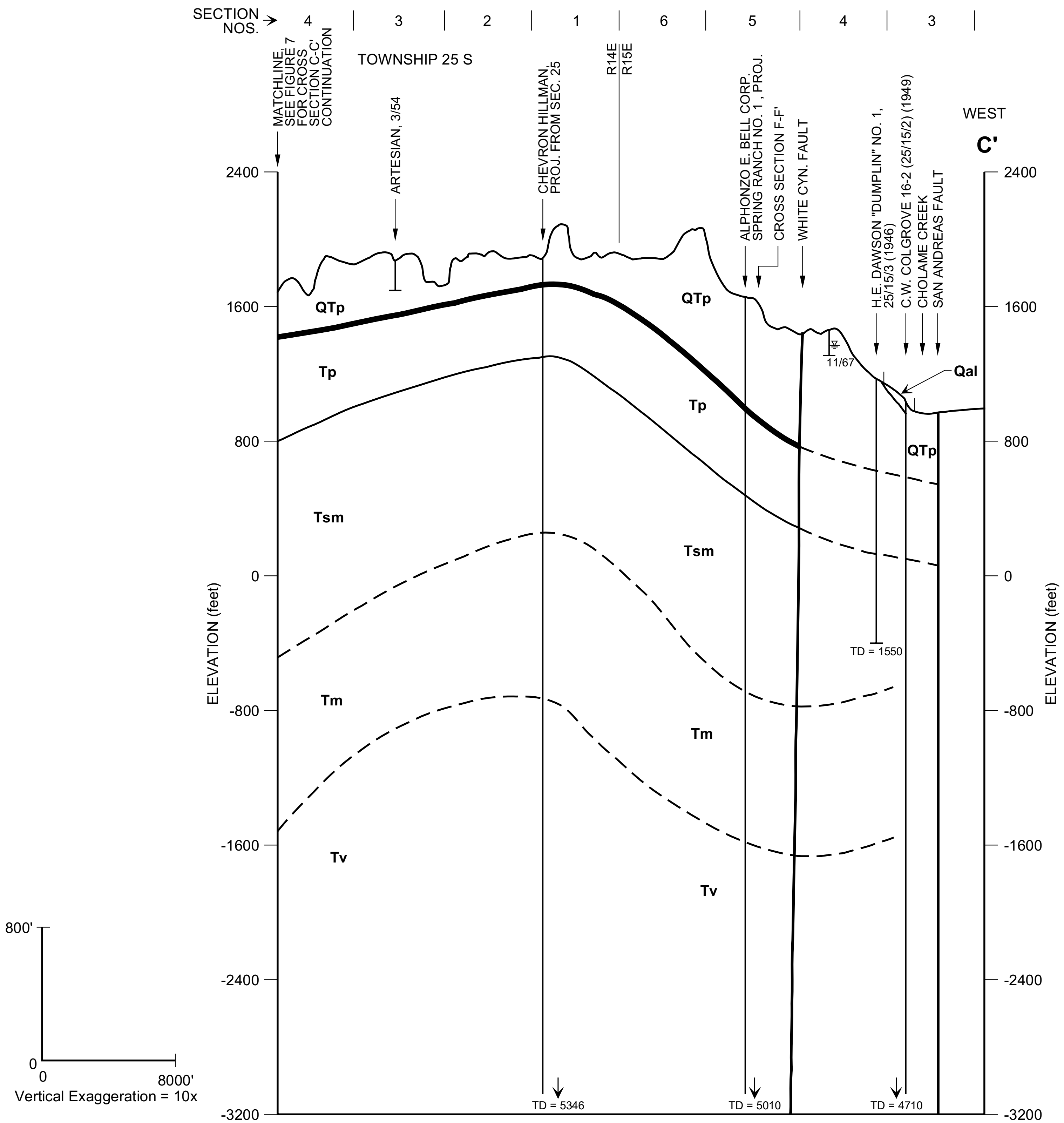
Qal	Alluvium	Tsm	Santa Margarita Formation	Kgr	Quartz Diorite or Granodiorite
QTp	Paso Robles Formation	Tm	Monterey Formation	Ka	Atascadero Formation
Tp	Pancho Rico Formation	Tv	Vaqueros Formation		

Fault, arrows show relative movement
Water level with date noted
Base of permeable sediments

GEOLOGIC CROSS-SECTION C-C'
Paso Robles Groundwater
Basin Study

FIGURE 12

98711137sec1.dsf.p5



LEGEND

Qal	Alluvium
QTp	Paso Robles Formation
Tp	Pancho Rico Formation
Tsm	Santa Margarita Formation
Tm	Monterey Formation
Tv	Vaqueros Formation
Kgr	Quartz Diorite or Granodiorite
Ka	Atascadero Formation

Fault, arrows show relative movement

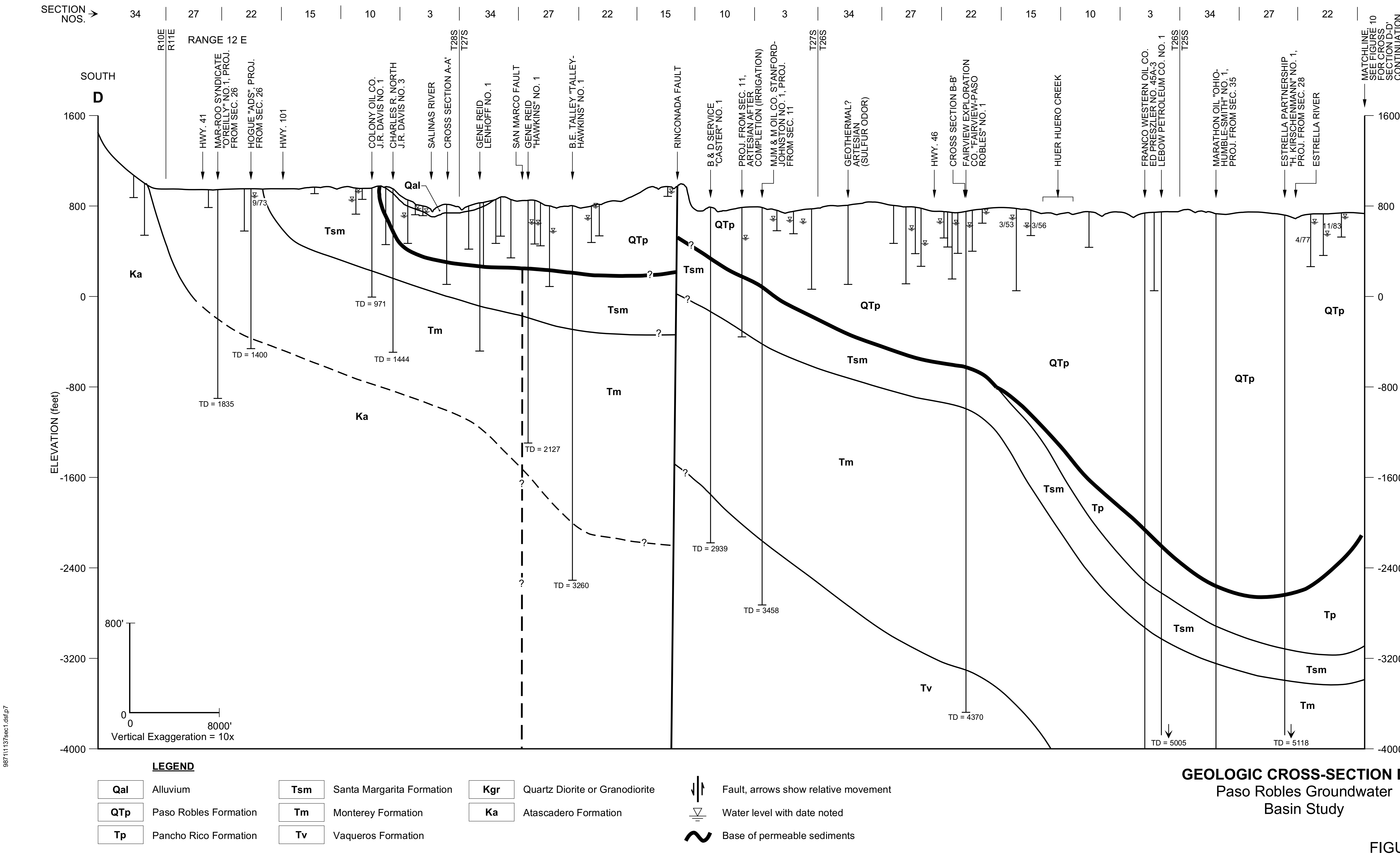
Water level with date noted

Base of permeable sediments

98711137sec1.dsf,p6

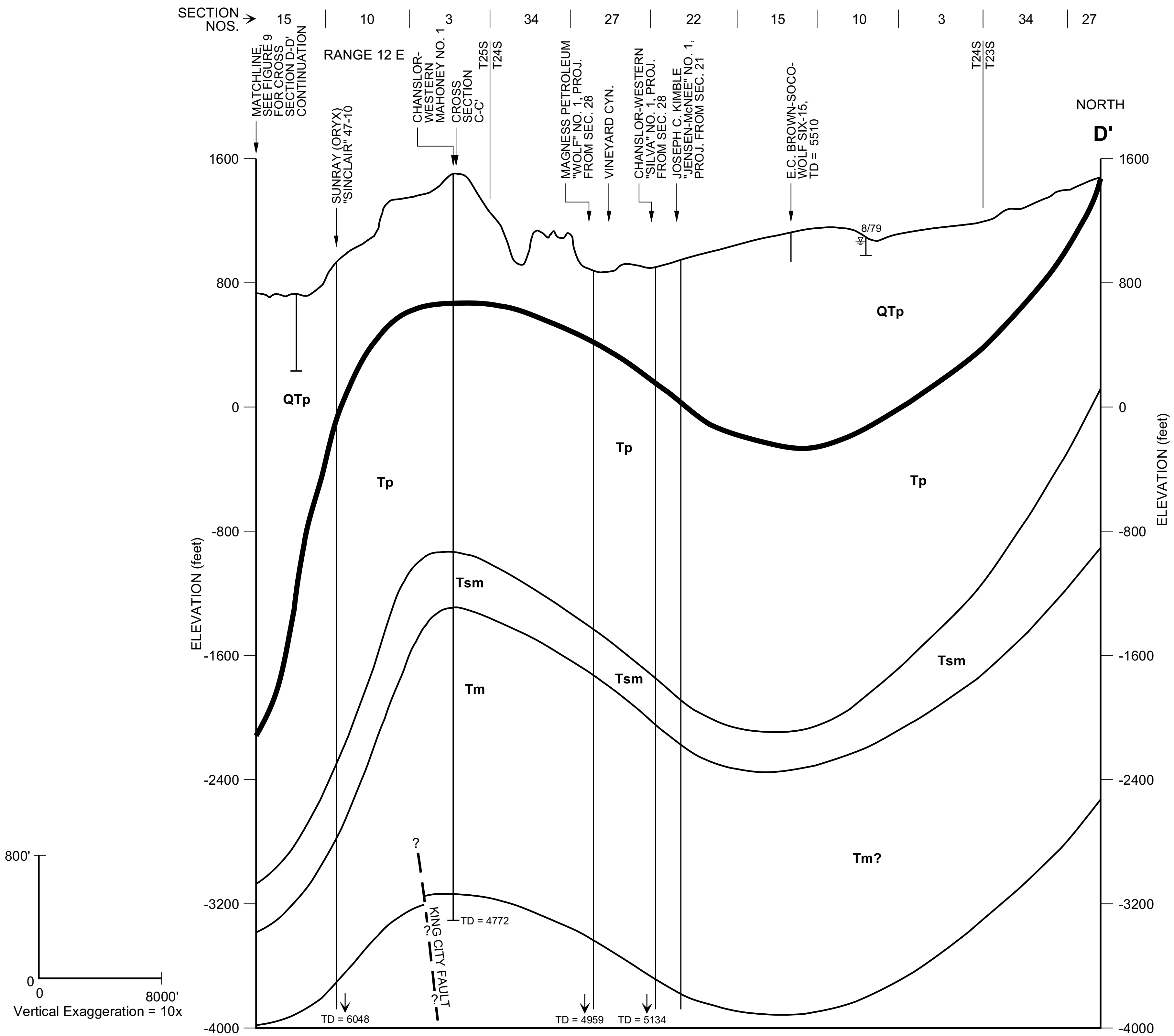
GEOLOGIC CROSS-SECTION C-C'
(Continued)
Paso Robles Groundwater
Basin Study

FIGURE 13



GEOLOGIC CROSS-SECTION D-D'
Paso Robles Groundwater
Basin Study

FIGURE 14



LEGEND

Qal	Alluvium	Tsm	Santa Margarita Formation	Kgr	Quartz Diorite or Granodiorite		Fault, arrows show relative movement
QTp	Paso Robles Formation	Tm	Monterey Formation	Ka	Atascadero Formation		Water level with date noted
Tp	Pancho Rico Formation	Tv	Vaqueros Formation				Base of permeable sediments

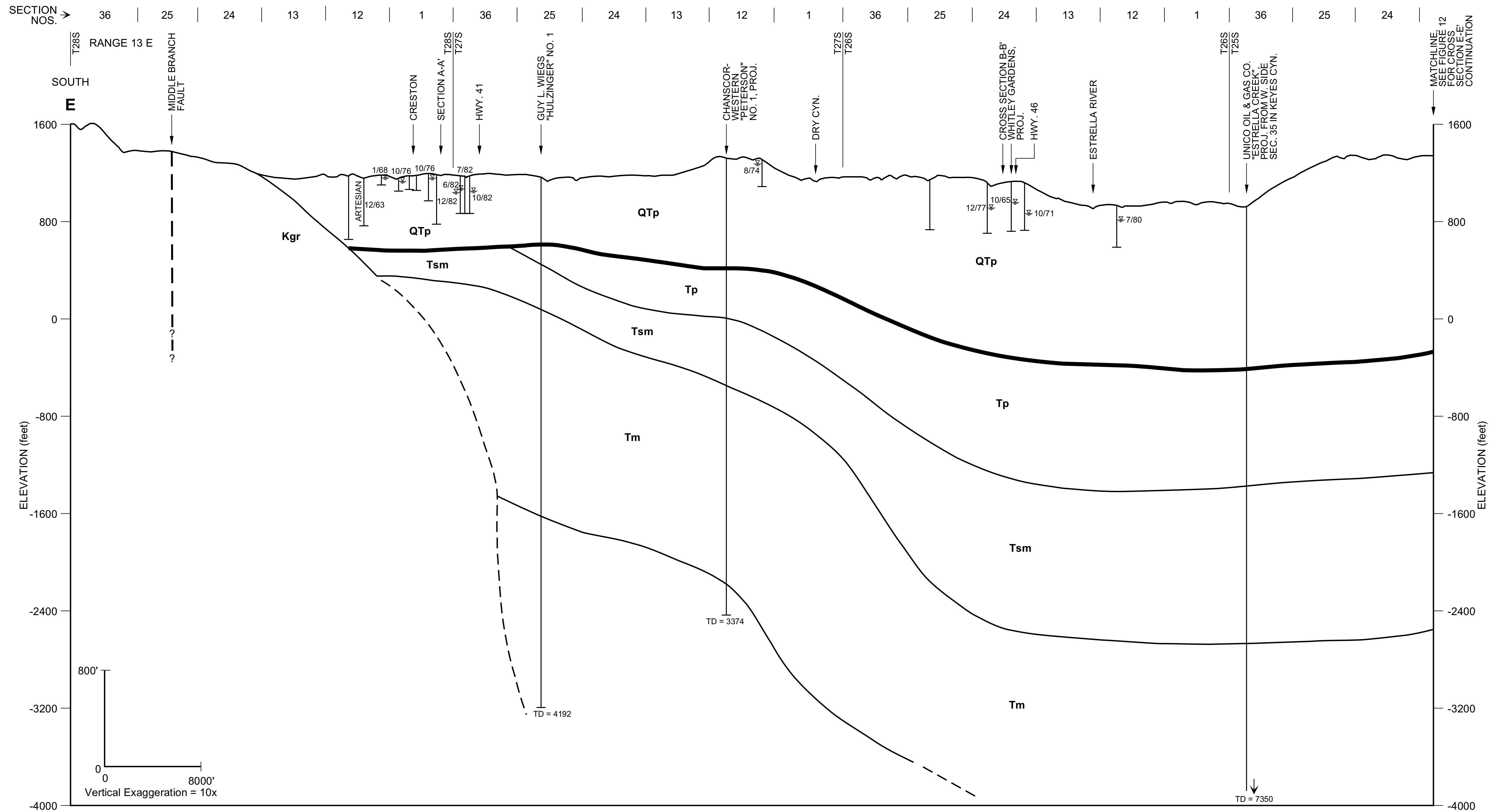
GEOLOGIC CROSS-SECTION D-D' (Continued)

Paso Robles Groundwater Basin Study

FIGURE 15

98711137sec1.dsf,p8

Project No. 98-71-1137



98711137sec1.dsf,p9

LEGEND

Qal	Alluvium	Tsm	Santa Margarita Formation	Kgr	Quartz Diorite or Granodiorite
QTp	Paso Robles Formation	Tm	Monterey Formation	Ka	Atascadero Formation
Tp	Pancho Rico Formation	Tv	Vaqueros Formation		

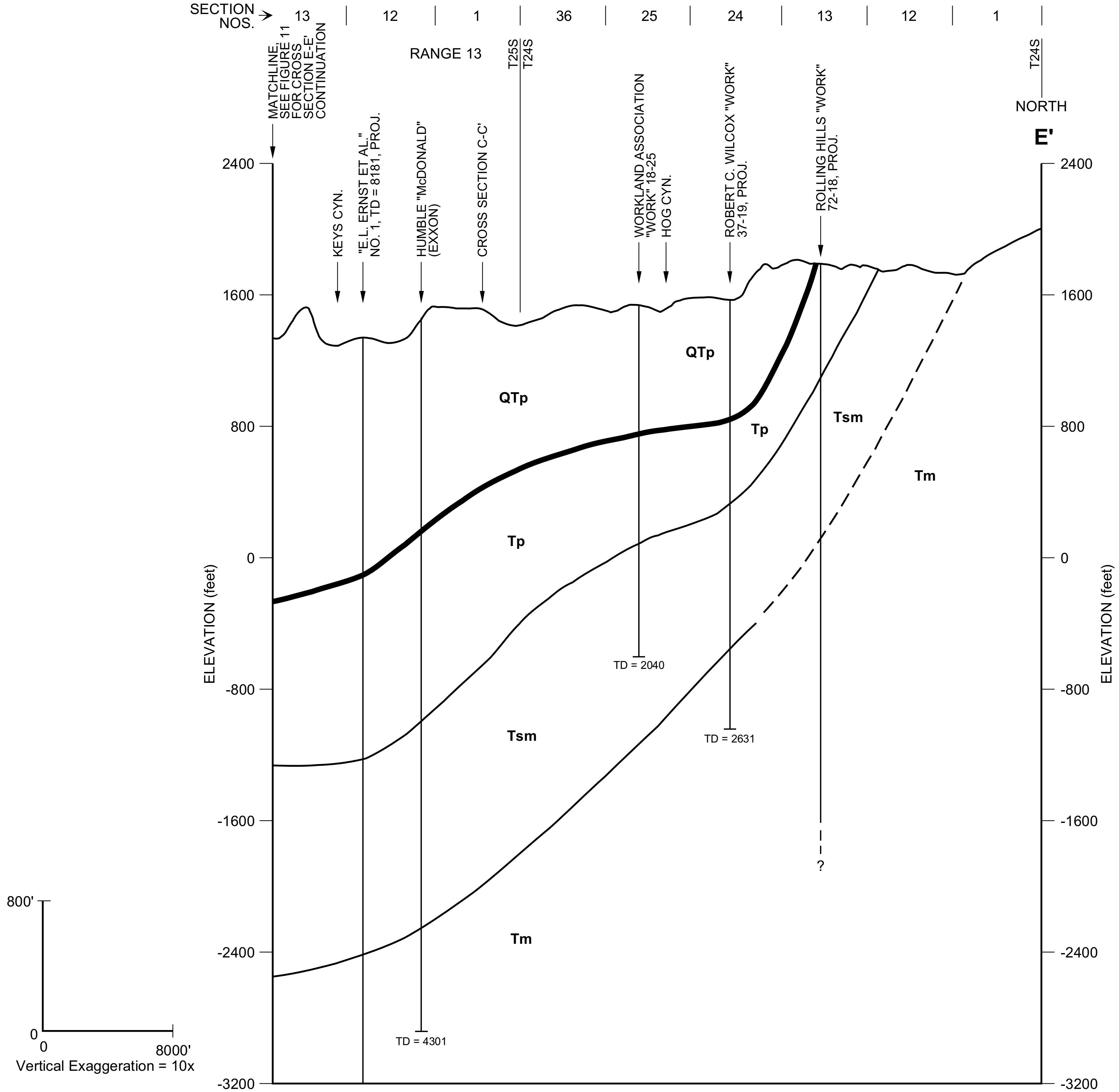
Fault, arrows show relative movement

Water level with date noted

Base of permeable sediments

GEOLOGIC CROSS-SECTION E-E'
Paso Robles Groundwater
Basin Study

FIGURE 16



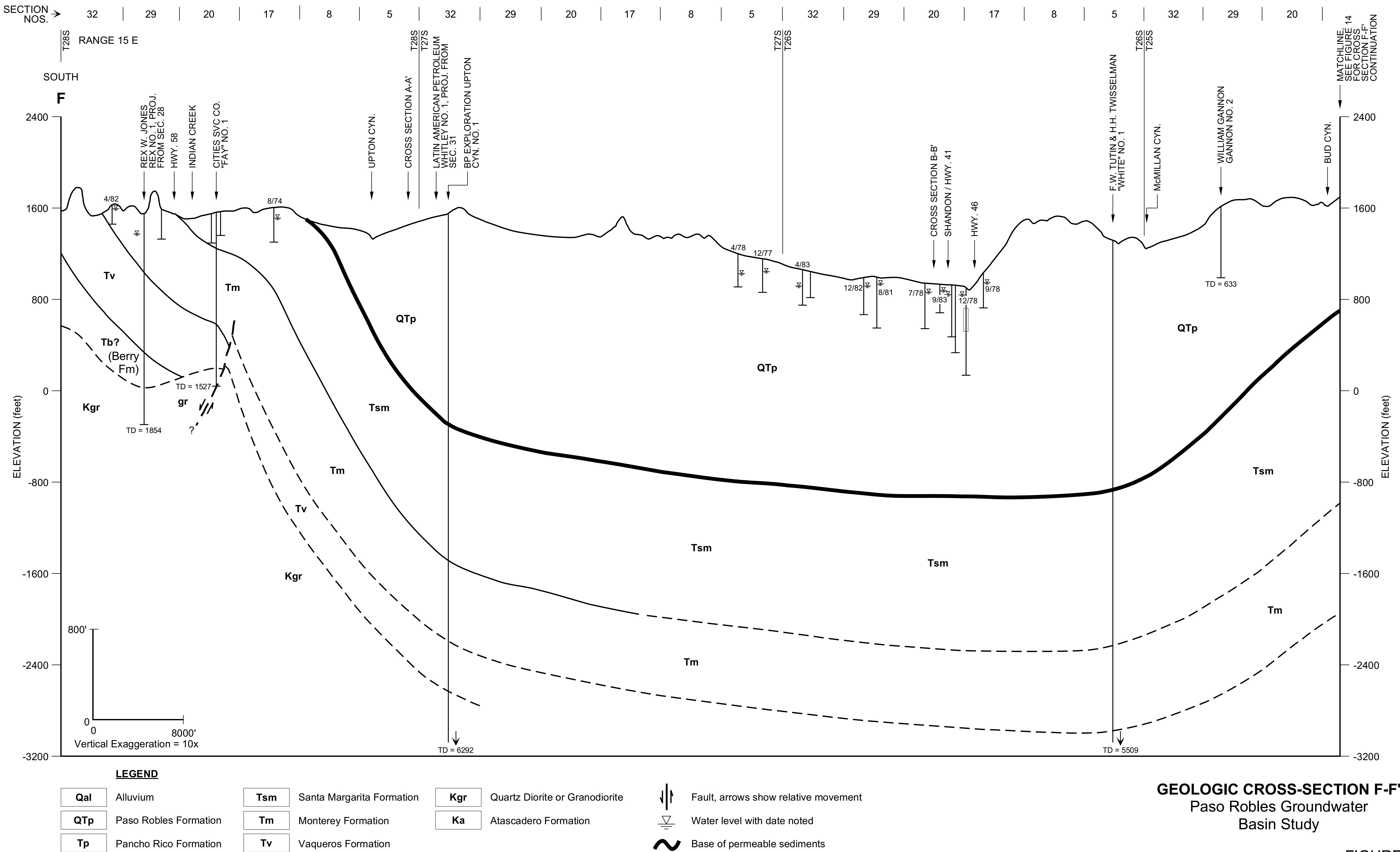
LEGEND

Qal	Alluvium	Tsm	Santa Margarita Formation	Kgr	Quartz Diorite or Granodiorite		Fault, arrows show relative movement
QTp	Paso Robles Formation	Tm	Monterey Formation	Ka	Atascadero Formation		Water level with date noted
Tp	Pancho Rico Formation	Tv	Vaqueros Formation				Base of permeable sediments

GEOLOGIC CROSS-SECTION E-E' (Continued)
Paso Robles Groundwater Basin Study

FIGURE 17

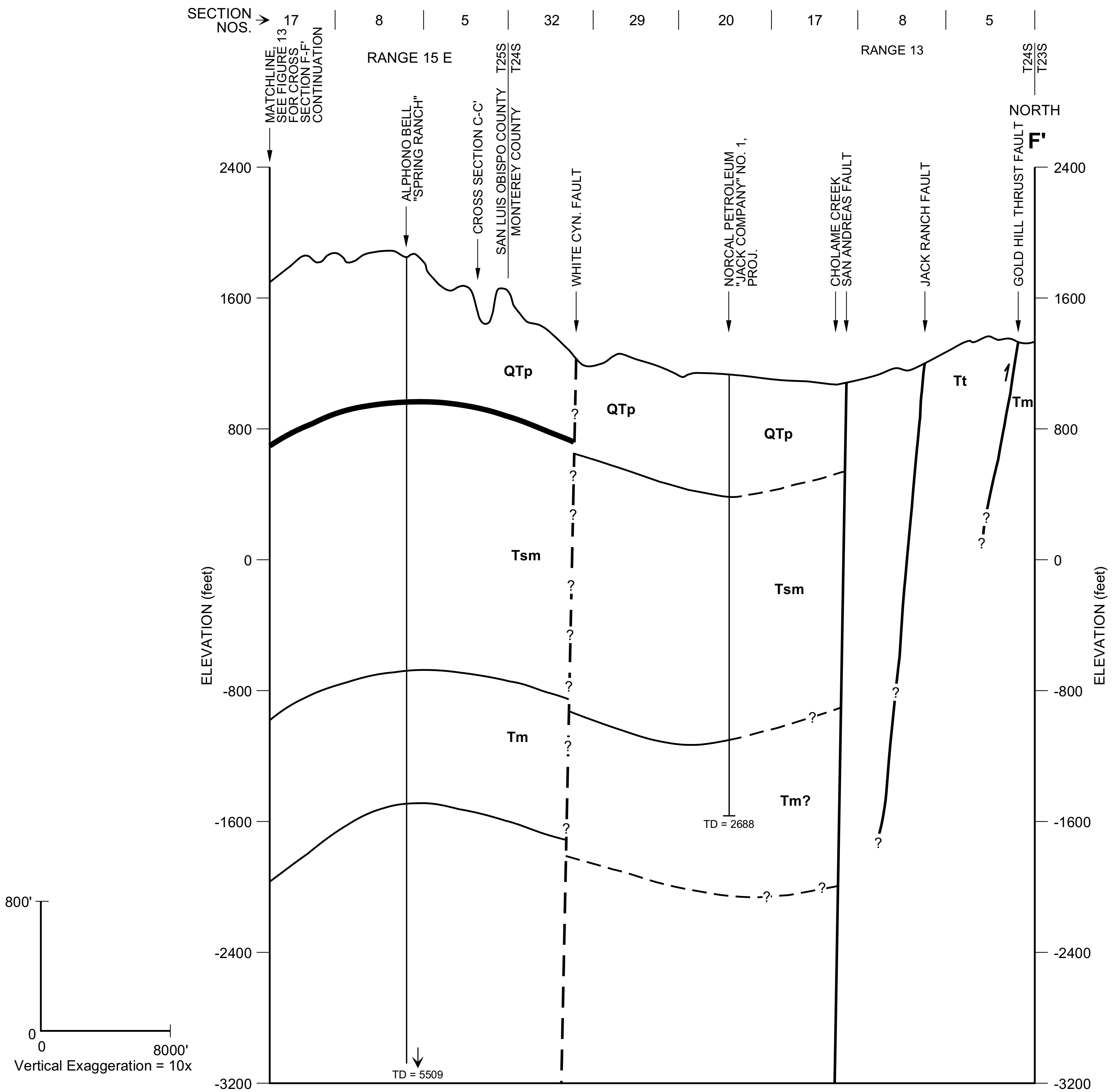
98711137sec1.dsf,p10



GEOLOGIC CROSS-SECTION F-F'
Paso Robles Groundwater
Basin Study

FIGURE 18

98711137sec1.dsf,p11



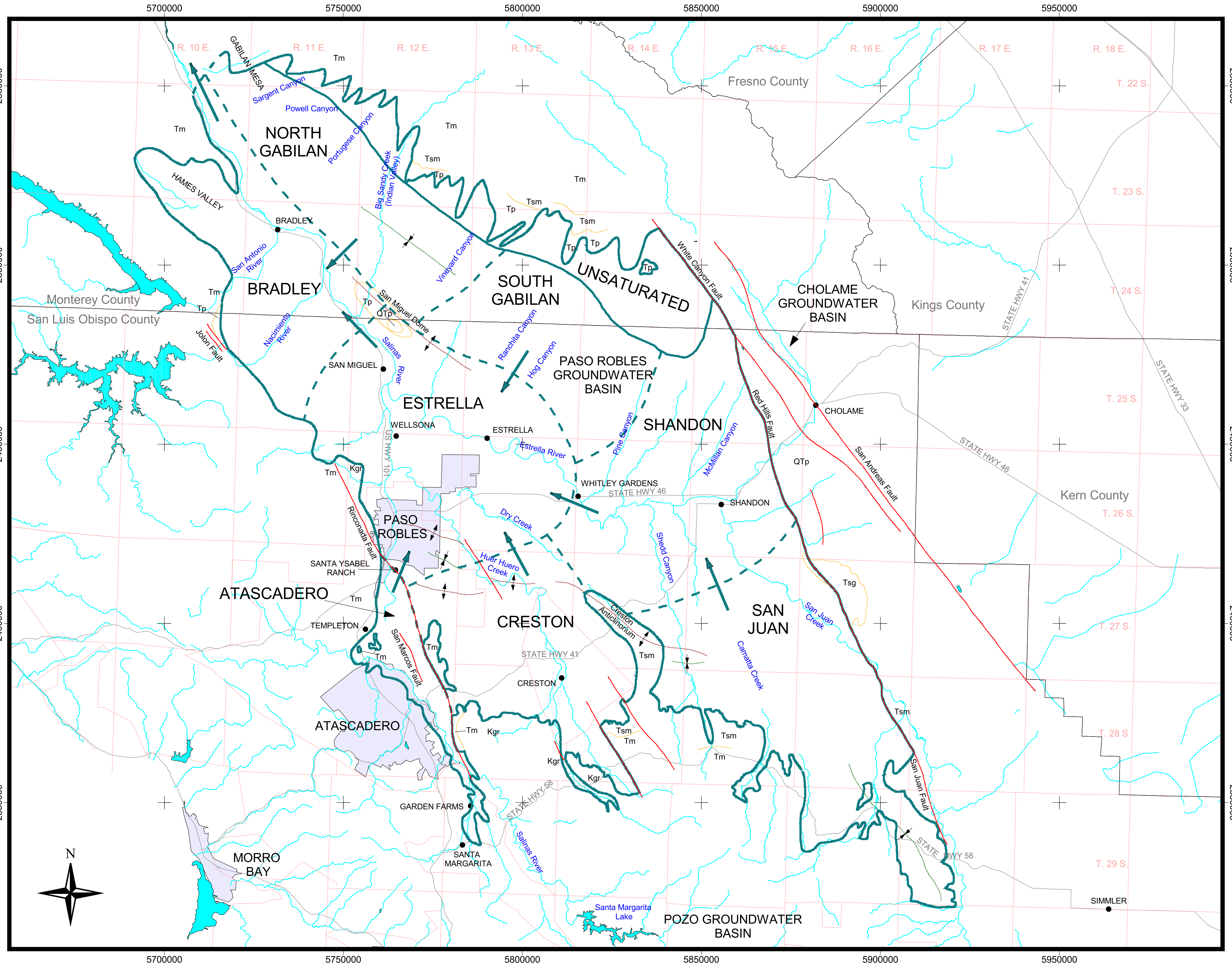
LEGEND

Qal	Alluvium	Tsm	Santa Margarita Formation	Kgr	Quartz Diorite or Granodiorite		Fault, arrows show relative movement
QTp	Paso Robles Formation	Tm	Monterey Formation	Ka	Atascadero Formation		Water level with date noted
Tp	Pancho Rico Formation	Tv	Vaqueros Formation				Base of permeable sediments

GEOLOGIC CROSS-SECTION F-F'
(Continued)
Paso Robles Groundwater
Basin Study

FIGURE 19

98711137sec1.dsf,p12



Legend

- City
- Basin Outline
- Basin Area
- Net Groundwater Flow Between Areas
- Fault
- Anticline
- Syncline
- Streams
- Highways
- County Line
- Township and Range Grid

Geologic Units

Paso Robles Groundwater Basin Sediments	Qa	Alluvium
	Qoa	Older Alluvium
	Qls	Landslide
	QTp	Paso Robles Formation
Other Geologic Units	Tp	Pancho Rico Formation
	Tsm	Santa Margarita Sandstone
	Tm	Monterey Shale
	Tv	Vaqueros Formation
	Ts	Simmler Formation
	Tsg	unnamed (maroon) conglomerate
	Kgr	granite rocks

Notes:
1. Geologic units shown on base map around basin boundary are for reference only. For a geologic map of the basin see Figure 5.
2. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

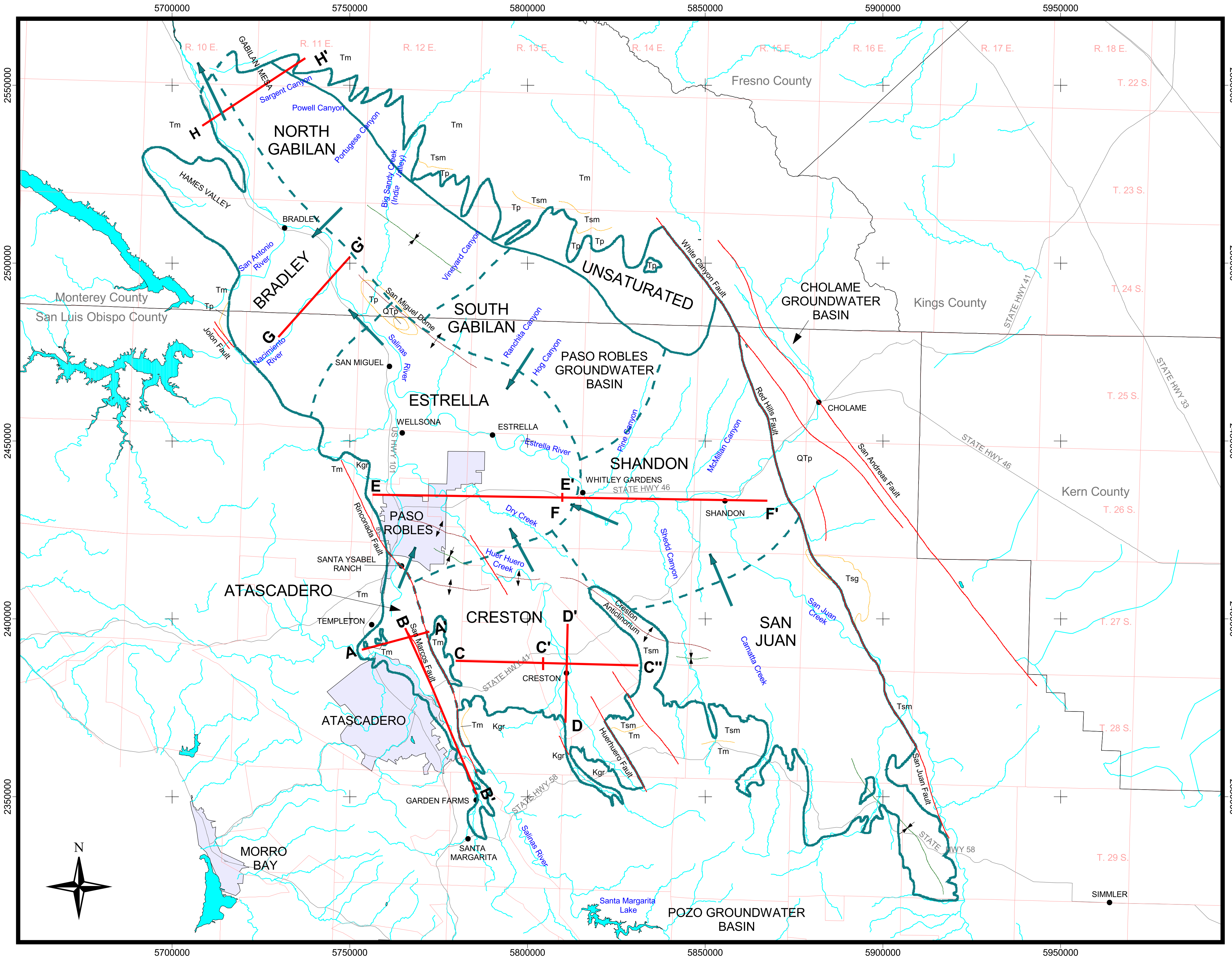
30000 0 30000 Feet

Basin Areas

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 20



Legend
- City
- Cross Section Line
- Basin Outline
- Basin Area
- Net Groundwater Flow Between Areas
- Fault
- Anticline
- Syncline
- Streams
- Highways
- County Line
- Township and Range Grid

Geologic Units

Paso Robles Groundwater Basin Sediments	Qa	Alluvium
	Qoa	Older Alluvium
	Qls	Landslide
	QTp	Paso Robles Formation
Other Geologic Units	Tp	Pancho Rico Formation
	Tsm	Santa Margarita Sandstone
	Tm	Monterey Shale
	Tv	Vaqueros Formation
	Ts	Simmler Formation
	Tsg	unnamed (maroon) conglomerate
	Kgr	granite rocks

Notes:
1. Geologic units shown on base map around basin boundary are for reference only. For a geologic map of the basin see Figure 5.
2. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

30000 0 30000 Feet

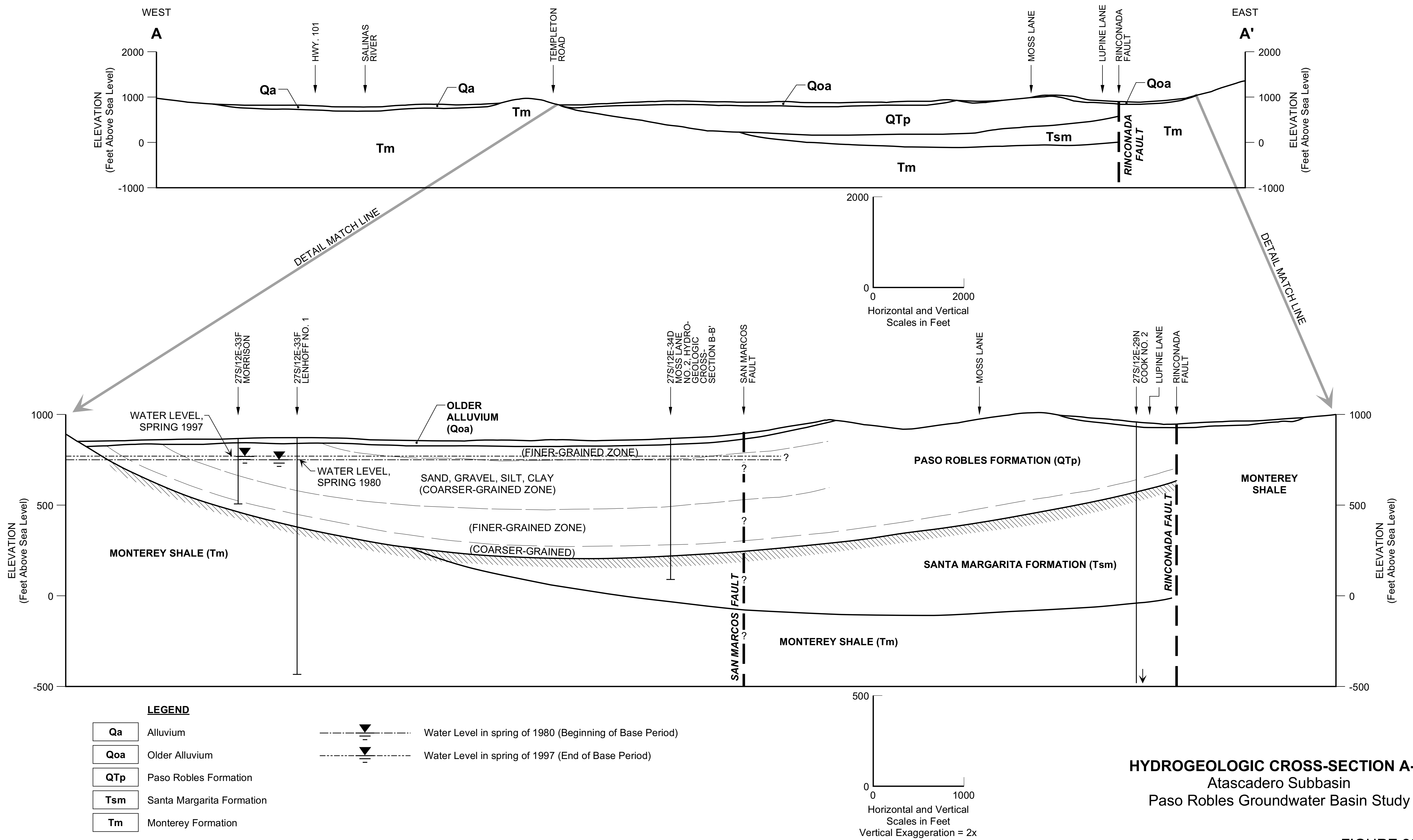
Hydrogeologic Cross Section Location Map

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 21

FUGRO



LEGEND

Qa	Alluvium
Qoa	Older Alluvium
QTp	Paso Robles Formation
Tsm	Santa Margarita Formation
Tm	Monterey Formation

Water Level in spring of 1980 (Beginning of Base Period)

Water Level in spring of 1997 (End of Base Period)

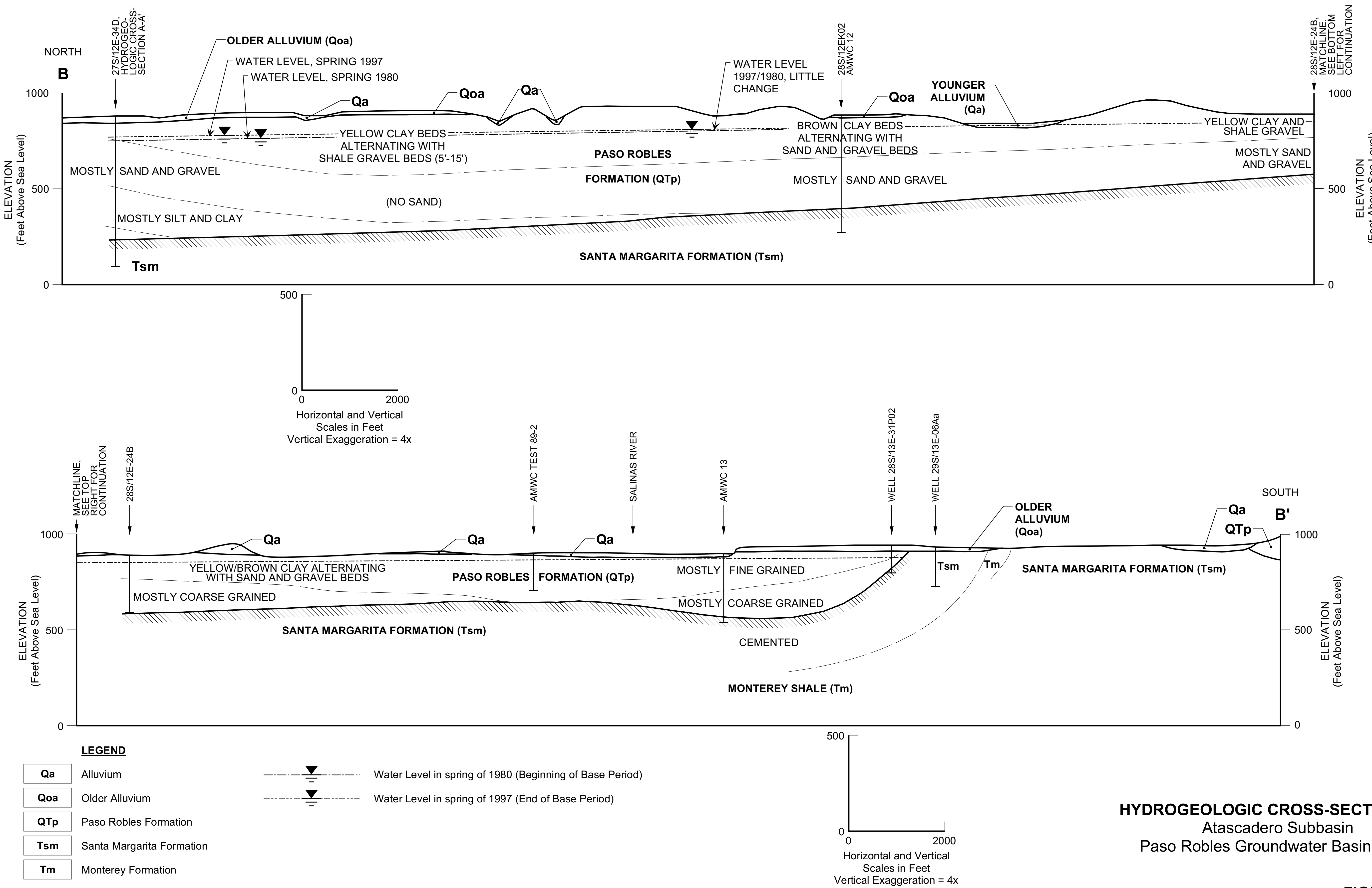
HYDROGEOLOGIC CROSS-SECTION A-A'

Atascadero Subbasin

Paso Robles Groundwater Basin Study

FIGURE 22

98711137sec2.dsf.p1

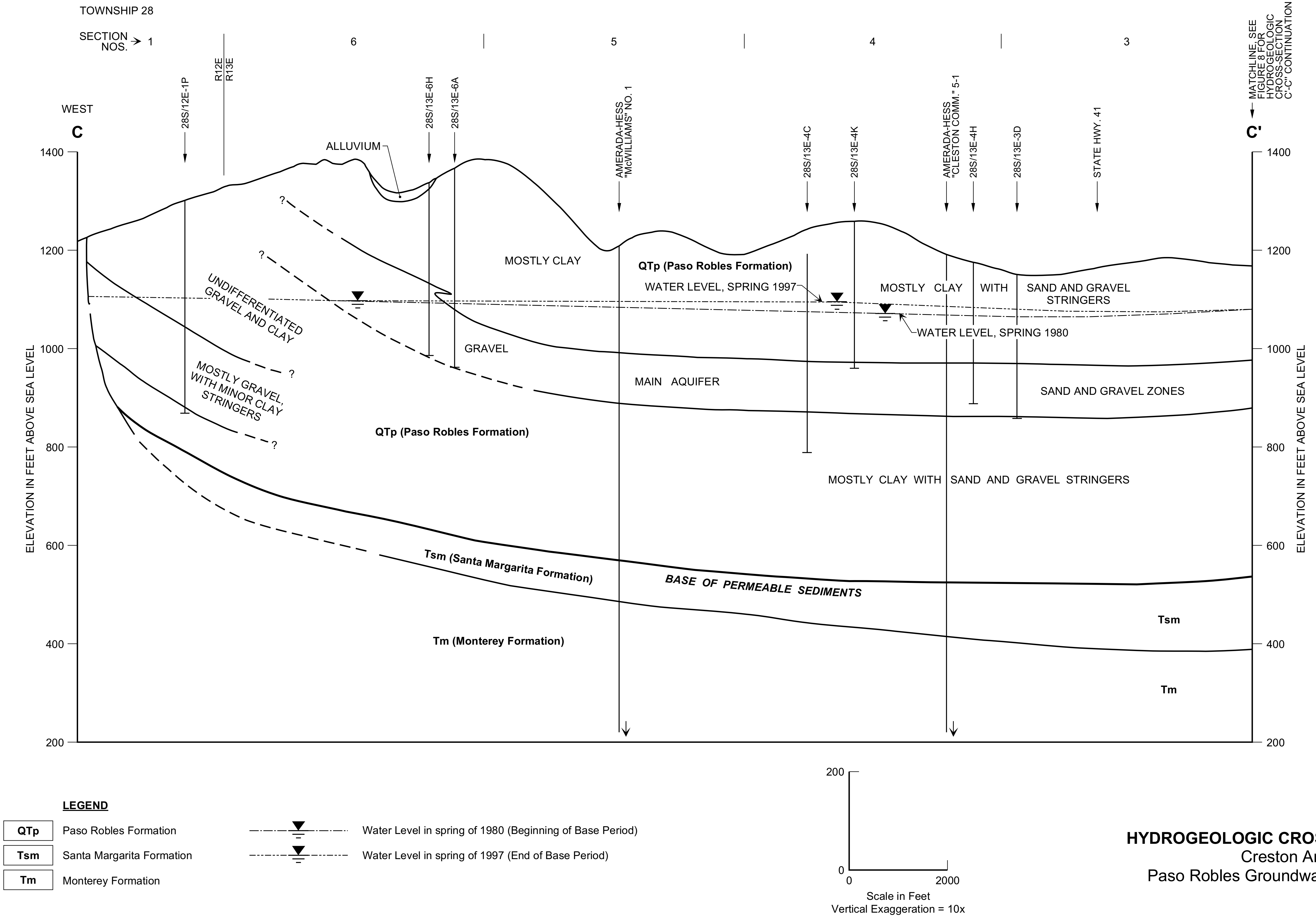


98711137sec2.dsf.p2

HYDROGEOLOGIC CROSS-SECTION B-B'

Atascadero Subbasin
Paso Robles Groundwater Basin Study

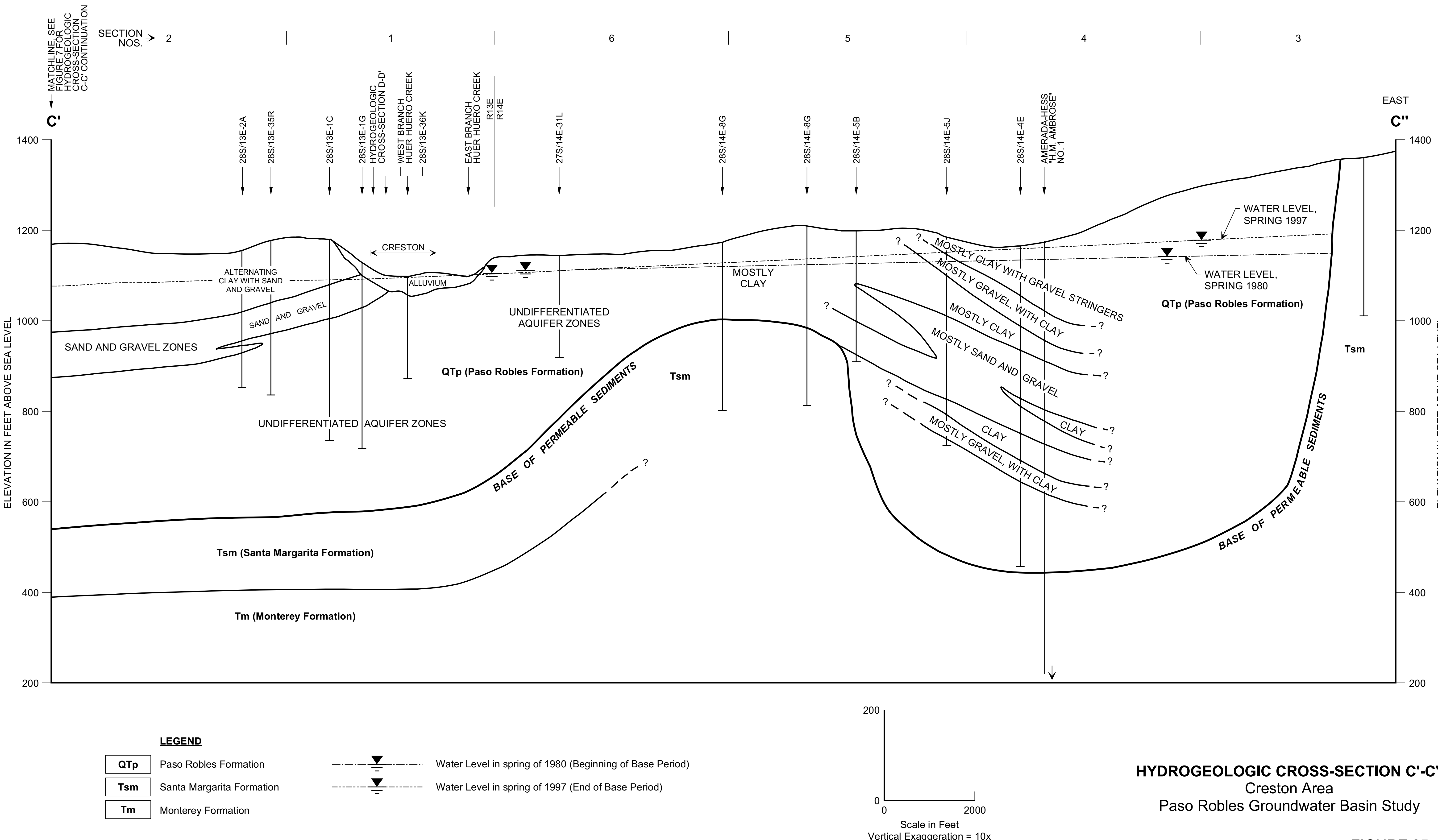
FIGURE 23



HYDROGEOLOGIC CROSS-SECTION C-C'
Creston Area
Paso Robles Groundwater Basin Study

FIGURE 24

98711137sec2.dsf.p3



9871\1137sec2.dsf.p4

LEGEND

QTp	Paso Robles Formation
Tsm	Santa Margarita Formation
Tm	Monterey Formation

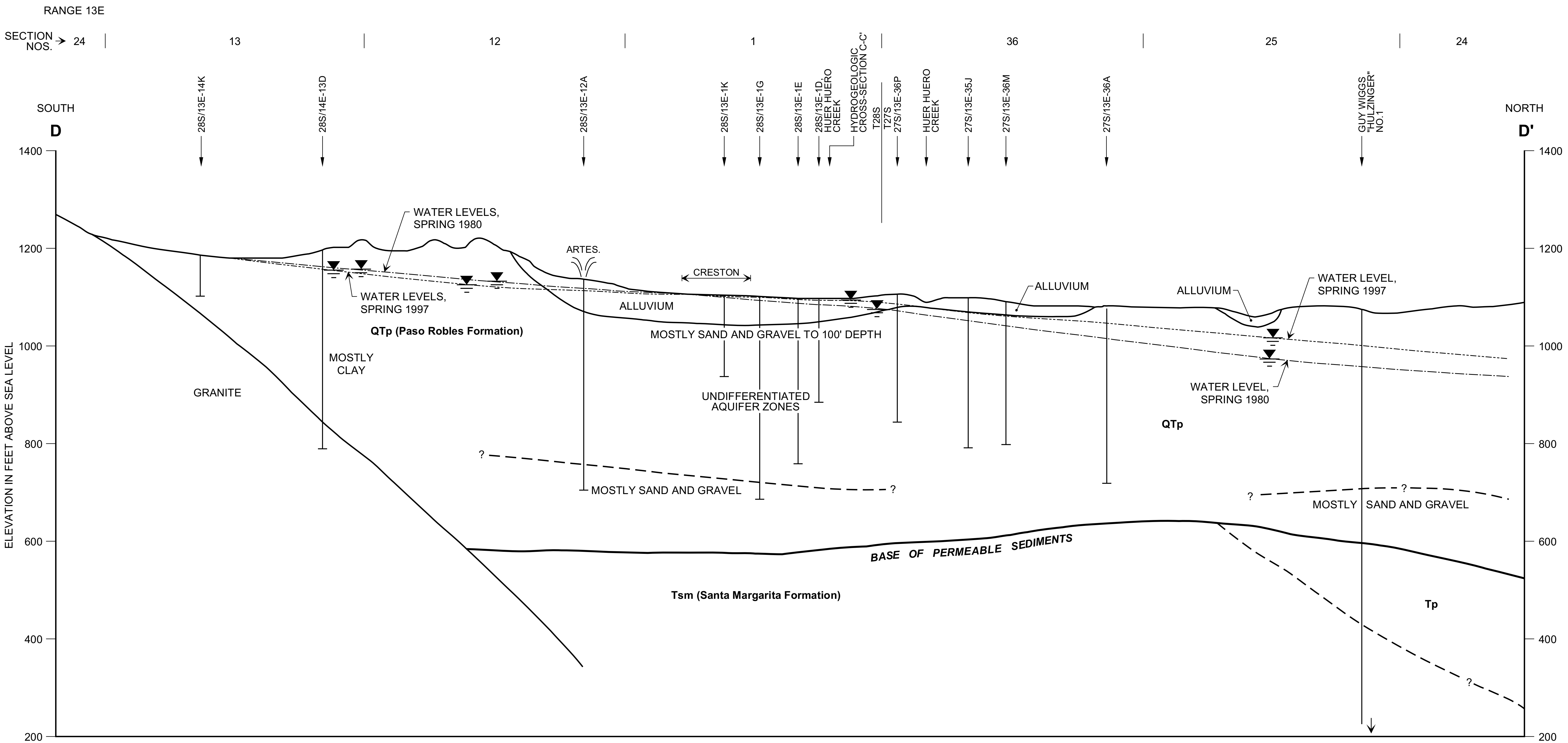
Water Level in spring of 1980 (Beginning of Base Period)

Water Level in spring of 1997 (End of Base Period)

HYDROGEOLOGIC CROSS-SECTION C'-C''
Creston Area
Paso Robles Groundwater Basin Study

FIGURE 25

Project No. 98-71-1137



9871\1137sec2.dsf.p5

LEGEND

QTp	Paso Robles Formation
Tp	Pancho Rico Formation
Tsm	Santa Margarita Formation
Tm	Monterey Formation

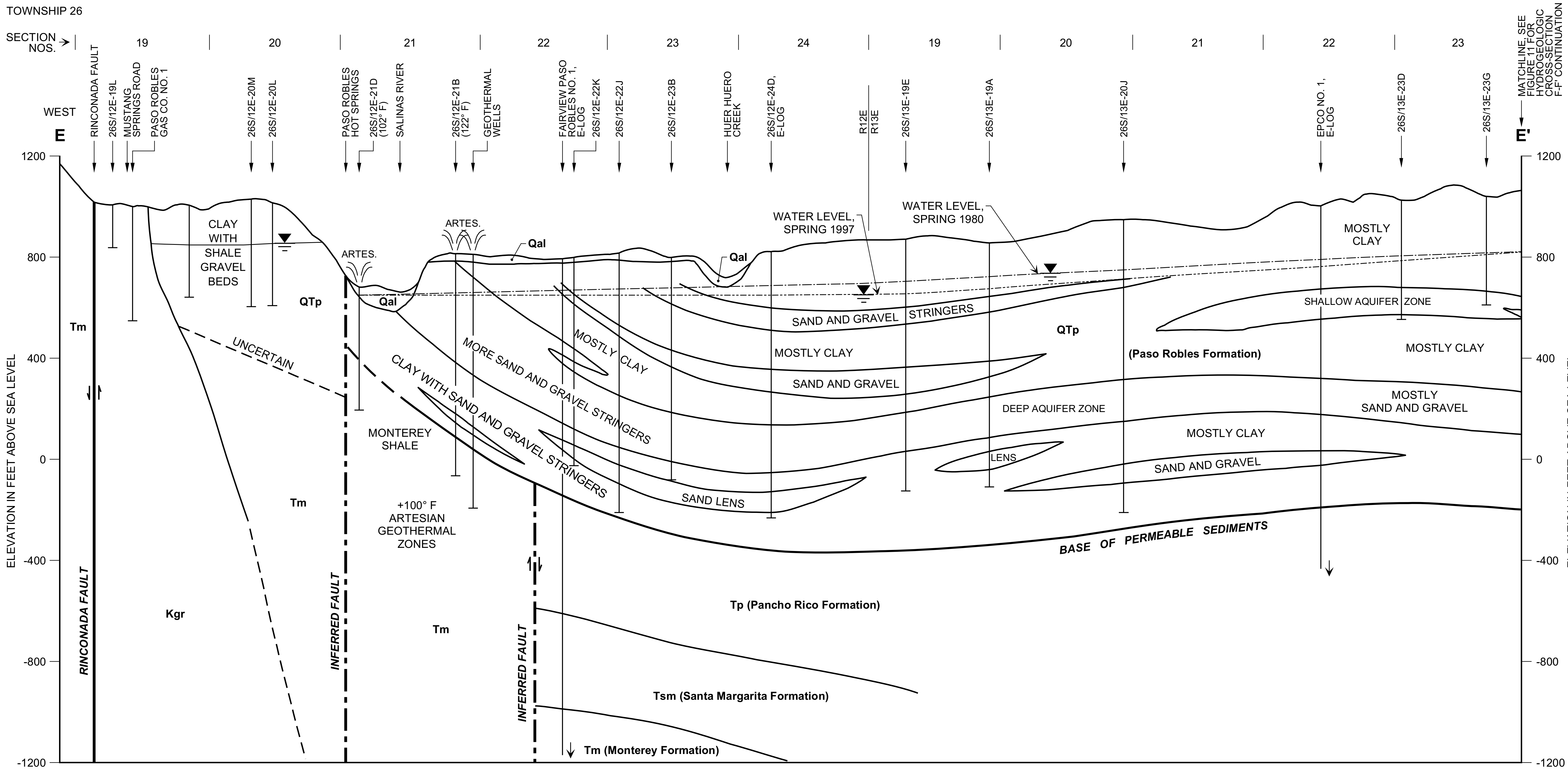
Water Level in spring of 1980 (Beginning of Base Period)

Water Level in spring of 1997 (End of Base Period)

200
0
0 2000
Scale in Feet
Vertical Exaggeration = 10x

HYDROGEOLOGIC CROSS-SECTION D-D'
Creston Area
Paso Robles Groundwater Basin Study

FIGURE 26



LEGEND

Qal	Alluvium
QTp	Paso Robles Formation
Tp	Pancho Rico Formation
Tsm	Santa Margarita Formation
Tm	Monterey Formation
Kgr	Quartz Diorite or Granodiorite

Water Level in spring of 1980 (Beginning of Base Period)

Water Level in spring of 1997 (End of Base Period)

400

0

0 4000

Scale in Feet

Vertical Exaggeration = 10x

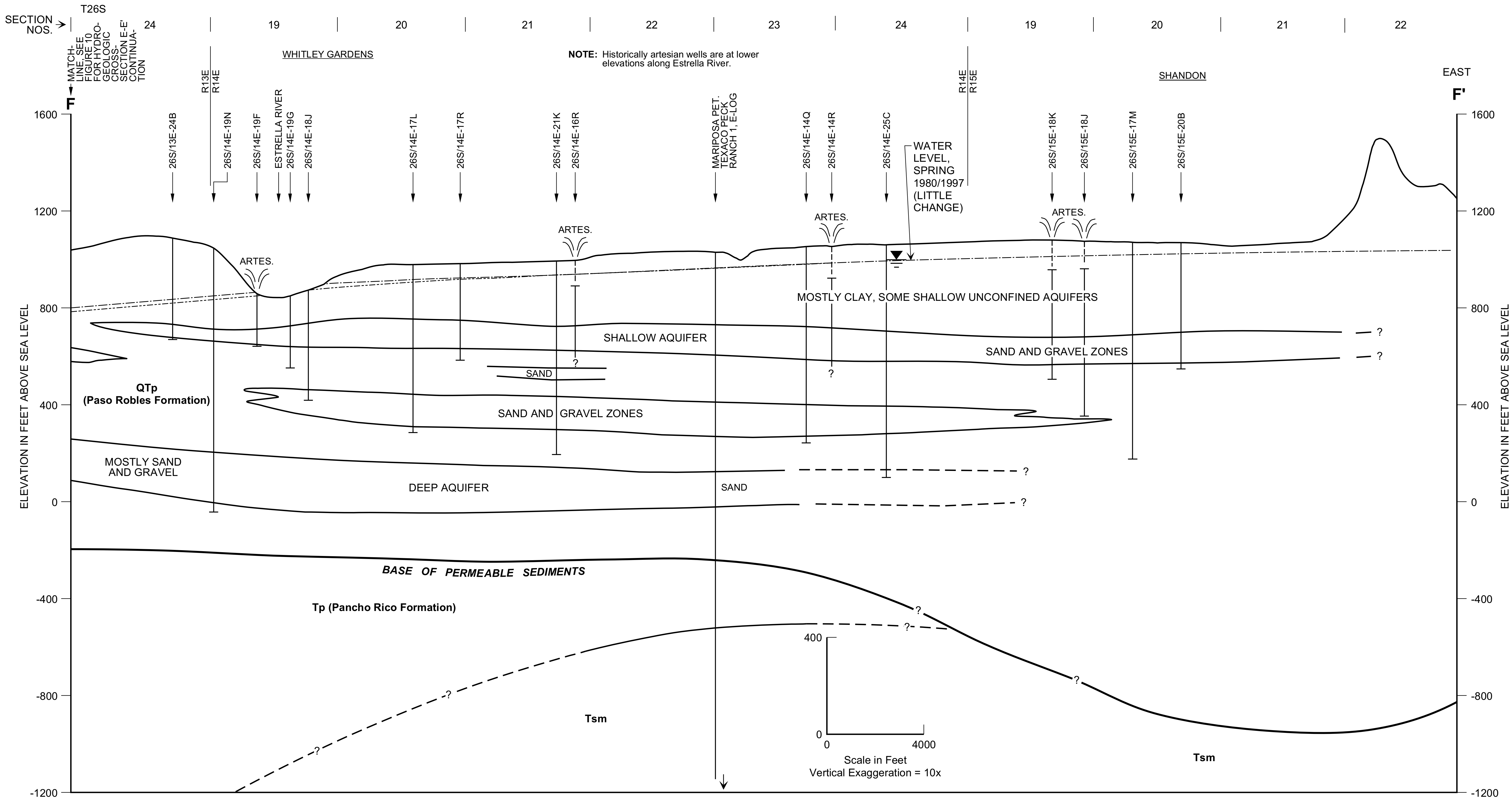
HYDROGEOLOGIC CROSS-SECTION E-E'

Estrella Area

Paso Robles Groundwater Basin Study

FIGURE 27

98711137sec2.dsf.p6



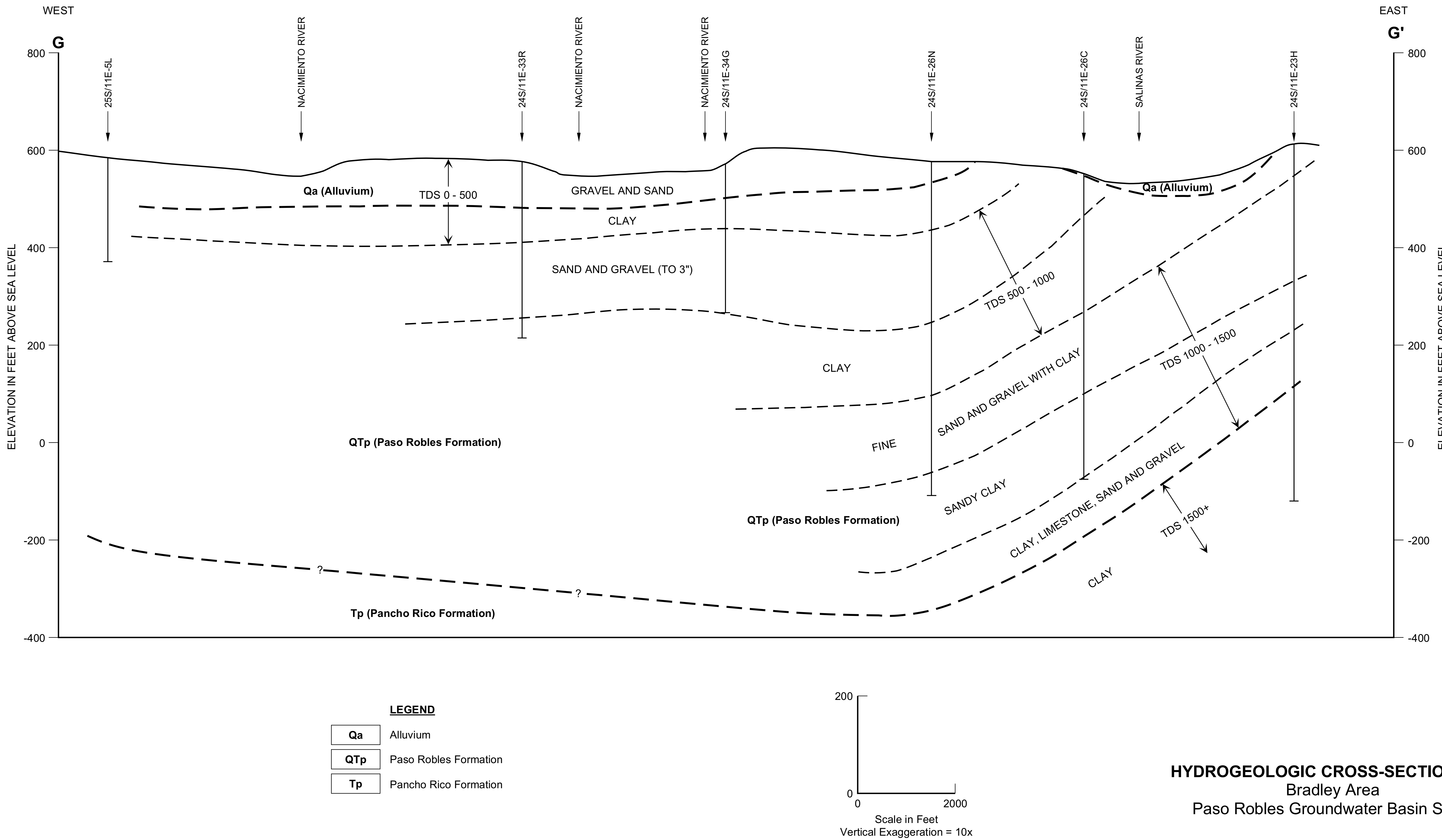
LEGEND

QTp	Paso Robles Formation
Tp	Pancho Rico Formation
Tsm	Santa Margarita Formation
Tm	Monterey Formation
—·—·—	Water Level in spring of 1980 (Beginning of Base Period)
—··—··—	Water Level in spring of 1997 (End of Base Period)

HYDROGEOLOGIC CROSS-SECTION F-F'
Shandon Area
Paso Robles Groundwater Basin Study

FIGURE 28

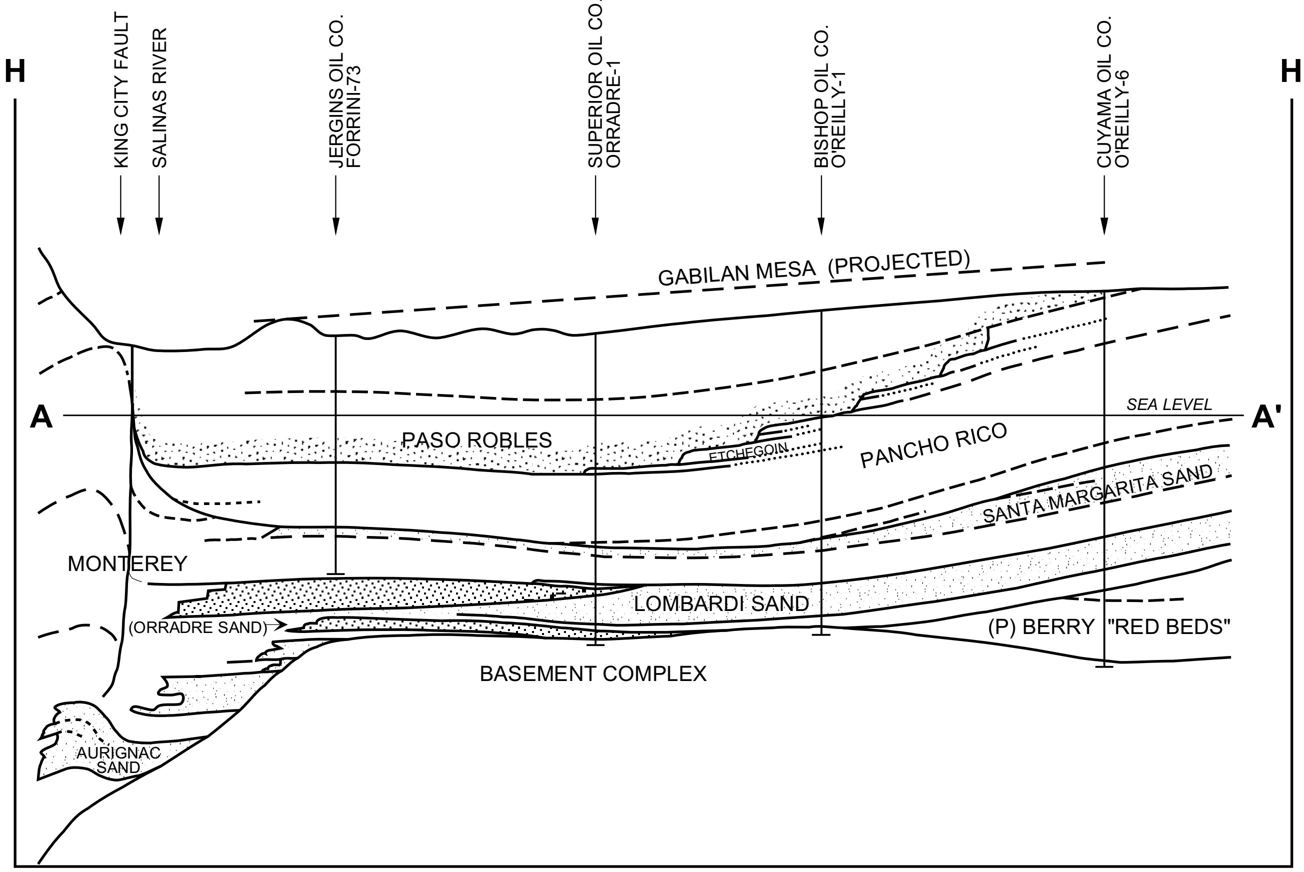
987111137sec2.dsf.p7



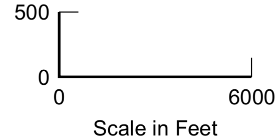
9871l1137sec2.dsf.p8

HYDROGEOLOGIC CROSS-SECTION G-G'
Bradley Area
Paso Robles Groundwater Basin Study

FIGURE 29



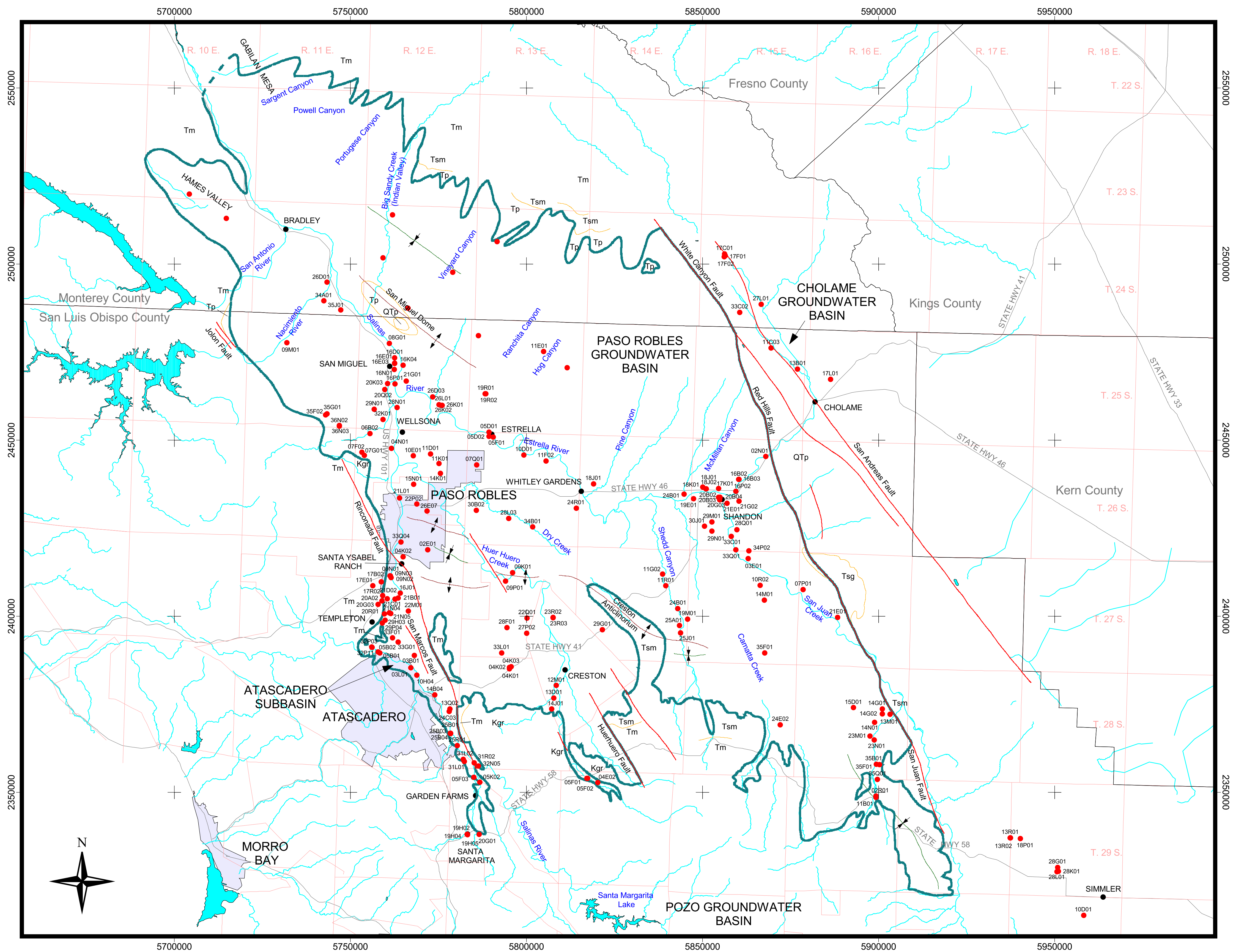
SOURCE: T.A. Baldwin, November 1948.



9871\1137sec2.dsf.p9

HYDROGEOLOGIC CROSS-SECTION H-H'
Bradley (San Ardo) Area
Paso Robles Groundwater Basin Study

FIGURE 30



Legend

- City
- Water Level Observation Wells
- Basin Outline
- Fault
- Anticline
- Syncline
- Streams
- Highways
- County Line
- Township and Range Grid

Geologic Units

Paso Robles Groundwater Basin Sediments	Qa	Alluvium
	Qoa	Older Alluvium
	Qls	Landslide
	QTp	Paso Robles Formation
Other Geologic Units	Tp	Pancho Rico Formation
	Tsm	Santa Margarita Sandstone
	Tm	Monterey Shale
	Tv	Vaqueros Formation
	Ts	Simmler Formation
	Tsg	unnamed (maroon) conglomerate
	Kgr	granite rocks

Notes:
1. Geologic units shown on base map around basin boundary are for reference only. For a geologic map of the basin see Figure 5.
2. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

30000 0 30000 Feet

Location of Water Level Observation Wells

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

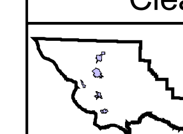


Figure 31

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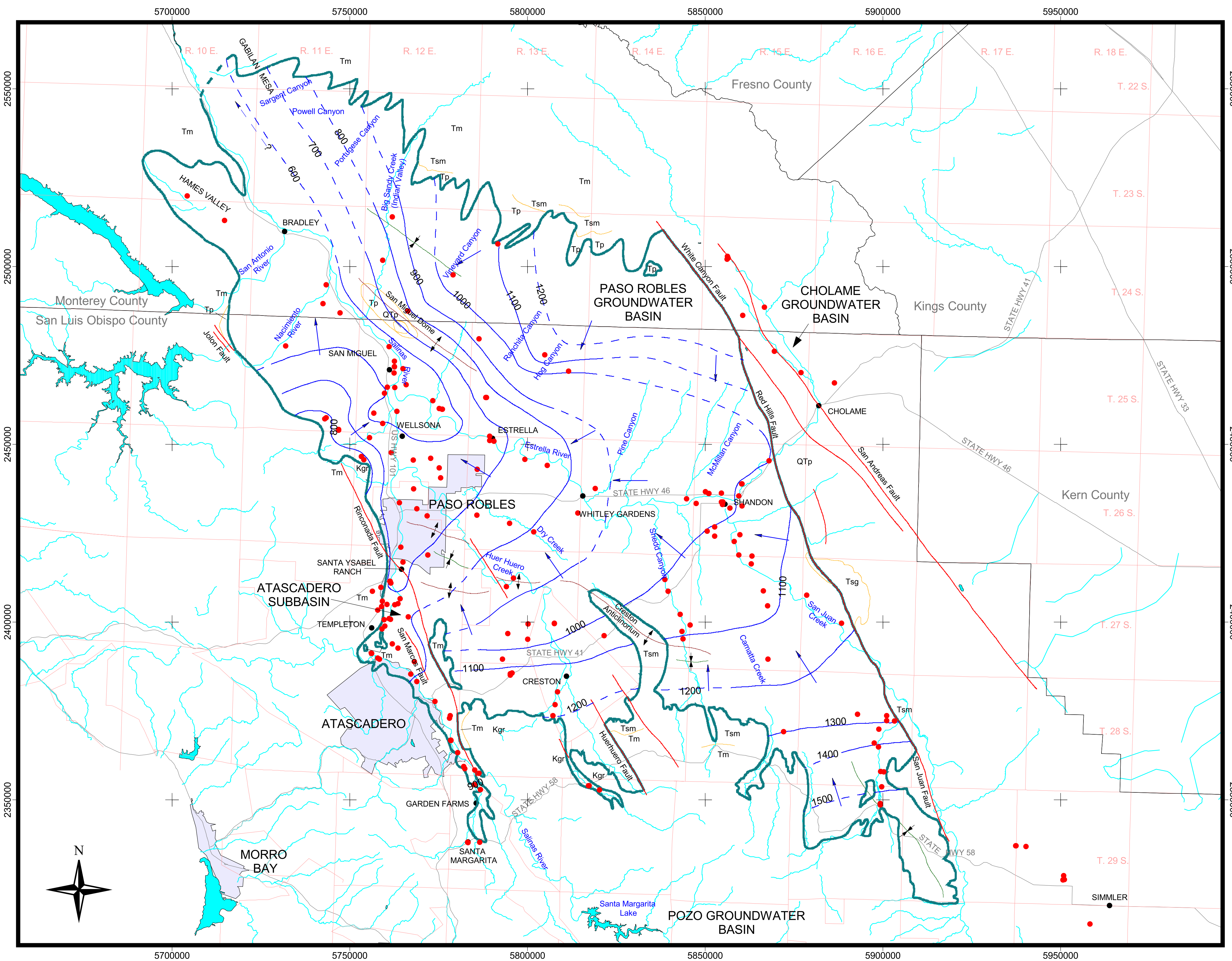
FUGRO



Legend

- City
- Water Level Observation Well
- Spring 1980 Regional Water Surface Elevation (feet MSL) Querried where infered. Contour interval = 100 ft
- Direction of Regional Groundwater Flow
- Basin Outline
- Fault
- Anticline
- Syncline
- Streams
- Highways
- County Line
- Township and Range Grid

Geologic Units

Paso Robles Groundwater Basin Sediments	Qa	Alluvium
	Qoa	Older Alluvium
	Qls	Landslide
	QTp	Paso Robles Formation
Other Geologic Units	Tp	Pancho Rico Formation
	Tsm	Santa Margarita Sandstone
	Tm	Monterey Shale
	Tv	Vaqueros Formation
	Ts	Simmler Formation
	Tsg	unnamed (maroon) conglomerate
	Kgr	granite rocks

Notes:
1. Geologic units shown on base map around basin boundary are for reference only. For a geologic map of the basin see Figure 5.
2. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

30000 0 30000 Feet

Spring 1980 Regional Water Surface

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

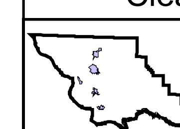
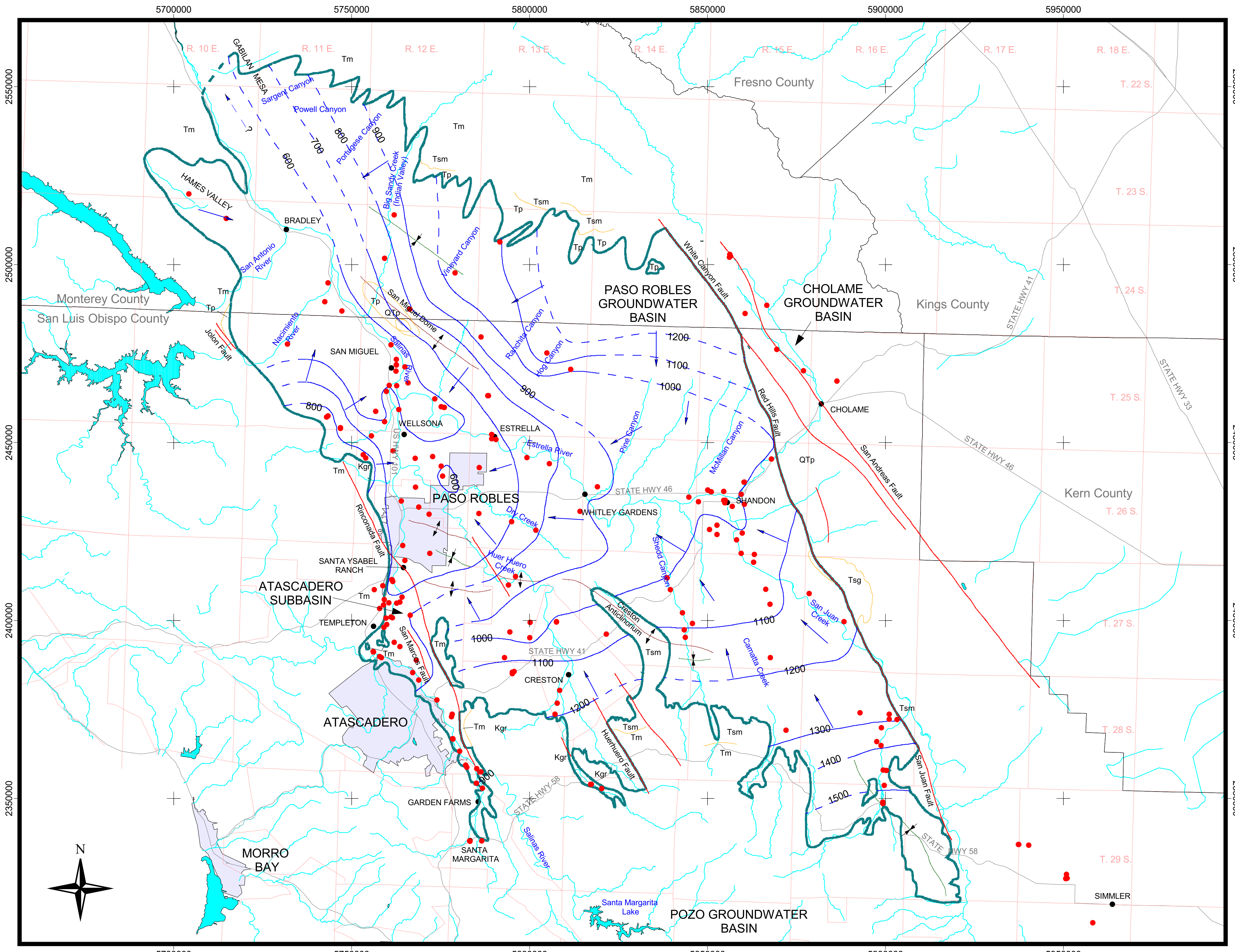


Figure 32

FUGRO



Legend

- City
- Water Level Observation Well
- Spring 1997 Regional Water Surface Elevation (feet MSL) Querried where infered. Contour interval = 100 ft
- Direction of Regional Groundwater Flow
- Basin Outline
- Fault
- Anticline
- Syncline
- Streams
- Highways
- County Line
- Township and Range Grid

Geologic Units

Paso Robles Groundwater Basin Sediments	Qa	Alluvium
	Qoa	Older Alluvium
	Qls	Landslide
	QTp	Paso Robles Formation
Other Geologic Units	Tp	Pancho Rico Formation
	Tsm	Santa Margarita Sandstone
	Tm	Monterey Shale
	Tv	Vaqueros Formation
	Ts	Simmler Formation
	Tsg	unnamed (maroon) conglomerate
	Kgr	granite rocks

Notes:
1. Geologic units shown on base map around basin boundary are for reference only. For a geologic map of the basin see Figure 5.
2. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

30000 0 30000 Feet

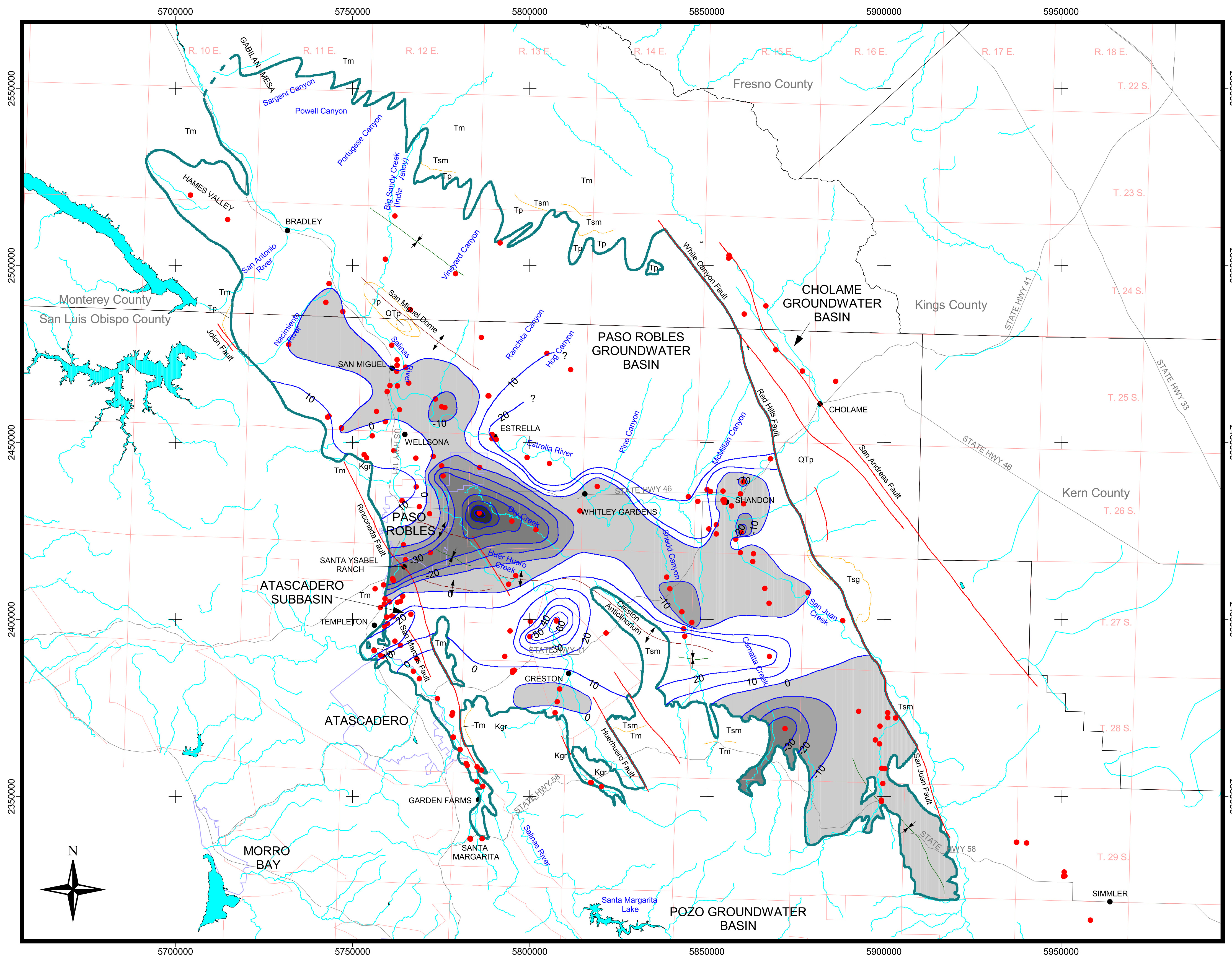
Spring 1997 Regional Water Surface

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 33

FUGRO



Legend

- City
- Water Level Observation Well
- Change in Regional Water Surface Elevation (Spring 1980 - Spring 1997) Querried where infered. Contour interval = 10 ft
- Basin Outline
- Fault
- Anticline
- Syncline
- Streams
- Highways
- County Line
- Township and Range Grid

Geologic Units

Paso Robles Groundwater Basin Sediments	Qa	Alluvium
	Qoa	Older Alluvium
	Qls	Landslide
	QTp	Paso Robles Formation
Other Geologic Units	Tp	Pancho Rico Formation
	Tsm	Santa Margarita Sandstone
	Tm	Monterey Shale
	Tv	Vaqueros Formation
	Ts	Simmler Formation
	Tsg	unnamed (maroon) conglomerate
	Kgr	granite rocks

Notes:
1. Shaded areas represent a negative change in the regional water surface elevation between the Spring of 1980 and the Spring of 1997.
2. Geologic units shown on base map around basin boundary are for reference only. For a geologic map of the basin see Figure 5.
3. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

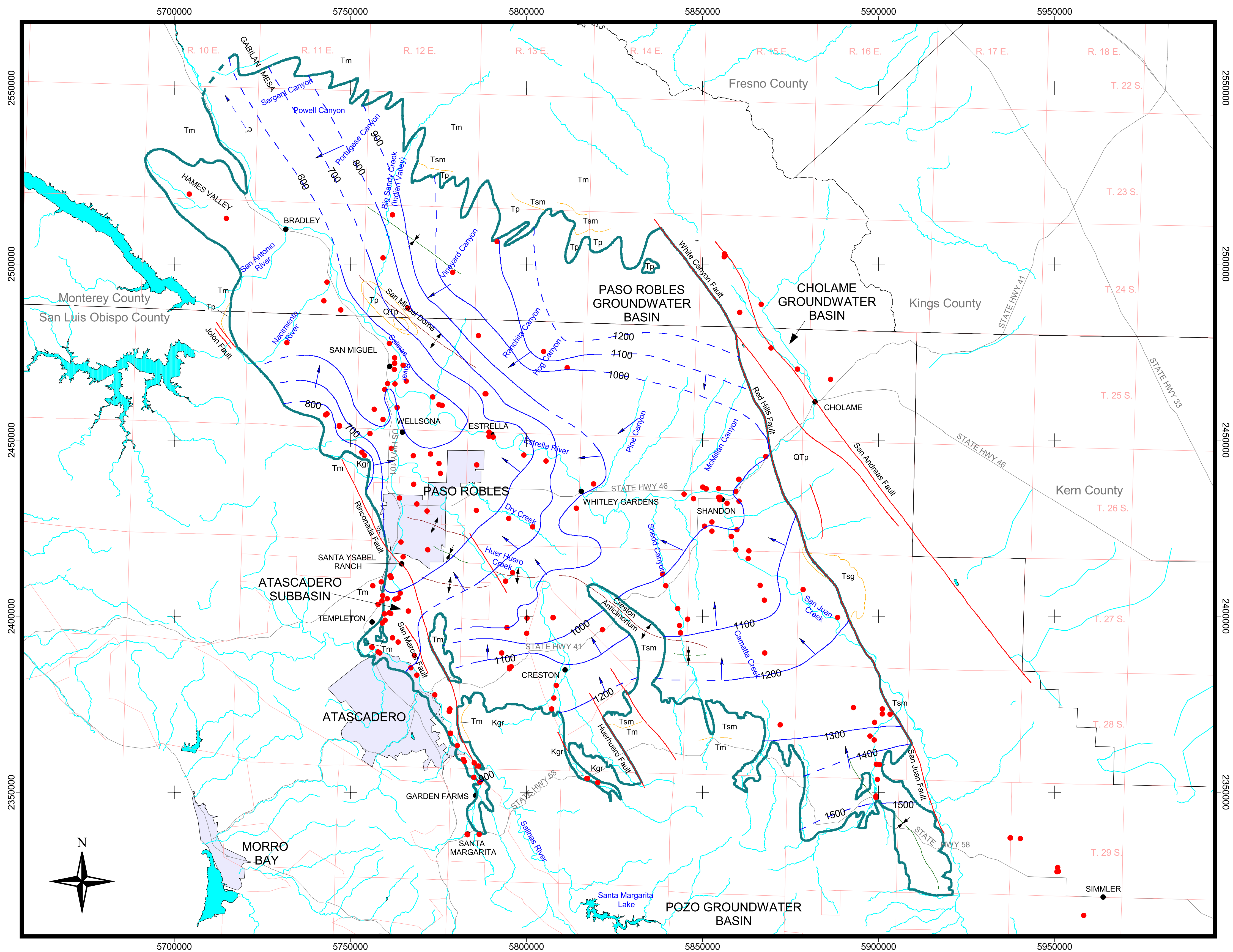
30000 0 30000 Feet

Change in Water Surface Elevation (Spring 1980 - Spring 1997)

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 34



Legend

- City
- Water Level Observation Well
- Fall 1990 Regional Water Surface Elevation (feet MSL) Querried where infered. Contour interval = 100 ft
- Direction of Regional Groundwater Flow
- Basin Outline
- Fault
- Anticline
- Syncline
- Streams
- Highways
- County Line
- Township and Range Grid

Geologic Units

Paso Robles Groundwater Basin Sediments	Qa	Alluvium
	Qoa	Older Alluvium
	Qls	Landslide
	QTp	Paso Robles Formation
Other Geologic Units	Tp	Pancho Rico Formation
	Tsm	Santa Margarita Sandstone
	Tm	Monterey Shale
	Tv	Vaqueros Formation
	Ts	Simmler Formation
	Tsg	unnamed (maroon) conglomerate
	Kgr	granite rocks

Notes:
1. Geologic units shown on base map around basin boundary are for reference only. For a geologic map of the basin see Figure 5.
2. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

30000 0 30000 Feet

Fall 1990 Regional Water Surface

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

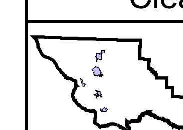
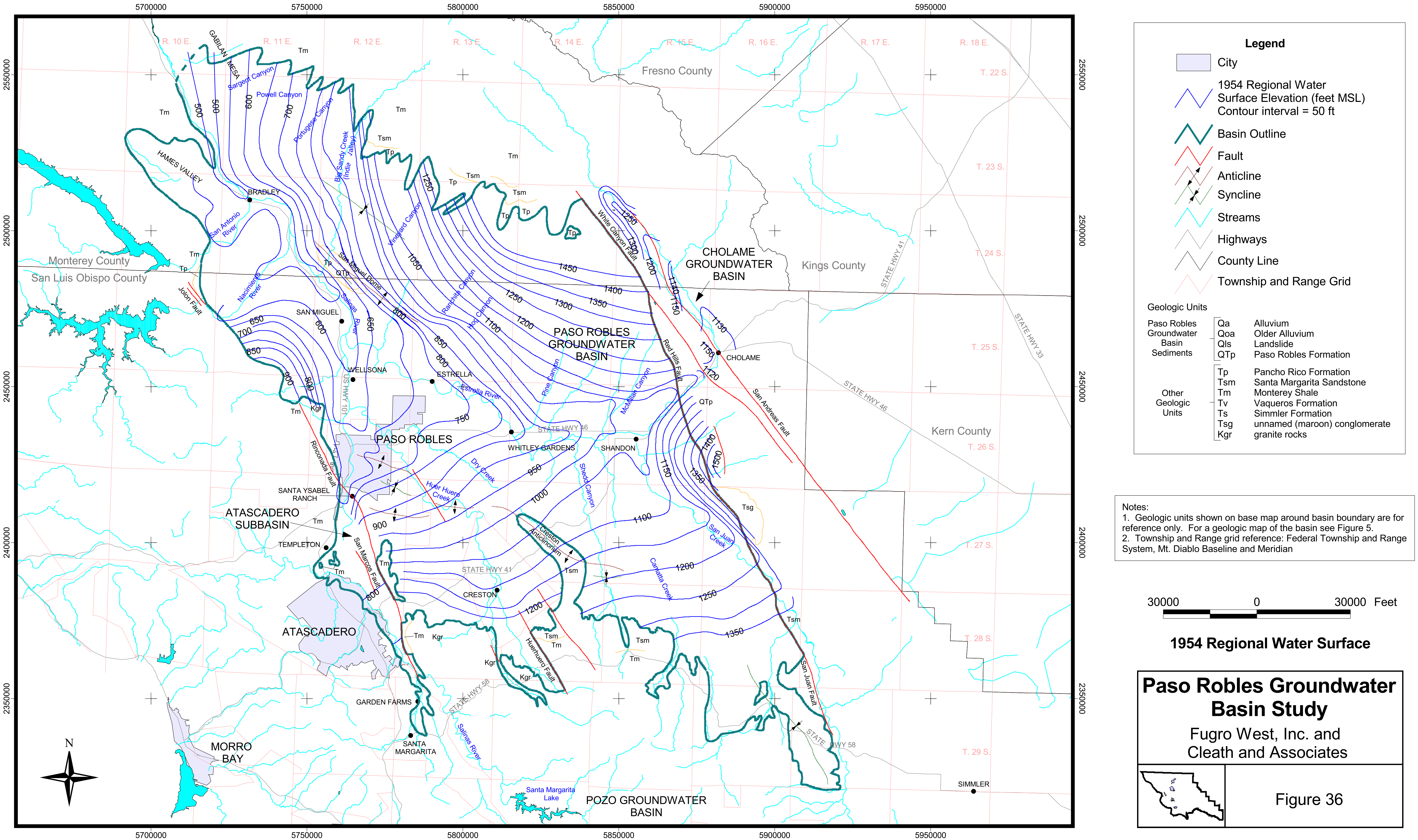


Figure 35

Project No. 98-71-1137



Notes:
1. Geologic units shown on base map around basin boundary are for reference only. For a geologic map of the basin see Figure 5.
2. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

30000 0 30000 Feet

1954 Regional Water Surface

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 36

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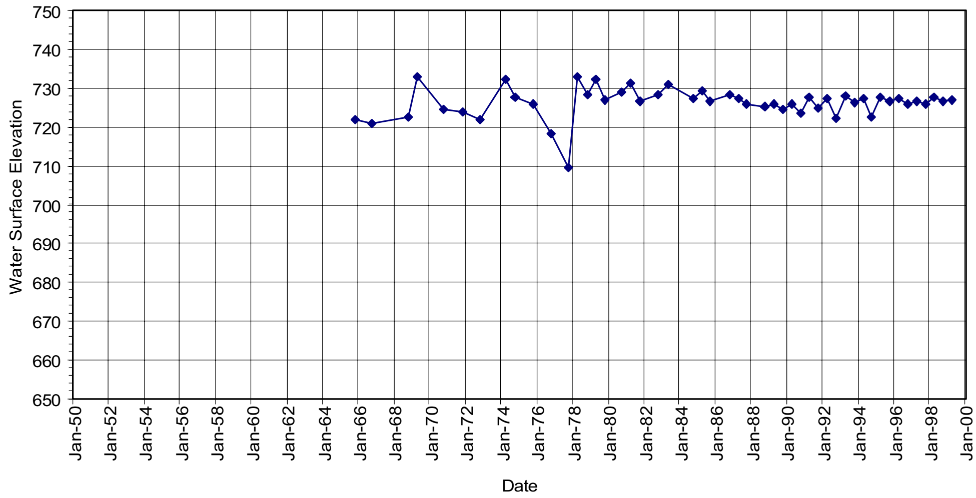
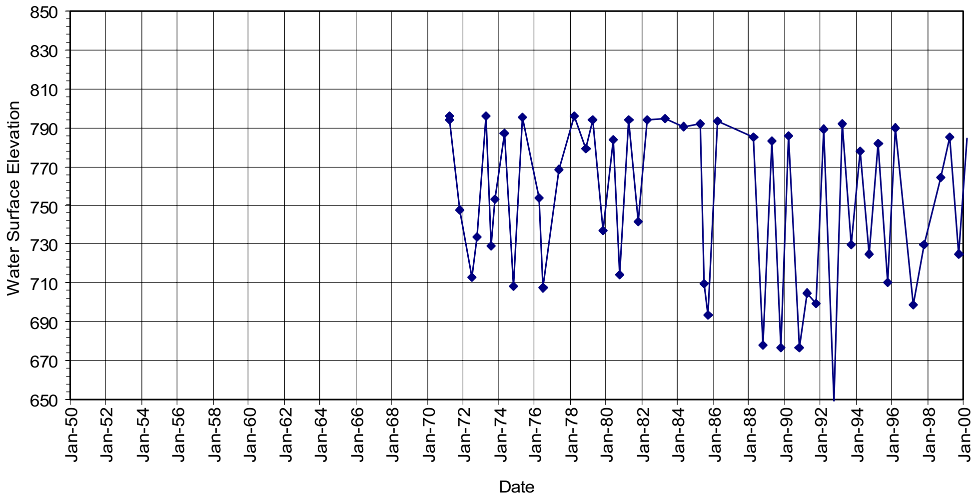
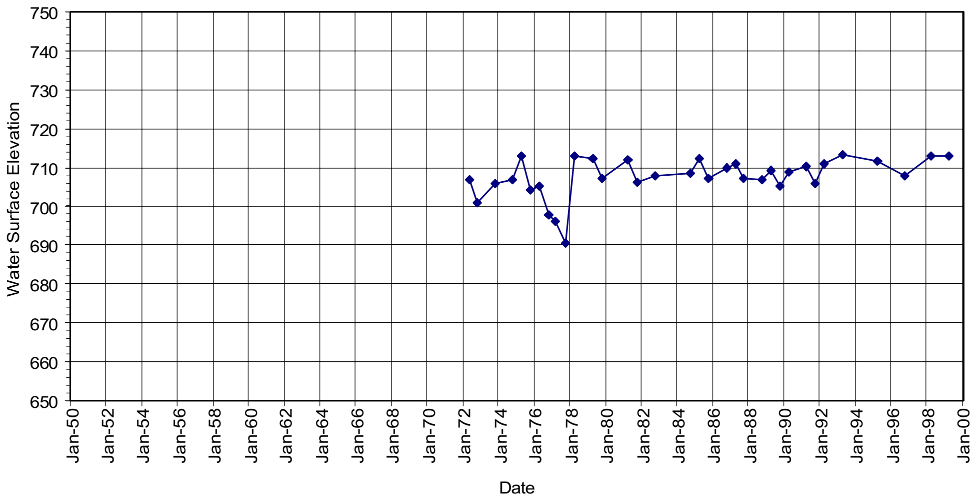


Well 27S/12E-21C01



Well 28S/12E-10H04



Well 27S/12E-16J01

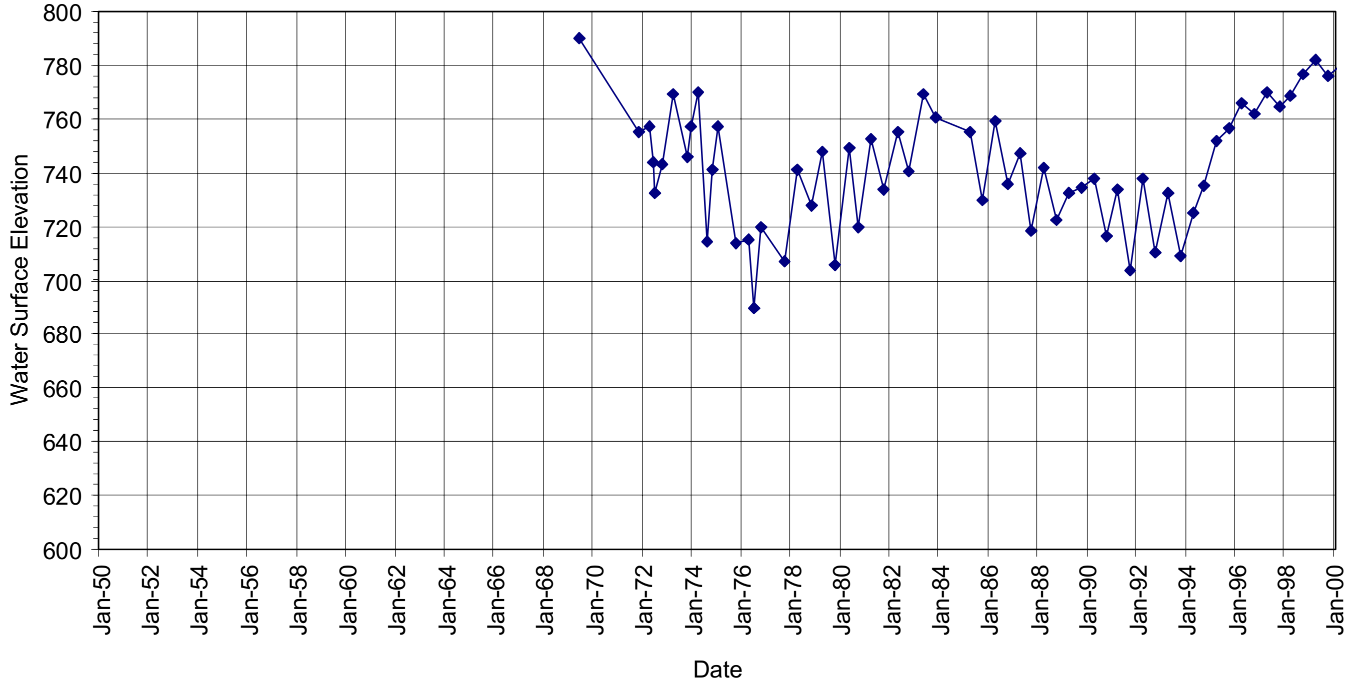
9871\1137wat1.dsf,p1

WATER LEVEL HYDROGRAPHS

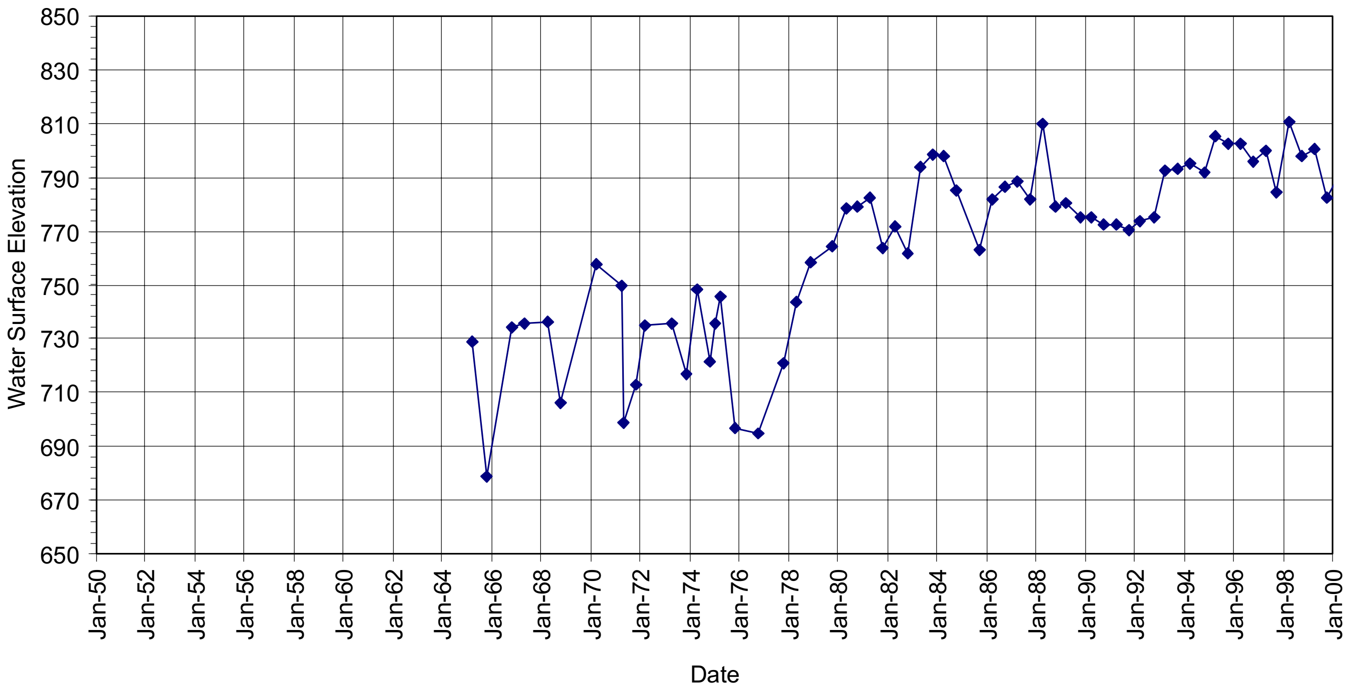
Atascadero Subbasin

Paso Robles Groundwater Basin Study

FIGURE 37



Well 27S/12E-33F01

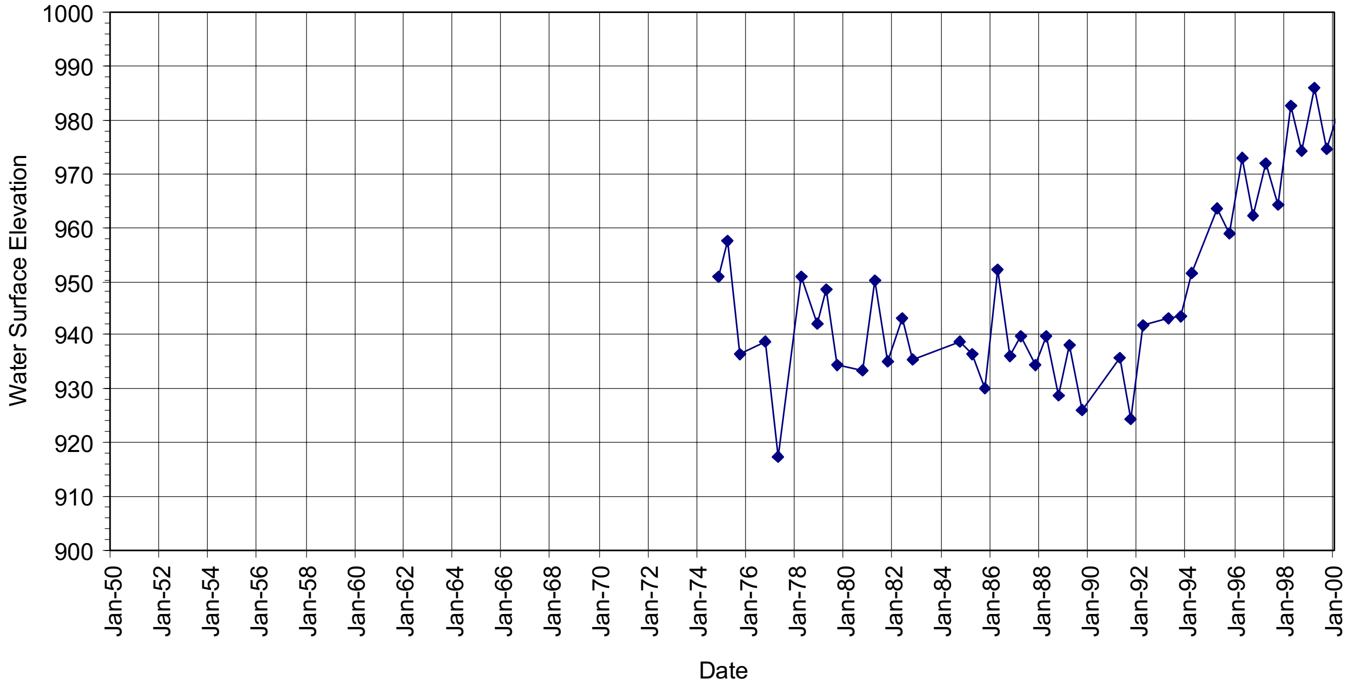


Well 27S/12E-22M01

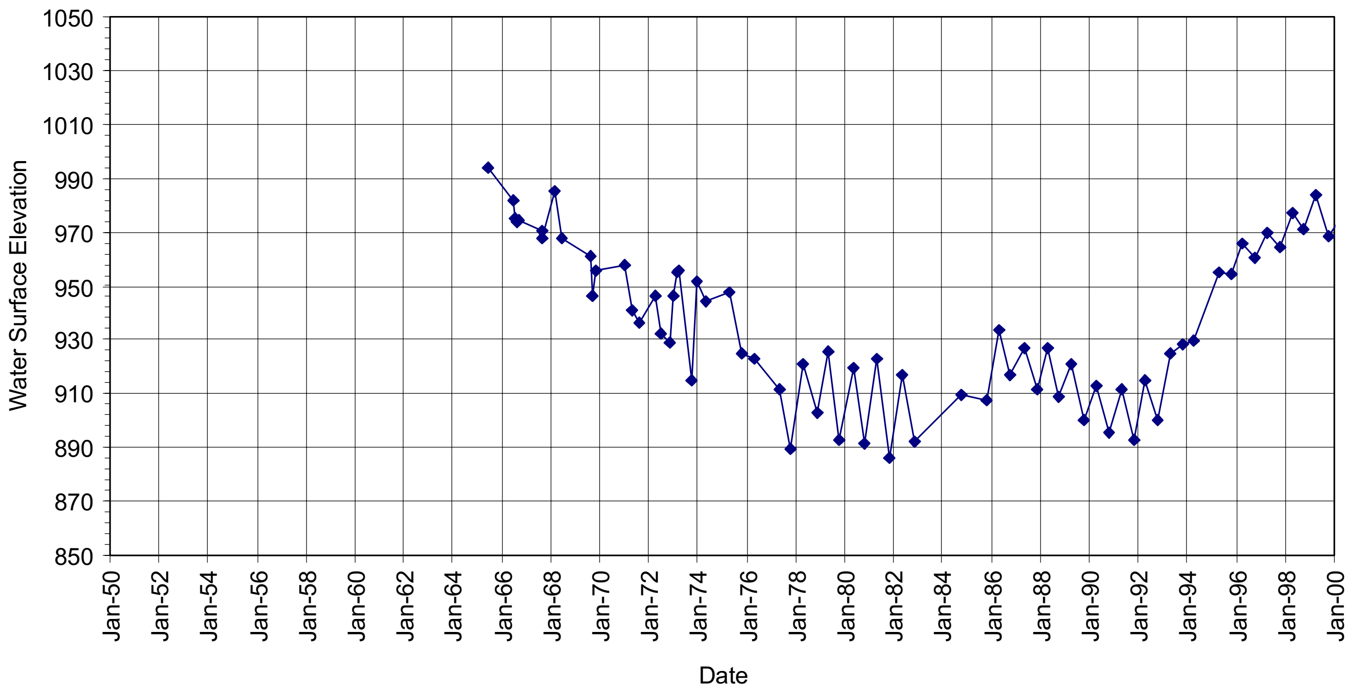
9871\1137wat1.dsf,p2

WATER LEVEL HYDROGRAPHS
Atascadero Subbasin
Paso Robles Groundwater Basin Study

FIGURE 38



Well 27S/13E-22Q01

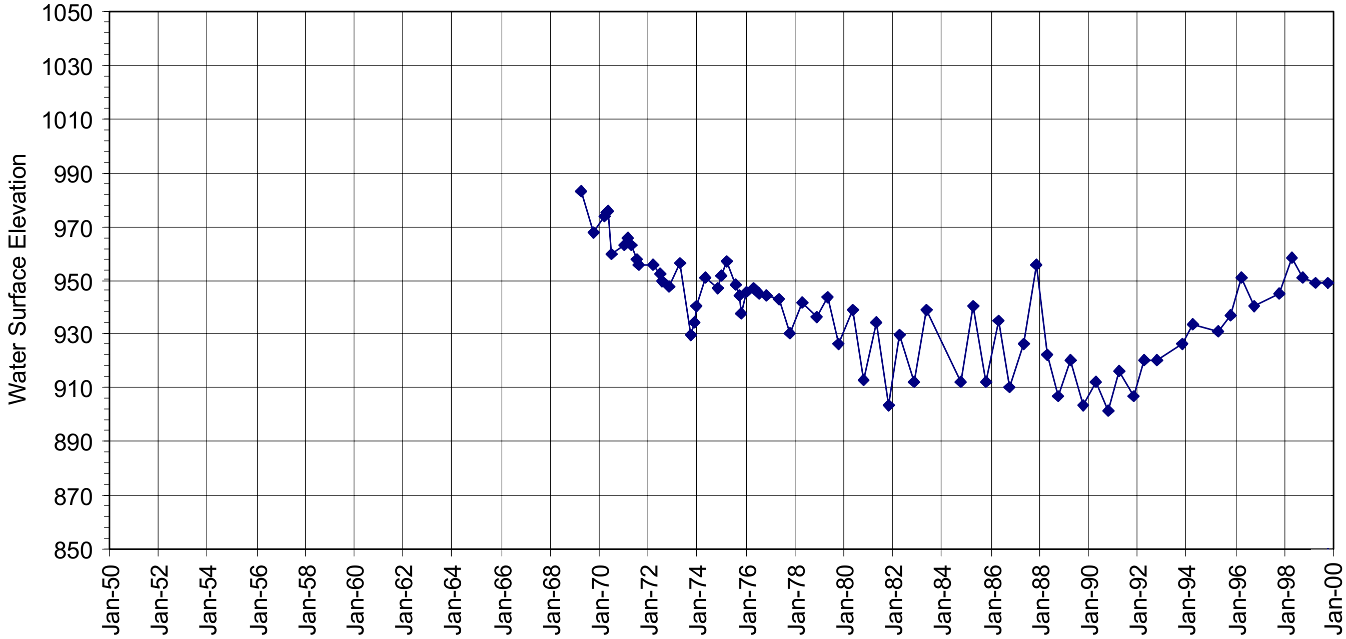


Well 27S/13E-27P02

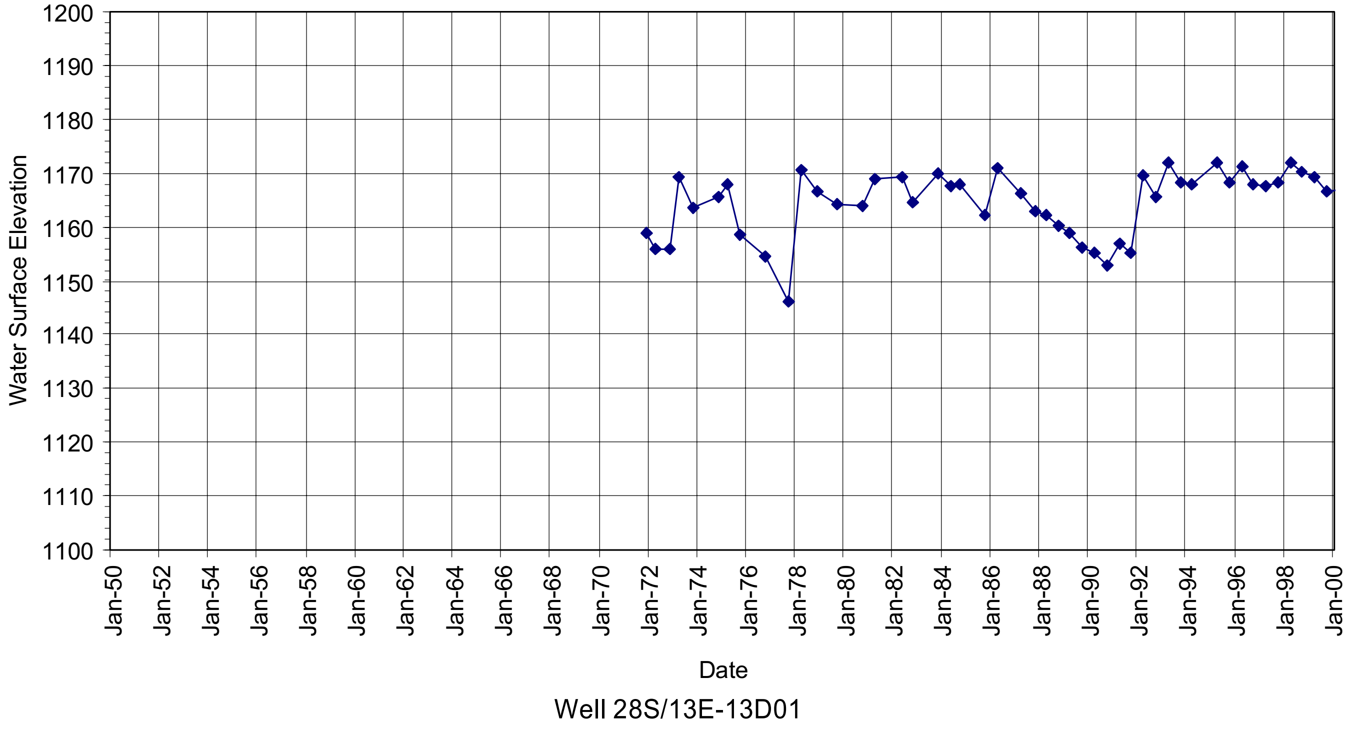
9871\1137wat1.dsf,p3

WATER LEVEL HYDROGRAPHS
Creston Area
Paso Robles Groundwater Basin Study

FIGURE 39



Well 27S/13E-28F01

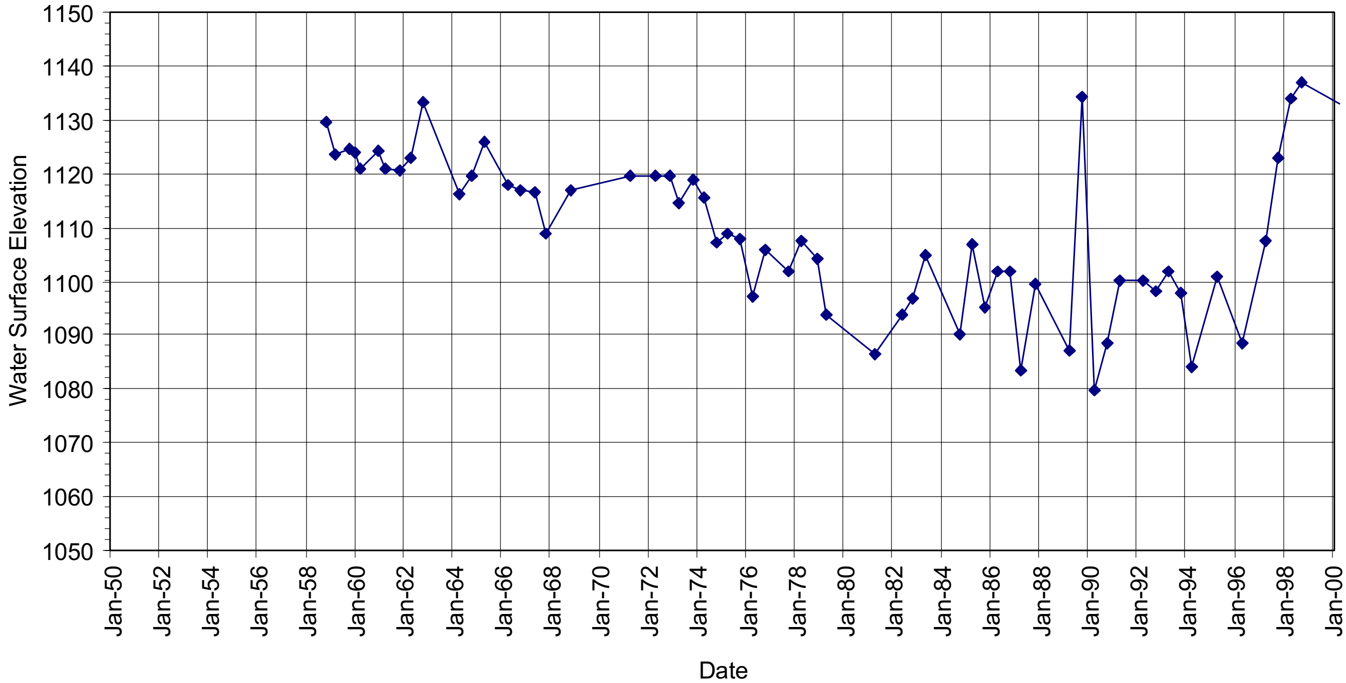


Well 28S/13E-13D01

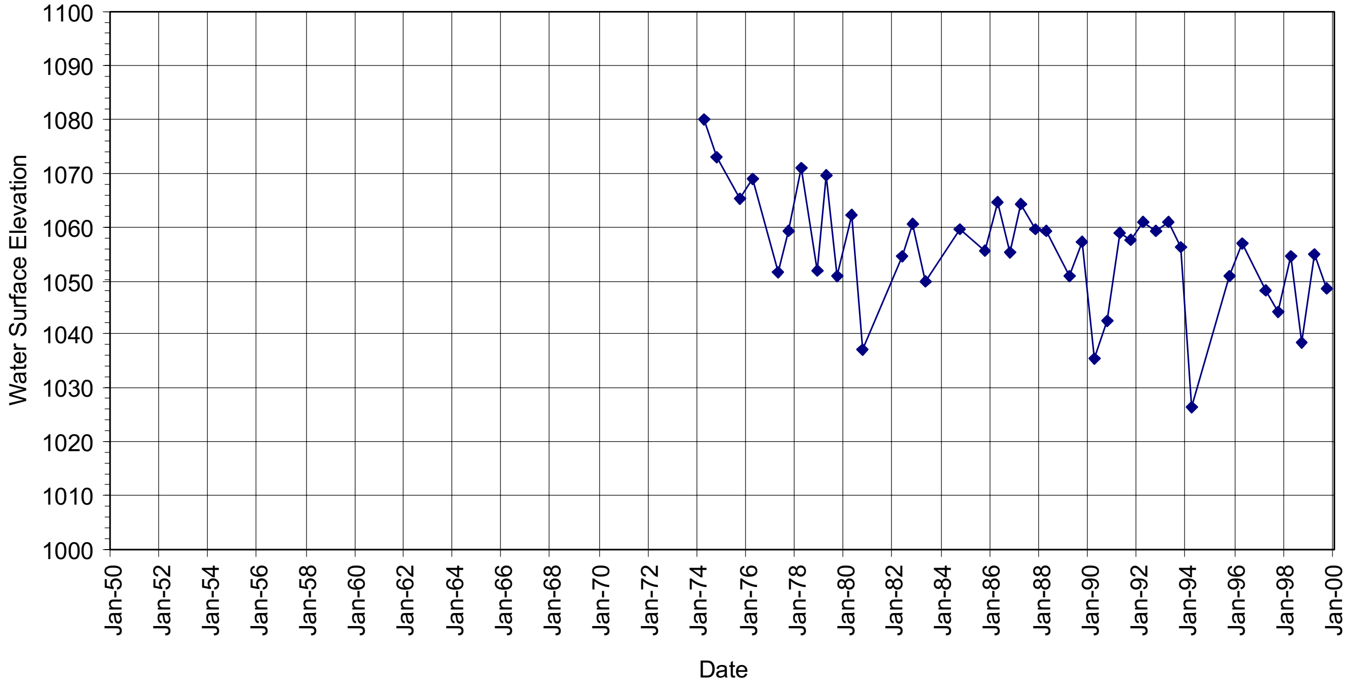
9871\1137wat1.dsf,p4

WATER LEVEL HYDROGRAPHS
Creston Area
Paso Robles Groundwater Basin Study

FIGURE 40



Well 27S/14E-25A01

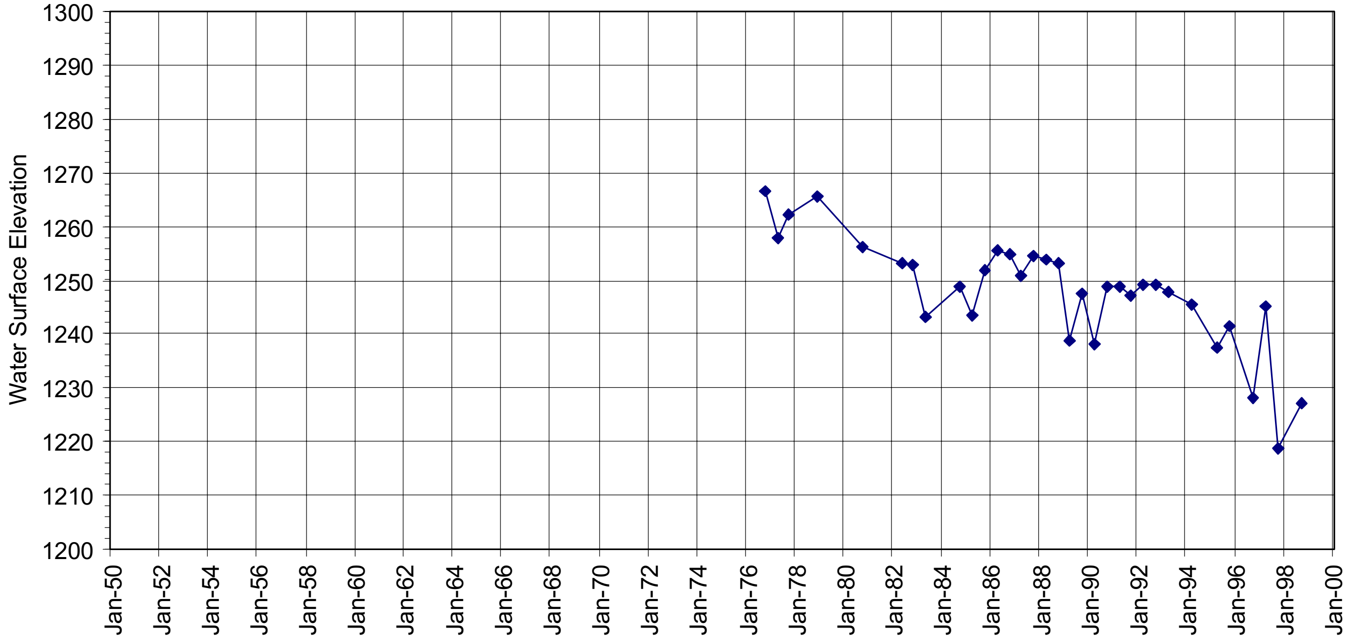


Well 27S/14E-11R01

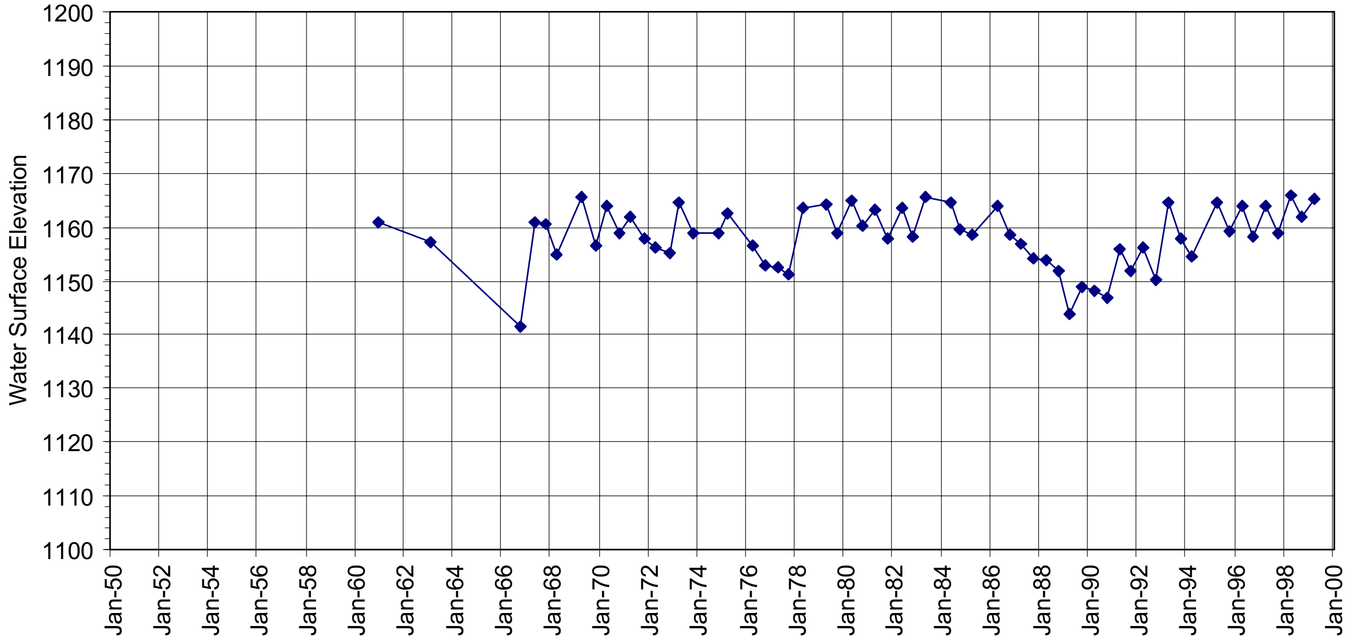
9871\1137wat1.dsf,p5

WATER LEVEL HYDROGRAPHS
San Juan Area
Paso Robles Groundwater Basin Study

FIGURE 41



Well 28S/16E-15D01

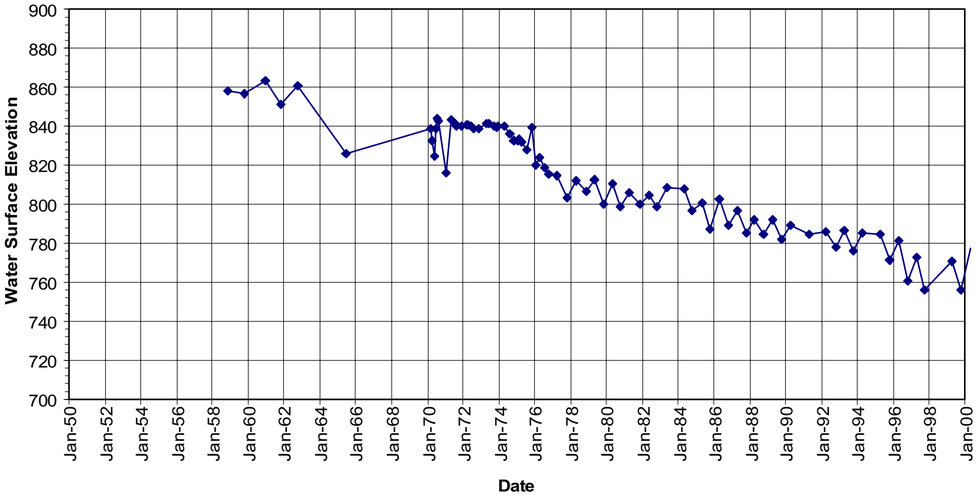


Well 27S/16E-07P01

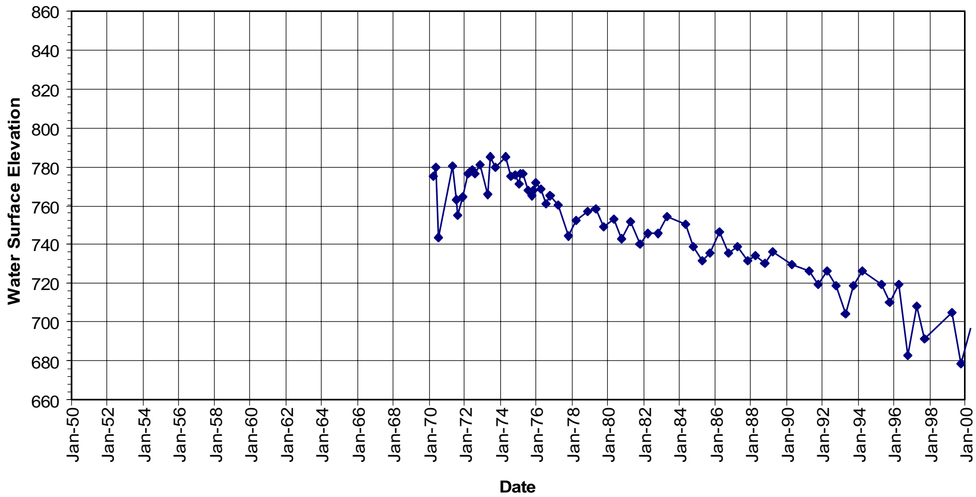
9871\1137wat1.dsf,p6

WATER LEVEL HYDROGRAPHS
San Juan Area
Paso Robles Groundwater Basin Study

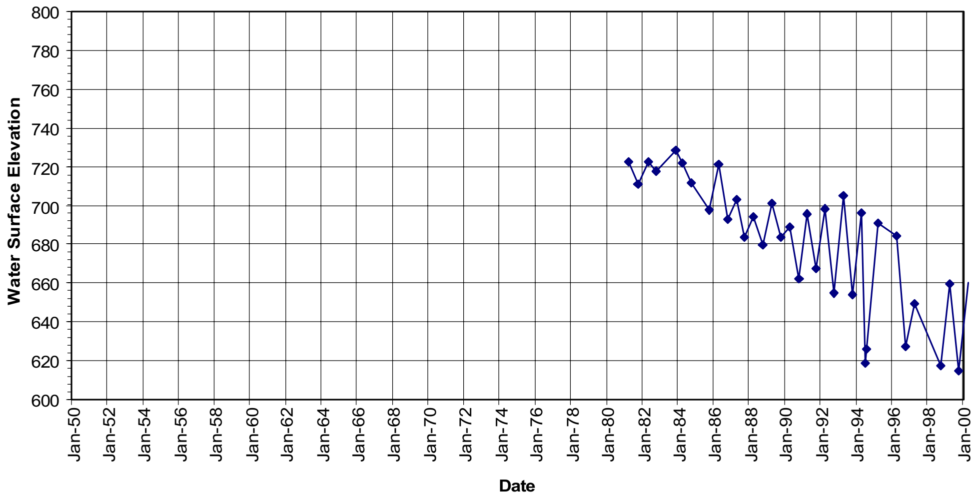
FIGURE 42



Well 26S/13E-34B01



Well 26S/13E-28L03

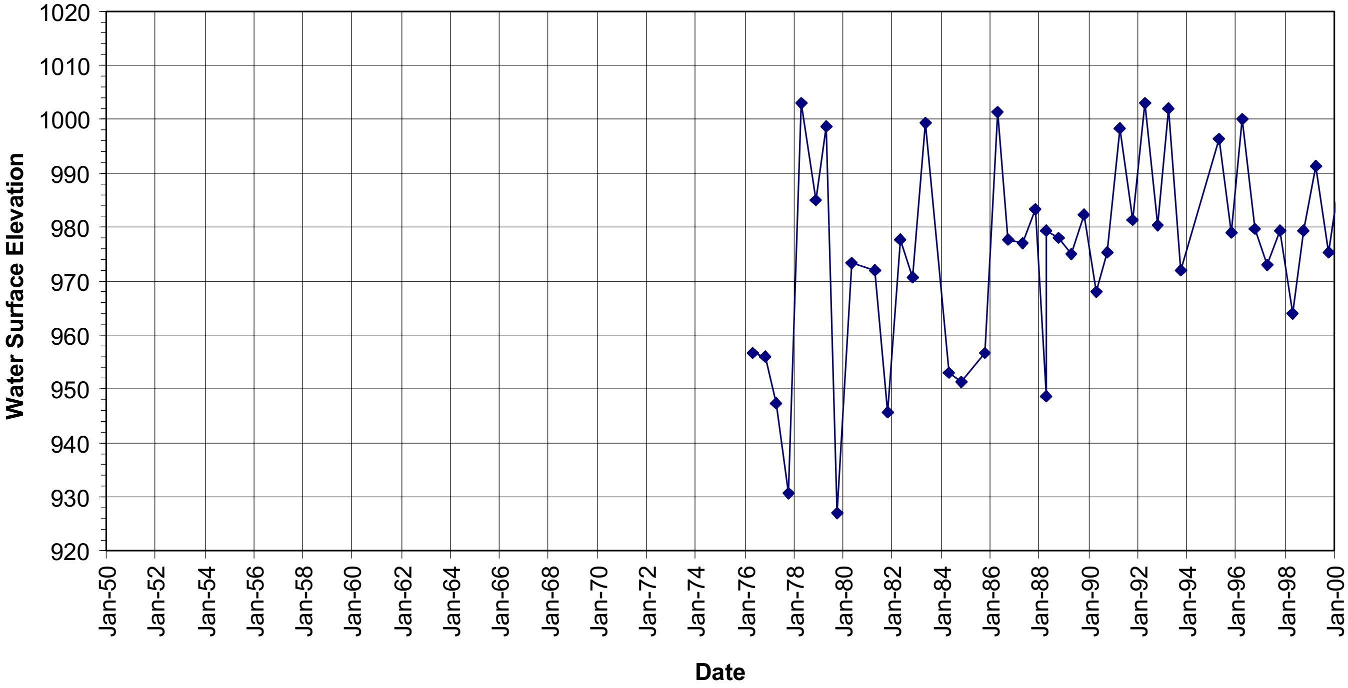


Well 26S/13E-30B02

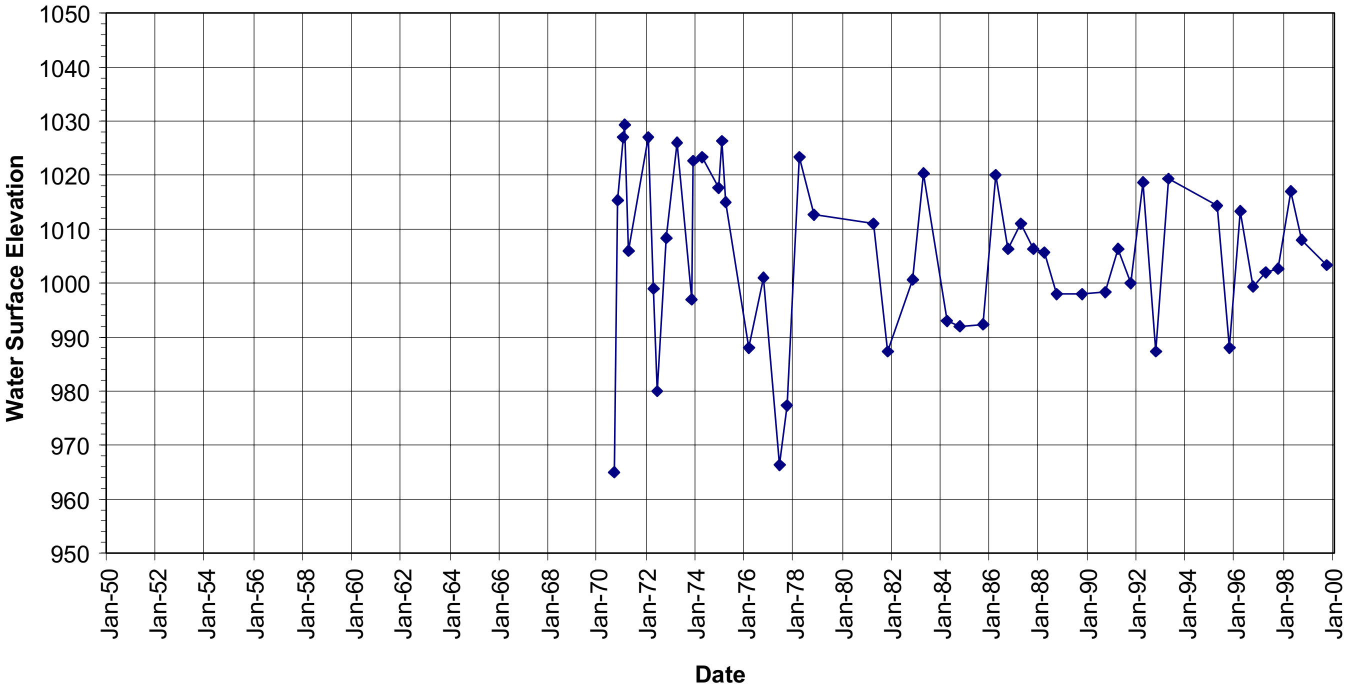
9871\1137wat2.dsf,p1

WATER LEVEL HYDROGRAPHS
Estrella Area
Paso Robles Groundwater Basin Study

FIGURE 43



Well 26S/15E-18J01

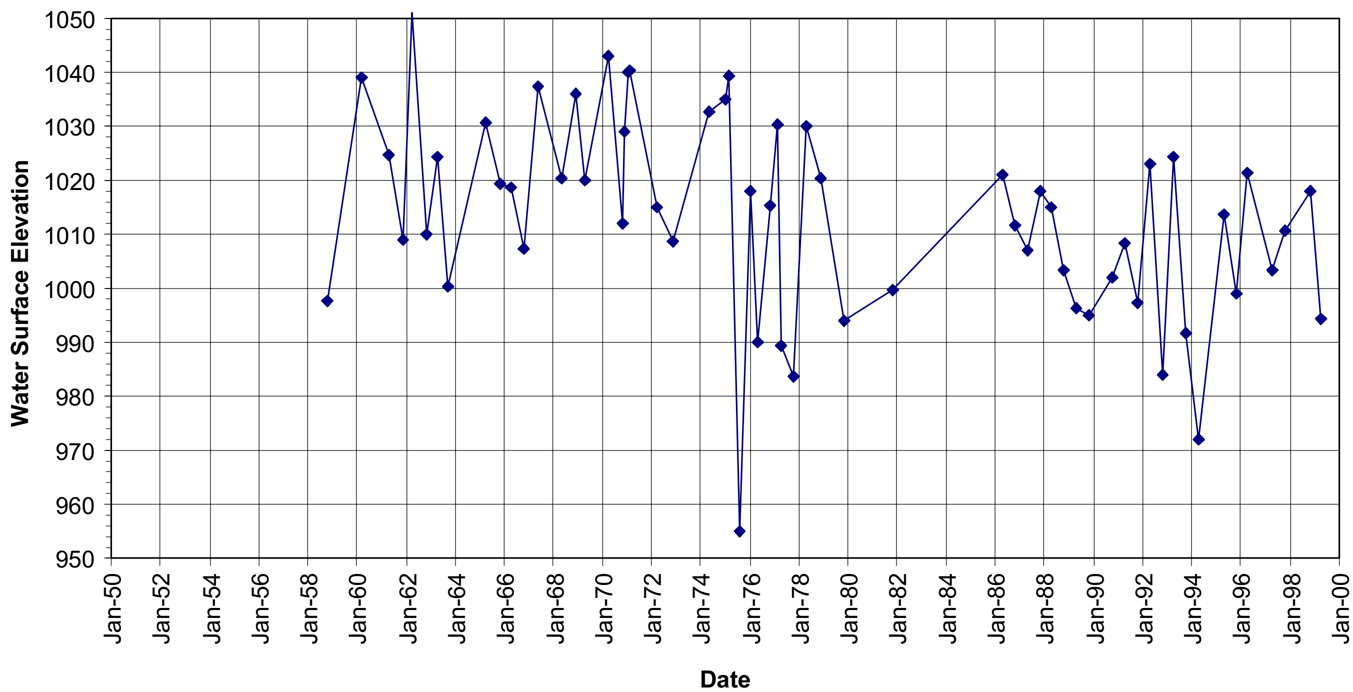


Well 26S/15E-21G02

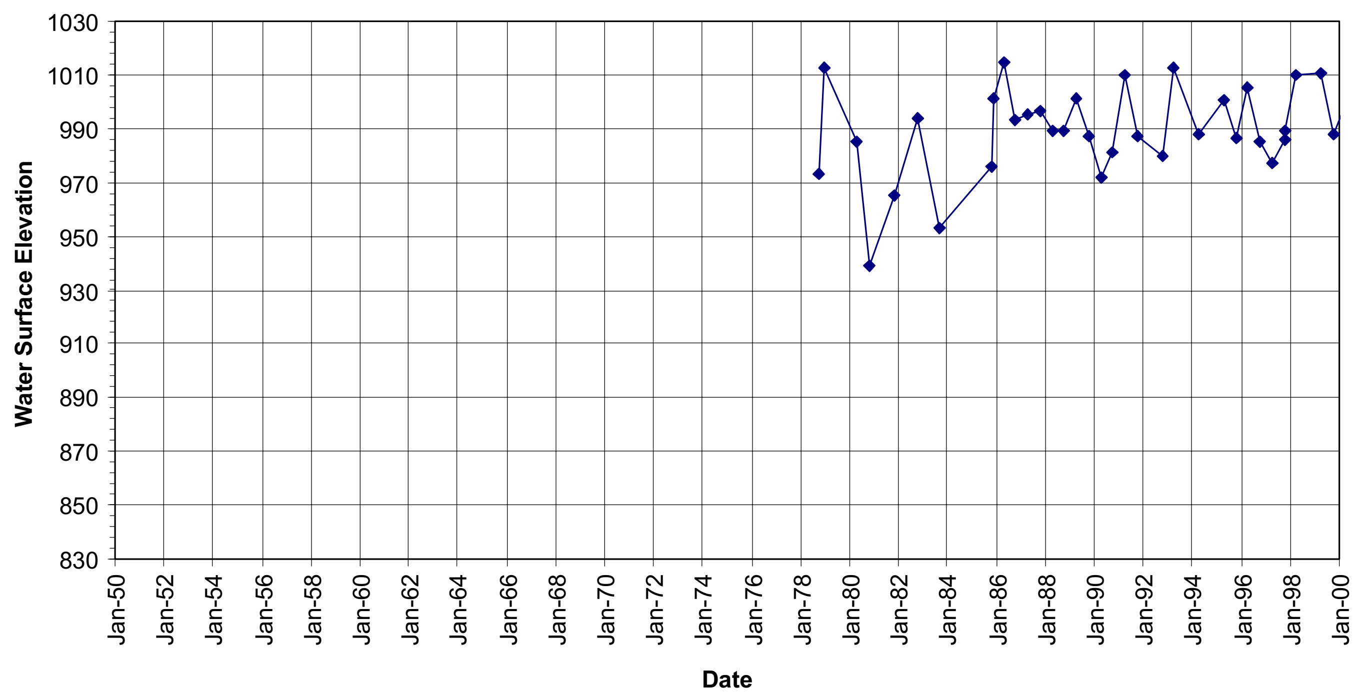
9871\1137wat2.dsf,p2

WATER LEVEL HYDROGRAPHS
Shandon Area
Paso Robles Groundwater Basin Study

FIGURE 44



Well 26S/15E-28Q01

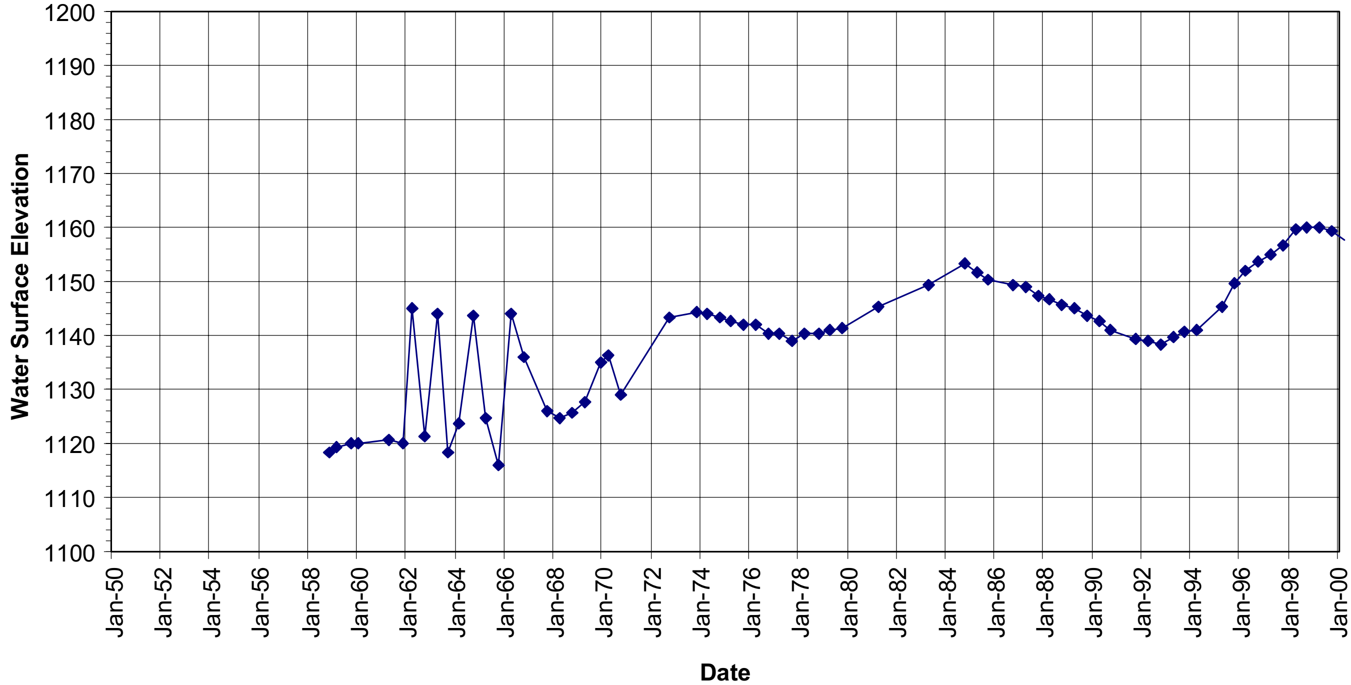


Well 26S/15E-20B03

9871\1137wat2.dsf,p3

WATER LEVEL HYDROGRAPHS
Shandon Area
Paso Robles Groundwater Basin Study

FIGURE 45

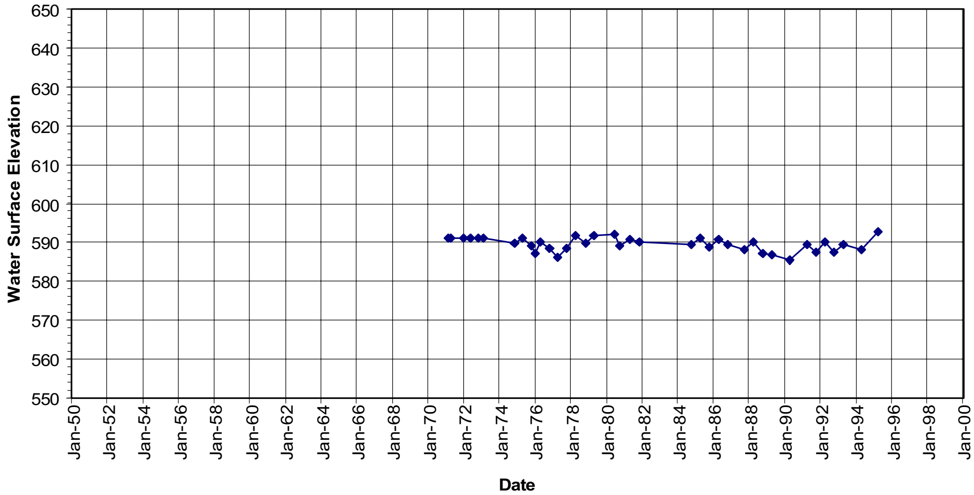


Well 25S/13E-11E01

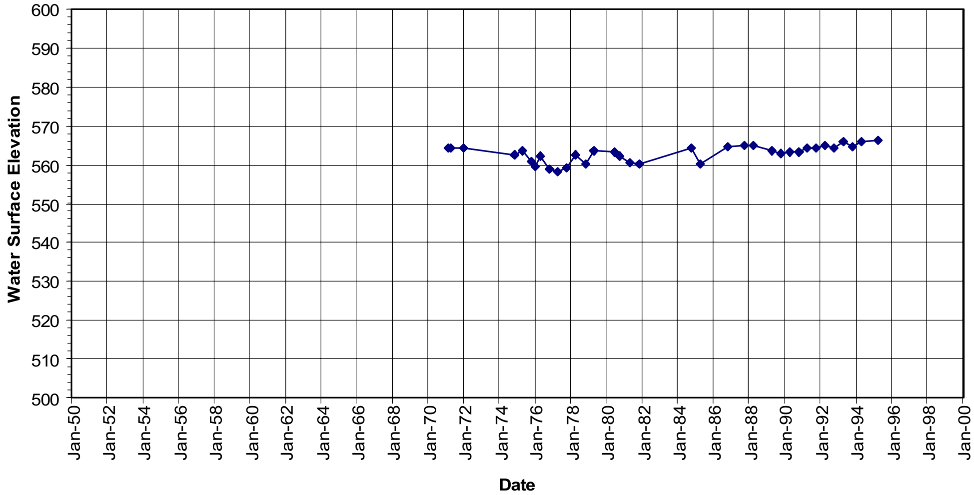
9871\1137wat2.dsf,p4

WATER LEVEL HYDROGRAPH
Gabilan Area
Paso Robles Groundwater Basin Study

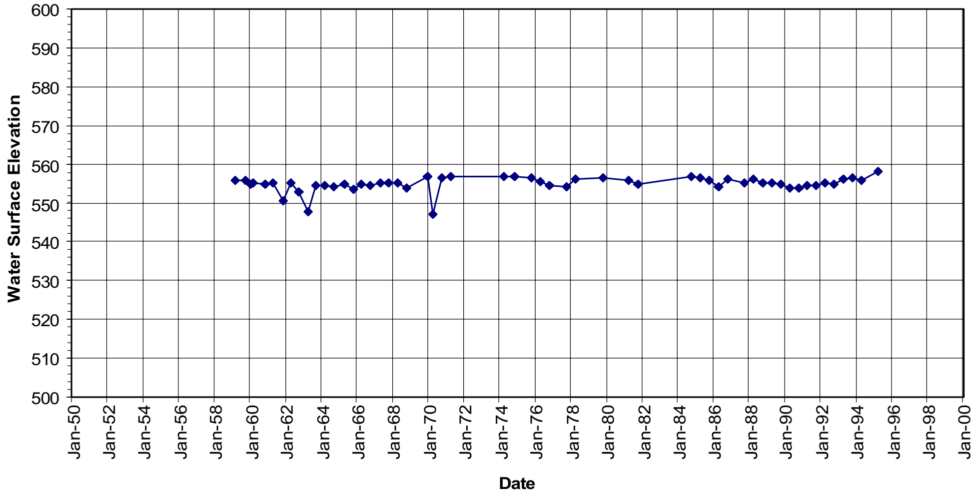
FIGURE 46



Well 24S/11E-35A01



Well 24S/11E-26D01



Well 24S/11E-35J01

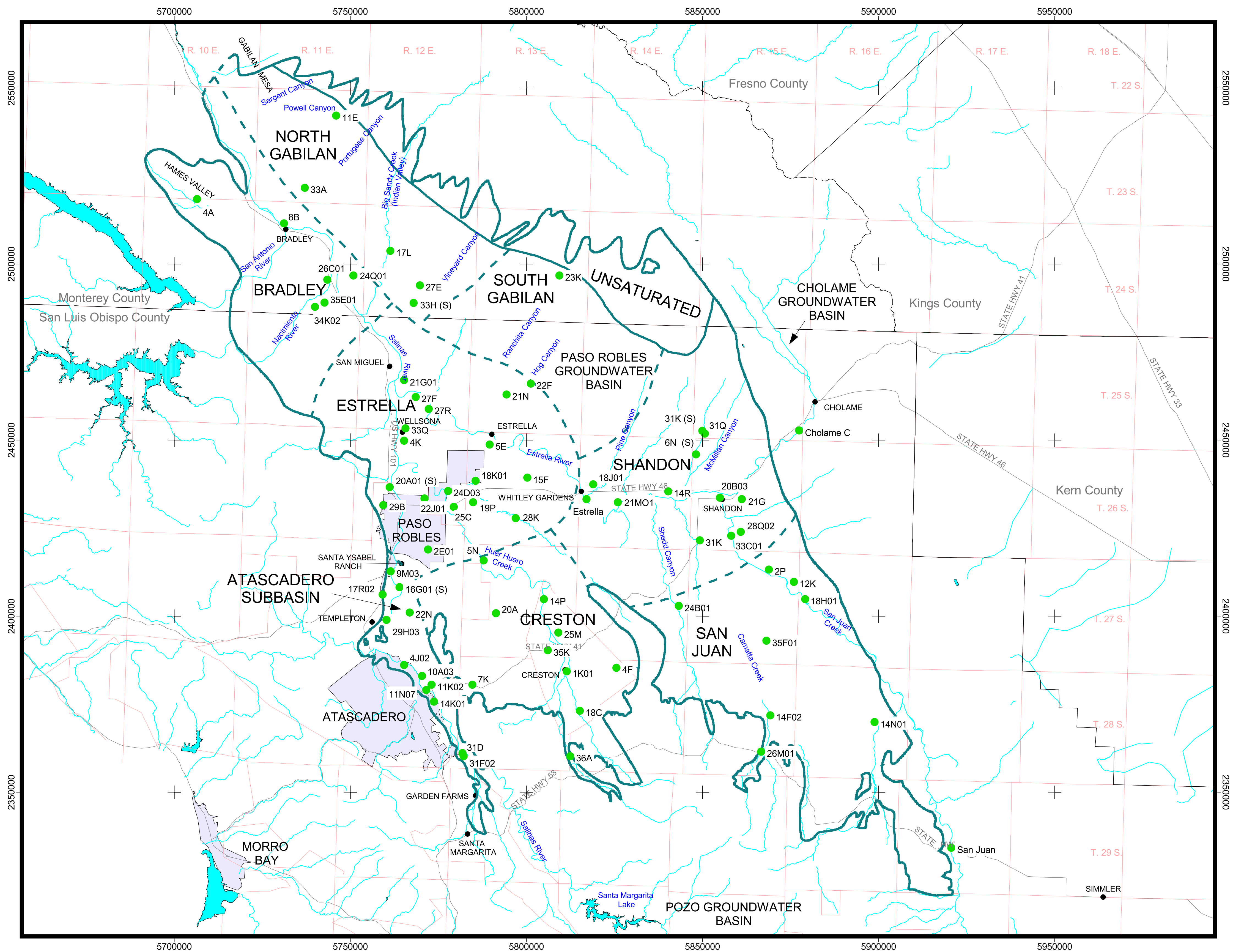
9871\1137wat2.dsf,p5

WATER LEVEL HYDROGRAPHS

Bradley Area

Paso Robles Groundwater Basin Study

FIGURE 47



Legend

- 35K Sample Locations
- City Outlines
- Basin Outline
- Streams
- Highways
- County Line
- Township and Range Grid

Note:
1. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

N

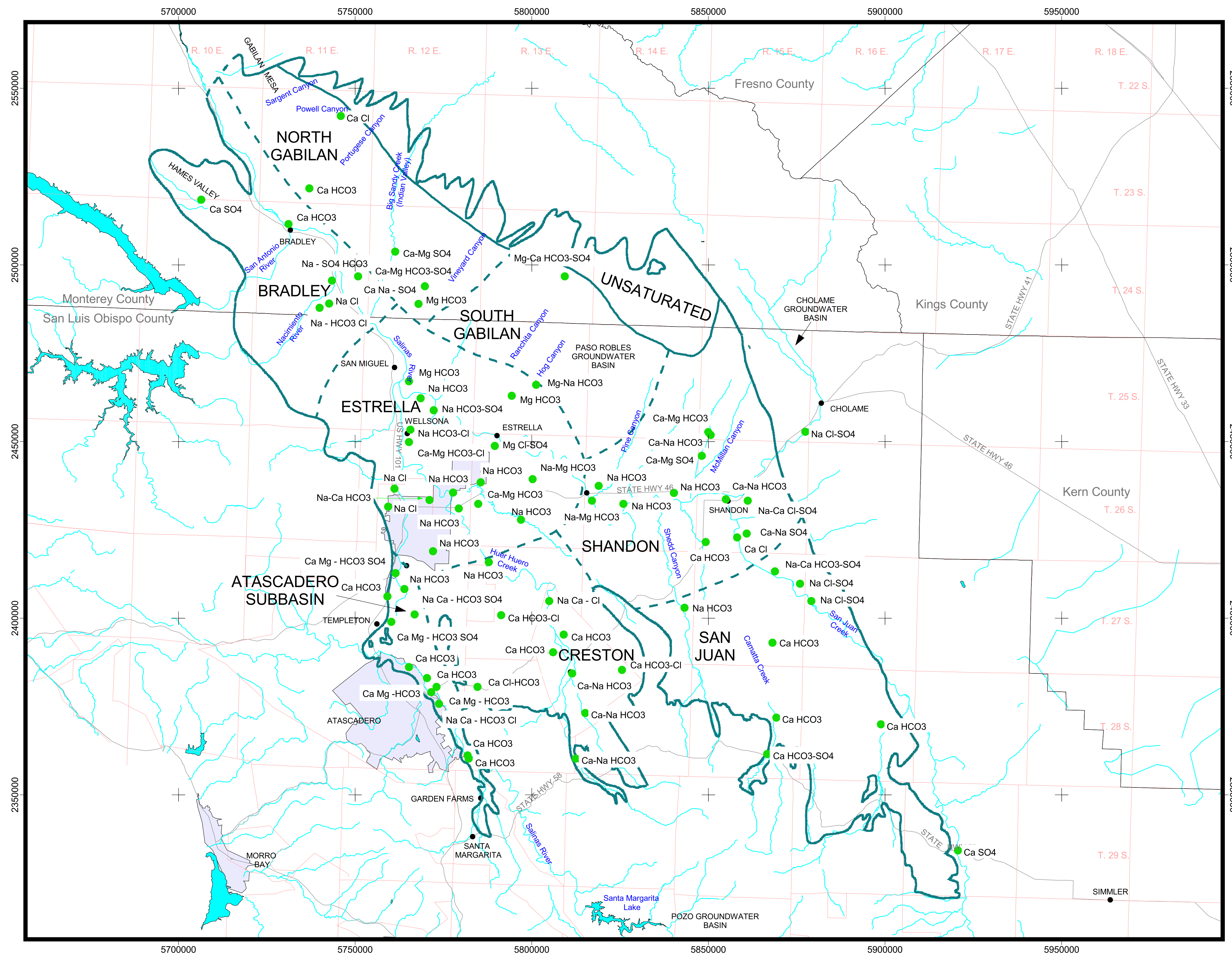
30000 0 30000 Feet

Water Quality Sample Locations

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 48



Legend

- Na Cl — Sample Location and Water Type
- City Outlines
- Basin Outline
- Streams
- Highways
- County Line
- Township and Range Grid

Note:
1. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

N

30000 0 30000 Feet

Water Type

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 49

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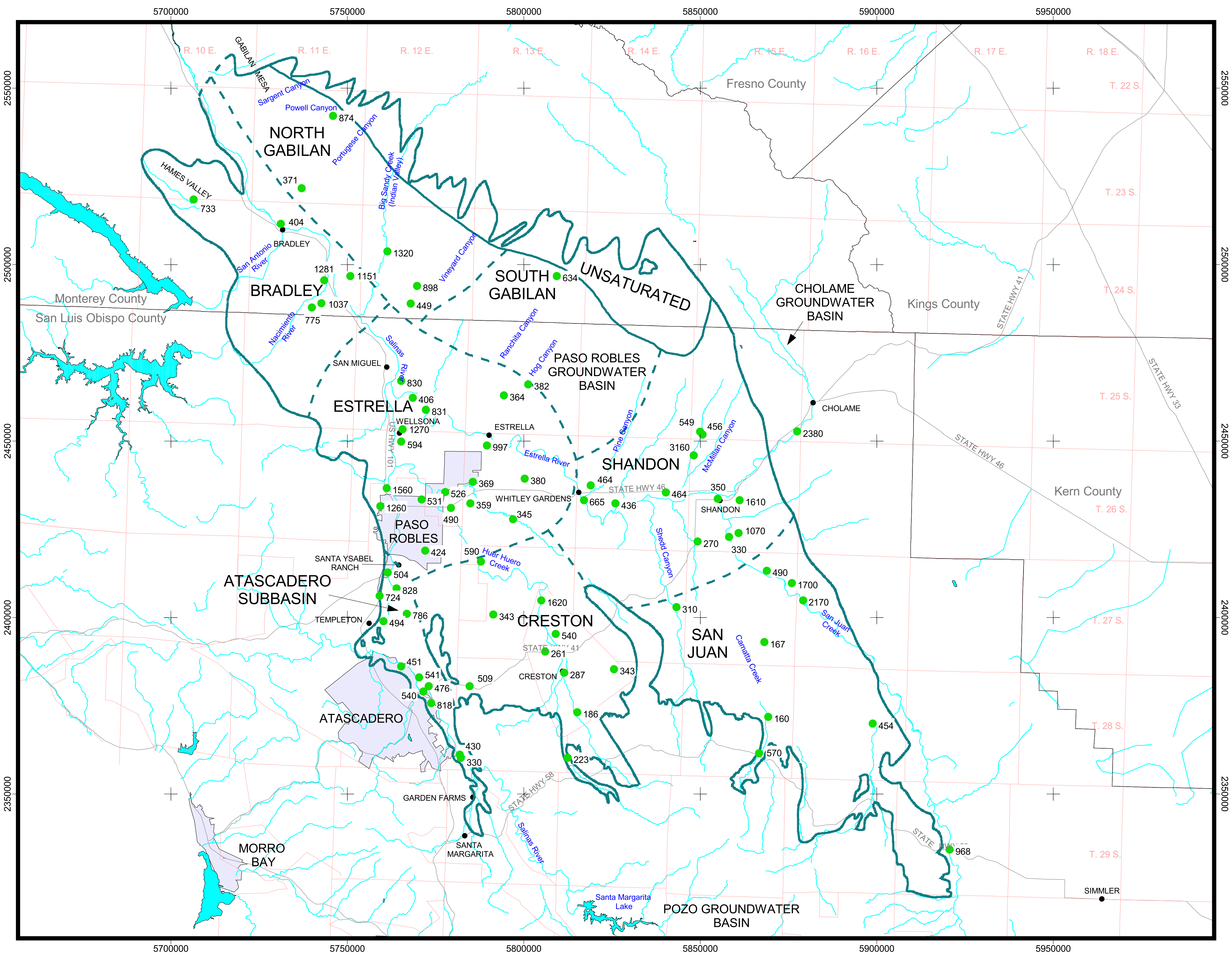
FUGRO



Legend

- 631 Sample Locations and Total Dissolved Solids
- City Outlines
- Basin Outline
- Streams
- Highways
- County Line
- Township and Range Grid

Note:
1. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

N

30000 0 30000 Feet

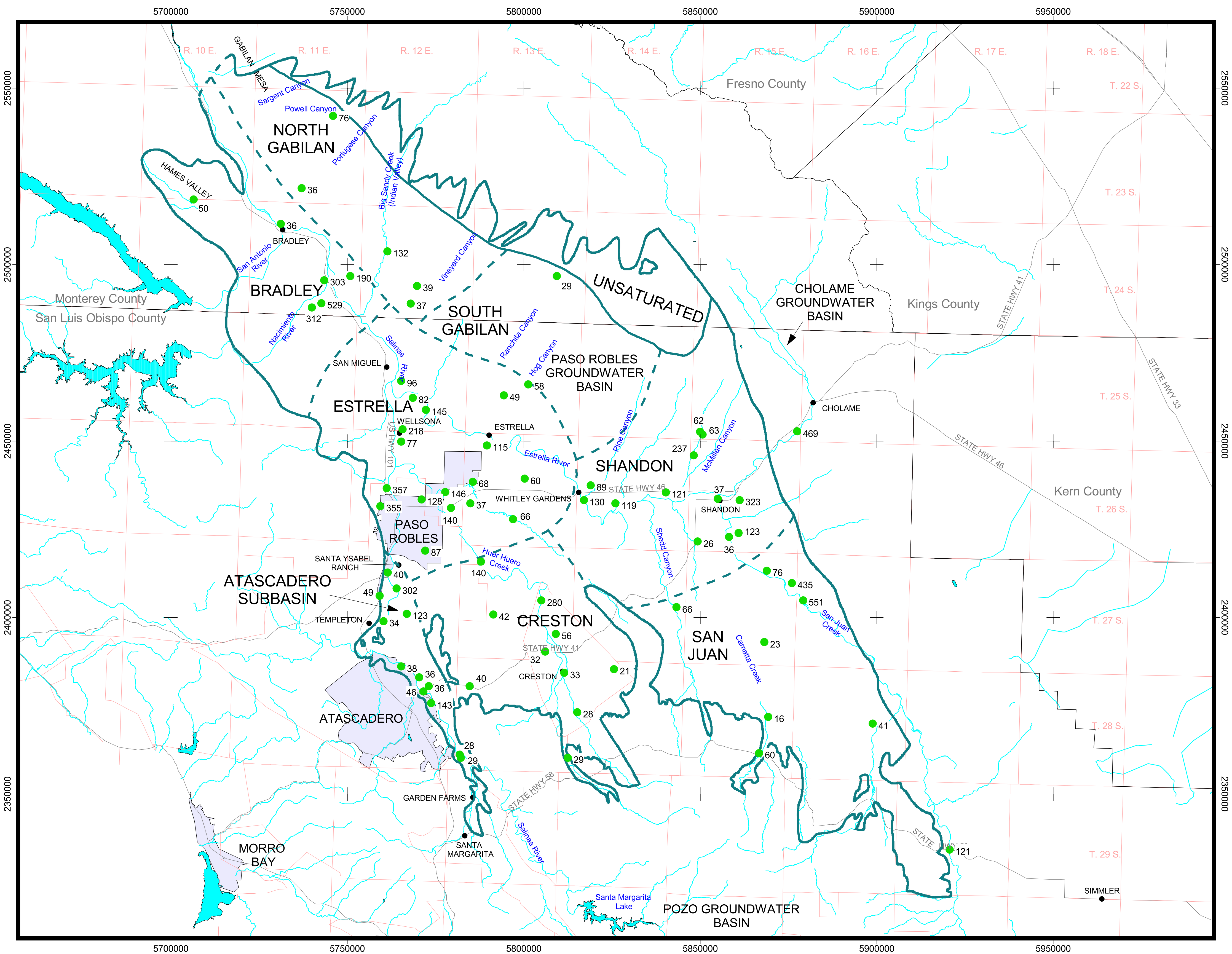
Total Dissolved Solids

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 50

Project No. 98-71-1137



Legend

- 39 Sample Locations and Sodium Concentration
- City Outlines
- Basin Outline
- Streams
- Highways
- County Line
- Township and Range Grid

Note:
1. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

N

30000 0 30000 Feet

Sodium Concentration

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

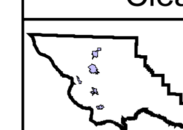


Figure 51

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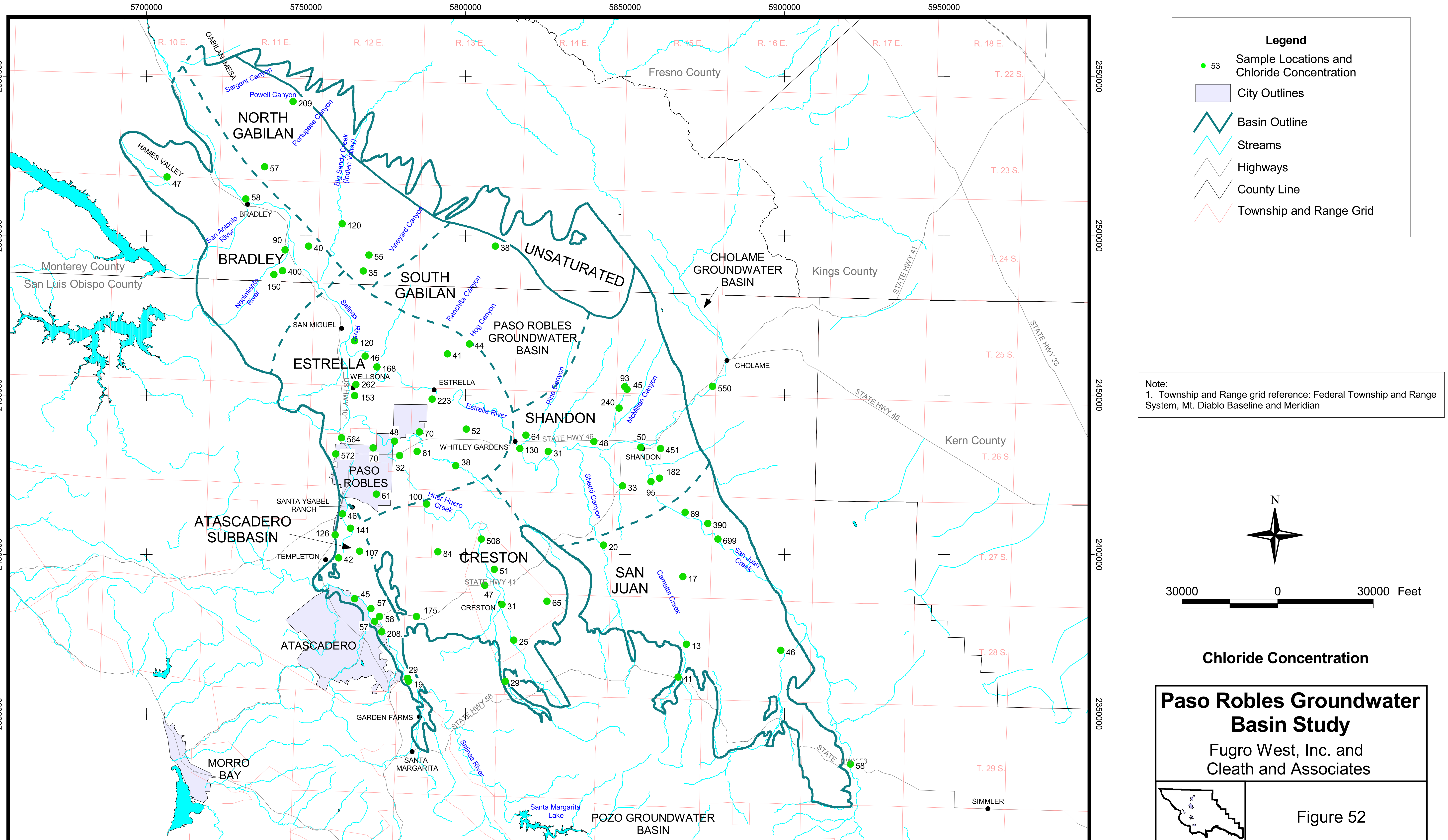
FUGRO



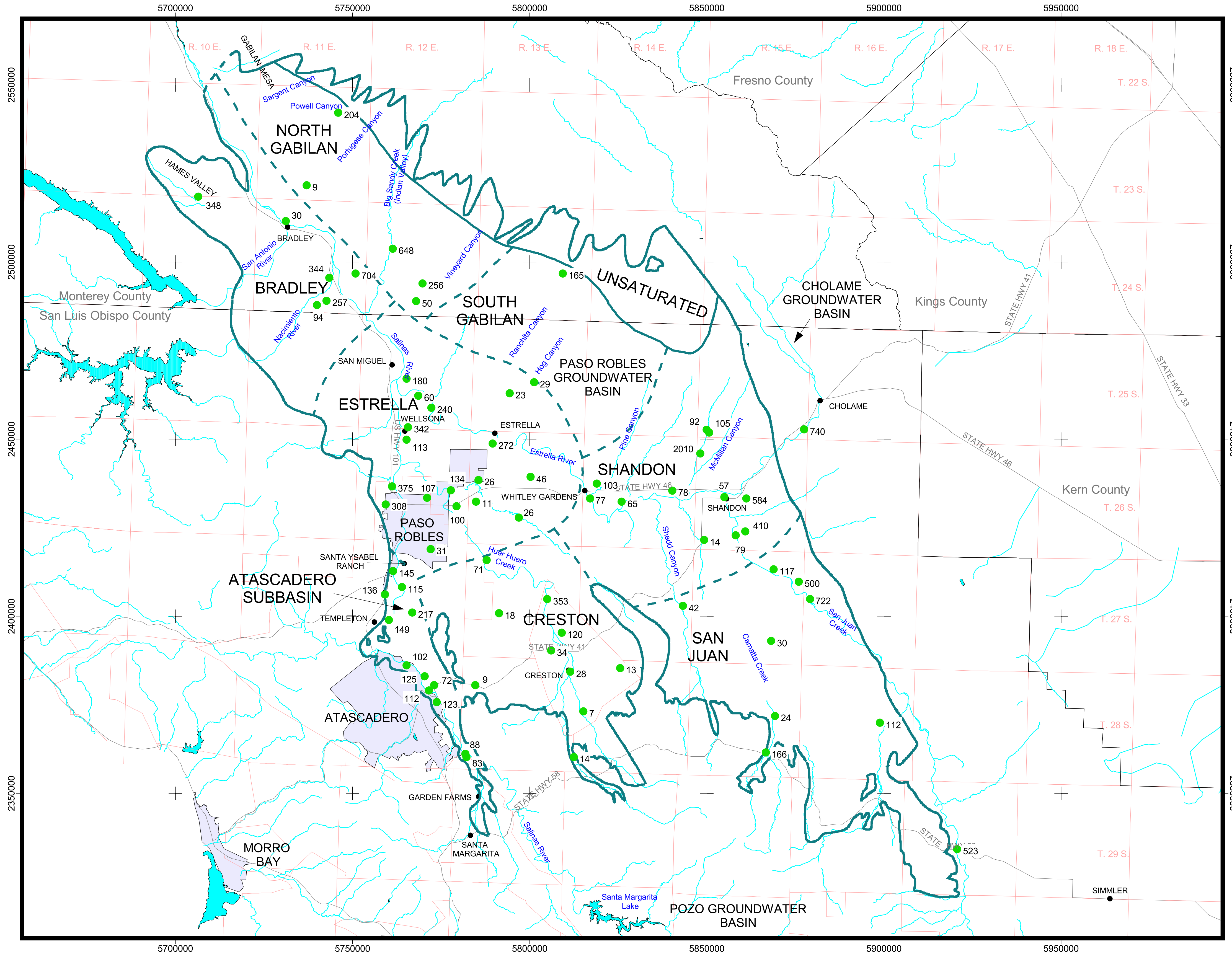
Chloride Concentration

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 52

Project No. 98-71-1137



Legend

- 50 Sample Locations and Sulfate Concentration
- City Outlines
- Basin Outline
- Streams
- Highways
- County Line
- Township and Range Grid

Note:
1. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

N

30000 0 30000 Feet

Sulfate Concentration

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

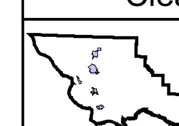


Figure 53

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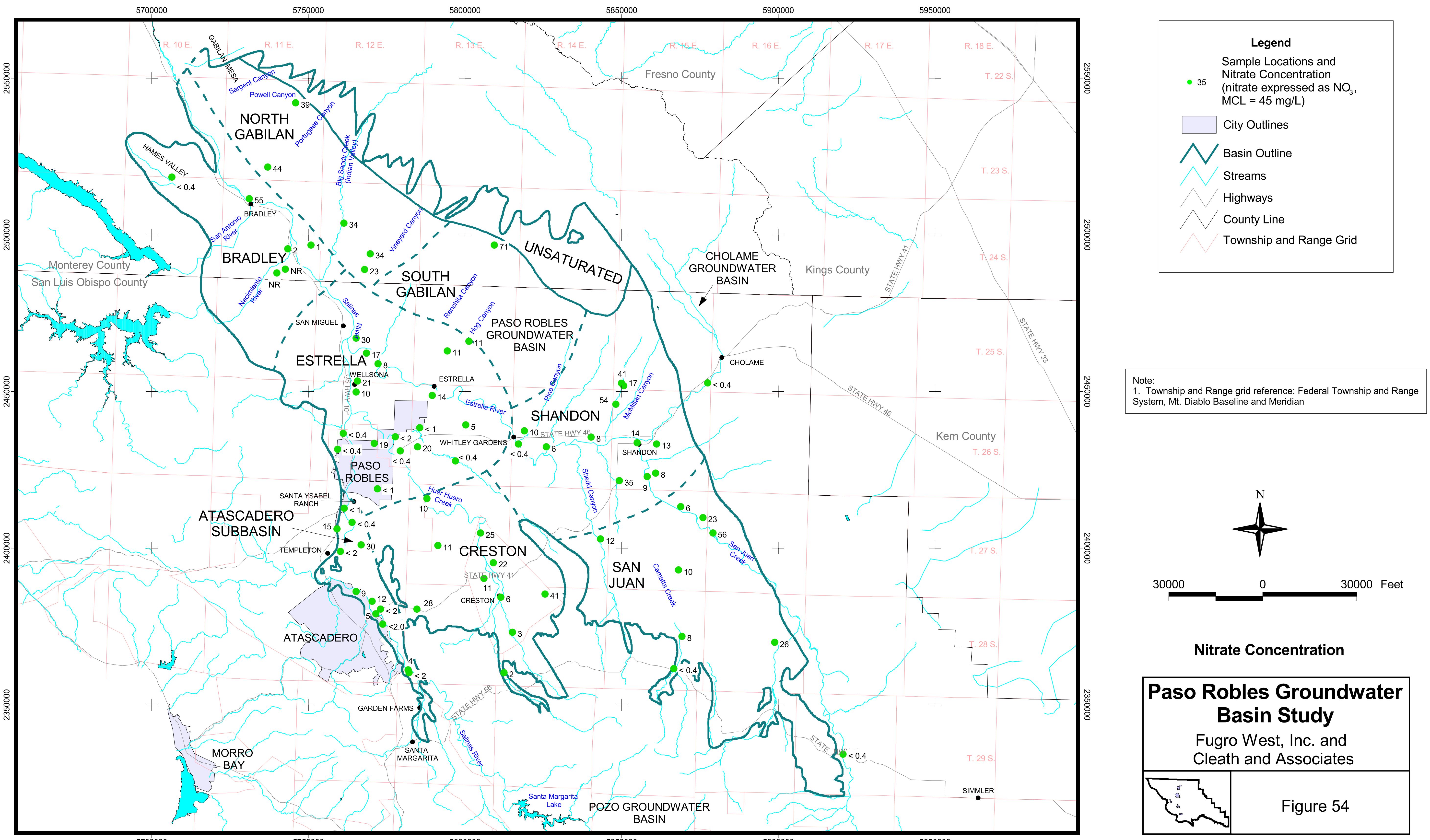


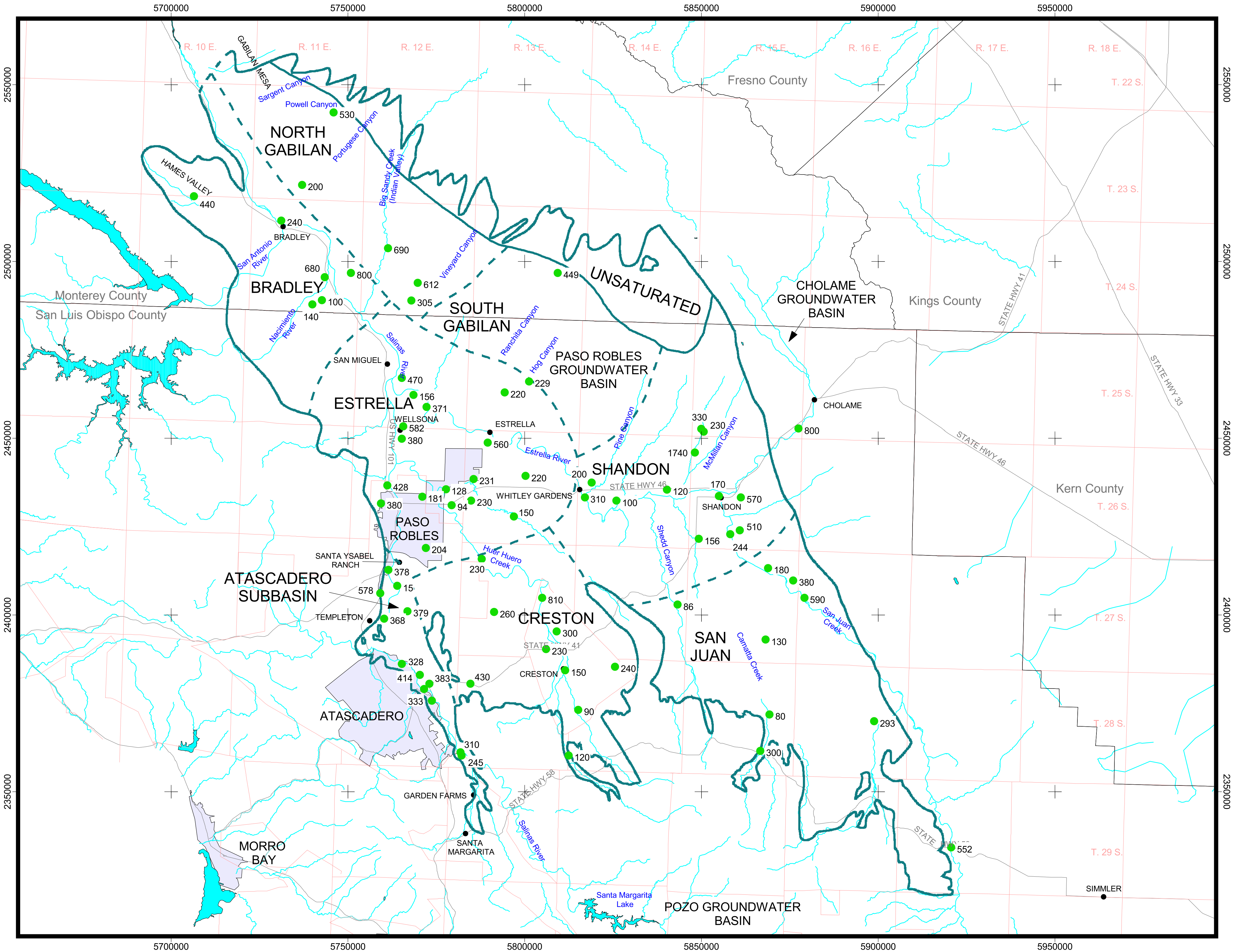
Nitrate Concentration

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 54

Project No. 98-71-1137



Legend

- 350 Sample Locations and Total Hardness
- City Outlines
- Basin Outline
- Streams
- Highways
- County Line
- Township and Range Grid

Note:
1. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

N

30000 0 30000 Feet

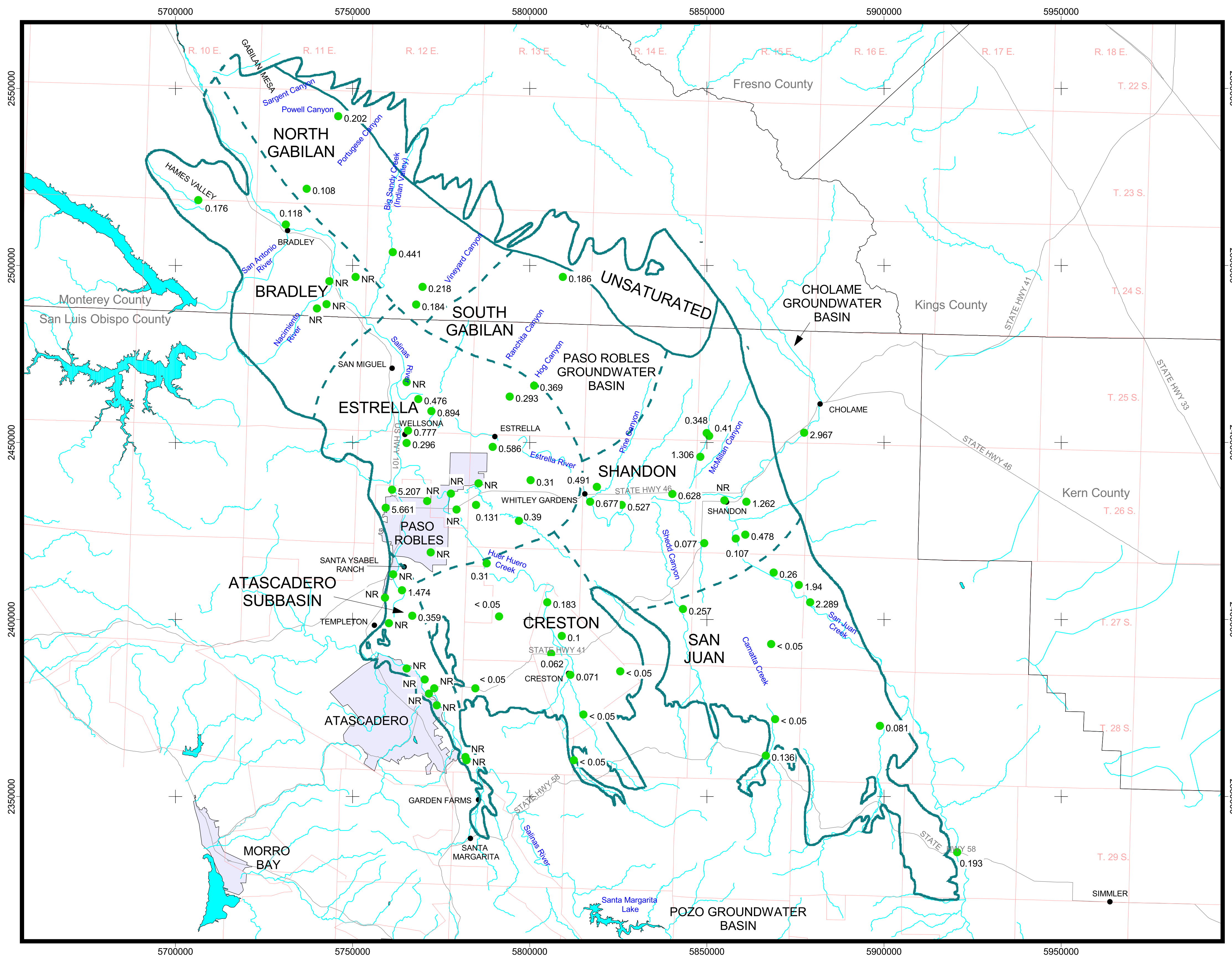
Total Hardness as CaCO3

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 55

Project No. 98-71-1137



Legend

- 0.41 Sample Locations and Boron Concentrations
- City Outlines
- Basin Outline
- Streams
- Highways
- County Line
- Township and Range Grid

Note:
1. Township and Range grid reference: Federal Township and Range System, Mt. Diablo Baseline and Meridian

N

30000 0 30000 Feet

Boron Concentrations

Paso Robles Groundwater Basin Study

Fugro West, Inc. and Cleath and Associates

Figure 56

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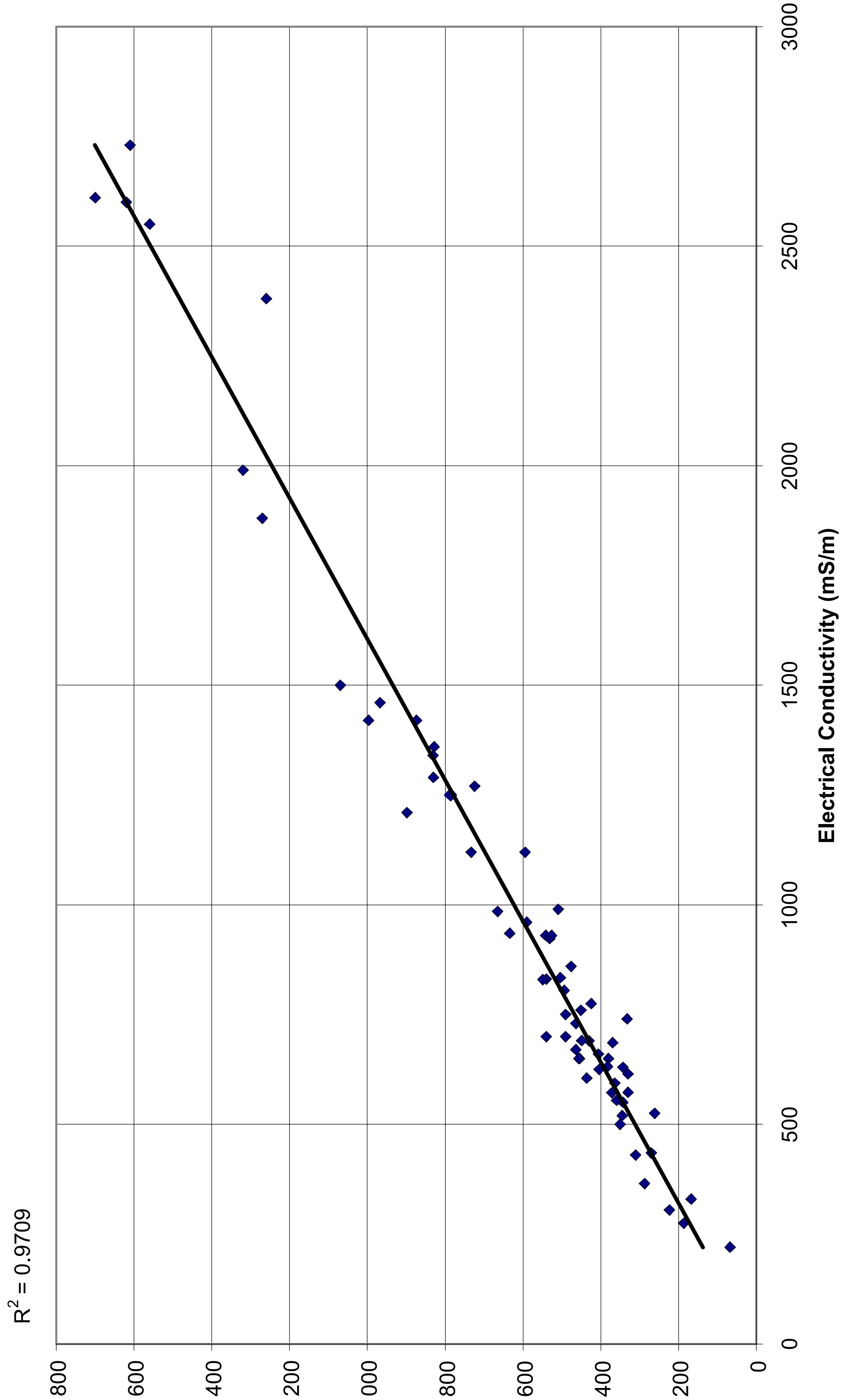
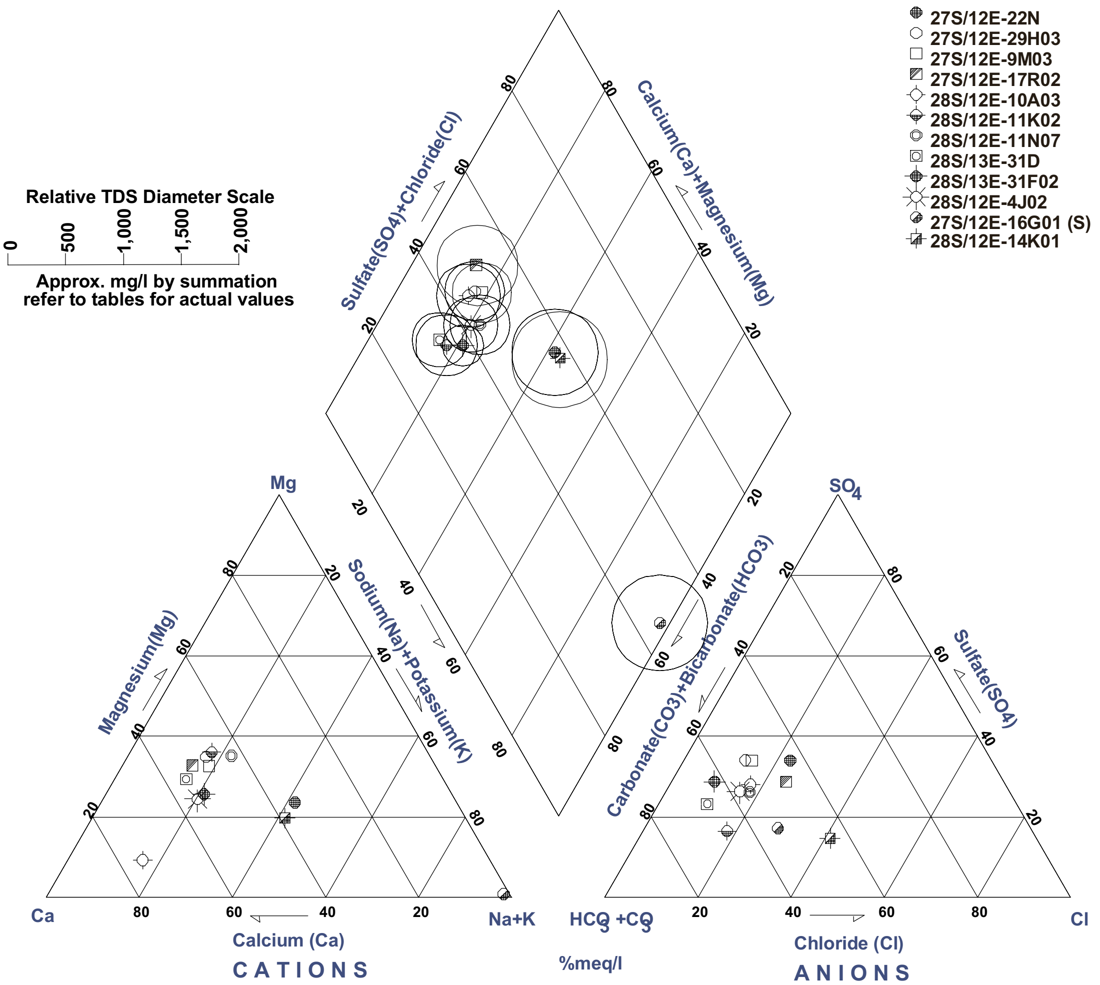


TDS/EC CORRELATION
Paso Robles Groundwater Basin Study

FIGURE 57

9871\1137tds.dsf

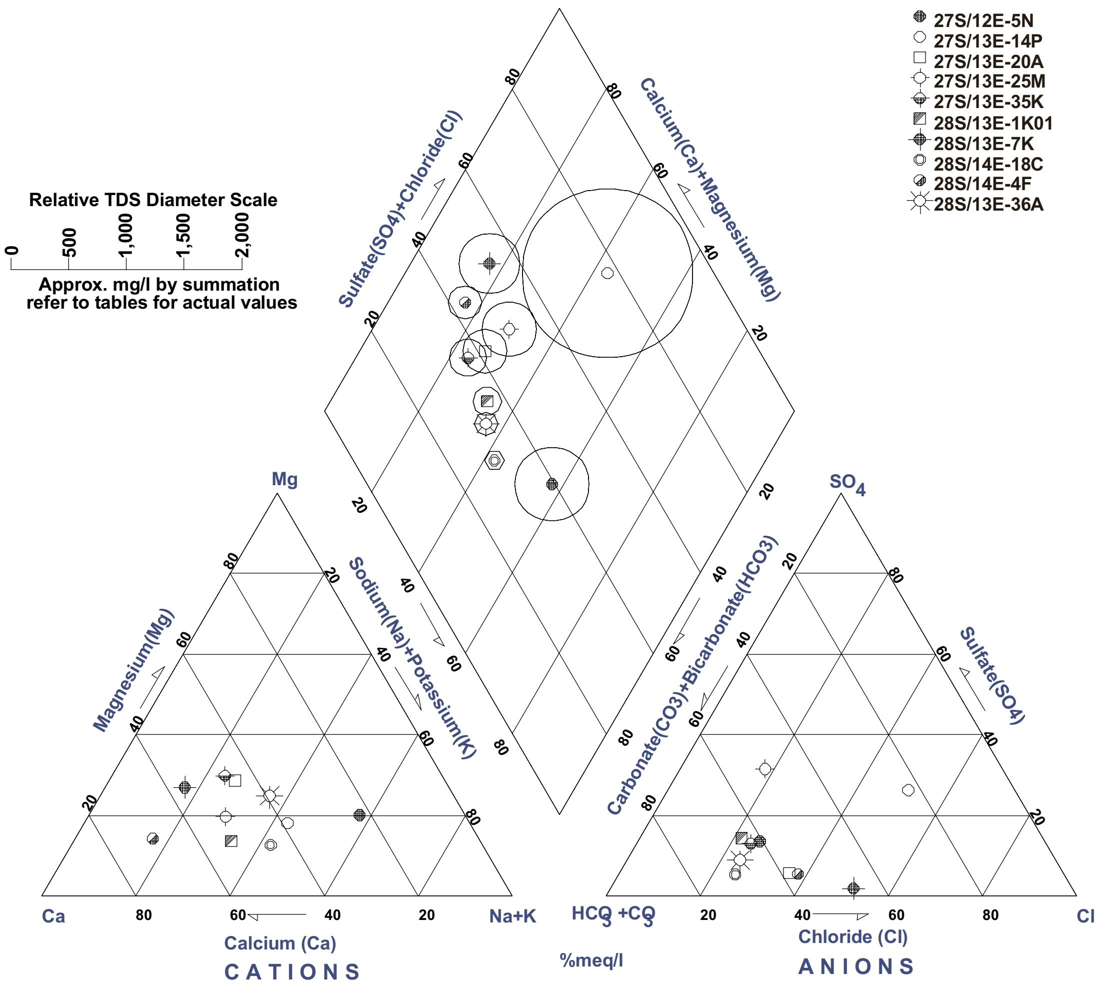


Note: Samples collected from 1999-2001
(see text for sample dates)

9871\1137tri.dsf.p1

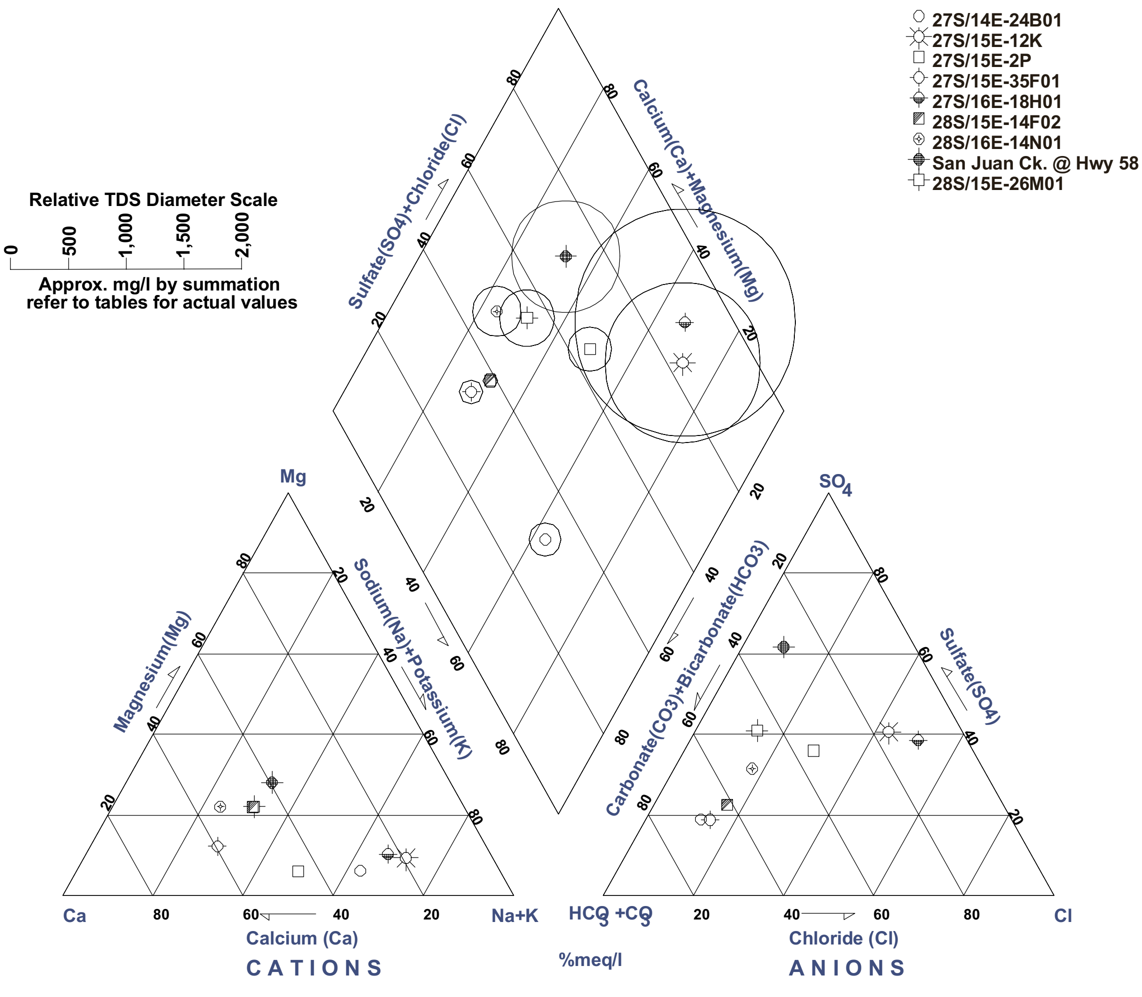
TRILINEAR DIAGRAM
Atascadero Subbasin
Paso Robles Groundwater Basin Study

FIGURE 58



Note: Samples collected from 1999-2001
(see text for sample dates)

TRILINEAR DIAGRAM
Creston Area
Paso Robles Groundwater Basin Study

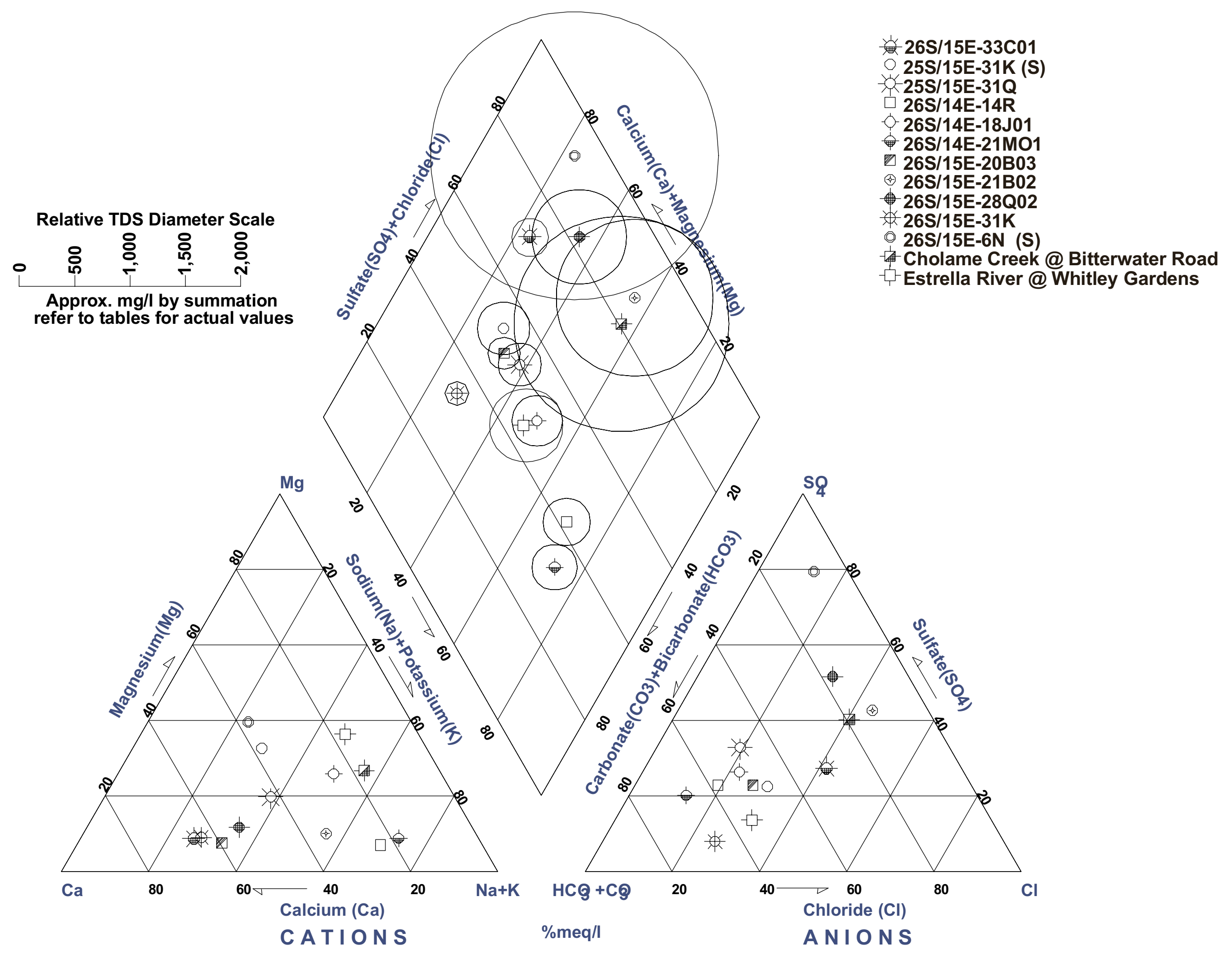


Note: Samples collected from 1999-2001
(see text for sample dates)

9871\1137tri.dsf.p3

TRILINEAR DIAGRAM
San Juan Area
Paso Robles Groundwater Basin Study

FIGURE 60



Note: Samples collected from 1999-2001
(see text for sample dates)

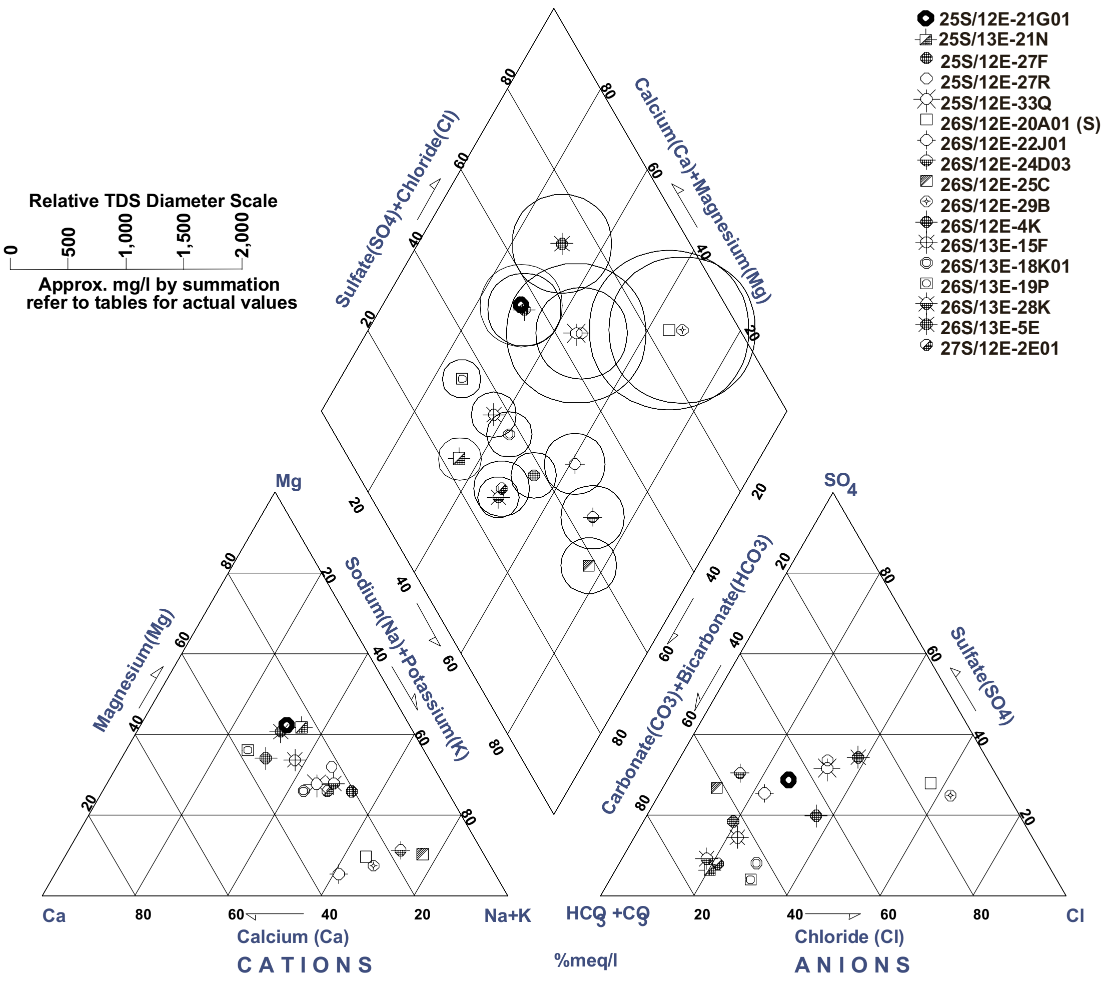
9871\1137tri.dsf.p4

TRILINEAR DIAGRAM

Shandon Area

Paso Robles Groundwater Basin Study

FIGURE 61

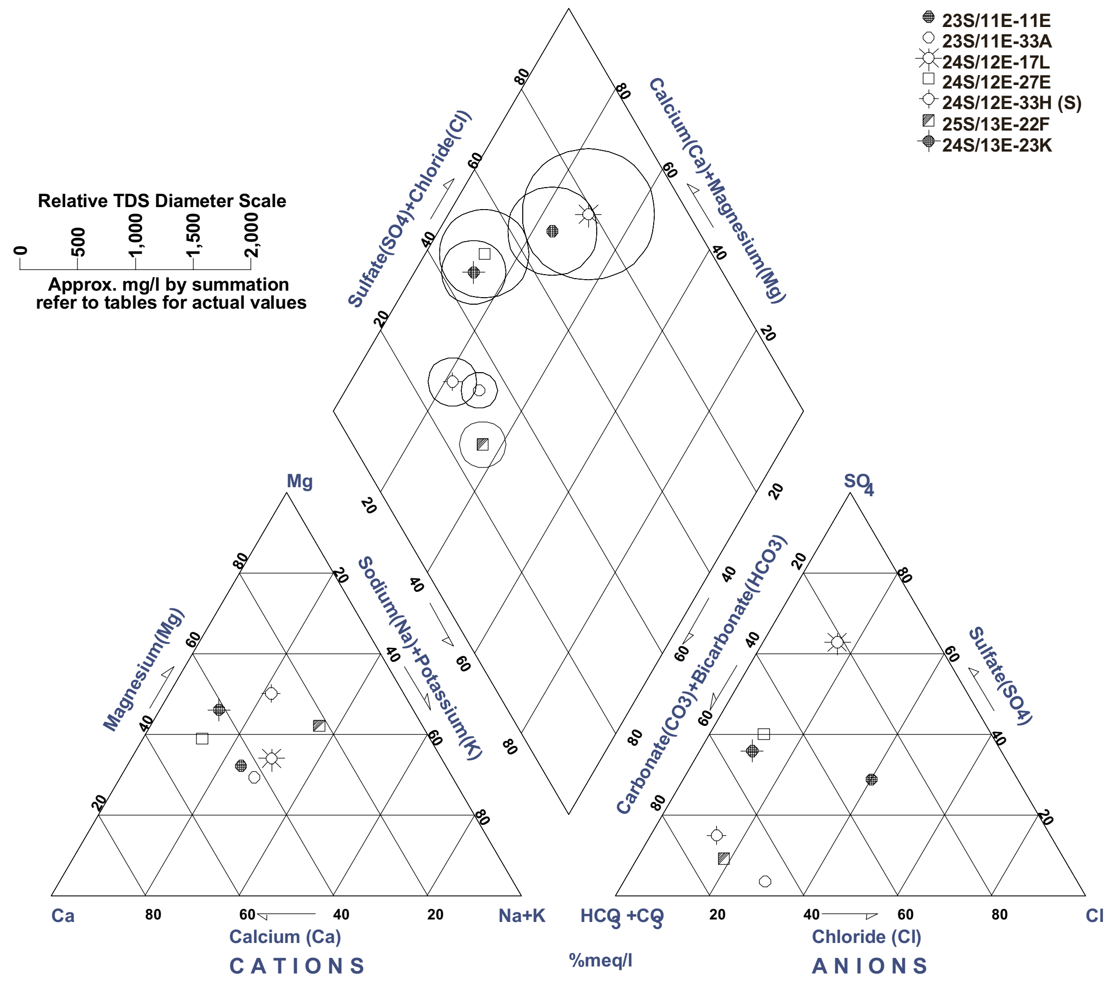


Note: Samples collected from 1999-2001
(see text for sample dates)

9871\1137tri.dsf.p5

TRILINEAR DIAGRAM
Estrella Area
Paso Robles Groundwater Basin Study

FIGURE 62

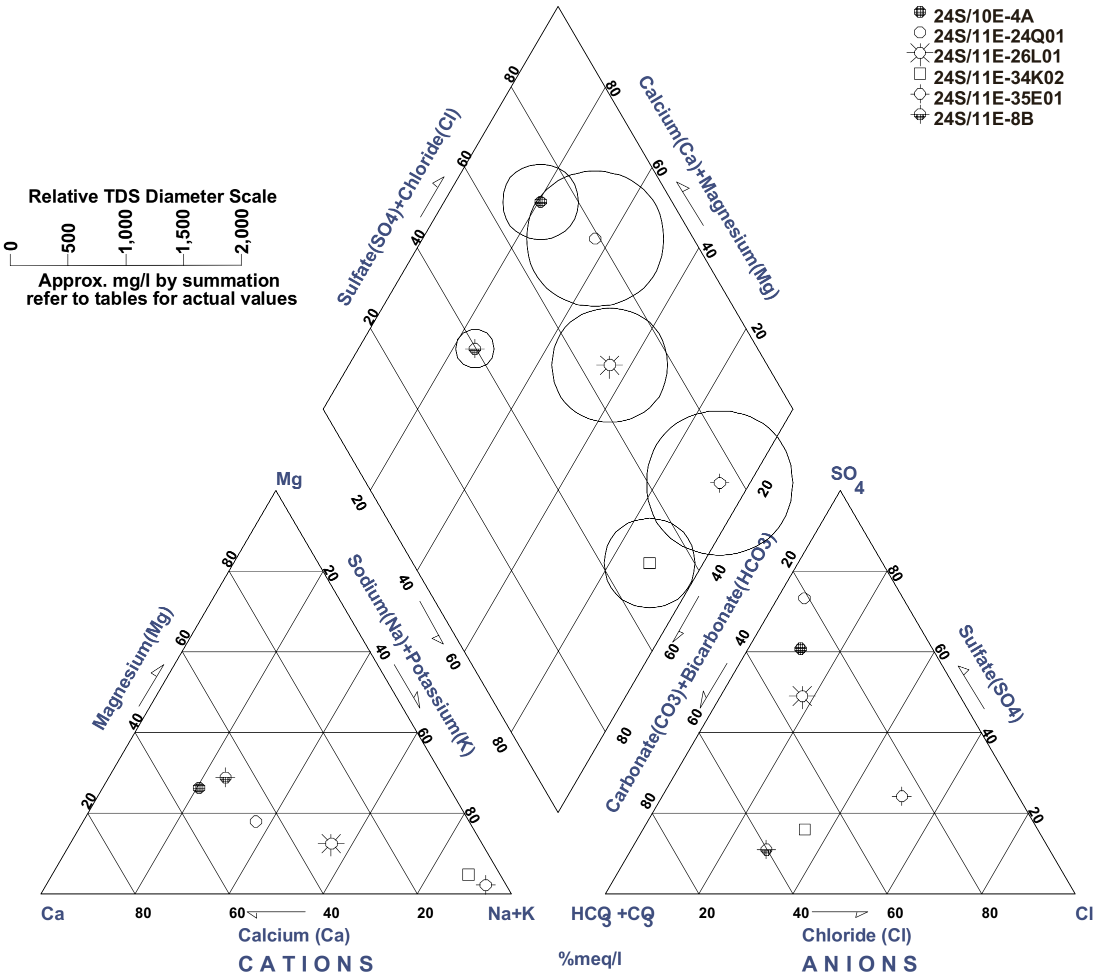


Note: Samples collected from 1999-2001
(see text for sample dates)

9871\1137tri.dsf.p6

TRILINEAR DIAGRAM
Gabilan Area
Paso Robles Groundwater Basin Study

FIGURE 63



Note: Samples collected from 1999-2001
(see text for sample dates)

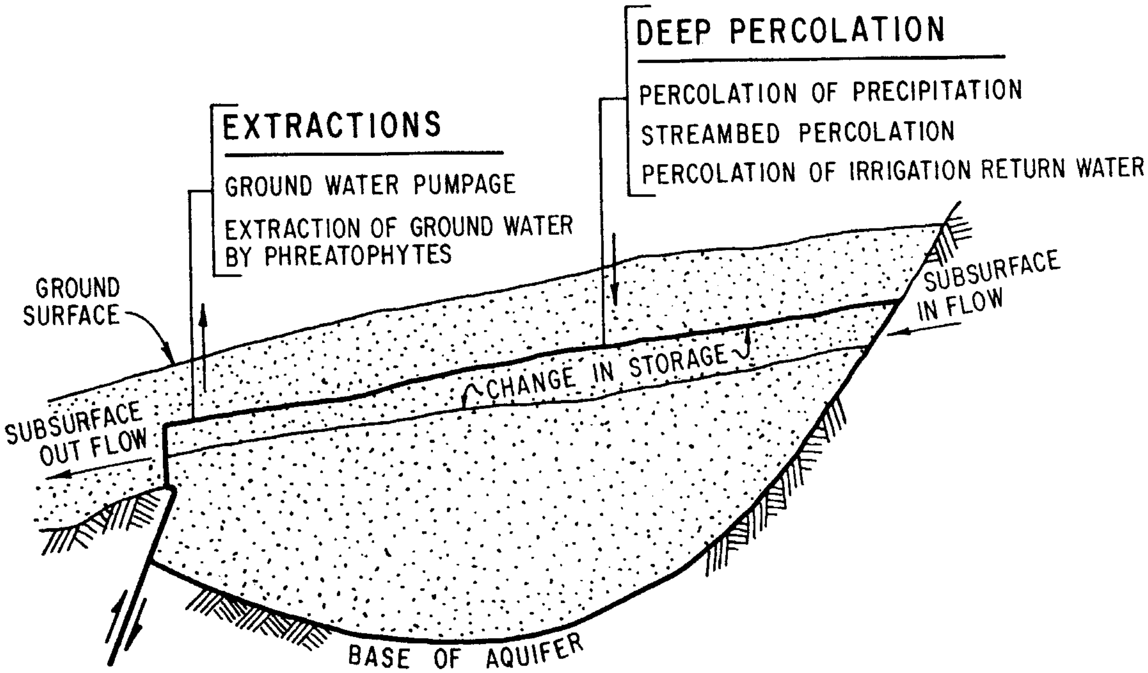
9871\1137tri.dsf.p7

TRILINEAR DIAGRAM

Bradley Area

Paso Robles Groundwater Basin Study

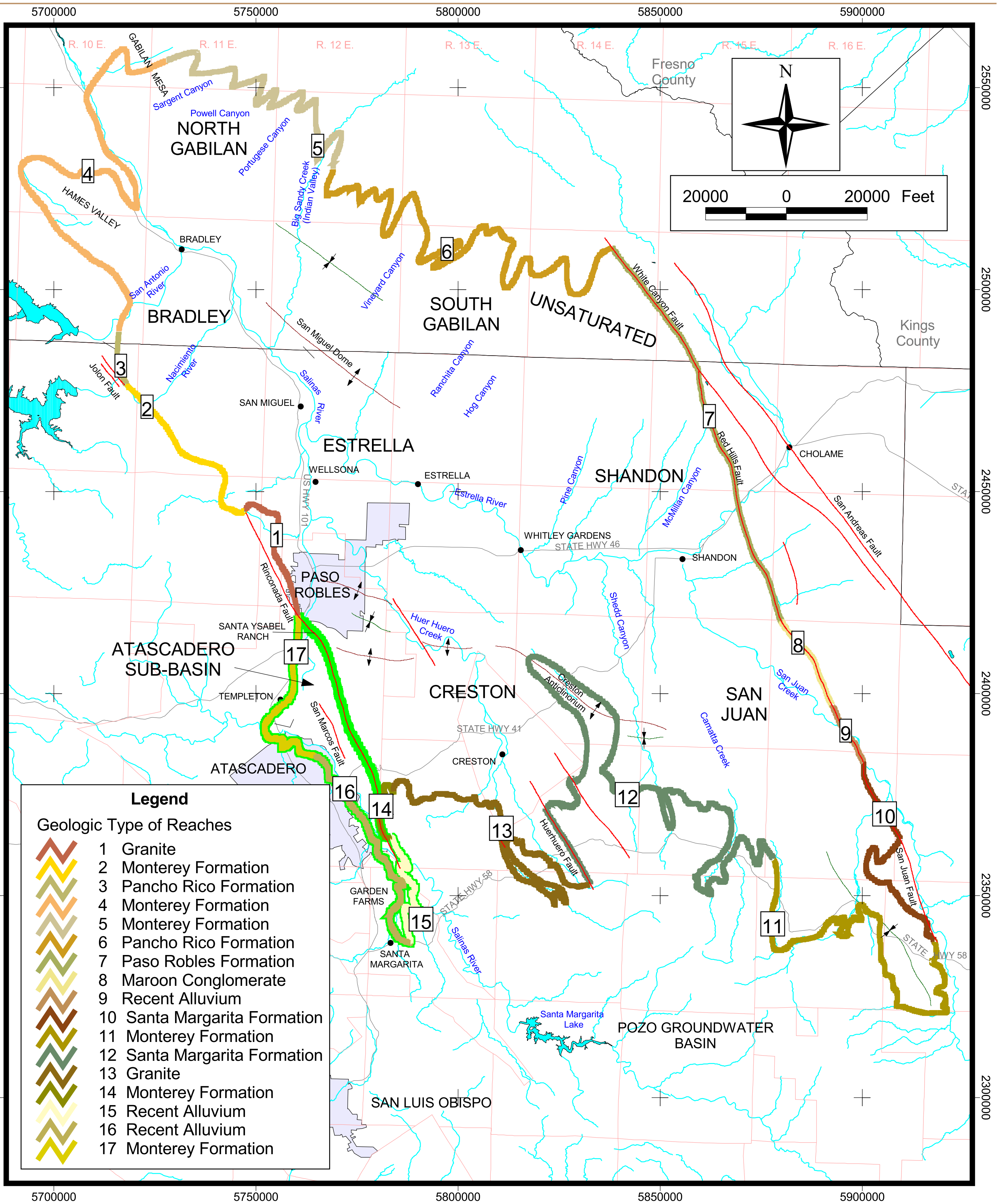
FIGURE 64



9871\1137water.dsf

WATER BALANCE COMPONENTS
Paso Robles Groundwater Basin Study

FIGURE 65



REACH LOCATION AND GEOLOGY

Paso Robles Groundwater Basin

FIGURE 66

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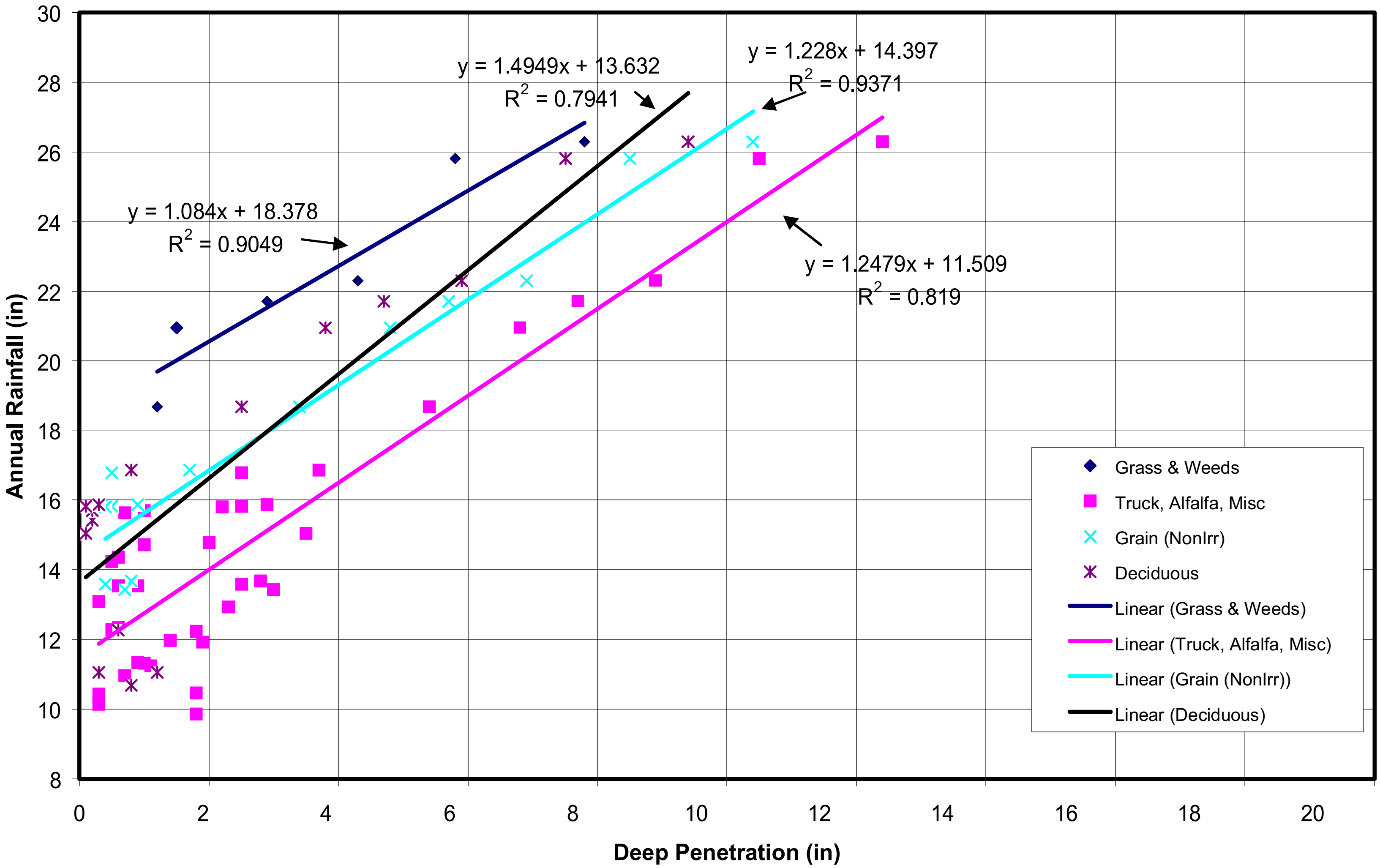
9871\1137curv.dsf

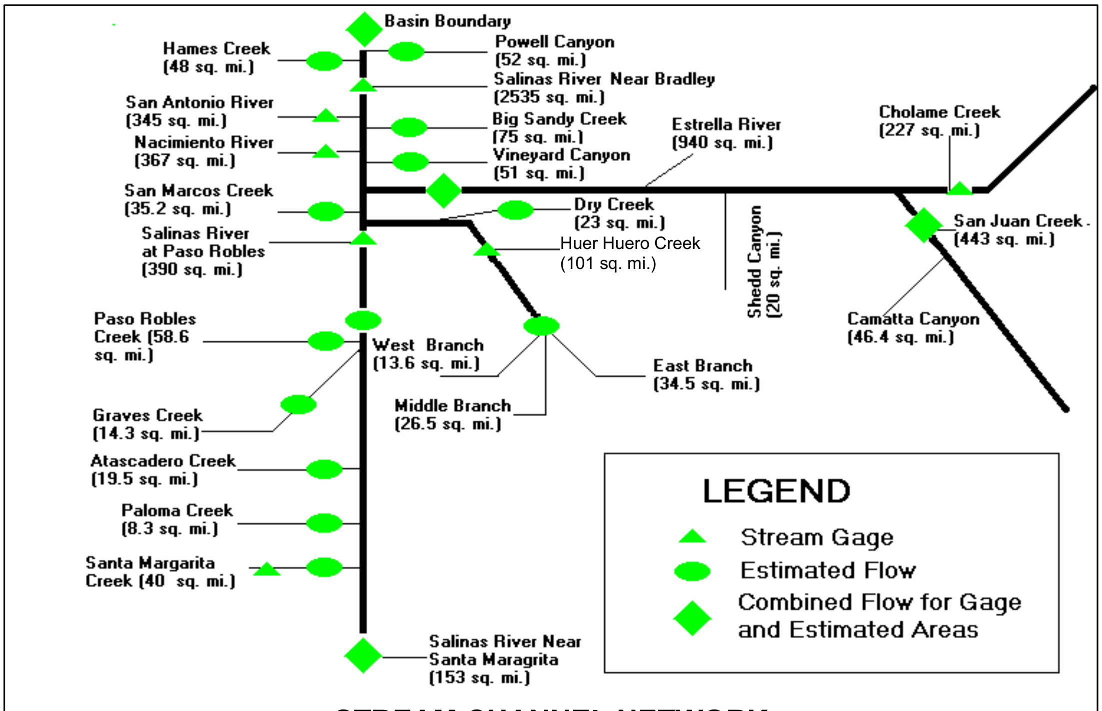


PRECIPITATION VS. DEEP PENETRATION CURVES
(Based on Blaney, 1933)
Paso Robles Groundwater Basin Study

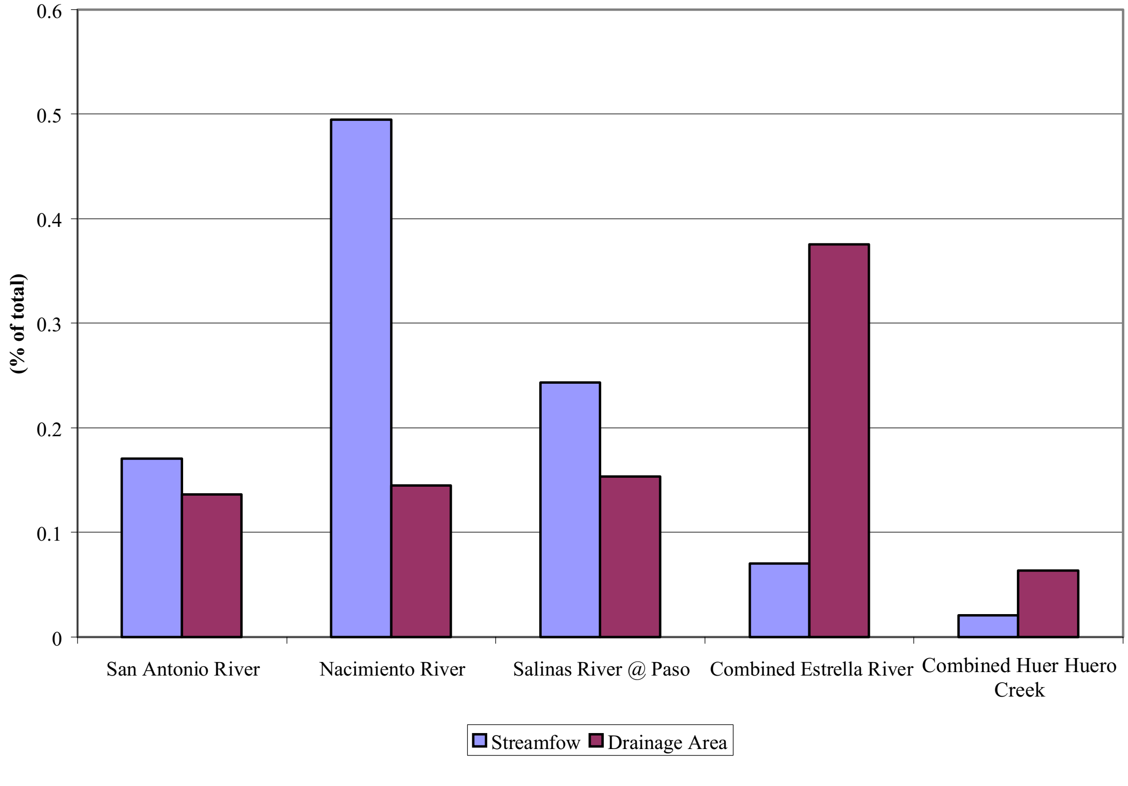
FIGURE 67

Project No. 98-71-1137

FUGRO



STREAM CHANNEL NETWORK

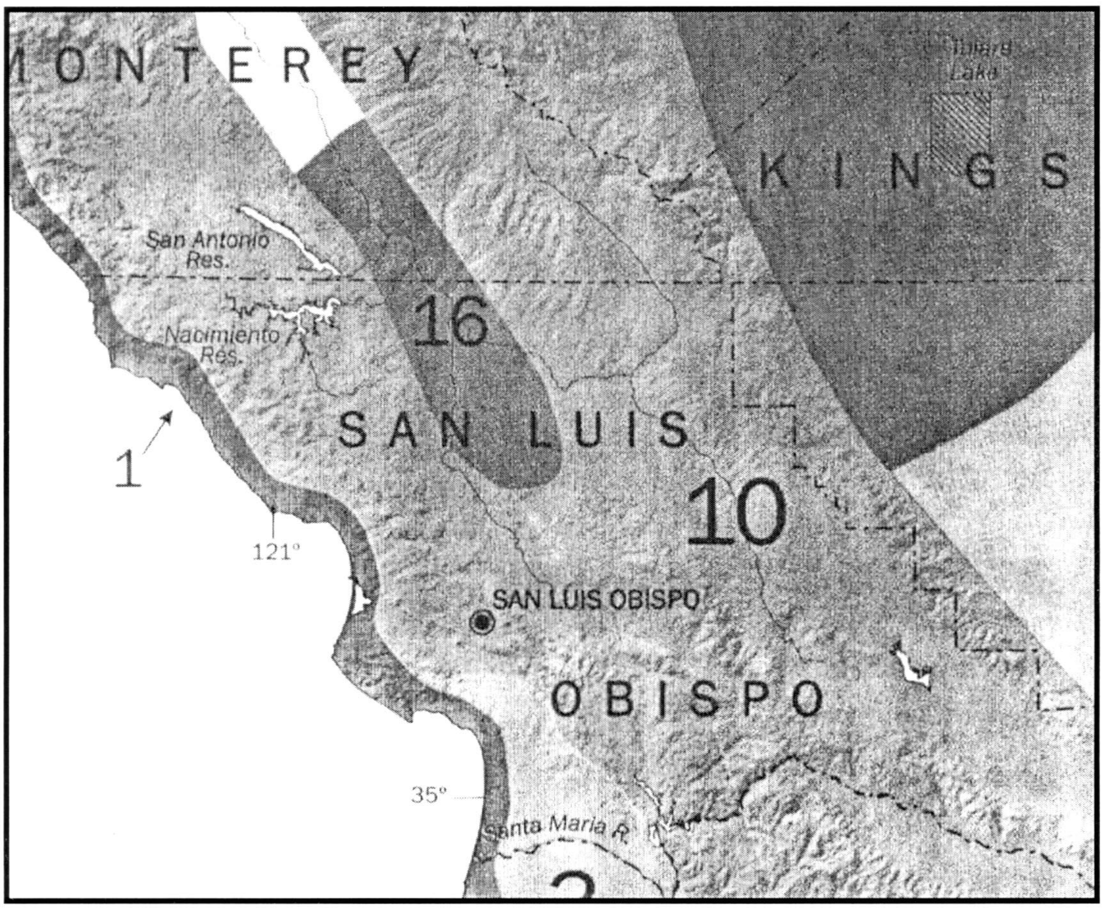


9871\1137fig.dsf,p1

AVERAGE ANNUAL STREAMFLOW AND DRAINAGE AREAS

Paso Robles Groundwater Basin Study

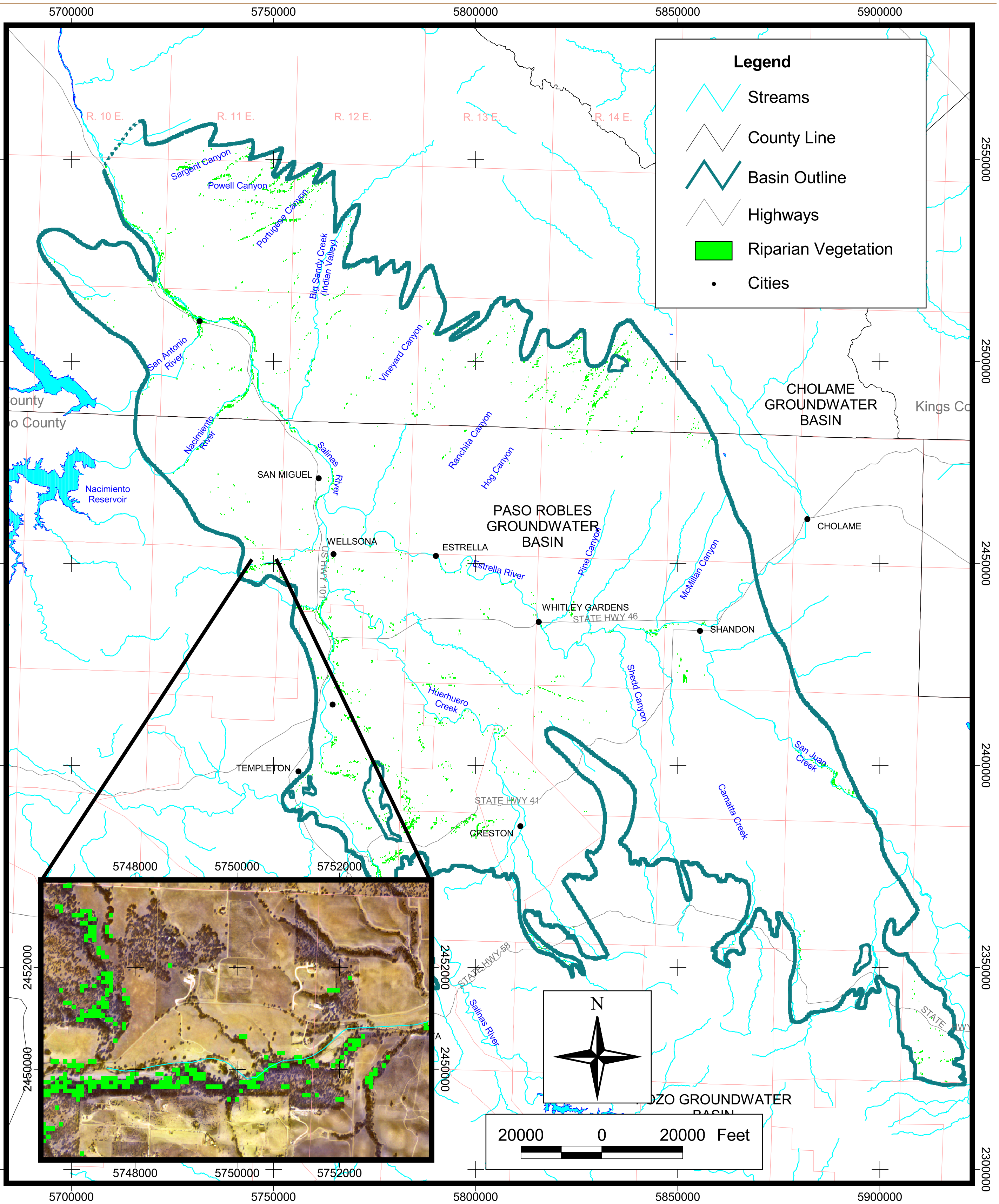
FIGURE 68



9871\1137stan.dsf

STANDARD REFERENCE EVAPOTRANSPIRATION ZONES MAP
Paso Robles Groundwater Basin Study

FIGURE 69



PHREATOPHYTE/RIPARIAN VEGETATION MAP

Paso Robles Groundwater Basin

FIGURE 70

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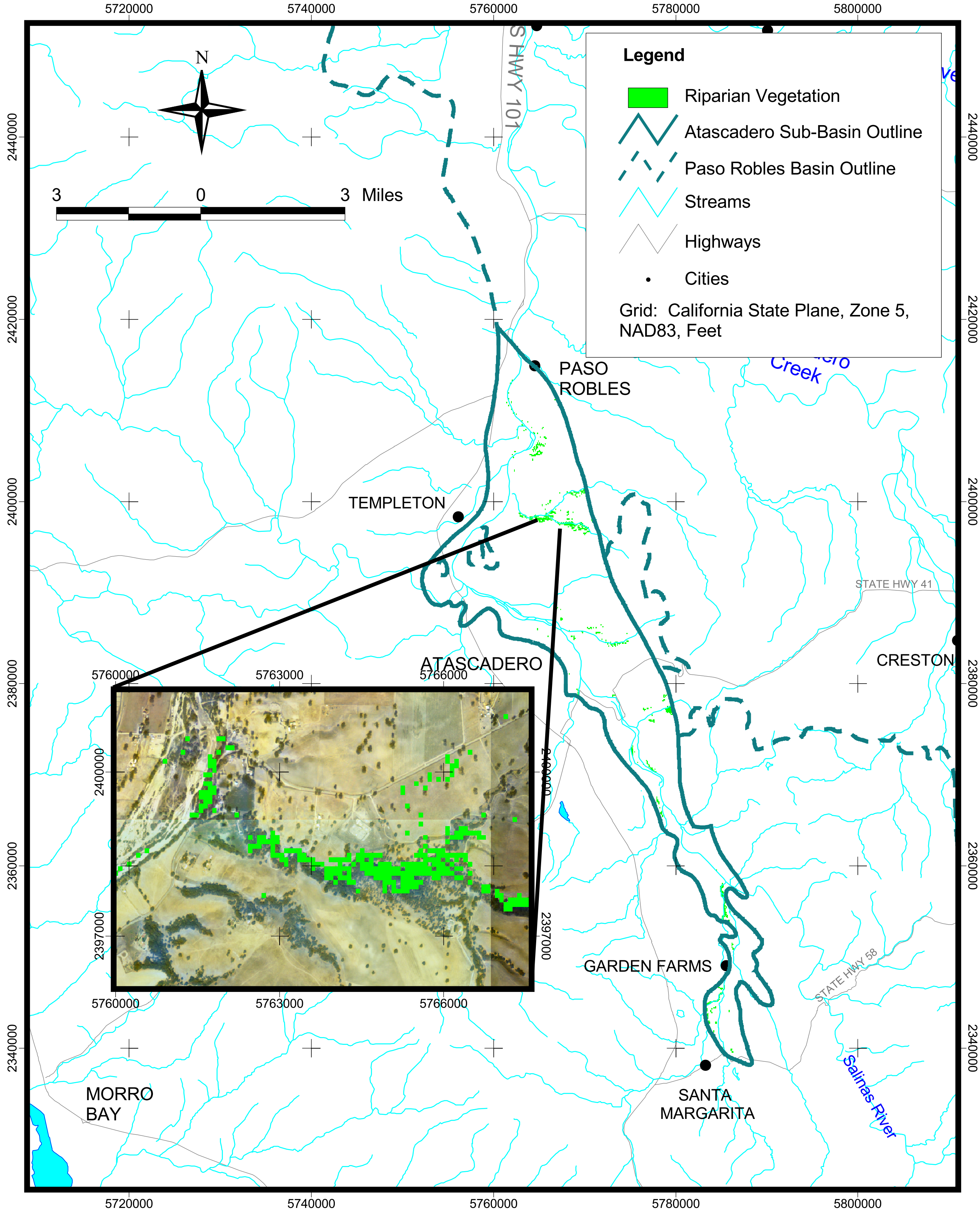
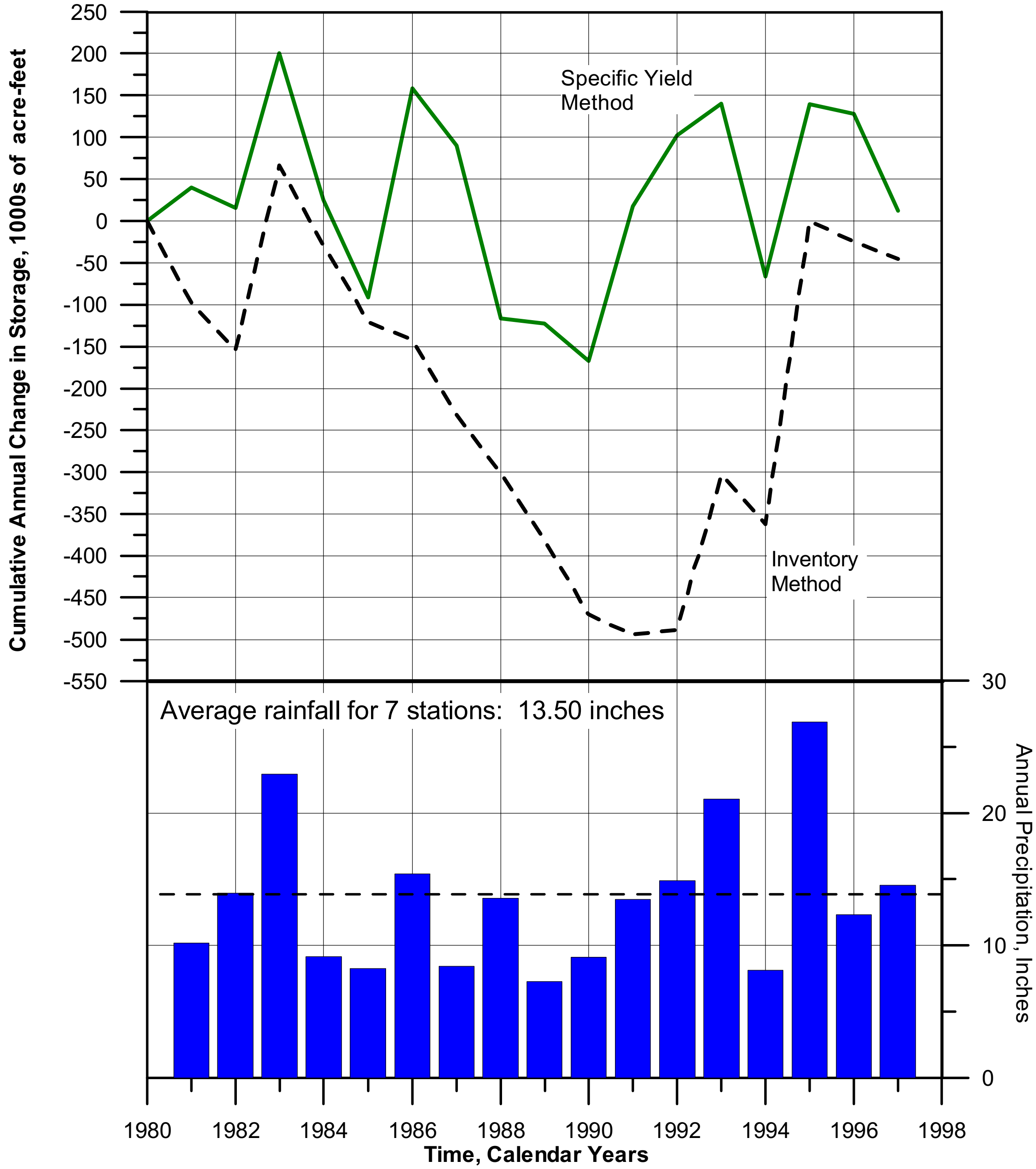


PHREATOPHYTE/RIPARIAN VEGETATION
MAP, ATASCADERO SUB-BASIN
Paso Robles Groundwater Basin

FIGURE 71

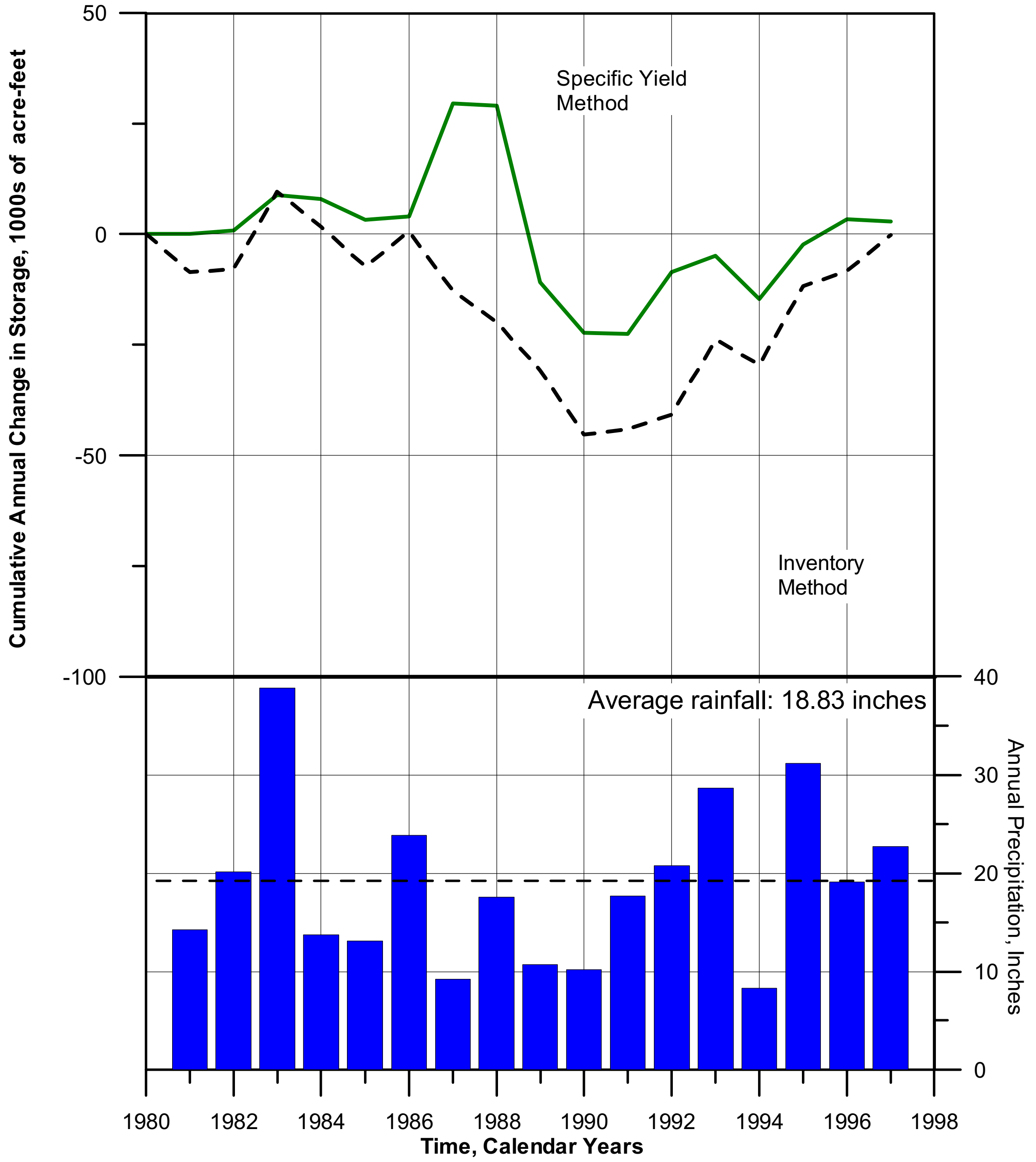
j:\gis\projects\slo\gis\odb\final-report\fig-71.odb, final-report, 03/14/2002



9871\1137fig.dsf,p2

CUMULATIVE ANNUAL CHANGE IN STORAGE
Paso Robles Groundwater Basin
Paso Robles Groundwater Basin Study

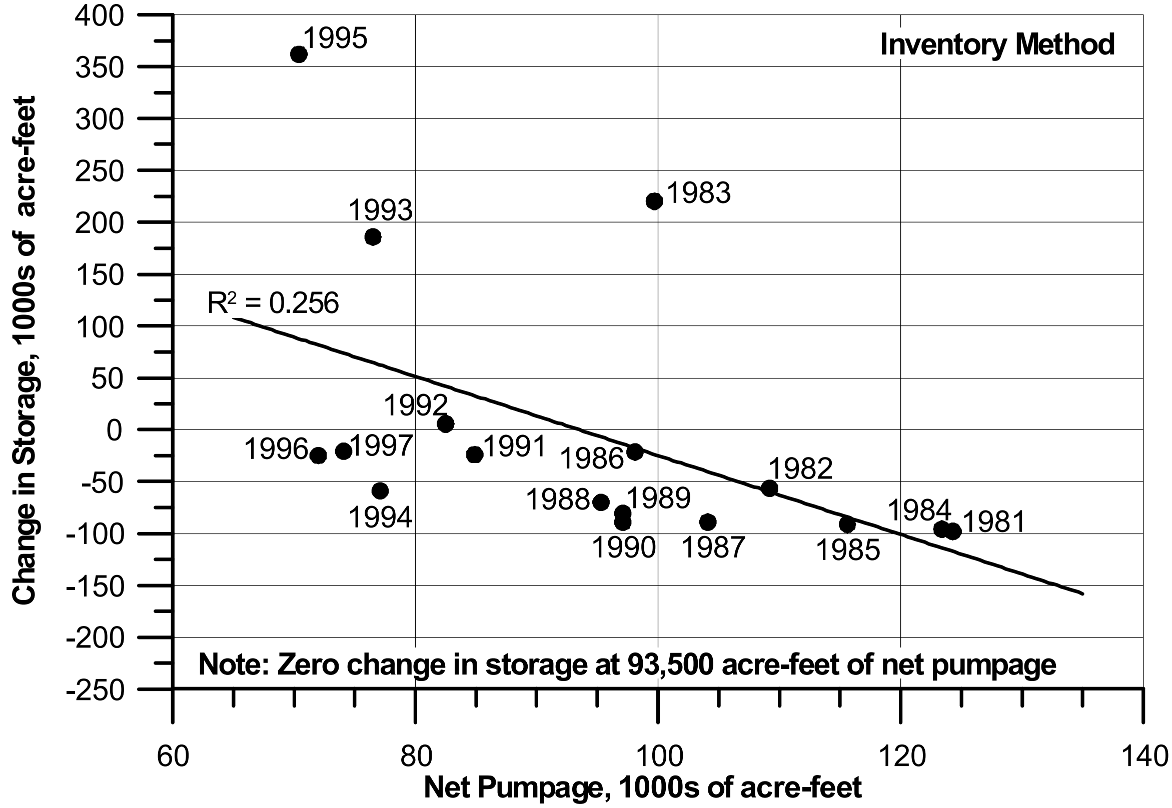
FIGURE 72

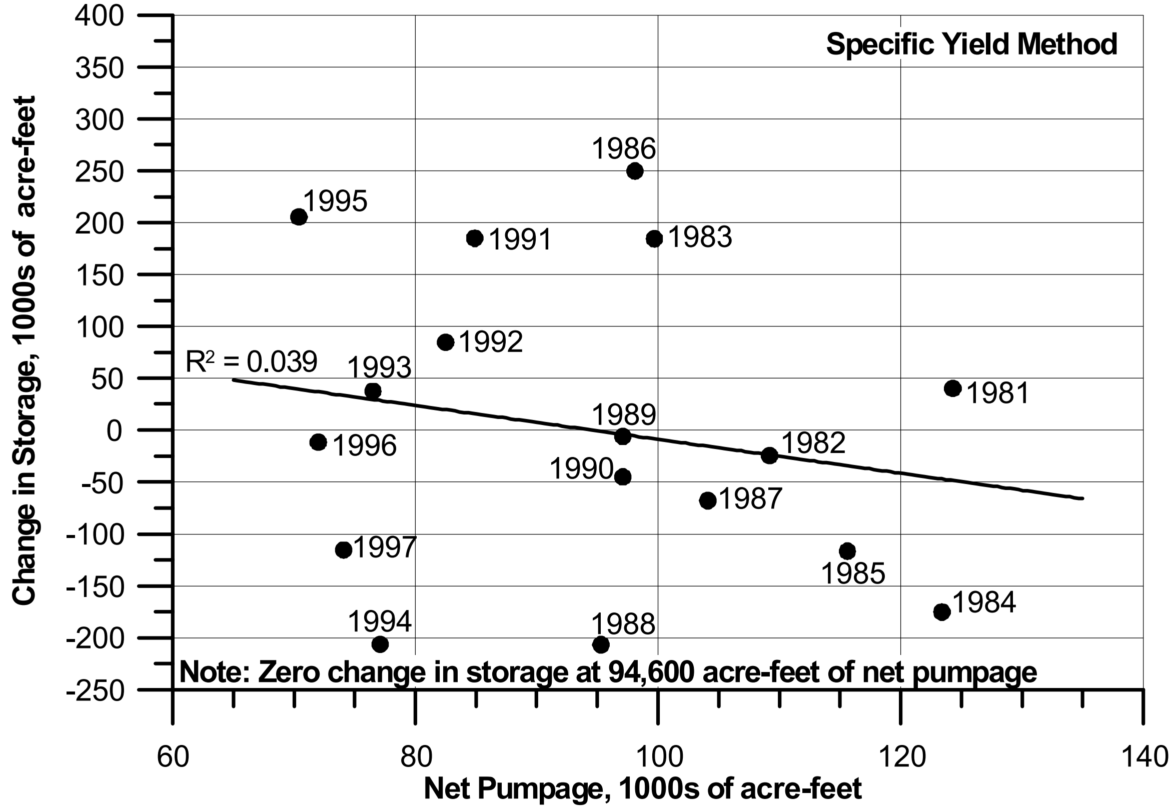


9871\1137fig.dsf,p3

CUMULATIVE ANNUAL CHANGE IN STORAGE
Atascadero Subbasin
Paso Robles Groundwater Basin Study

FIGURE 73

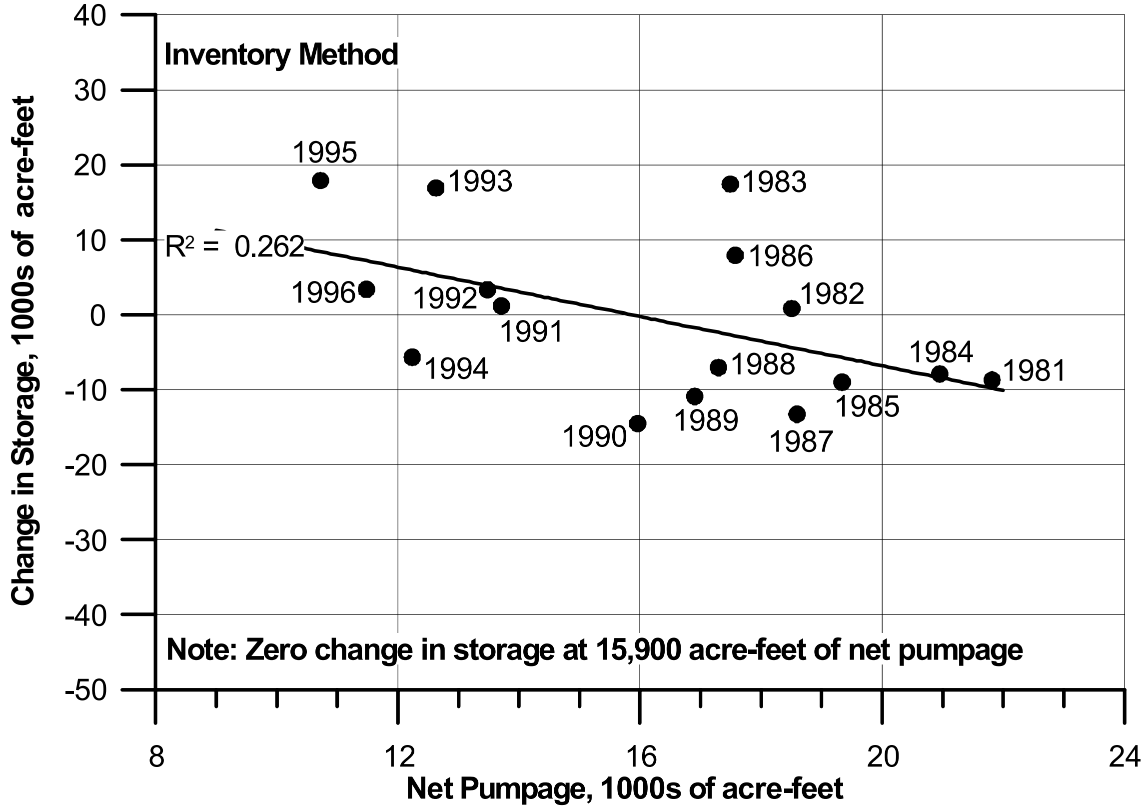


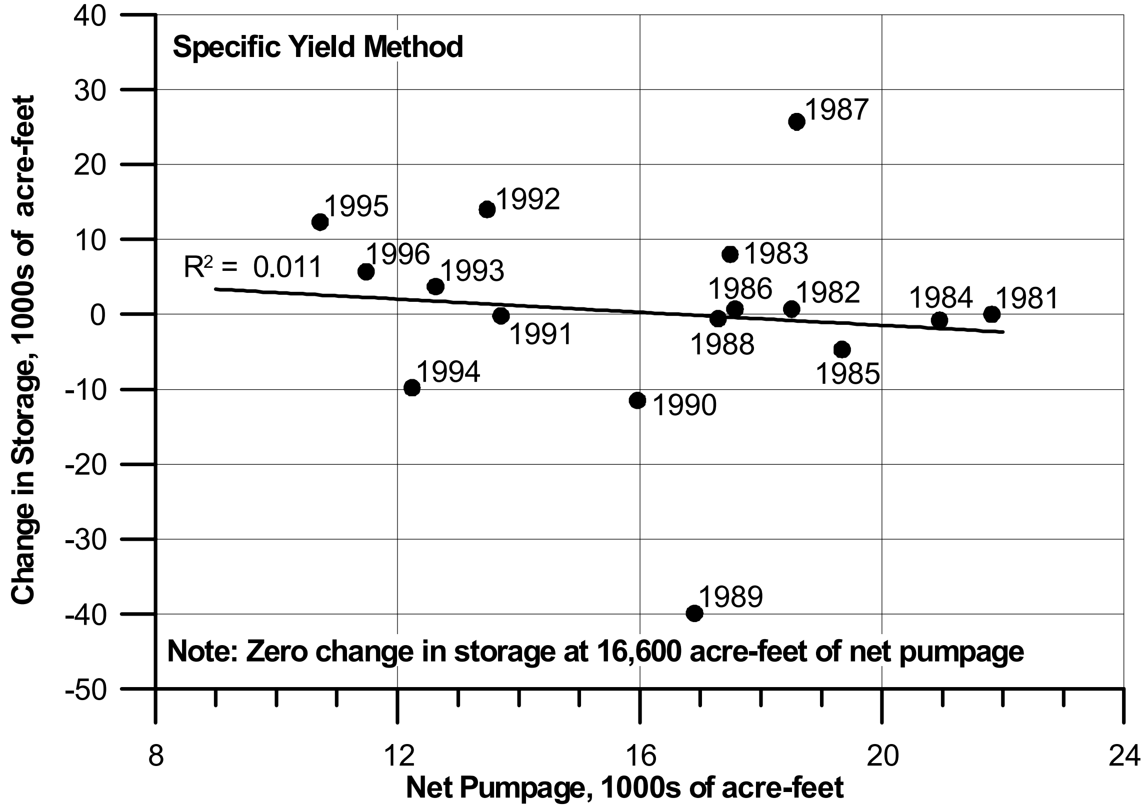


9871\1137fig.dsf.p4

PRACTICAL RATE OF WITHDRAWAL
Paso Robles Groundwater Basin
Paso Robles Groundwater Basin Study

FIGURE 74

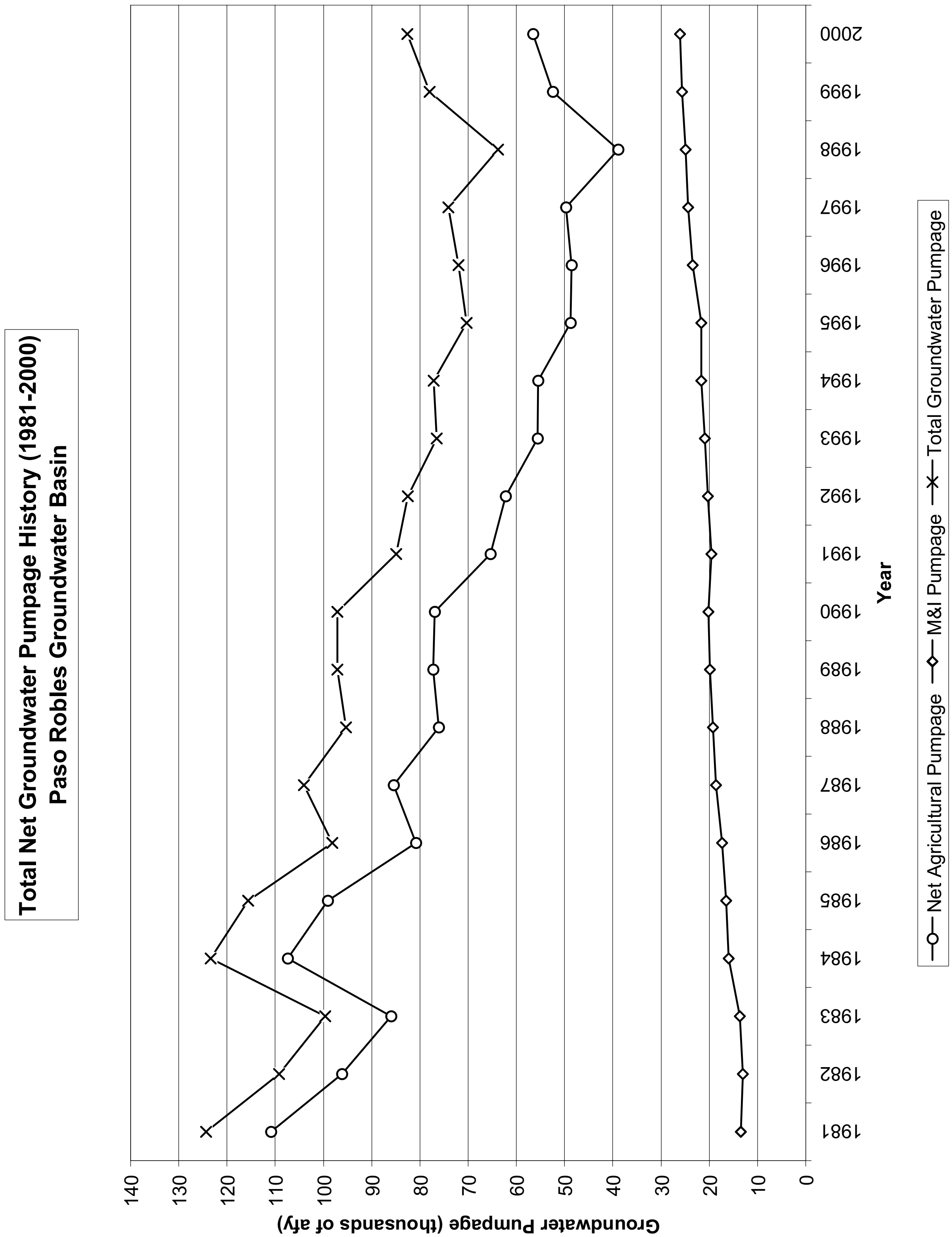




9871\1137fig.dsf.p5

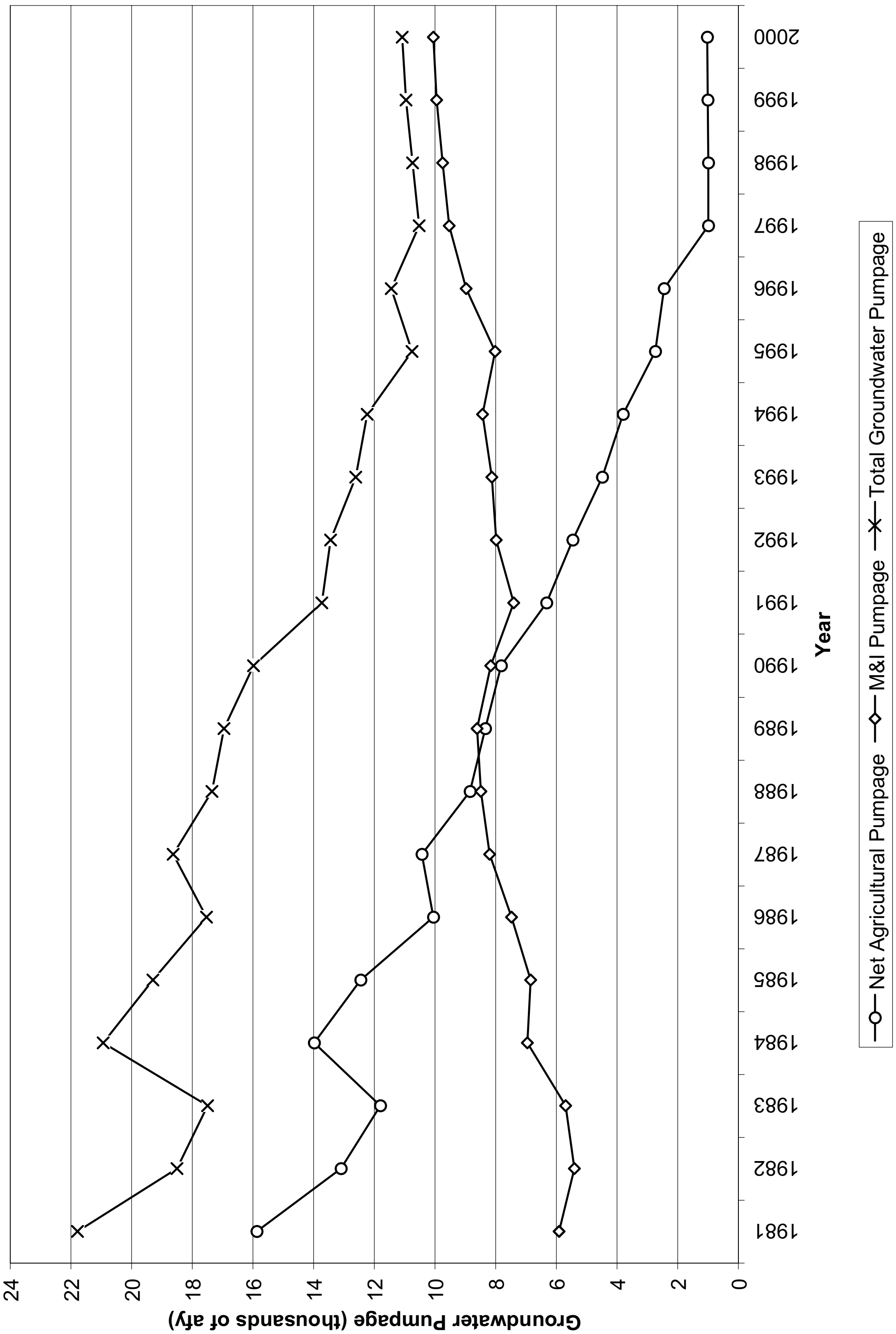
PRACTICAL RATE OF WITHDRAWAL
Atascadero Subbasin
Paso Robles Groundwater Basin Study

FIGURE 75



TOTAL NET GROUNDWATER PUMPAGE HISTORY (1981-2000)
Paso Robles Groundwater Basin
Paso Robles Groundwater Basin Study

9871\1137grph.dsf,p3



TOTAL NET GROUNDWATER PUMPAGE HISTORY (1981-2000)
Atascadero Subbasin
Paso Robles Groundwater Basin Study

9871\1137grph.dsf,p4

FIGURE 77

APPENDIX A
ANALYTICAL LABORATORY RESULTS

CREEK ENVIRONMENTAL LABORATORIES, INC.
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Paul Sorensen
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San Luis Obispo, CA 93401

Log Number: 01-C8473
Order: I3441
Project: Paso Robles Basin 98-71-1
Received: 10/19/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
23S/11E-11E	David Williams	10/19/01@12:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/30/01
Bicarbonate Alkalinity as CaCO3	230	1	mg/L	EPA 310.1	10/30/01
Total Alkalinity as CaCO3	230	2	mg/L	EPA 310.1	10/30/01
Chloride	210	20	mg/L	EPA 300.0	10/19/01
Electrical Conductance	1,400	1	umhos/cm	EPA 120.1	10/19/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/19/01
Nitrate as N	8.8	0.1	mg/L	EPA 300.0	10/19/01
Nitrate as NO3	39	0.4	mg/L	EPA 300.0	10/19/01
pH	7.7	0.1	units	EPA 150.1	10/19/01
Sulfate	200	0.5	mg/L	EPA 300.0	10/19/01
Total Dissolved Solids	870	10	mg/L	EPA 160.1	10/21/01
Boron	0.20	0.05	mg/L	EPA 200.7	10/26/01
Calcium	120	0.03	mg/L	EPA 200.7	10/26/01
Hardness	530	1	mg/L CaCO3	EPA 200.7	10/26/01
Sodium Adsorption Ratio	1.5	0.1		EPA 200.7	10/26/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/26/01
Iron	0.1	0.1	mg/L	EPA 200.7	10/26/01
Potassium	4.4	0.1	mg/L	EPA 200.7	10/26/01
Magnesium	55	0.03	mg/L	EPA 200.7	10/26/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/26/01
Sodium	76	0.05	mg/L	EPA 200.7	10/26/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/26/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8473
Order: I3441
Project: Paso Robles Basin 98-71-1
Received: 10/19/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
23S/11E-11E	David Williams	10/19/01@12:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

Lab Director, Orval Osborne

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Log Number: 01-C8256
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
23S/11E-33A	Spencer Harris	10/11/01@14:45	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/22/01
Bicarbonate Alkalinity as CaCO3	180	1	mg/L	EPA 310.1	10/22/01
Total Alkalinity as CaCO3	180	2	mg/L	EPA 310.1	10/22/01
Chloride	57	1	mg/L	EPA 300.0	10/12/01
Electrical Conductance	570	1	umhos/cm	EPA 120.1	10/12/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/12/01
Nitrate as N	10	0.1	mg/L	EPA 300.0	10/12/01
Nitrate as NO3	44	0.4	mg/L	EPA 300.0	10/12/01
pH	7.4	0.1	units	EPA 150.1	10/12/01
Sulfate	8.9	0.5	mg/L	EPA 300.0	10/12/01
Total Dissolved Solids	370	10	mg/L	EPA 160.1	10/17/01
Boron	0.11	0.05	mg/L	EPA 200.7	10/17/01
Calcium	48	0.03	mg/L	EPA 200.7	10/17/01
Hardness	200	1	mg/L CaCO3	EPA 200.7	10/17/01
Sodium Adsorption Ratio	1.1	0.1		EPA 200.7	10/17/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/17/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/17/01
Potassium	1.7	0.1	mg/L	EPA 200.7	10/17/01
Magnesium	20	0.03	mg/L	EPA 200.7	10/17/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/17/01
Sodium	36	0.05	mg/L	EPA 200.7	10/17/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/17/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8256
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
23S/11E-33A	Spencer Harris	10/11/01@14:45	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

Lab Director, Orval Osborne

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Log Number: 01-C8254
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
24S/10E-4A	Spencer Harris	10/11/01@11:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/22/01
Bicarbonate Alkalinity as CaCO3	170	1	mg/L	EPA 310.1	10/22/01
Total Alkalinity as CaCO3	170	2	mg/L	EPA 310.1	10/22/01
Chloride	47	1	mg/L	EPA 300.0	10/12/01
Electrical Conductance	1,100	1	umhos/cm	EPA 120.1	10/12/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/12/01
Nitrate as N	Not Detected	0.1	mg/L	EPA 300.0	10/12/01
Nitrate as NO3	Not Detected	0.4	mg/L	EPA 300.0	10/12/01
pH	7.5	0.1	units	EPA 150.1	10/12/01
Sulfate	350	10	mg/L	EPA 300.0	10/12/01
Total Dissolved Solids	730	10	mg/L	EPA 160.1	10/17/01
Boron	0.18	0.05	mg/L	EPA 200.7	10/17/01
Calcium	120	0.03	mg/L	EPA 200.7	10/17/01
Hardness	440	1	mg/L CaCO3	EPA 200.7	10/17/01
Sodium Adsorption Ratio	1.1	0.1		EPA 200.7	10/17/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/17/01
Iron	0.5	0.1	mg/L	EPA 200.7	10/17/01
Potassium	3.2	0.1	mg/L	EPA 200.7	10/17/01
Magnesium	35	0.03	mg/L	EPA 200.7	10/17/01
Manganese	0.067	0.03	mg/L	EPA 200.7	10/17/01
Sodium	50	0.05	mg/L	EPA 200.7	10/17/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/17/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8254
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
24S/10E-4A	Spencer Harris	10/11/01@11:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C8255
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
24S/11E-8B	Spencer Harris	10/11/01@12:40	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/22/01
Bicarbonate Alkalinity as CaCO3	170	1	mg/L	EPA 310.1	10/22/01
Total Alkalinity as CaCO3	170	2	mg/L	EPA 310.1	10/22/01
Chloride	58	1	mg/L	EPA 300.0	10/12/01
Electrical Conductance	620	1	umhos/cm	EPA 120.1	10/12/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/12/01
Nitrate as N	12	0.1	mg/L	EPA 300.0	10/12/01
Nitrate as NO3	54	0.4	mg/L	EPA 300.0	10/12/01
pH	7.4	0.1	units	EPA 150.1	10/12/01
Sulfate	30	0.5	mg/L	EPA 300.0	10/12/01
Total Dissolved Solids	400	10	mg/L	EPA 160.1	10/17/01
Boron	0.12	0.05	mg/L	EPA 200.7	10/17/01
Calcium	60	0.03	mg/L	EPA 200.7	10/17/01
Hardness	240	1	mg/L CaCO3	EPA 200.7	10/17/01
Sodium Adsorption Ratio	1.0	0.1		EPA 200.7	10/17/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/17/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/17/01
Potassium	1.5	0.1	mg/L	EPA 200.7	10/17/01
Magnesium	23	0.03	mg/L	EPA 200.7	10/17/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/17/01
Sodium	36	0.05	mg/L	EPA 200.7	10/17/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/17/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8255
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
24S/11E-8B	Spencer Harris	10/11/01@12:40	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

Lab Director, Orval Osborne

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Log Number: 01-C8257
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
24S/12E-17L	Spencer Harris	10/11/01@16:40	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/22/01
Bicarbonate Alkalinity as CaCO3	230	1	mg/L	EPA 310.1	10/22/01
Total Alkalinity as CaCO3	230	2	mg/L	EPA 310.1	10/22/01
Chloride	120	20	mg/L	EPA 300.0	10/12/01
Electrical Conductance	2,000	1	umhos/cm	EPA 120.1	10/12/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/12/01
Nitrate as N	7.7	0.1	mg/L	EPA 300.0	10/12/01
Nitrate as NO3	34	0.4	mg/L	EPA 300.0	10/12/01
pH	7.2	0.1	units	EPA 150.1	10/12/01
Sulfate	650	10	mg/L	EPA 300.0	10/12/01
Total Dissolved Solids	1,300	10	mg/L	EPA 160.1	10/17/01
Boron	0.44	0.05	mg/L	EPA 200.7	10/23/01
Calcium	140	0.03	mg/L	EPA 200.7	10/23/01
Hardness	690	1	mg/L CaCO3	EPA 200.7	10/23/01
Sodium Adsorption Ratio	2.2	0.1		EPA 200.7	10/23/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/23/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/23/01
Potassium	4.7	0.1	mg/L	EPA 200.7	10/23/01
Magnesium	81	0.03	mg/L	EPA 200.7	10/23/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/23/01
Sodium	130	0.05	mg/L	EPA 200.7	10/23/01
Zinc	0.066	0.05	mg/L	EPA 200.7	10/23/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

CREEK ENVIRONMENTAL LABORATORIES, INC.
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Log Number: 01-C8257
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
24S/12E-17L	Spencer Harris	10/11/01@16:40	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

Lab Director, Orval Osborne

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Log Number: 01-C8311
Order: I3382
Project: Paso Robles Basin 98-71-1
Received: 10/16/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
24S/12E-27E	David Williams	10/15/01@01:10	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/24/01
Bicarbonate Alkalinity as CaCO3	320	1	mg/L	EPA 310.1	10/24/01
Total Alkalinity as CaCO3	320	2	mg/L	EPA 310.1	10/24/01
Chloride	55	1	mg/L	EPA 300.0	10/16/01
Electrical Conductance	1,200	1	umhos/cm	EPA 120.1	10/16/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/16/01
Nitrate as N	7.7	0.1	mg/L	EPA 300.0	10/16/01
Nitrate as NO3	34	0.4	mg/L	EPA 300.0	10/16/01
pH	6.9	0.1	units	EPA 150.1	10/16/01
Sulfate	260	0.5	mg/L	EPA 300.0	10/16/01
Total Dissolved Solids	900	10	mg/L	EPA 160.1	10/17/01
Boron	0.22	0.05	mg/L	EPA 200.7	10/25/01
Calcium	140	0.03	mg/L	EPA 200.7	10/25/01
Hardness	610	1	mg/L CaCO3	EPA 200.7	10/25/01
Sodium Adsorption Ratio	0.7	0.1		EPA 200.7	10/25/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/25/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/25/01
Potassium	2.9	0.1	mg/L	EPA 200.7	10/25/01
Magnesium	66	0.03	mg/L	EPA 200.7	10/25/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/25/01
Sodium	39	0.05	mg/L	EPA 200.7	10/25/01
Zinc	1.3	0.05	mg/L	EPA 200.7	10/25/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8311
Order: I3382
Project: Paso Robles Basin 98-71-1
Received: 10/16/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
24S/12E-27E	David Williams	10/15/01@01:10	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

Lab Director, Orval Osborne

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Log Number: 01-C8312
Order: I3382
Project: Paso Robles Basin 98-71-1
Received: 10/16/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
24S/12E-33H (S)	David Williams	10/15/01@01:47	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/24/01
Bicarbonate Alkalinity as CaCO3	250	1	mg/L	EPA 310.1	10/24/01
Total Alkalinity as CaCO3	250	2	mg/L	EPA 310.1	10/24/01
Chloride	35	1	mg/L	EPA 300.0	10/16/01
Electrical Conductance	690	1	umhos/cm	EPA 120.1	10/16/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/16/01
Nitrate as N	5.1	0.1	mg/L	EPA 300.0	10/16/01
Nitrate as NO3	22	0.4	mg/L	EPA 300.0	10/16/01
pH	7.4	0.1	units	EPA 150.1	10/16/01
Sulfate	50	0.5	mg/L	EPA 300.0	10/16/01
Total Dissolved Solids	450	10	mg/L	EPA 160.1	10/17/01
Boron	0.18	0.05	mg/L	EPA 200.7	10/25/01
Calcium	44	0.03	mg/L	EPA 200.7	10/25/01
Hardness	300	1	mg/L CaCO3	EPA 200.7	10/25/01
Sodium Adsorption Ratio	0.9	0.1		EPA 200.7	10/25/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/25/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/25/01
Potassium	2.5	0.1	mg/L	EPA 200.7	10/25/01
Magnesium	47	0.03	mg/L	EPA 200.7	10/25/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/25/01
Sodium	37	0.05	mg/L	EPA 200.7	10/25/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/25/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Order: I3382
Project: Paso Robles Basin 98-71-1
Received: 10/16/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
24S/12E-33H (S)	David Williams	10/15/01@01:47	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8372
Order: I3399
Project: Paso Robles Basin 98-71-1
Received: 10/17/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
24S/13E-23K	David Williams	10/16/01@12:50	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/26/01
Bicarbonate Alkalinity as CaCO3	250	1	mg/L	EPA 310.1	10/26/01
Total Alkalinity as CaCO3	250	2	mg/L	EPA 310.1	10/26/01
Chloride	38	1	mg/L	EPA 300.0	10/17/01
Electrical Conductance	940	1	umhos/cm	EPA 120.1	10/17/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/18/01
Nitrate as N	16	0.1	mg/L	EPA 300.0	10/17/01
Nitrate as NO3	71	0.4	mg/L	EPA 300.0	10/17/01
pH	7.5	0.1	units	EPA 150.1	10/17/01
Sulfate	160	0.5	mg/L	EPA 300.0	10/17/01
Total Dissolved Solids	630	10	mg/L	EPA 160.1	10/21/01
Boron	0.19	0.05	mg/L	EPA 200.7	10/26/01
Calcium	85	0.03	mg/L	EPA 200.7	10/26/01
Hardness	450	1	mg/L CaCO3	EPA 200.7	10/26/01
Sodium Adsorption Ratio	0.6	0.1		EPA 200.7	10/26/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/26/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/26/01
Potassium	2.1	0.1	mg/L	EPA 200.7	10/26/01
Magnesium	58	0.03	mg/L	EPA 200.7	10/26/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/26/01
Sodium	29	0.05	mg/L	EPA 200.7	10/26/01
Zinc	0.38	0.05	mg/L	EPA 200.7	10/26/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8372
Order: I3399
Project: Paso Robles Basin 98-71-1
Received: 10/17/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
24S/13E-23K	David Williams	10/16/01@12:50	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8370
Order: I3399
Project: Paso Robles Basin 98-71-1
Received: 10/17/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/12E-27F	David Williams	10/16/01@09:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/26/01
Bicarbonate Alkalinity as CaCO3	210	1	mg/L	EPA 310.1	10/26/01
Total Alkalinity as CaCO3	210	2	mg/L	EPA 310.1	10/26/01
Chloride	46	1	mg/L	EPA 300.0	10/17/01
Electrical Conductance	660	1	umhos/cm	EPA 120.1	10/17/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/18/01
Nitrate as N	3.9	0.1	mg/L	EPA 300.0	10/17/01
Nitrate as NO3	17	0.4	mg/L	EPA 300.0	10/17/01
pH	7.7	0.1	units	EPA 150.1	10/17/01
Sulfate	60	0.5	mg/L	EPA 300.0	10/17/01
Total Dissolved Solids	410	10	mg/L	EPA 160.1	10/21/01
Boron	0.48	0.05	mg/L	EPA 200.7	10/26/01
Calcium	28	0.03	mg/L	EPA 200.7	10/26/01
Hardness	160	1	mg/L CaCO3	EPA 200.7	10/26/01
Sodium Adsorption Ratio	2.9	0.1		EPA 200.7	10/26/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/26/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/26/01
Potassium	1.4	0.1	mg/L	EPA 200.7	10/26/01
Magnesium	21	0.03	mg/L	EPA 200.7	10/26/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/26/01
Sodium	82	0.05	mg/L	EPA 200.7	10/26/01
Zinc	0.21	0.05	mg/L	EPA 200.7	10/26/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Order: I3399
Project: Paso Robles Basin 98-71-1
Received: 10/17/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/12E-27F	David Williams	10/16/01@09:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8371
Order: I3399
Project: Paso Robles Basin 98-71-1
Received: 10/17/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/12E-27R	David Williams	10/16/01@10:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/26/01
Bicarbonate Alkalinity as CaCO3	260	1	mg/L	EPA 310.1	10/26/01
Total Alkalinity as CaCO3	260	2	mg/L	EPA 310.1	10/26/01
Chloride	170	20	mg/L	EPA 300.0	10/17/01
Electrical Conductance	1,300	1	umhos/cm	EPA 120.1	10/17/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/18/01
Nitrate as N	1.8	0.1	mg/L	EPA 300.0	10/17/01
Nitrate as NO3	8.1	0.4	mg/L	EPA 300.0	10/17/01
pH	7.4	0.1	units	EPA 150.1	10/17/01
Sulfate	240	0.5	mg/L	EPA 300.0	10/17/01
Total Dissolved Solids	830	10	mg/L	EPA 160.1	10/21/01
Boron	0.89	0.05	mg/L	EPA 200.7	10/26/01
Calcium	60	0.03	mg/L	EPA 200.7	10/26/01
Hardness	370	1	mg/L CaCO3	EPA 200.7	10/26/01
Sodium Adsorption Ratio	3.3	0.1		EPA 200.7	10/26/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/26/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/26/01
Potassium	3.2	0.1	mg/L	EPA 200.7	10/26/01
Magnesium	54	0.03	mg/L	EPA 200.7	10/26/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/26/01
Sodium	140	0.05	mg/L	EPA 200.7	10/26/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/26/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Received: 10/17/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/12E-27R	David Williams	10/16/01@10:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8369
Order: I3399
Project: Paso Robles Basin 98-71-1
Received: 10/17/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/12E-33Q	David Williams	10/16/01@09:10	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/26/01
Bicarbonate Alkalinity as CaCO3	400	1	mg/L	EPA 310.1	10/26/01
Total Alkalinity as CaCO3	400	2	mg/L	EPA 310.1	10/26/01
Chloride	260	20	mg/L	EPA 300.0	10/17/01
Electrical Conductance	1,900	1	umhos/cm	EPA 120.1	10/17/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/18/01
Nitrate as N	4.7	0.1	mg/L	EPA 300.0	10/17/01
Nitrate as NO3	21	0.4	mg/L	EPA 300.0	10/17/01
pH	7.0	0.1	units	EPA 150.1	10/17/01
Sulfate	340	10	mg/L	EPA 300.0	10/17/01
Total Dissolved Solids	1,300	10	mg/L	EPA 160.1	10/21/01
Boron	0.78	0.05	mg/L	EPA 200.7	10/26/01
Calcium	120	0.03	mg/L	EPA 200.7	10/26/01
Hardness	580	1	mg/L CaCO3	EPA 200.7	10/26/01
Sodium Adsorption Ratio	4.0	0.1		EPA 200.7	10/26/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/26/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/26/01
Potassium	4.0	0.1	mg/L	EPA 200.7	10/26/01
Magnesium	71	0.03	mg/L	EPA 200.7	10/26/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/26/01
Sodium	220	0.05	mg/L	EPA 200.7	10/26/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/26/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8369
Order: I3399
Project: Paso Robles Basin 98-71-1
Received: 10/17/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/12E-33Q	David Williams	10/16/01@09:10	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8313
Order: I3382
Project: Paso Robles Basin 98-71-1
Received: 10/16/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/13E-21N	David Williams	10/15/01@03:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/24/01
Bicarbonate Alkalinity as CaCO3	230	1	mg/L	EPA 310.1	10/24/01
Total Alkalinity as CaCO3	230	2	mg/L	EPA 310.1	10/24/01
Chloride	41	1	mg/L	EPA 300.0	10/16/01
Electrical Conductance	590	1	umhos/cm	EPA 120.1	10/16/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/16/01
Nitrate as N	2.6	0.1	mg/L	EPA 300.0	10/16/01
Nitrate as NO3	11	0.4	mg/L	EPA 300.0	10/16/01
pH	7.4	0.1	units	EPA 150.1	10/16/01
Sulfate	23	0.5	mg/L	EPA 300.0	10/16/01
Total Dissolved Solids	360	10	mg/L	EPA 160.1	10/17/01
Boron	0.29	0.05	mg/L	EPA 200.7	10/25/01
Calcium	33	0.03	mg/L	EPA 200.7	10/25/01
Hardness	220	1	mg/L CaCO3	EPA 200.7	10/25/01
Sodium Adsorption Ratio	1.5	0.1		EPA 200.7	10/25/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/25/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/25/01
Potassium	2.1	0.1	mg/L	EPA 200.7	10/25/01
Magnesium	33	0.03	mg/L	EPA 200.7	10/25/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/25/01
Sodium	49	0.05	mg/L	EPA 200.7	10/25/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/25/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8313
Order: I3382
Project: Paso Robles Basin 98-71-1
Received: 10/16/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/13E-21N	David Williams	10/15/01@03:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8314
Order: I3382
Project: Paso Robles Basin 98-71-1
Received: 10/16/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/13E-22F	David Williams	10/15/01@03:45	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/24/01
Bicarbonate Alkalinity as CaCO3	240	1	mg/L	EPA 310.1	10/24/01
Total Alkalinity as CaCO3	240	2	mg/L	EPA 310.1	10/24/01
Chloride	44	1	mg/L	EPA 300.0	10/16/01
Electrical Conductance	630	1	umhos/cm	EPA 120.1	10/16/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/16/01
Nitrate as N	2.5	0.1	mg/L	EPA 300.0	10/16/01
Nitrate as NO3	11	0.4	mg/L	EPA 300.0	10/16/01
pH	7.5	0.1	units	EPA 150.1	10/16/01
Sulfate	29	0.5	mg/L	EPA 300.0	10/16/01
Total Dissolved Solids	380	10	mg/L	EPA 160.1	10/17/01
Boron	0.37	0.05	mg/L	EPA 200.7	10/25/01
Calcium	31	0.03	mg/L	EPA 200.7	10/25/01
Hardness	230	1	mg/L CaCO3	EPA 200.7	10/25/01
Sodium Adsorption Ratio	1.7	0.1		EPA 200.7	10/25/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/25/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/25/01
Potassium	2.3	0.1	mg/L	EPA 200.7	10/25/01
Magnesium	37	0.03	mg/L	EPA 200.7	10/25/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/25/01
Sodium	58	0.05	mg/L	EPA 200.7	10/25/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/25/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8314
Order: I3382
Project: Paso Robles Basin 98-71-1
Received: 10/16/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/13E-22F	David Williams	10/15/01@03:45	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C8250
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/15E-31K (S)	Spencer Harris	10/11/01@16:35	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/22/01
Bicarbonate Alkalinity as CaCO3	200	1	mg/L	EPA 310.1	10/22/01
Total Alkalinity as CaCO3	200	2	mg/L	EPA 310.1	10/22/01
Chloride	93	1	mg/L	EPA 300.0	10/12/01
Electrical Conductance	830	1	umhos/cm	EPA 120.1	10/12/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/12/01
Nitrate as N	9.2	0.1	mg/L	EPA 300.0	10/12/01
Nitrate as NO3	41	0.4	mg/L	EPA 300.0	10/12/01
pH	7.1	0.1	units	EPA 150.1	10/12/01
Sulfate	92	0.5	mg/L	EPA 300.0	10/12/01
Total Dissolved Solids	550	10	mg/L	EPA 160.1	10/17/01
Boron	0.35	0.05	mg/L	EPA 200.7	10/17/01
Calcium	70	0.03	mg/L	EPA 200.7	10/17/01
Hardness	330	1	mg/L CaCO3	EPA 200.7	10/17/01
Sodium Adsorption Ratio	1.5	0.1		EPA 200.7	10/17/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/17/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/17/01
Potassium	1.2	0.1	mg/L	EPA 200.7	10/17/01
Magnesium	37	0.03	mg/L	EPA 200.7	10/17/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/17/01
Sodium	62	0.05	mg/L	EPA 200.7	10/17/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/17/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8250
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/15E-31K (S)	Spencer Harris	10/11/01@16:35	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8249
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/15E-31Q	Spencer Harris	10/11/01@16:20	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/22/01
Bicarbonate Alkalinity as CaCO3	160	1	mg/L	EPA 310.1	10/22/01
Total Alkalinity as CaCO3	160	2	mg/L	EPA 310.1	10/22/01
Chloride	45	1	mg/L	EPA 300.0	10/12/01
Electrical Conductance	650	1	umhos/cm	EPA 120.1	10/12/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/12/01
Nitrate as N	3.9	0.1	mg/L	EPA 300.0	10/12/01
Nitrate as NO3	17	0.4	mg/L	EPA 300.0	10/12/01
pH	7.2	0.1	units	EPA 150.1	10/12/01
Sulfate	100	0.5	mg/L	EPA 300.0	10/12/01
Total Dissolved Solids	460	10	mg/L	EPA 160.1	10/17/01
Boron	0.41	0.05	mg/L	EPA 200.7	10/17/01
Calcium	63	0.03	mg/L	EPA 200.7	10/17/01
Hardness	230	1	mg/L CaCO3	EPA 200.7	10/17/01
Sodium Adsorption Ratio	1.8	0.1		EPA 200.7	10/17/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/17/01
Iron	0.1	0.1	mg/L	EPA 200.7	10/17/01
Potassium	3.2	0.1	mg/L	EPA 200.7	10/17/01
Magnesium	18	0.03	mg/L	EPA 200.7	10/17/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/17/01
Sodium	63	0.05	mg/L	EPA 200.7	10/17/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/17/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8249
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
25S/15E-31Q	Spencer Harris	10/11/01@16:20	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8474
Order: I3441
Project: Paso Robles Basin 98-71-1
Received: 10/19/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/12E-4K	David Williams	10/19/01@14:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/30/01
Bicarbonate Alkalinity as CaCO3	260	1	mg/L	EPA 310.1	10/30/01
Total Alkalinity as CaCO3	260	2	mg/L	EPA 310.1	10/30/01
Chloride	150	20	mg/L	EPA 300.0	10/19/01
Electrical Conductance	1,100	1	umhos/cm	EPA 120.1	10/19/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/19/01
Nitrate as N	2.3	0.1	mg/L	EPA 300.0	10/19/01
Nitrate as NO3	10	0.4	mg/L	EPA 300.0	10/19/01
pH	7.4	0.1	units	EPA 150.1	10/19/01
Sulfate	110	0.5	mg/L	EPA 300.0	10/19/01
Total Dissolved Solids	590	10	mg/L	EPA 160.1	10/21/01
Boron	0.30	0.05	mg/L	EPA 200.7	10/26/01
Calcium	77	0.03	mg/L	EPA 200.7	10/26/01
Hardness	380	1	mg/L CaCO3	EPA 200.7	10/26/01
Sodium Adsorption Ratio	1.8	0.1		EPA 200.7	10/26/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/26/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/26/01
Potassium	2.2	0.1	mg/L	EPA 200.7	10/26/01
Magnesium	46	0.03	mg/L	EPA 200.7	10/26/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/26/01
Sodium	77	0.05	mg/L	EPA 200.7	10/26/01
Zinc	0.10	0.05	mg/L	EPA 200.7	10/26/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8474
Order: I3441
Project: Paso Robles Basin 98-71-1
Received: 10/19/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/12E-4K	David Williams	10/19/01@14:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8433
Order: I3421
Project: Paso Robles Basin 98-71-1
Received: 10/18/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/12E-20A01 (S)	Spencer Harris	10/17/01@01:20	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/29/01
Bicarbonate Alkalinity as CaCO3	210	1	mg/L	EPA 310.1	10/29/01
Total Alkalinity as CaCO3	210	2	mg/L	EPA 310.1	10/29/01
Chloride	560	20	mg/L	EPA 300.0	10/18/01
Electrical Conductance	2,600	1	umhos/cm	EPA 120.1	10/18/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/18/01
Nitrate as N	Not Detected	0.1	mg/L	EPA 300.0	10/18/01
Nitrate as NO3	Not Detected	0.4	mg/L	EPA 300.0	10/18/01
pH	7.2	0.1	units	EPA 150.1	10/18/01
Sulfate	380	10	mg/L	EPA 300.0	10/18/01
Total Dissolved Solids	1,600	10	mg/L	EPA 160.1	10/21/01
Boron	5.2	0.05	mg/L	EPA 200.7	10/26/01
Calcium	120	0.03	mg/L	EPA 200.7	10/26/01
Hardness	430	1	mg/L CaCO3	EPA 200.7	10/26/01
Sodium Adsorption Ratio	7.6	0.1		EPA 200.7	10/26/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/26/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/26/01
Potassium	4.7	0.1	mg/L	EPA 200.7	10/26/01
Magnesium	29	0.03	mg/L	EPA 200.7	10/26/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/26/01
Sodium	360	0.05	mg/L	EPA 200.7	10/26/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/26/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8433
Order: I3421
Project: Paso Robles Basin 98-71-1
Received: 10/18/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/12E-20A01 (S)	Spencer Harris	10/17/01@01:20	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8472
Order: I3441
Project: Paso Robles Basin 98-71-1
Received: 10/19/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/12E-29B	David Williams	10/19/01@10:10	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/30/01
Bicarbonate Alkalinity as CaCO3	160	1	mg/L	EPA 310.1	10/30/01
Total Alkalinity as CaCO3	160	2	mg/L	EPA 310.1	10/30/01
Chloride	570	20	mg/L	EPA 300.0	10/19/01
Electrical Conductance	2,400	1	umhos/cm	EPA 120.1	10/19/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/19/01
Nitrate as N	Not Detected	0.1	mg/L	EPA 300.0	10/19/01
Nitrate as NO3	Not Detected	0.4	mg/L	EPA 300.0	10/19/01
pH	7.2	0.1	units	EPA 150.1	10/19/01
Sulfate	310	10	mg/L	EPA 300.0	10/19/01
Sulfide, Total	5.1	1	mg/L	EPA 376.2	10/24/01
Total Dissolved Solids	1,300	10	mg/L	EPA 160.1	10/21/01
Boron	5.7	0.05	mg/L	EPA 200.7	10/26/01
Calcium	120	0.03	mg/L	EPA 200.7	10/26/01
Hardness	380	1	mg/L CaCO3	EPA 200.7	10/26/01
Sodium Adsorption Ratio	8.1	0.1		EPA 200.7	10/26/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/26/01
Iron	0.2	0.1	mg/L	EPA 200.7	10/26/01
Potassium	4.3	0.1	mg/L	EPA 200.7	10/26/01
Magnesium	21	0.03	mg/L	EPA 200.7	10/26/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/26/01
Sodium	360	0.05	mg/L	EPA 200.7	10/26/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/26/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8472
Order: I3441
Project: Paso Robles Basin 98-71-1
Received: 10/19/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/12E-29B	David Williams	10/19/01@10:10	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C8004
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/13E-5E	Spencer Harris	10/04/01@16:10	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/17/01
Bicarbonate Alkalinity as CaCO3	230	1	mg/L	EPA 310.1	10/17/01
Total Alkalinity as CaCO3	230	2	mg/L	EPA 310.1	10/17/01
Chloride	220	10	mg/L	EPA 300.0	10/05/01
Electrical Conductance	1,400	1	umhos/cm	EPA 120.1	10/05/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/05/01
Nitrate as N	3.2	0.1	mg/L	EPA 300.0	10/05/01
Nitrate as NO3	14	0.4	mg/L	EPA 300.0	10/05/01
pH	7.8	0.1	units	EPA 150.1	10/05/01
Sulfate	270	0.5	mg/L	EPA 300.0	10/05/01
Total Dissolved Solids	1,000	10	mg/L	EPA 160.1	10/09/01
Boron	0.59	0.05	mg/L	EPA 200.7	10/12/01
Calcium	93	0.03	mg/L	EPA 200.7	10/12/01
Hardness	560	1	mg/L CaCO3	EPA 200.7	10/12/01
Sodium Adsorption Ratio	2.1	0.1		EPA 200.7	10/12/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/12/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/12/01
Potassium	2.7	0.1	mg/L	EPA 200.7	10/12/01
Magnesium	81	0.03	mg/L	EPA 200.7	10/12/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/12/01
Sodium	110	0.05	mg/L	EPA 200.7	10/12/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/12/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8004
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/13E-5E	Spencer Harris	10/04/01@16:10	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C8005
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/13E-19P	Spencer Harris	10/04/01@16:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/17/01
Bicarbonate Alkalinity as CaCO3	190	1	mg/L	EPA 310.1	10/17/01
Total Alkalinity as CaCO3	190	2	mg/L	EPA 310.1	10/17/01
Chloride	61	1	mg/L	EPA 300.0	10/05/01
Electrical Conductance	560	1	umhos/cm	EPA 120.1	10/05/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/05/01
Nitrate as N	4.5	0.1	mg/L	EPA 300.0	10/05/01
Nitrate as NO3	20	0.4	mg/L	EPA 300.0	10/05/01
pH	7.6	0.1	units	EPA 150.1	10/05/01
Sulfate	11	0.5	mg/L	EPA 300.0	10/05/01
Total Dissolved Solids	360	10	mg/L	EPA 160.1	10/09/01
Boron	0.13	0.05	mg/L	EPA 200.7	10/12/01
Calcium	47	0.03	mg/L	EPA 200.7	10/12/01
Hardness	230	1	mg/L CaCO3	EPA 200.7	10/12/01
Sodium Adsorption Ratio	1.1	0.1		EPA 200.7	10/12/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/12/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/12/01
Potassium	1.5	0.1	mg/L	EPA 200.7	10/12/01
Magnesium	27	0.03	mg/L	EPA 200.7	10/12/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/12/01
Sodium	37	0.05	mg/L	EPA 200.7	10/12/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/12/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8005
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/13E-19P	Spencer Harris	10/04/01@16:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C8003
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/13E-28K	Spencer Harris	10/04/01@14:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/17/01
Bicarbonate Alkalinity as CaCO3	210	1	mg/L	EPA 310.1	10/17/01
Total Alkalinity as CaCO3	210	2	mg/L	EPA 310.1	10/17/01
Chloride	38	1	mg/L	EPA 300.0	10/05/01
Electrical Conductance	520	1	umhos/cm	EPA 120.1	10/05/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/05/01
Nitrate as N	Not Detected	0.1	mg/L	EPA 300.0	10/05/01
Nitrate as NO3	Not Detected	0.4	mg/L	EPA 300.0	10/05/01
pH	7.8	0.1	units	EPA 150.1	10/05/01
Sulfate	26	0.5	mg/L	EPA 300.0	10/05/01
Total Dissolved Solids	340	10	mg/L	EPA 160.1	10/09/01
Boron	0.39	0.05	mg/L	EPA 200.7	10/12/01
Calcium	28	0.03	mg/L	EPA 200.7	10/12/01
Hardness	150	1	mg/L CaCO3	EPA 200.7	10/12/01
Sodium Adsorption Ratio	2.4	0.1		EPA 200.7	10/12/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/12/01
Iron	0.9	0.1	mg/L	EPA 200.7	10/12/01
Potassium	1.7	0.1	mg/L	EPA 200.7	10/12/01
Magnesium	20	0.03	mg/L	EPA 200.7	10/12/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/12/01
Sodium	66	0.05	mg/L	EPA 200.7	10/12/01
Zinc	1.9	0.05	mg/L	EPA 200.7	10/12/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8003
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/13E-28K	Spencer Harris	10/04/01@14:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C7999
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/14E-14R	Spencer Harris	10/04/01@08:45	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/17/01
Bicarbonate Alkalinity as CaCO3	210	1	mg/L	EPA 310.1	10/17/01
Total Alkalinity as CaCO3	210	2	mg/L	EPA 310.1	10/17/01
Chloride	48	1	mg/L	EPA 300.0	10/05/01
Electrical Conductance	670	1	umhos/cm	EPA 120.1	10/05/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/05/01
Nitrate as N	1.8	0.1	mg/L	EPA 300.0	10/05/01
Nitrate as NO3	7.8	0.4	mg/L	EPA 300.0	10/05/01
pH	7.7	0.1	units	EPA 150.1	10/05/01
Sulfate	78	0.5	mg/L	EPA 300.0	10/05/01
Total Dissolved Solids	460	10	mg/L	EPA 160.1	10/09/01
Boron	0.63	0.05	mg/L	EPA 200.7	10/12/01
Calcium	36	0.03	mg/L	EPA 200.7	10/12/01
Hardness	120	1	mg/L CaCO3	EPA 200.7	10/12/01
Sodium Adsorption Ratio	4.9	0.1		EPA 200.7	10/12/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/12/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/12/01
Potassium	2.9	0.1	mg/L	EPA 200.7	10/12/01
Magnesium	6.5	0.03	mg/L	EPA 200.7	10/12/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/12/01
Sodium	120	0.05	mg/L	EPA 200.7	10/12/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/12/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C7999
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/14E-14R	Spencer Harris	10/04/01@08:45	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C7870
Order: I3193
Project: Paso Robles Basin 98-71-1
Received: 10/03/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/14E-18J01	Spencer Harris	10/02/01@15:20	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/11/01
Bicarbonate Alkalinity as CaCO3	210	1	mg/L	EPA 310.1	10/11/01
Total Alkalinity as CaCO3	210	2	mg/L	EPA 310.1	10/11/01
Chloride	64	1	mg/L	EPA 300.0	10/03/01
Electrical Conductance	730	1	umhos/cm	EPA 120.1	10/03/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/04/01
Nitrate as N	2.2	0.1	mg/L	EPA 300.0	10/03/01
Nitrate as NO3	9.7	0.4	mg/L	EPA 300.0	10/03/01
pH	7.4	0.1	units	EPA 150.1	10/03/01
Sulfate	100	0.5	mg/L	EPA 300.0	10/03/01
Total Dissolved Solids	460	10	mg/L	EPA 160.1	10/06/01
Boron	0.49	0.05	mg/L	EPA 200.7	10/08/01
Calcium	39	0.03	mg/L	EPA 200.7	10/08/01
Hardness	200	1	mg/L CaCO3	EPA 200.7	10/08/01
Sodium Adsorption Ratio	2.8	0.1		EPA 200.7	10/08/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/08/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/08/01
Potassium	2.8	0.1	mg/L	EPA 200.7	10/08/01
Magnesium	25	0.03	mg/L	EPA 200.7	10/08/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/08/01
Sodium	89	0.05	mg/L	EPA 200.7	10/08/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/08/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C7870
Order: I3193
Project: Paso Robles Basin 98-71-1
Received: 10/03/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/14E-18J01	Spencer Harris	10/02/01@15:20	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C8000
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/14E-21M01	Spencer Harris	10/04/01@09:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/17/01
Bicarbonate Alkalinity as CaCO3	220	1	mg/L	EPA 310.1	10/17/01
Total Alkalinity as CaCO3	220	2	mg/L	EPA 310.1	10/17/01
Chloride	31	1	mg/L	EPA 300.0	10/05/01
Electrical Conductance	600	1	umhos/cm	EPA 120.1	10/05/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/05/01
Nitrate as N	1.3	0.1	mg/L	EPA 300.0	10/05/01
Nitrate as NO3	5.6	0.4	mg/L	EPA 300.0	10/05/01
pH	7.8	0.1	units	EPA 150.1	10/05/01
Sulfate	64	0.5	mg/L	EPA 300.0	10/05/01
Total Dissolved Solids	440	10	mg/L	EPA 160.1	10/09/01
Boron	0.53	0.05	mg/L	EPA 200.7	10/12/01
Calcium	26	0.03	mg/L	EPA 200.7	10/12/01
Hardness	100	1	mg/L CaCO3	EPA 200.7	10/12/01
Sodium Adsorption Ratio	5.3	0.1		EPA 200.7	10/12/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/12/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/12/01
Potassium	2.7	0.1	mg/L	EPA 200.7	10/12/01
Magnesium	7.6	0.03	mg/L	EPA 200.7	10/12/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/12/01
Sodium	120	0.05	mg/L	EPA 200.7	10/12/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/12/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8000
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/14E-21M01	Spencer Harris	10/04/01@09:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8251
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/15E-6N (S)	Spencer Harris	10/11/01@17:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/22/01
Bicarbonate Alkalinity as CaCO3	210	1	mg/L	EPA 310.1	10/22/01
Total Alkalinity as CaCO3	210	2	mg/L	EPA 310.1	10/22/01
Chloride	240	20	mg/L	EPA 300.0	10/12/01
Electrical Conductance	3,500	1	umhos/cm	EPA 120.1	10/12/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/12/01
Nitrate as N	12	0.1	mg/L	EPA 300.0	10/12/01
Nitrate as NO3	54	0.4	mg/L	EPA 300.0	10/12/01
pH	7.0	0.1	units	EPA 150.1	10/12/01
Sulfate	2,000	10	mg/L	EPA 300.0	10/12/01
Total Dissolved Solids	3,200	10	mg/L	EPA 160.1	10/17/01
Boron	1.3	0.05	mg/L	EPA 200.7	10/17/01
Calcium	340	0.03	mg/L	EPA 200.7	10/23/01
Hardness	1,700	1	mg/L CaCO3	EPA 200.7	10/23/01
Sodium Adsorption Ratio	2.5	0.1		EPA 200.7	10/23/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/17/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/17/01
Potassium	3.9	0.1	mg/L	EPA 200.7	10/17/01
Magnesium	220	0.03	mg/L	EPA 200.7	10/23/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/17/01
Sodium	240	0.05	mg/L	EPA 200.7	10/17/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/17/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8251
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/15E-6N (S)	Spencer Harris	10/11/01@17:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8252
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/15E-21G	Spencer Harris	10/11/01@17:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/22/01
Bicarbonate Alkalinity as CaCO3	180	1	mg/L	EPA 310.1	10/22/01
Total Alkalinity as CaCO3	180	2	mg/L	EPA 310.1	10/22/01
Chloride	450	20	mg/L	EPA 300.0	10/12/01
Electrical Conductance	2,700	1	umhos/cm	EPA 120.1	10/12/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/12/01
Nitrate as N	2.9	0.1	mg/L	EPA 300.0	10/12/01
Nitrate as NO3	13	0.4	mg/L	EPA 300.0	10/12/01
pH	7.2	0.1	units	EPA 150.1	10/12/01
Sulfate	580	10	mg/L	EPA 300.0	10/12/01
Total Dissolved Solids	1,600	10	mg/L	EPA 160.1	10/17/01
Boron	1.3	0.05	mg/L	EPA 200.7	10/17/01
Calcium	180	0.03	mg/L	EPA 200.7	10/17/01
Hardness	570	1	mg/L CaCO3	EPA 200.7	10/17/01
Sodium Adsorption Ratio	6.0	0.1		EPA 200.7	10/17/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/17/01
Iron	0.6	0.1	mg/L	EPA 200.7	10/17/01
Potassium	5.4	0.1	mg/L	EPA 200.7	10/17/01
Magnesium	31	0.03	mg/L	EPA 200.7	10/17/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/17/01
Sodium	320	0.05	mg/L	EPA 200.7	10/17/01
Zinc	0.12	0.05	mg/L	EPA 200.7	10/17/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8252
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/15E-21G	Spencer Harris	10/11/01@17:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8253
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/15E-28Q02	Spencer Harris	10/11/01@17:45	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/22/01
Bicarbonate Alkalinity as CaCO3	140	1	mg/L	EPA 310.1	10/22/01
Total Alkalinity as CaCO3	140	2	mg/L	EPA 310.1	10/22/01
Chloride	180	20	mg/L	EPA 300.0	10/12/01
Electrical Conductance	1,500	1	umhos/cm	EPA 120.1	10/12/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/12/01
Nitrate as N	1.9	0.1	mg/L	EPA 300.0	10/12/01
Nitrate as NO3	8.3	0.4	mg/L	EPA 300.0	10/12/01
pH	7.3	0.1	units	EPA 150.1	10/12/01
Sulfate	410	10	mg/L	EPA 300.0	10/12/01
Total Dissolved Solids	1,100	10	mg/L	EPA 160.1	10/17/01
Boron	0.48	0.05	mg/L	EPA 200.7	10/17/01
Calcium	170	0.03	mg/L	EPA 200.7	10/17/01
Hardness	510	1	mg/L CaCO3	EPA 200.7	10/17/01
Sodium Adsorption Ratio	2.4	0.1		EPA 200.7	10/17/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/17/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/17/01
Potassium	3.3	0.1	mg/L	EPA 200.7	10/17/01
Magnesium	22	0.03	mg/L	EPA 200.7	10/17/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/17/01
Sodium	120	0.05	mg/L	EPA 200.7	10/17/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/17/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8253
Order: I3352
Project: Paso Robles Basin 98-71-1
Received: 10/12/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/15E-28Q02	Spencer Harris	10/11/01@17:45	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8434
Order: I3421
Project: Paso Robles Basin 98-71-1
Received: 10/18/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/15E-31K	Spencer Harris	10/17/01@03:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/29/01
Bicarbonate Alkalinity as CaCO3	120	1	mg/L	EPA 310.1	10/29/01
Total Alkalinity as CaCO3	120	2	mg/L	EPA 310.1	10/29/01
Chloride	33	1	mg/L	EPA 300.0	10/18/01
Electrical Conductance	440	1	umhos/cm	EPA 120.1	10/18/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/18/01
Nitrate as N	7.9	0.1	mg/L	EPA 300.0	10/18/01
Nitrate as NO3	35	0.4	mg/L	EPA 300.0	10/18/01
pH	7.6	0.1	units	EPA 150.1	10/18/01
Sulfate	14	0.5	mg/L	EPA 300.0	10/18/01
Total Dissolved Solids	270	10	mg/L	EPA 160.1	10/21/01
Boron	0.077	0.05	mg/L	EPA 200.7	10/26/01
Calcium	55	0.03	mg/L	EPA 200.7	10/26/01
Hardness	160	1	mg/L CaCO3	EPA 200.7	10/26/01
Sodium Adsorption Ratio	0.9	0.1		EPA 200.7	10/26/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/26/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/26/01
Potassium	2.0	0.1	mg/L	EPA 200.7	10/26/01
Magnesium	4.7	0.03	mg/L	EPA 200.7	10/26/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/26/01
Sodium	26	0.05	mg/L	EPA 200.7	10/26/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/26/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8434
Order: I3421
Project: Paso Robles Basin 98-71-1
Received: 10/18/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/15E-31K	Spencer Harris	10/17/01@03:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C7868
Order: I3193
Project: Paso Robles Basin 98-71-1
Received: 10/03/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/15E-33C01	Spencer Harris	10/02/01@10:37	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/11/01
Bicarbonate Alkalinity as CaCO3	98	1	mg/L	EPA 310.1	10/11/01
Total Alkalinity as CaCO3	98	2	mg/L	EPA 310.1	10/11/01
Chloride	95	1	mg/L	EPA 300.0	10/03/01
Electrical Conductance	570	1	umhos/cm	EPA 120.1	10/03/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/04/01
Nitrate as N	2.0	0.1	mg/L	EPA 300.0	10/03/01
Nitrate as NO3	8.8	0.4	mg/L	EPA 300.0	10/03/01
pH	7.3	0.1	units	EPA 150.1	10/03/01
Sulfate	79	0.5	mg/L	EPA 300.0	10/03/01
Total Dissolved Solids	330	10	mg/L	EPA 160.1	10/06/01
Boron	0.11	0.05	mg/L	EPA 200.7	10/09/01
Calcium	87	0.03	mg/L	EPA 200.7	10/09/01
Hardness	240	1	mg/L CaCO3	EPA 200.7	10/09/01
Sodium Adsorption Ratio	1.0	0.1		EPA 200.7	10/09/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/09/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/09/01
Potassium	2.7	0.1	mg/L	EPA 200.7	10/09/01
Magnesium	6.3	0.03	mg/L	EPA 200.7	10/09/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/09/01
Sodium	36	0.05	mg/L	EPA 200.7	10/09/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/09/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C7868
Order: I3193
Project: Paso Robles Basin 98-71-1
Received: 10/03/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
26S/15E-33C01	Spencer Harris	10/02/01@10:37	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8432
Order: I3421
Project: Paso Robles Basin 98-71-1
Received: 10/18/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/12E-16G01 (S)	Spencer Harris	10/17/01@11:15	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	20	1	mg/L	EPA 310.1	10/24/01
Bicarbonate Alkalinity as CaCO3	360	1	mg/L	EPA 310.1	10/24/01
Total Alkalinity as CaCO3	380	2	mg/L	EPA 310.1	10/24/01
Chloride	140	20	mg/L	EPA 300.0	10/18/01
Electrical Conductance	1,400	1	umhos/cm	EPA 120.1	10/18/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/18/01
Nitrate as N	Not Detected	0.1	mg/L	EPA 300.0	10/18/01
Nitrate as NO3	Not Detected	0.4	mg/L	EPA 300.0	10/18/01
pH	8.7	0.1	units	EPA 150.1	10/18/01
Sulfate	120	0.5	mg/L	EPA 300.0	10/18/01
Total Dissolved Solids	830	10	mg/L	EPA 160.1	10/21/01
Boron	1.5	0.05	mg/L	EPA 200.7	10/26/01
Calcium	3.7	0.03	mg/L	EPA 200.7	10/26/01
Hardness	15	1	mg/L CaCO3	EPA 200.7	10/26/01
Sodium Adsorption Ratio	35	0.1		EPA 200.7	10/26/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/26/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/26/01
Potassium	2.4	0.1	mg/L	EPA 200.7	10/26/01
Magnesium	1.4	0.03	mg/L	EPA 200.7	10/26/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/26/01
Sodium	300	0.05	mg/L	EPA 200.7	10/26/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/26/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8432
Order: I3421
Project: Paso Robles Basin 98-71-1
Received: 10/18/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/12E-16G01 (S)	Spencer Harris	10/17/01@11:15	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8431
Order: I3421
Project: Paso Robles Basin 98-71-1
Received: 10/18/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/12E-22N	Spencer Harris	10/17/01@10:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/29/01
Bicarbonate Alkalinity as CaCO3	290	1	mg/L	EPA 310.1	10/29/01
Total Alkalinity as CaCO3	290	2	mg/L	EPA 310.1	10/29/01
Chloride	110	20	mg/L	EPA 300.0	10/18/01
Electrical Conductance	1,200	1	umhos/cm	EPA 120.1	10/18/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/18/01
Nitrate as N	6.9	0.1	mg/L	EPA 300.0	10/18/01
Nitrate as NO3	30	0.4	mg/L	EPA 300.0	10/18/01
pH	7.5	0.1	units	EPA 150.1	10/18/01
Sulfate	220	0.5	mg/L	EPA 300.0	10/18/01
Total Dissolved Solids	790	10	mg/L	EPA 160.1	10/21/01
Boron	0.36	0.05	mg/L	EPA 200.7	10/26/01
Calcium	91	0.03	mg/L	EPA 200.7	10/26/01
Hardness	380	1	mg/L CaCO3	EPA 200.7	10/26/01
Sodium Adsorption Ratio	2.8	0.1		EPA 200.7	10/26/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/26/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/26/01
Potassium	3.0	0.1	mg/L	EPA 200.7	10/26/01
Magnesium	37	0.03	mg/L	EPA 200.7	10/26/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/26/01
Sodium	120	0.05	mg/L	EPA 200.7	10/26/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/26/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8431
Order: I3421
Project: Paso Robles Basin 98-71-1
Received: 10/18/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/12E-22N	Spencer Harris	10/17/01@10:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8163
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/13E-14P	David Williams	10/08/01@11:00	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/18/01
Bicarbonate Alkalinity as CaCO3	320	1	mg/L	EPA 310.1	10/18/01
Total Alkalinity as CaCO3	320	2	mg/L	EPA 310.1	10/18/01
Chloride	510	20	mg/L	EPA 300.0	10/10/01
Electrical Conductance	2,600	1	umhos/cm	EPA 120.1	10/10/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/10/01
Nitrate as N	5.7	0.1	mg/L	EPA 300.0	10/10/01
Nitrate as NO3	25	0.4	mg/L	EPA 300.0	10/10/01
pH	7.0	0.1	units	EPA 150.1	10/10/01
Sulfate	350	10	mg/L	EPA 300.0	10/10/01
Total Dissolved Solids	1,600	10	mg/L	EPA 160.1	10/12/01
Boron	0.18	0.05	mg/L	EPA 200.7	10/15/01
Calcium	220	0.03	mg/L	EPA 200.7	10/15/01
Hardness	810	1	mg/L CaCO3	EPA 200.7	10/15/01
Sodium Adsorption Ratio	4.4	0.1		EPA 200.7	10/15/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/15/01
Potassium	2.7	0.1	mg/L	EPA 200.7	10/15/01
Magnesium	62	0.03	mg/L	EPA 200.7	10/15/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/15/01
Sodium	280	0.05	mg/L	EPA 200.7	10/15/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/15/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8163
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/13E-14P	David Williams	10/08/01@11:00	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8164
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/13E-20A	David Williams	10/08/01@11:15	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/18/01
Bicarbonate Alkalinity as CaCO3	190	1	mg/L	EPA 310.1	10/18/01
Total Alkalinity as CaCO3	190	2	mg/L	EPA 310.1	10/18/01
Chloride	84	1	mg/L	EPA 300.0	10/10/01
Electrical Conductance	630	1	umhos/cm	EPA 120.1	10/10/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/10/01
Nitrate as N	2.4	0.1	mg/L	EPA 300.0	10/10/01
Nitrate as NO3	10	0.4	mg/L	EPA 300.0	10/10/01
pH	7.3	0.1	units	EPA 150.1	10/10/01
Sulfate	18	0.5	mg/L	EPA 300.0	10/10/01
Total Dissolved Solids	340	10	mg/L	EPA 160.1	10/12/01
Boron	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Calcium	63	0.03	mg/L	EPA 200.7	10/15/01
Hardness	260	1	mg/L CaCO3	EPA 200.7	10/15/01
Sodium Adsorption Ratio	1.2	0.1		EPA 200.7	10/15/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/15/01
Potassium	1.5	0.1	mg/L	EPA 200.7	10/15/01
Magnesium	24	0.03	mg/L	EPA 200.7	10/15/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/15/01
Sodium	42	0.05	mg/L	EPA 200.7	10/15/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/15/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8164
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/13E-20A	David Williams	10/08/01@11:15	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C8043
Order: I3258
Project: Paso Robles Basin/98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/13E-25M	David Williams	10/05/01@13:15	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/17/01
Bicarbonate Alkalinity as CaCO3	200	1	mg/L	EPA 310.1	10/17/01
Total Alkalinity as CaCO3	200	2	mg/L	EPA 310.1	10/17/01
Chloride	51	1	mg/L	EPA 300.0	10/05/01
Electrical Conductance	700	1	umhos/cm	EPA 120.1	10/05/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/05/01
Nitrate as N	5.0	0.1	mg/L	EPA 300.0	10/05/01
Nitrate as NO3	22	0.4	mg/L	EPA 300.0	10/05/01
pH	7.3	0.1	units	EPA 150.1	10/05/01
Sulfate	120	0.5	mg/L	EPA 300.0	10/05/01
Total Dissolved Solids	540	10	mg/L	EPA 160.1	10/09/01
Boron	0.10	0.05	mg/L	EPA 200.7	10/12/01
Calcium	88	0.03	mg/L	EPA 200.7	10/12/01
Hardness	300	1	mg/L CaCO3	EPA 200.7	10/12/01
Sodium Adsorption Ratio	1.4	0.1		EPA 200.7	10/12/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/12/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/12/01
Potassium	2.7	0.1	mg/L	EPA 200.7	10/12/01
Magnesium	20	0.03	mg/L	EPA 200.7	10/12/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/12/01
Sodium	56	0.05	mg/L	EPA 200.7	10/12/01
Zinc	0.076	0.05	mg/L	EPA 200.7	10/12/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8043
Order: I3258
Project: Paso Robles Basin/98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/13E-25M	David Williams	10/05/01@13:15	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C8161
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/13E-35K	David Williams	10/08/01@15:55	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/18/01
Bicarbonate Alkalinity as CaCO3	170	1	mg/L	EPA 310.1	10/18/01
Total Alkalinity as CaCO3	170	2	mg/L	EPA 310.1	10/18/01
Chloride	46	1	mg/L	EPA 300.0	10/10/01
Electrical Conductance	520	1	umhos/cm	EPA 120.1	10/10/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/10/01
Nitrate as N	2.4	0.1	mg/L	EPA 300.0	10/10/01
Nitrate as NO3	11	0.4	mg/L	EPA 300.0	10/10/01
pH	7.4	0.1	units	EPA 150.1	10/10/01
Sulfate	34	0.5	mg/L	EPA 300.0	10/10/01
Total Dissolved Solids	260	10	mg/L	EPA 160.1	10/12/01
Boron	0.062	0.05	mg/L	EPA 200.7	10/15/01
Calcium	56	0.03	mg/L	EPA 200.7	10/15/01
Hardness	230	1	mg/L CaCO3	EPA 200.7	10/15/01
Sodium Adsorption Ratio	0.9	0.1		EPA 200.7	10/15/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Iron	0.5	0.1	mg/L	EPA 200.7	10/15/01
Potassium	1.7	0.1	mg/L	EPA 200.7	10/15/01
Magnesium	22	0.03	mg/L	EPA 200.7	10/15/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/15/01
Sodium	32	0.05	mg/L	EPA 200.7	10/15/01
Zinc	1.3	0.05	mg/L	EPA 200.7	10/15/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8161
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/13E-35K	David Williams	10/08/01@15:55	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

Lab Director, Orval Osborne

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Log Number: 01-C7871
Order: I3193
Project: Paso Robles Basin 98-71-1
Received: 10/03/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/14E-24B01	Spencer Harris	10/02/01@16:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/11/01
Bicarbonate Alkalinity as CaCO3	160	1	mg/L	EPA 310.1	10/11/01
Total Alkalinity as CaCO3	160	2	mg/L	EPA 310.1	10/11/01
Chloride	20	1	mg/L	EPA 300.0	10/03/01
Electrical Conductance	430	1	umhos/cm	EPA 120.1	10/03/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/04/01
Nitrate as N	2.7	0.1	mg/L	EPA 300.0	10/03/01
Nitrate as NO3	12	0.4	mg/L	EPA 300.0	10/03/01
pH	7.5	0.1	units	EPA 150.1	10/03/01
Sulfate	42	0.5	mg/L	EPA 300.0	10/03/01
Total Dissolved Solids	310	10	mg/L	EPA 160.1	10/06/01
Boron	0.26	0.05	mg/L	EPA 200.7	10/08/01
Calcium	29	0.03	mg/L	EPA 200.7	10/08/01
Hardness	86	1	mg/L CaCO3	EPA 200.7	10/08/01
Sodium Adsorption Ratio	3.1	0.1		EPA 200.7	10/08/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/08/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/08/01
Potassium	2.2	0.1	mg/L	EPA 200.7	10/08/01
Magnesium	3.5	0.03	mg/L	EPA 200.7	10/08/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/08/01
Sodium	66	0.05	mg/L	EPA 200.7	10/08/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/08/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Order: I3193
Project: Paso Robles Basin 98-71-1
Received: 10/03/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/14E-24B01	Spencer Harris	10/02/01@16:30	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C8165
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/15E-35F01	David Williams	10/06/01@	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/18/01
Bicarbonate Alkalinity as CaCO3	110	1	mg/L	EPA 310.1	10/18/01
Total Alkalinity as CaCO3	110	2	mg/L	EPA 310.1	10/18/01
Chloride	17	1	mg/L	EPA 300.0	10/10/01
Electrical Conductance	330	1	umhos/cm	EPA 120.1	10/10/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/10/01
Nitrate as N	2.3	0.1	mg/L	EPA 300.0	10/10/01
Nitrate as NO3	10	0.4	mg/L	EPA 300.0	10/10/01
pH	7.6	0.1	units	EPA 150.1	10/10/01
Sulfate	30	0.5	mg/L	EPA 300.0	10/10/01
Total Dissolved Solids	170	10	mg/L	EPA 160.1	10/12/01
Boron	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Calcium	44	0.03	mg/L	EPA 200.7	10/15/01
Hardness	130	1	mg/L CaCO3	EPA 200.7	10/15/01
Sodium Adsorption Ratio	0.9	0.1		EPA 200.7	10/15/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/15/01
Potassium	1.8	0.1	mg/L	EPA 200.7	10/15/01
Magnesium	5.4	0.03	mg/L	EPA 200.7	10/15/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/15/01
Sodium	23	0.05	mg/L	EPA 200.7	10/15/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/15/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8165
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/15E-35F01	David Williams	10/06/01@	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C7869
Order: I3193
Project: Paso Robles Basin 98-71-1
Received: 10/03/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/16E-18H01	Spencer Harris	10/02/01@13:40	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/11/01
Bicarbonate Alkalinity as CaCO3	210	1	mg/L	EPA 310.1	10/11/01
Total Alkalinity as CaCO3	210	2	mg/L	EPA 310.1	10/11/01
Chloride	700	20	mg/L	EPA 300.0	10/03/01
Electrical Conductance	3,200	1	umhos/cm	EPA 120.1	10/03/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/04/01
Nitrate as N	13	0.1	mg/L	EPA 300.0	10/03/01
Nitrate as NO3	56	0.4	mg/L	EPA 300.0	10/03/01
pH	7.2	0.1	units	EPA 150.1	10/03/01
Sulfate	720	10	mg/L	EPA 300.0	10/03/01
Total Dissolved Solids	2,200	10	mg/L	EPA 160.1	10/06/01
Boron	2.3	0.05	mg/L	EPA 200.7	10/09/01
Calcium	160	0.03	mg/L	EPA 200.7	10/09/01
Hardness	590	1	mg/L CaCO3	EPA 200.7	10/09/01
Sodium Adsorption Ratio	10	0.1		EPA 200.7	10/12/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/09/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/09/01
Potassium	4.0	0.1	mg/L	EPA 200.7	10/09/01
Magnesium	44	0.03	mg/L	EPA 200.7	10/09/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/09/01
Sodium	550	0.05	mg/L	EPA 200.7	10/12/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/09/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C7869
Order: I3193
Project: Paso Robles Basin 98-71-1
Received: 10/03/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
27S/16E-18H01	Spencer Harris	10/02/01@13:40	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8042
Order: I3258
Project: Paso Robles Basin/98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/13E-1K01	David Williams	10/05/01@11:05	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/17/01
Bicarbonate Alkalinity as CaCO3	130	1	mg/L	EPA 310.1	10/17/01
Total Alkalinity as CaCO3	130	2	mg/L	EPA 310.1	10/17/01
Chloride	30	1	mg/L	EPA 300.0	10/05/01
Electrical Conductance	360	1	umhos/cm	EPA 120.1	10/05/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/05/01
Nitrate as N	1.4	0.1	mg/L	EPA 300.0	10/05/01
Nitrate as NO3	6.2	0.4	mg/L	EPA 300.0	10/05/01
pH	7.0	0.1	units	EPA 150.1	10/05/01
Sulfate	28	0.5	mg/L	EPA 300.0	10/05/01
Total Dissolved Solids	290	10	mg/L	EPA 160.1	10/09/01
Boron	0.071	0.05	mg/L	EPA 200.7	10/12/01
Calcium	47	0.03	mg/L	EPA 200.7	10/12/01
Hardness	150	1	mg/L CaCO3	EPA 200.7	10/12/01
Sodium Adsorption Ratio	1.2	0.1		EPA 200.7	10/12/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/12/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/12/01
Potassium	1.8	0.1	mg/L	EPA 200.7	10/12/01
Magnesium	7.3	0.03	mg/L	EPA 200.7	10/12/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/12/01
Sodium	33	0.05	mg/L	EPA 200.7	10/12/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/12/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8042
Order: I3258
Project: Paso Robles Basin/98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/13E-1K01	David Williams	10/05/01@11:05	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C8162
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/13E-7K	David Williams	10/08/01@17:30	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/18/01
Bicarbonate Alkalinity as CaCO3	220	1	mg/L	EPA 310.1	10/18/01
Total Alkalinity as CaCO3	220	2	mg/L	EPA 310.1	10/18/01
Chloride	180	20	mg/L	EPA 300.0	10/10/01
Electrical Conductance	990	1	umhos/cm	EPA 120.1	10/10/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/10/01
Nitrate as N	6.2	0.1	mg/L	EPA 300.0	10/10/01
Nitrate as NO3	28	0.4	mg/L	EPA 300.0	10/10/01
pH	7.4	0.1	units	EPA 150.1	10/10/01
Sulfate	8.5	0.5	mg/L	EPA 300.0	10/10/01
Total Dissolved Solids	510	10	mg/L	EPA 160.1	10/12/01
Boron	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Calcium	120	0.03	mg/L	EPA 200.7	10/15/01
Hardness	430	1	mg/L CaCO3	EPA 200.7	10/15/01
Sodium Adsorption Ratio	0.8	0.1		EPA 200.7	10/15/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/15/01
Potassium	0.7	0.1	mg/L	EPA 200.7	10/15/01
Magnesium	34	0.03	mg/L	EPA 200.7	10/15/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/15/01
Sodium	40	0.05	mg/L	EPA 200.7	10/15/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/15/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8162
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/13E-7K	David Williams	10/08/01@17:30	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8041
Order: I3258
Project: Paso Robles Basin/98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/13E-36A01	David Williams	10/05/01@09:40	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/17/01
Bicarbonate Alkalinity as CaCO3	110	1	mg/L	EPA 310.1	10/17/01
Total Alkalinity as CaCO3	110	2	mg/L	EPA 310.1	10/17/01
Chloride	28	1	mg/L	EPA 300.0	10/05/01
Electrical Conductance	300	1	umhos/cm	EPA 120.1	10/05/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/05/01
Nitrate as N	0.5	0.1	mg/L	EPA 300.0	10/05/01
Nitrate as NO3	2.0	0.4	mg/L	EPA 300.0	10/05/01
pH	6.8	0.1	units	EPA 150.1	10/05/01
Sulfate	14	0.5	mg/L	EPA 300.0	10/05/01
Total Dissolved Solids	220	10	mg/L	EPA 160.1	10/09/01
Boron	Not Detected	0.05	mg/L	EPA 200.7	10/12/01
Calcium	28	0.03	mg/L	EPA 200.7	10/12/01
Hardness	120	1	mg/L CaCO3	EPA 200.7	10/12/01
Sodium Adsorption Ratio	1.2	0.1		EPA 200.7	10/12/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/12/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/12/01
Potassium	0.9	0.1	mg/L	EPA 200.7	10/12/01
Magnesium	11	0.03	mg/L	EPA 200.7	10/12/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/12/01
Sodium	29	0.05	mg/L	EPA 200.7	10/12/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/12/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8041
Order: I3258
Project: Paso Robles Basin/98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/13E-36A01	David Williams	10/05/01@09:40	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C8160
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/14E-4F	David Williams	10/08/01@13:35	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/19/01
Bicarbonate Alkalinity as CaCO3	140	1	mg/L	EPA 310.1	10/19/01
Total Alkalinity as CaCO3	140	2	mg/L	EPA 310.1	10/19/01
Chloride	65	1	mg/L	EPA 300.0	10/10/01
Electrical Conductance	550	1	umhos/cm	EPA 120.1	10/10/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/10/01
Nitrate as N	9.4	0.1	mg/L	EPA 300.0	10/10/01
Nitrate as NO3	41	0.4	mg/L	EPA 300.0	10/10/01
pH	7.4	0.1	units	EPA 150.1	10/10/01
Sulfate	12	0.5	mg/L	EPA 300.0	10/10/01
Total Dissolved Solids	340	10	mg/L	EPA 160.1	10/12/01
Boron	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Calcium	80	0.03	mg/L	EPA 200.7	10/15/01
Hardness	240	1	mg/L CaCO3	EPA 200.7	10/15/01
Sodium Adsorption Ratio	0.6	0.1		EPA 200.7	10/15/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/15/01
Potassium	1.7	0.1	mg/L	EPA 200.7	10/15/01
Magnesium	10	0.03	mg/L	EPA 200.7	10/15/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/15/01
Sodium	21	0.05	mg/L	EPA 200.7	10/15/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/15/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

CREEK ENVIRONMENTAL LABORATORIES, INC.

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Log Number: 01-C8160
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/14E-4F	David Williams	10/08/01@13:35	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

CREEK ENVIRONMENTAL LABORATORIES

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Log Number: 01-C8159
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/14E-18C	David Williams	10/08/01@12:40	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/19/01
Bicarbonate Alkalinity as CaCO3	98	1	mg/L	EPA 310.1	10/19/01
Total Alkalinity as CaCO3	98	2	mg/L	EPA 310.1	10/19/01
Chloride	25	1	mg/L	EPA 300.0	10/10/01
Electrical Conductance	280	1	umhos/cm	EPA 120.1	10/10/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/10/01
Nitrate as N	0.8	0.1	mg/L	EPA 300.0	10/10/01
Nitrate as NO3	3.4	0.4	mg/L	EPA 300.0	10/10/01
pH	7.2	0.1	units	EPA 150.1	10/10/01
Sulfate	7.2	0.5	mg/L	EPA 300.0	10/10/01
Total Dissolved Solids	190	10	mg/L	EPA 160.1	10/12/01
Boron	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Calcium	27	0.03	mg/L	EPA 200.7	10/15/01
Hardness	90	1	mg/L CaCO3	EPA 200.7	10/15/01
Sodium Adsorption Ratio	1.3	0.1		EPA 200.7	10/15/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/15/01
Potassium	2.4	0.1	mg/L	EPA 200.7	10/15/01
Magnesium	4.6	0.03	mg/L	EPA 200.7	10/15/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/15/01
Sodium	28	0.05	mg/L	EPA 200.7	10/15/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/15/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8159
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/14E-18C	David Williams	10/08/01@12:40	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8167
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/15E-14F02	David Williams	10/06/01@16:00	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/18/01
Bicarbonate Alkalinity as CaCO3	67	1	mg/L	EPA 310.1	10/18/01
Total Alkalinity as CaCO3	67	2	mg/L	EPA 310.1	10/18/01
Chloride	13	1	mg/L	EPA 300.0	10/10/01
Electrical Conductance	220	1	umhos/cm	EPA 120.1	10/10/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/10/01
Nitrate as N	1.9	0.1	mg/L	EPA 300.0	10/10/01
Nitrate as NO3	8.4	0.4	mg/L	EPA 300.0	10/10/01
pH	6.9	0.1	units	EPA 150.1	10/10/01
Sulfate	24	0.5	mg/L	EPA 300.0	10/10/01
Total Dissolved Solids	67	10	mg/L	EPA 160.1	10/12/01
Boron	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Calcium	22	0.03	mg/L	EPA 200.7	10/15/01
Hardness	80	1	mg/L CaCO3	EPA 200.7	10/15/01
Sodium Adsorption Ratio	0.8	0.1		EPA 200.7	10/15/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Iron	0.1	0.1	mg/L	EPA 200.7	10/15/01
Potassium	1.3	0.1	mg/L	EPA 200.7	10/15/01
Magnesium	6.2	0.03	mg/L	EPA 200.7	10/15/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/15/01
Sodium	16	0.05	mg/L	EPA 200.7	10/15/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/15/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8167
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/15E-14F02	David Williams	10/06/01@16:00	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/15E-26M01	David Williams	10/06/01@16:00	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/18/01
Bicarbonate Alkalinity as CaCO3	190	1	mg/L	EPA 310.1	10/18/01
Total Alkalinity as CaCO3	190	2	mg/L	EPA 310.1	10/18/01
Chloride	41	1	mg/L	EPA 300.0	10/10/01
Electrical Conductance	740	1	umhos/cm	EPA 120.1	10/10/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/10/01
Nitrate as N	Not Detected	0.1	mg/L	EPA 300.0	10/10/01
Nitrate as NO3	Not Detected	0.4	mg/L	EPA 300.0	10/10/01
pH	7.1	0.1	units	EPA 150.1	10/10/01
Sulfate	170	0.5	mg/L	EPA 300.0	10/10/01
Total Dissolved Solids	570	10	mg/L	Calculated	10/18/01
Boron	0.14	0.05	mg/L	EPA 200.7	10/15/01
Calcium	80	0.03	mg/L	EPA 200.7	10/15/01
Hardness	300	1	mg/L CaCO3	EPA 200.7	10/15/01
Sodium Adsorption Ratio	1.5	0.1		EPA 200.7	10/15/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Iron	2.5	0.1	mg/L	EPA 200.7	10/15/01
Potassium	4.3	0.1	mg/L	EPA 200.7	10/15/01
Magnesium	23	0.03	mg/L	EPA 200.7	10/15/01
Manganese	0.22	0.03	mg/L	EPA 200.7	10/15/01
Sodium	60	0.05	mg/L	EPA 200.7	10/15/01
Zinc	0.12	0.05	mg/L	EPA 200.7	10/15/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/15E-26M01	David Williams	10/06/01@16:00	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/15E-14F02	David Williams	10/06/01@16:00	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/18/01
Bicarbonate Alkalinity as CaCO3	67	1	mg/L	EPA 310.1	10/18/01
Total Alkalinity as CaCO3	67	2	mg/L	EPA 310.1	10/18/01
Chloride	13	1	mg/L	EPA 300.0	10/10/01
Electrical Conductance	220	1	umhos/cm	EPA 120.1	10/10/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/10/01
Nitrate as N	1.9	0.1	mg/L	EPA 300.0	10/10/01
Nitrate as NO3	8.4	0.4	mg/L	EPA 300.0	10/10/01
pH	6.9	0.1	units	EPA 150.1	10/10/01
Sulfate	24	0.5	mg/L	EPA 300.0	10/10/01
Total Dissolved Solids	160	10	mg/L	Calculated	10/18/01
Boron	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Calcium	22	0.03	mg/L	EPA 200.7	10/15/01
Hardness	80	1	mg/L CaCO3	EPA 200.7	10/15/01
Sodium Adsorption Ratio	0.8	0.1		EPA 200.7	10/15/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/15/01
Iron	0.1	0.1	mg/L	EPA 200.7	10/15/01
Potassium	1.3	0.1	mg/L	EPA 200.7	10/15/01
Magnesium	6.2	0.03	mg/L	EPA 200.7	10/15/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/15/01
Sodium	16	0.05	mg/L	EPA 200.7	10/15/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/15/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8167
Order: I3305
Project: Paso Robles Basin/98-71-1
Received: 10/10/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
28S/15E-14F02	David Williams	10/06/01@16:00	Drinking Water

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8435
Order: I3421
Project: Paso Robles Basin 98-71-1
Received: 10/18/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
San Juan Ck. @ Hwy 58	Spencer Harris	10/17/01@04:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/29/01
Bicarbonate Alkalinity as CaCO3	260	1	mg/L	EPA 310.1	10/29/01
Total Alkalinity as CaCO3	260	2	mg/L	EPA 310.1	10/29/01
Chloride	58	1	mg/L	EPA 300.0	10/18/01
Electrical Conductance	1,500	1	umhos/cm	EPA 120.1	10/18/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/18/01
Nitrate as N	Not Detected	0.1	mg/L	EPA 300.0	10/18/01
Nitrate as NO3	Not Detected	0.4	mg/L	EPA 300.0	10/18/01
pH	7.7	0.1	units	EPA 150.1	10/18/01
Sulfate	520	10	mg/L	EPA 300.0	10/18/01
Total Dissolved Solids	970	10	mg/L	EPA 160.1	10/21/01
Boron	0.19	0.05	mg/L	EPA 200.7	10/26/01
Calcium	130	0.03	mg/L	EPA 200.7	10/26/01
Hardness	550	1	mg/L CaCO3	EPA 200.7	10/26/01
Sodium Adsorption Ratio	2.3	0.1		EPA 200.7	10/26/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/26/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/26/01
Potassium	1.8	0.1	mg/L	EPA 200.7	10/26/01
Magnesium	56	0.03	mg/L	EPA 200.7	10/26/01
Manganese	0.14	0.03	mg/L	EPA 200.7	10/26/01
Sodium	120	0.05	mg/L	EPA 200.7	10/26/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/26/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8435
Order: I3421
Project: Paso Robles Basin 98-71-1
Received: 10/18/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
San Juan Ck. @ Hwy 58	Spencer Harris	10/17/01@04:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8001
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
Cholame Creek @ Bitterwater Road	Spencer Harris	10/04/01@10:40	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/17/01
Bicarbonate Alkalinity as CaCO3	370	1	mg/L	EPA 310.1	10/17/01
Total Alkalinity as CaCO3	370	2	mg/L	EPA 310.1	10/17/01
Chloride	550	10	mg/L	EPA 300.0	10/05/01
Electrical Conductance	3,000	1	umhos/cm	EPA 120.1	10/05/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/05/01
Nitrate as N	Not Detected	0.1	mg/L	EPA 300.0	10/05/01
Nitrate as NO3	Not Detected	0.4	mg/L	EPA 300.0	10/05/01
pH	7.6	0.1	units	EPA 150.1	10/05/01
Sulfate	740	5	mg/L	EPA 300.0	10/05/01
Total Dissolved Solids	2,400	10	mg/L	EPA 160.1	10/09/01
Boron	3.0	0.05	mg/L	EPA 200.7	10/12/01
Calcium	130	0.03	mg/L	EPA 200.7	10/12/01
Hardness	800	1	mg/L CaCO3	EPA 200.7	10/12/01
Sodium Adsorption Ratio	7.3	0.1		EPA 200.7	10/15/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/12/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/12/01
Potassium	5.2	0.1	mg/L	EPA 200.7	10/12/01
Magnesium	120	0.03	mg/L	EPA 200.7	10/12/01
Manganese	Not Detected	0.03	mg/L	EPA 200.7	10/12/01
Sodium	470	0.05	mg/L	EPA 200.7	10/15/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/12/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8001
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
Cholame Creek @ Bitterwater Road	Spencer Harris	10/04/01@10:40	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

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Log Number: 01-C8002
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
Estrella River @ Whitley Gardens	Spencer Harris	10/04/01@12:00	Aqueous

ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED
Carbonate Alkalinity as CaCO3	Not Detected	1	mg/L	EPA 310.1	10/17/01
Bicarbonate Alkalinity as CaCO3	320	1	mg/L	EPA 310.1	10/17/01
Total Alkalinity as CaCO3	320	2	mg/L	EPA 310.1	10/17/01
Chloride	130	10	mg/L	EPA 300.0	10/05/01
Electrical Conductance	980	1	umhos/cm	EPA 120.1	10/05/01
MBAS (Anionic Surfactants)	Not Detected	0.05	mg/L	EPA 425.1	10/05/01
Nitrate as N	Not Detected	0.1	mg/L	EPA 300.0	10/05/01
Nitrate as NO3	Not Detected	0.4	mg/L	EPA 300.0	10/05/01
pH	8.6	0.1	units	EPA 150.1	10/05/01
Sulfate	77	0.5	mg/L	EPA 300.0	10/05/01
Total Dissolved Solids	660	10	mg/L	EPA 160.1	10/09/01
Boron	0.68	0.05	mg/L	EPA 200.7	10/12/01
Calcium	40	0.03	mg/L	EPA 200.7	10/12/01
Hardness	310	1	mg/L CaCO3	EPA 200.7	10/12/01
Sodium Adsorption Ratio	3.2	0.1		EPA 200.7	10/12/01
Copper	Not Detected	0.05	mg/L	EPA 200.7	10/12/01
Iron	Not Detected	0.1	mg/L	EPA 200.7	10/12/01
Potassium	4.5	0.1	mg/L	EPA 200.7	10/12/01
Magnesium	52	0.03	mg/L	EPA 200.7	10/12/01
Manganese	0.031	0.03	mg/L	EPA 200.7	10/12/01
Sodium	130	0.05	mg/L	EPA 200.7	10/12/01
Zinc	Not Detected	0.05	mg/L	EPA 200.7	10/12/01

* R.L. - Reporting Limit. 'RESULTS' reported as "Not Detected" means not detected above R.L.

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Log Number: 01-C8002
Order: I3246
Project: Paso Robles Basin 98-71-1
Received: 10/05/01

REPORT OF ANALYTICAL RESULTS

SAMPLE DESCRIPTION	SAMPLED BY	SAMPLED DATE @ TIME	MATRIX
Estrella River @ Whitley Gardens	Spencer Harris	10/04/01@12:00	Aqueous

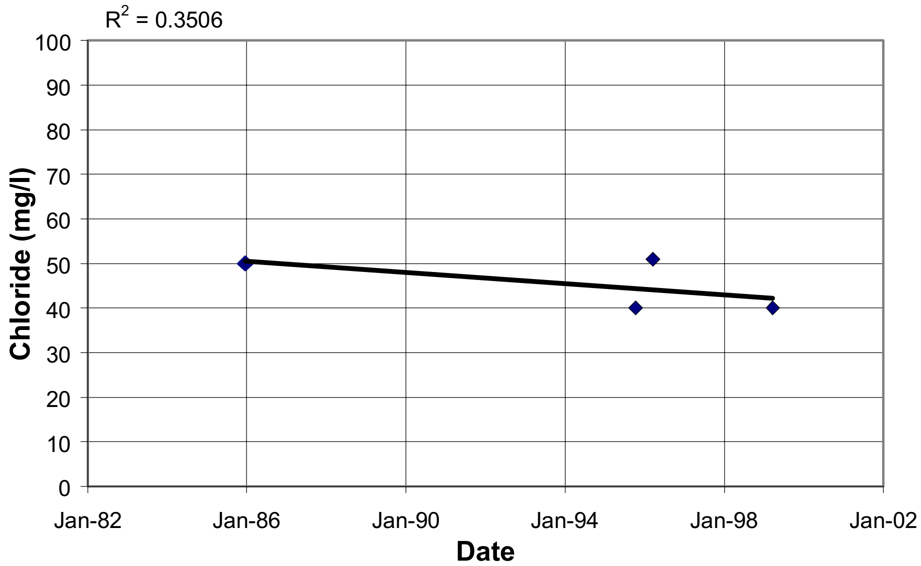
ANALYTE	RESULT	* R.L.	UNITS	METHOD	ANALYZED

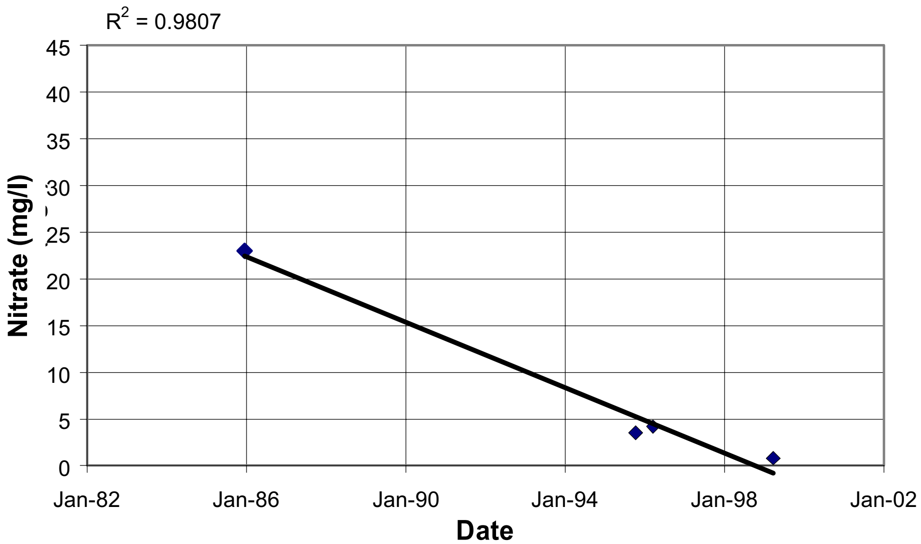
CREEK ENVIRONMENTAL LABORATORIES

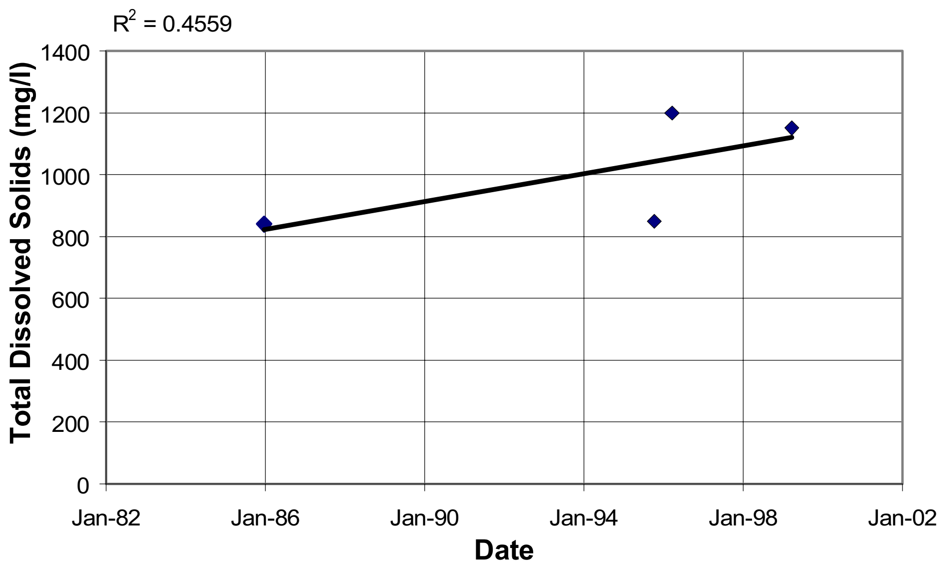
Lab Director, Orval Osborne

APPENDIX B
WATER QUALITY TRENDS

24S/11E-14Q01







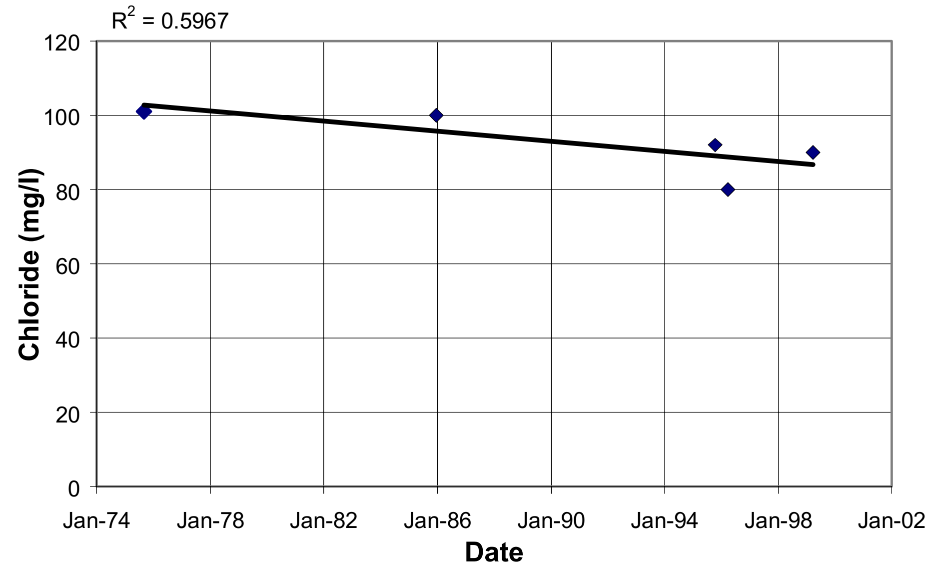
9871\1137gr01.dsf,p1

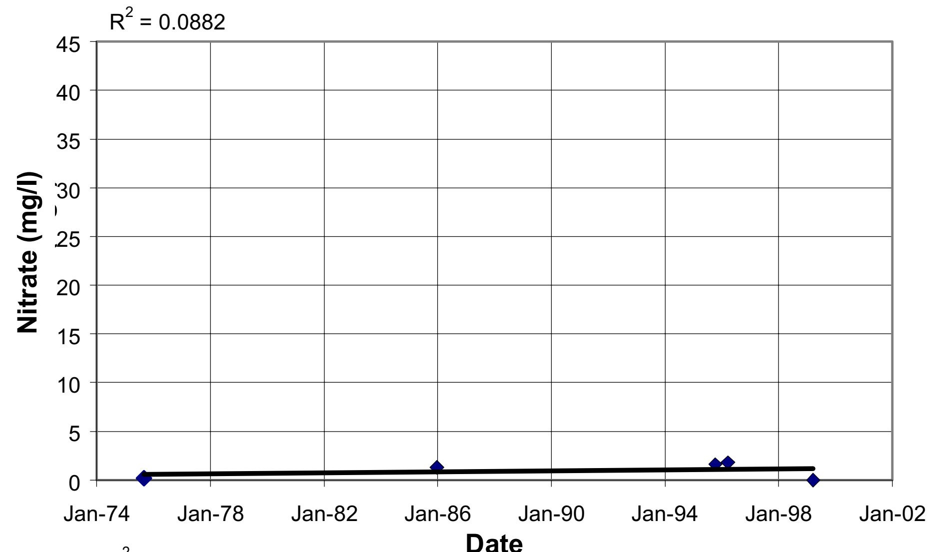
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

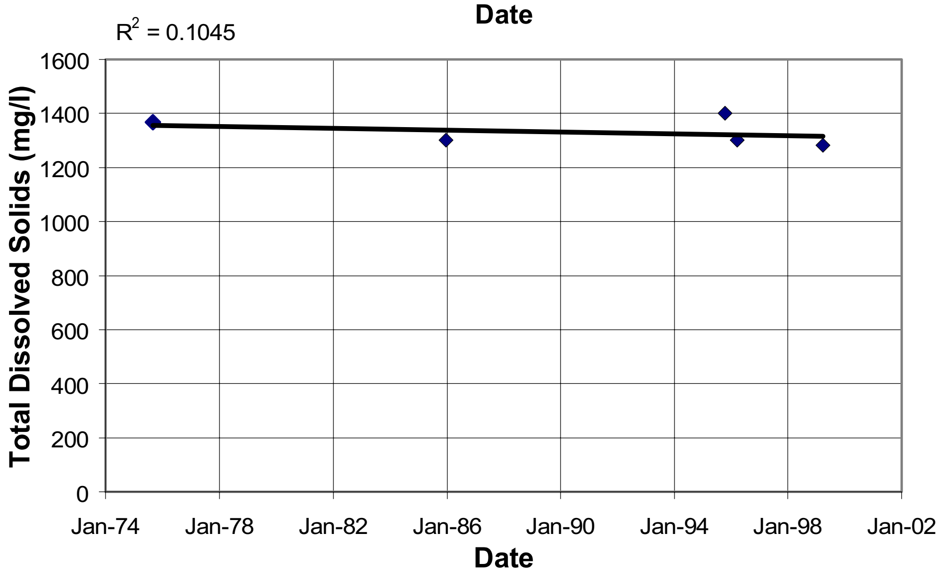
CHEMICAL HYDROGRAPHS
24S/11E-14Q01
Bradley Area
Paso Robles Groundwater Basin Study

Project No. 98-71-1137

24S/11E-26C01





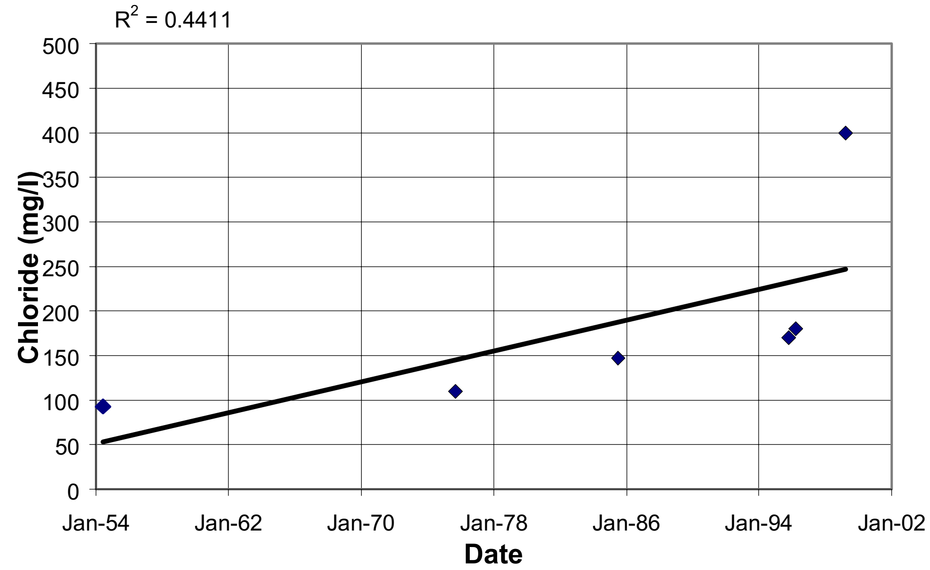


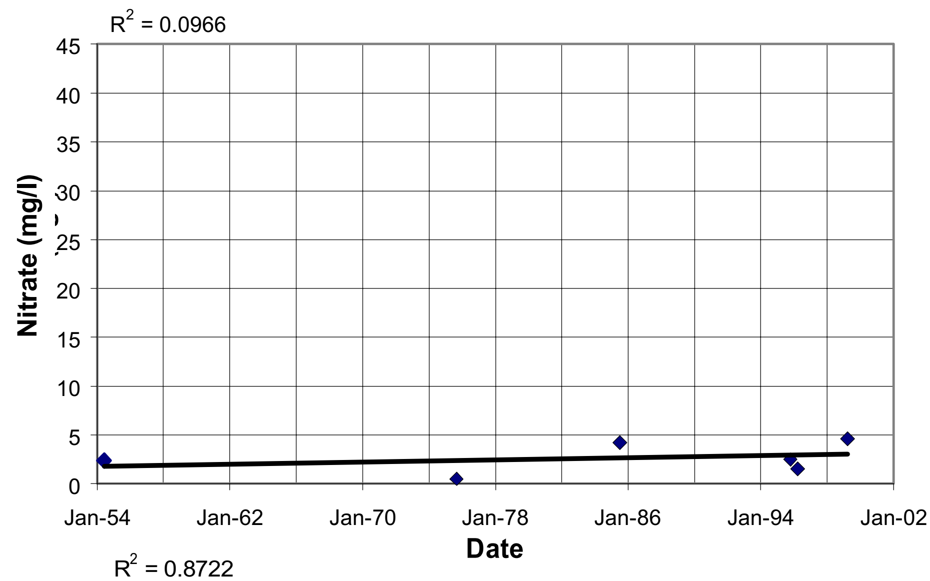
9871\1137gr01.dsf,p2

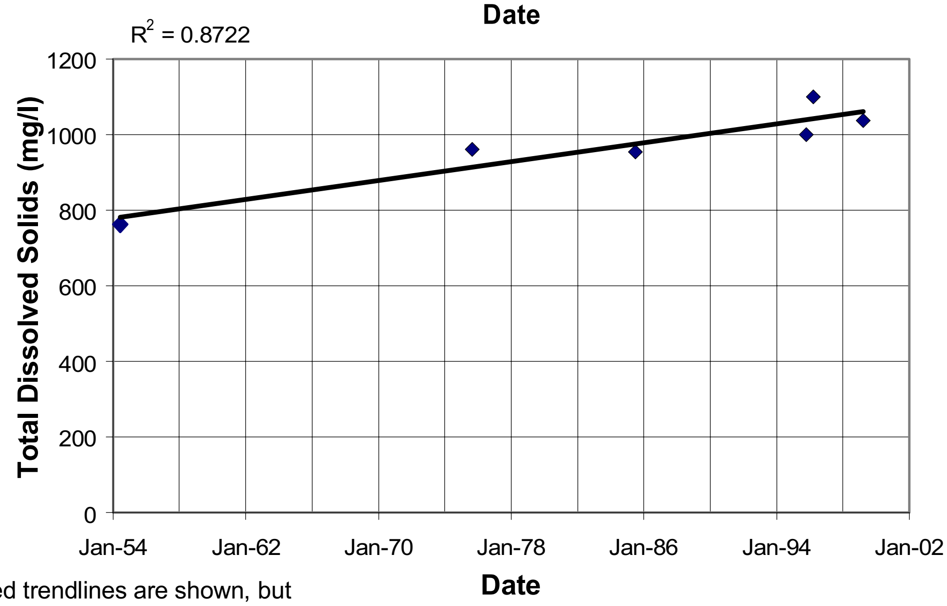
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
24S/11E-26C01
Bradley Area
Paso Robles Groundwater Basin Study

24S/11E-35E01



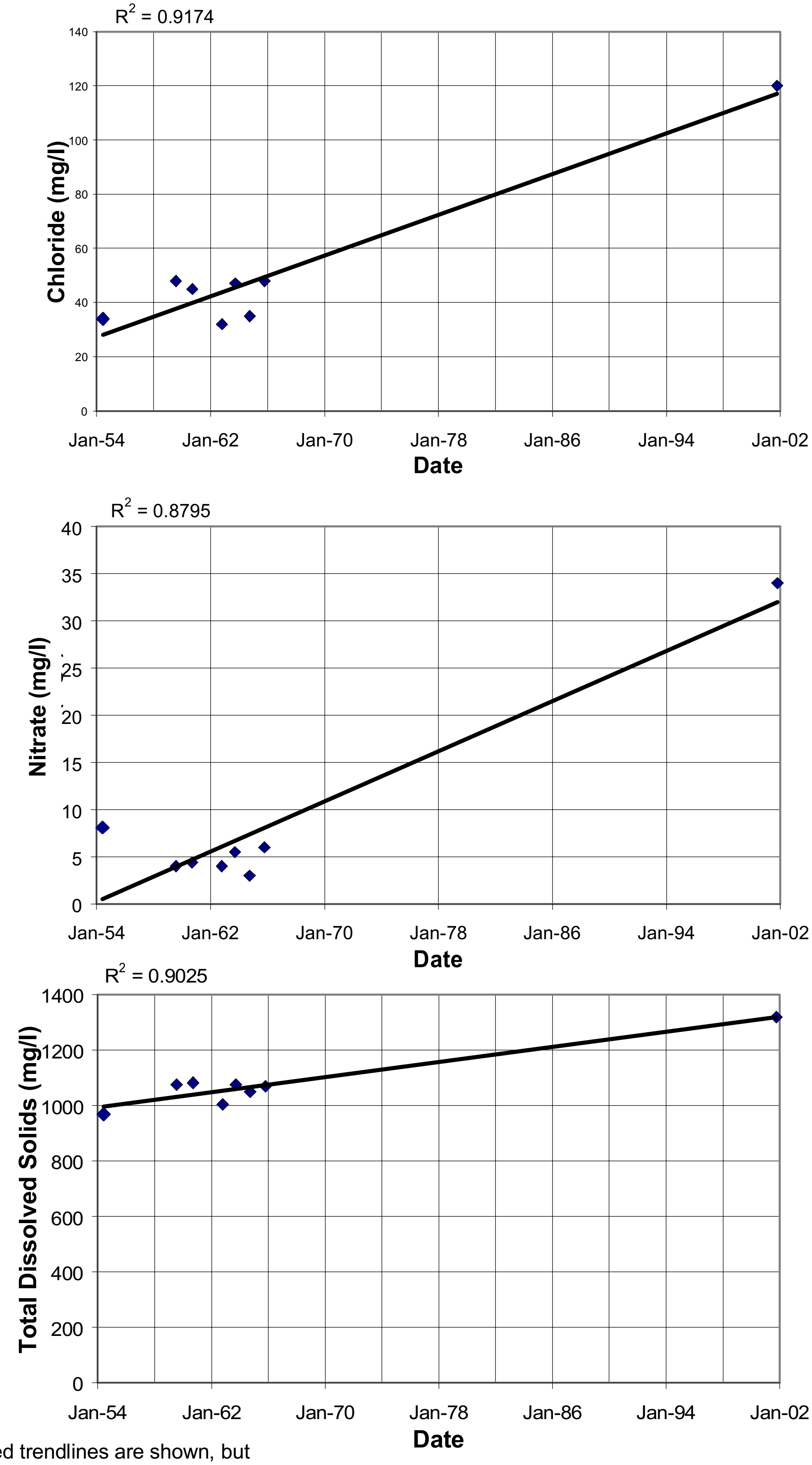




NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
24S/11E-35E01
Bradley Area
Paso Robles Groundwater Basin Study

24S/12E-17L, L01, L02

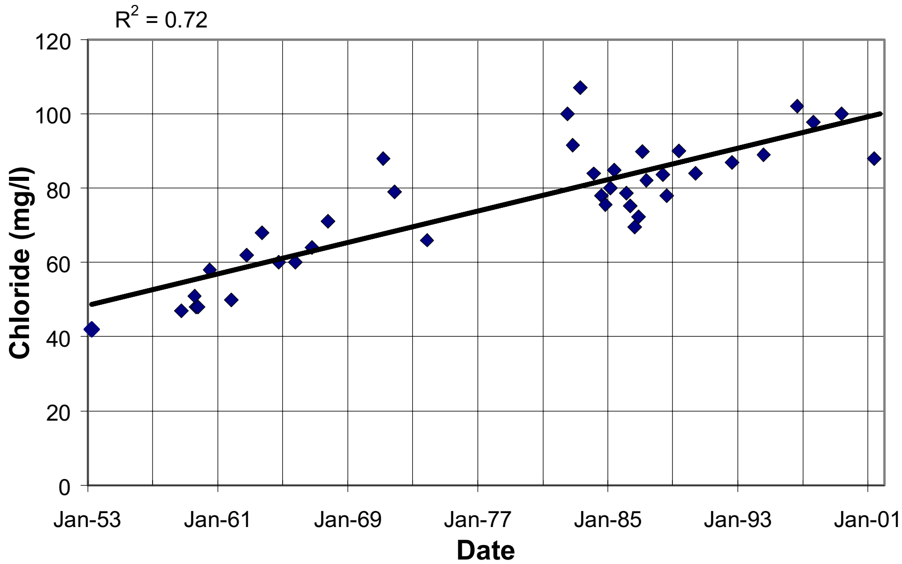


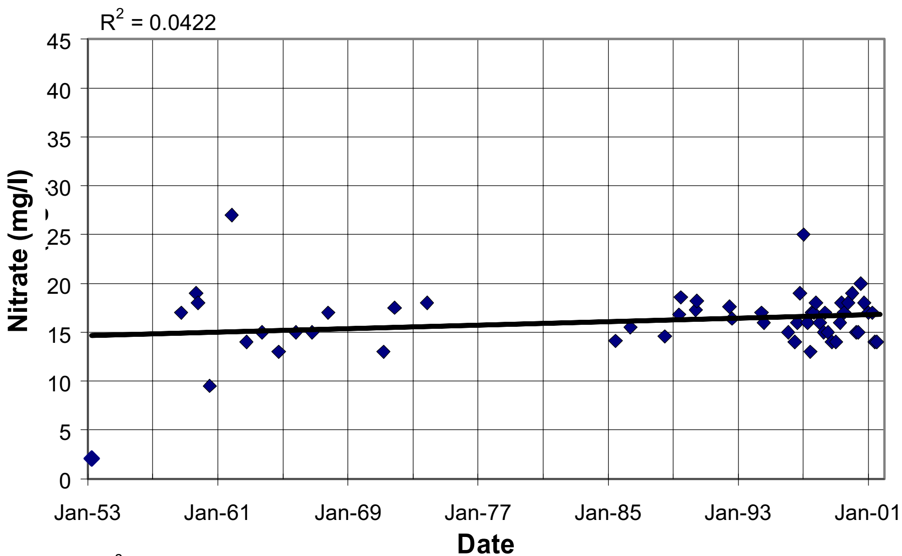
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

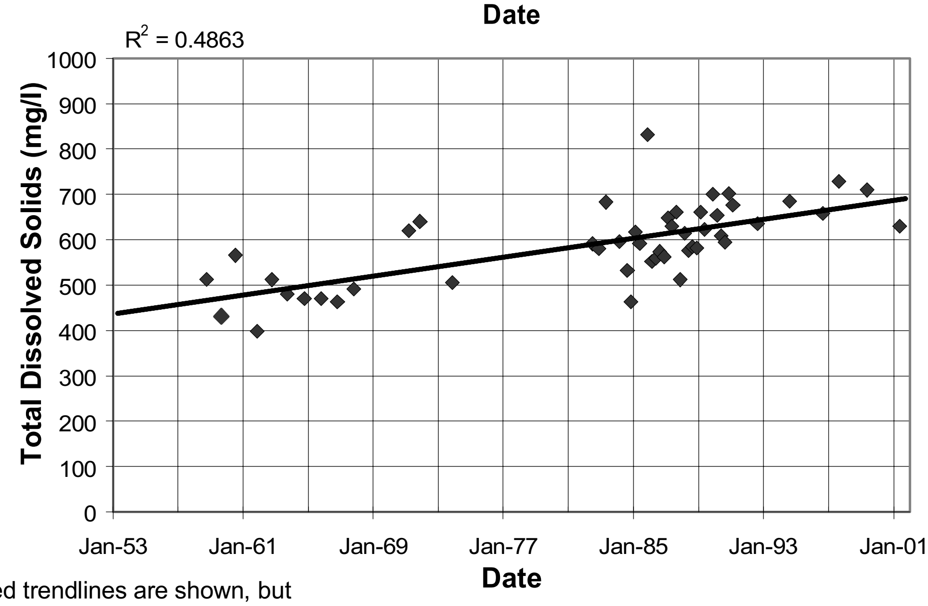
CHEMICAL HYDROGRAPHS
24S/12E-17L, L01, L02
Gabilan Area
Paso Robles Groundwater Basin Study

9871\1137gr01.dsf,p4

25S/12E-16N01







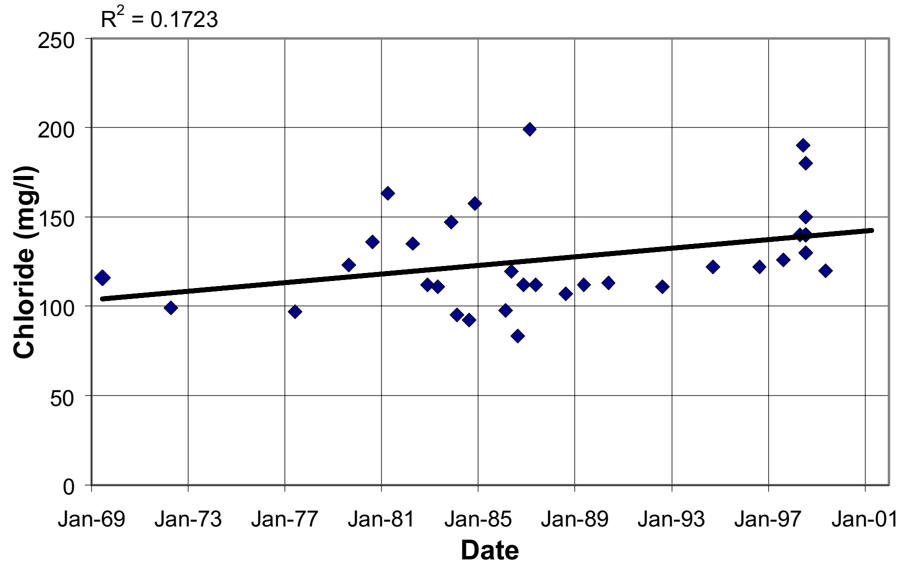
9871\1137gr01.dsf,p5

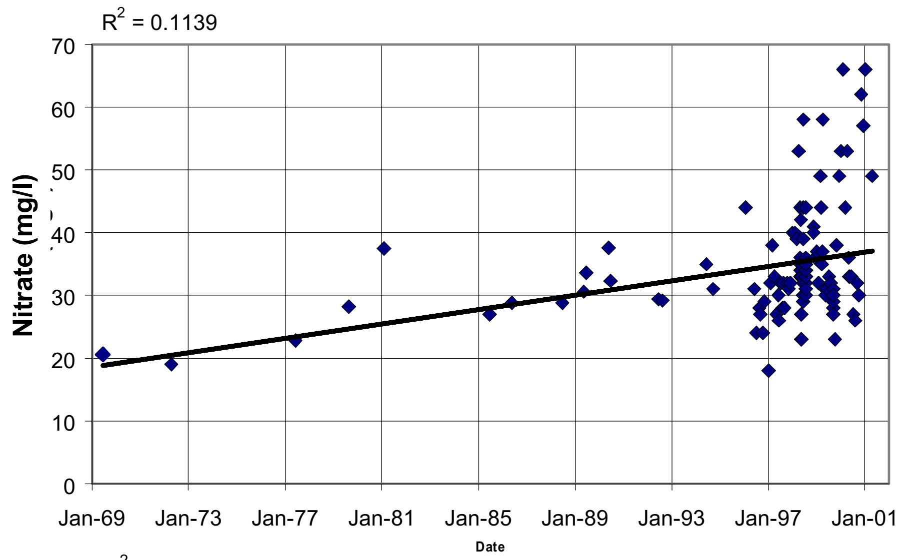
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

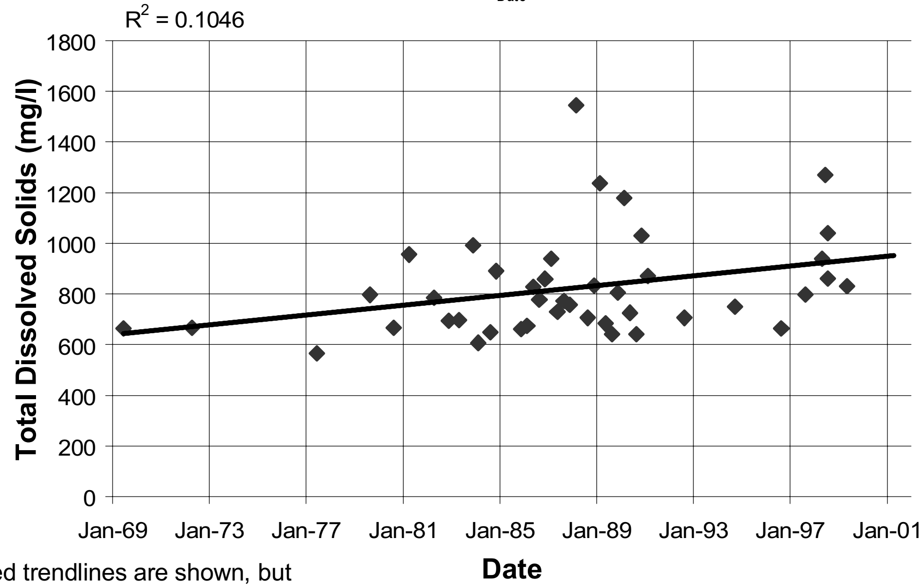
CHEMICAL HYDROGRAPHS
25S/12E-16N01
Estrella Area
Paso Robles Groundwater Basin Study

Project No. 98-71-1137

25S/12E-21G01





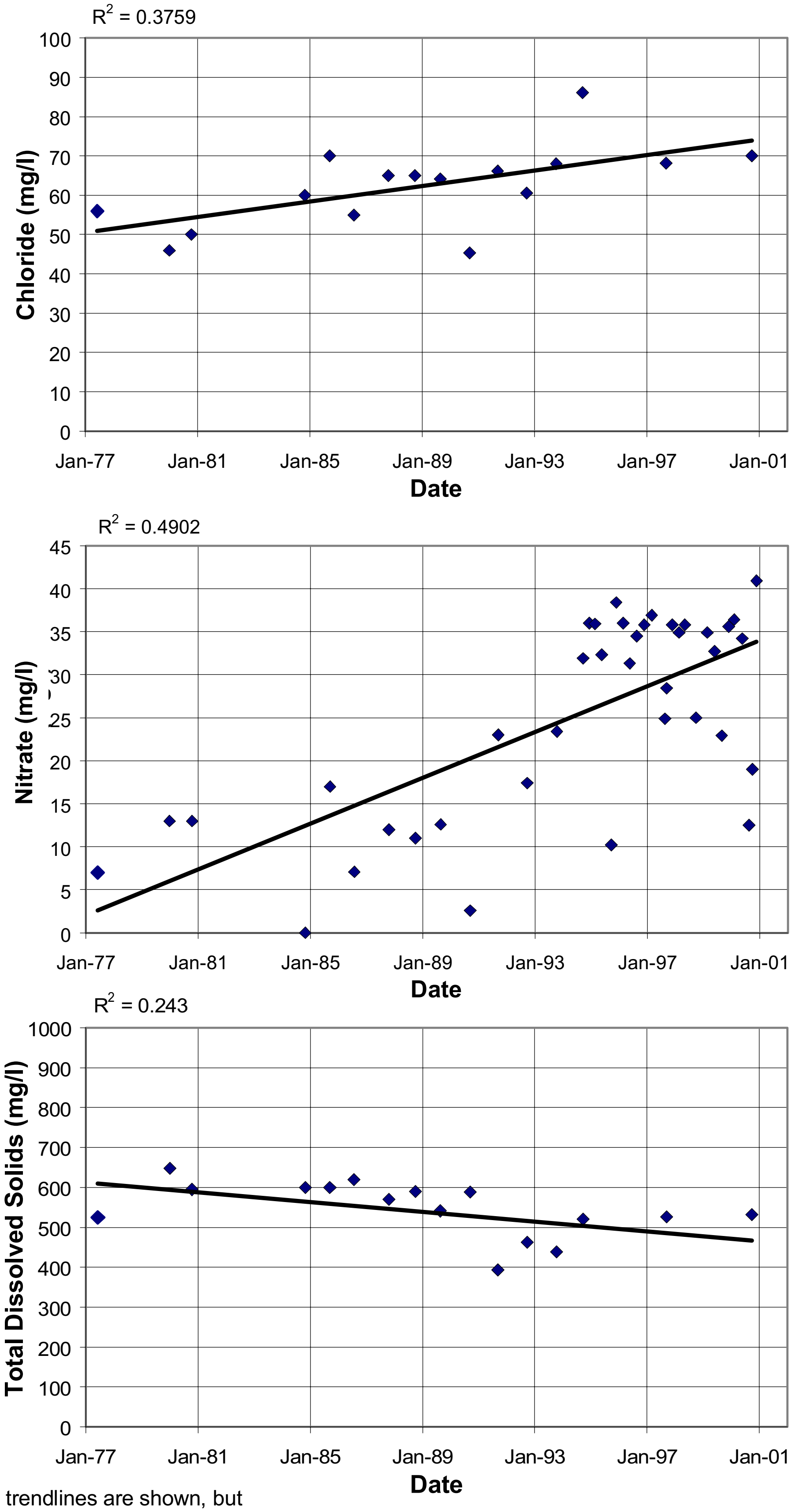


9871\1137gr01.dsf,p6

NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
24S/12E-21G01
Estrella Area
Paso Robles Groundwater Basin Study

26S/12E-22J01

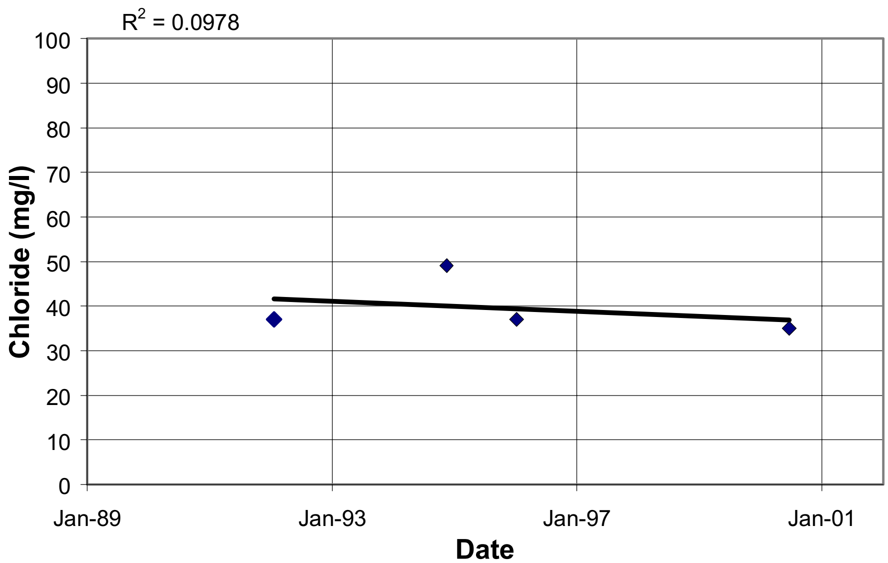


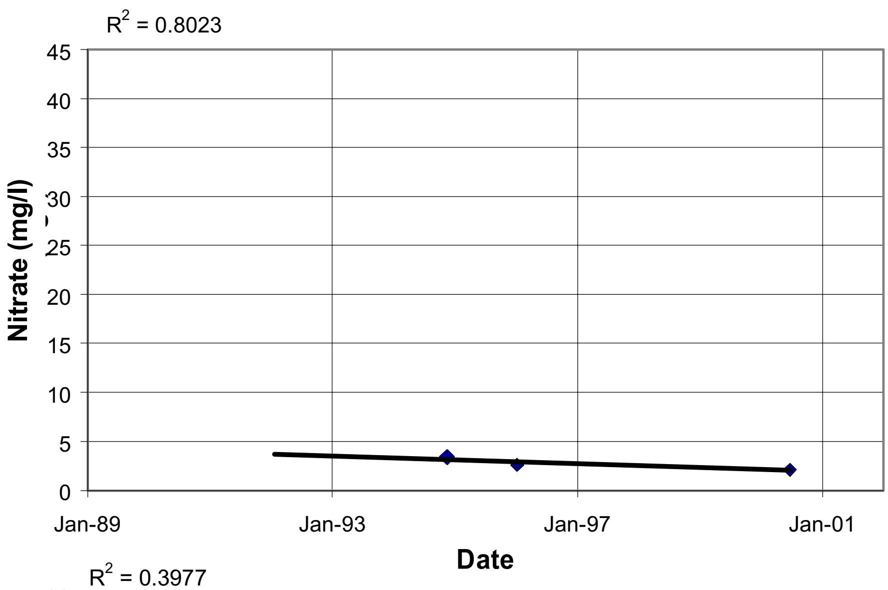
9871\1137gr01.dsf,p7

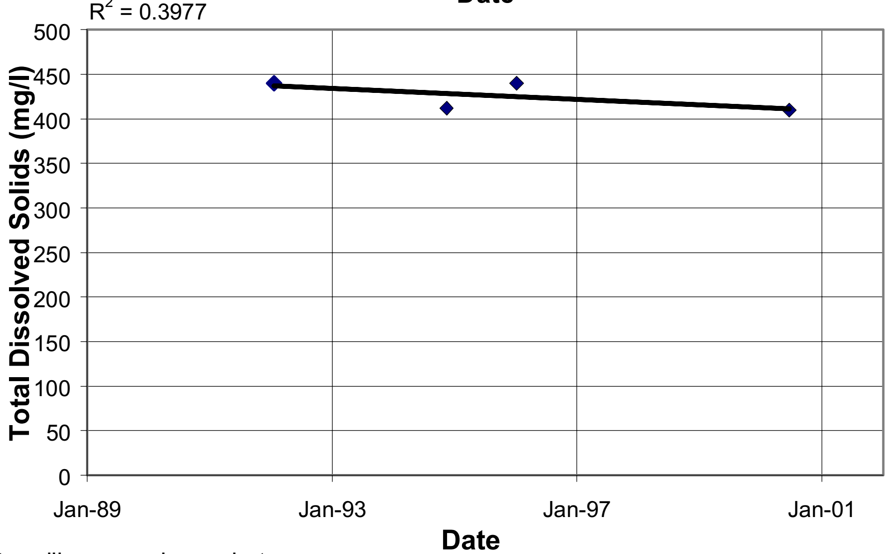
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
26S/12E-22J01
Estrella Area
Paso Robles Groundwater Basin Study

26S/13E-15F01





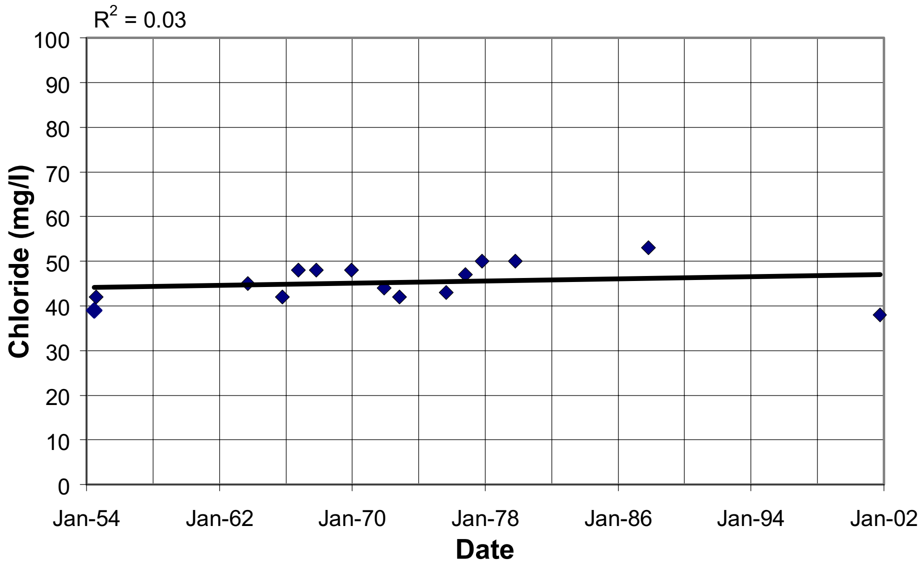


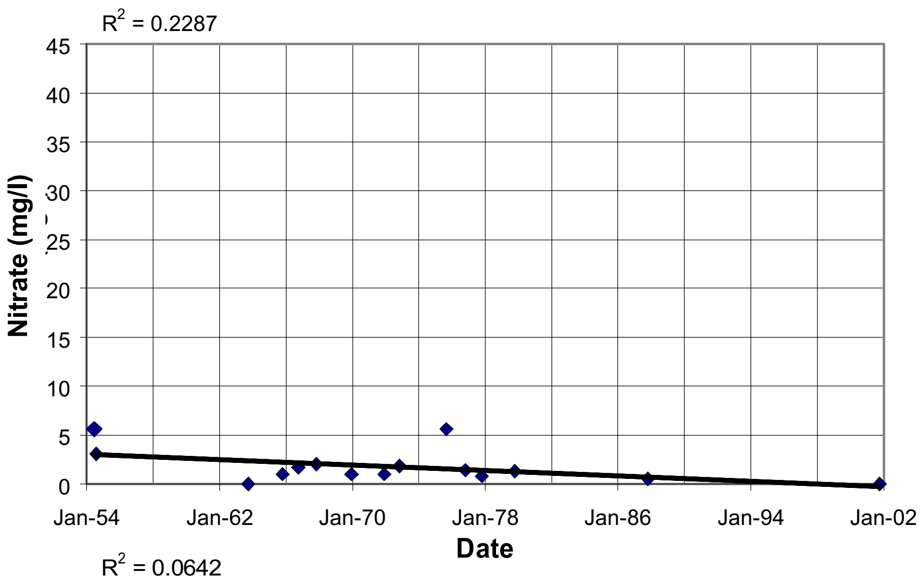
9871\1137gr01.dsf,p8

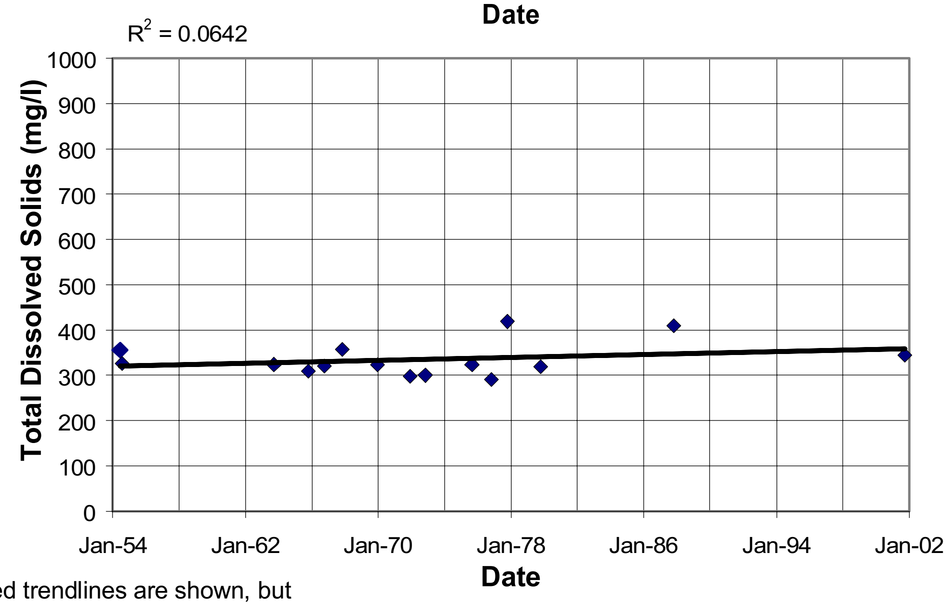
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
26S/13E-15F01
Estrella Area
Paso Robles Groundwater Basin Study

26S/13E-28J01, K, L02





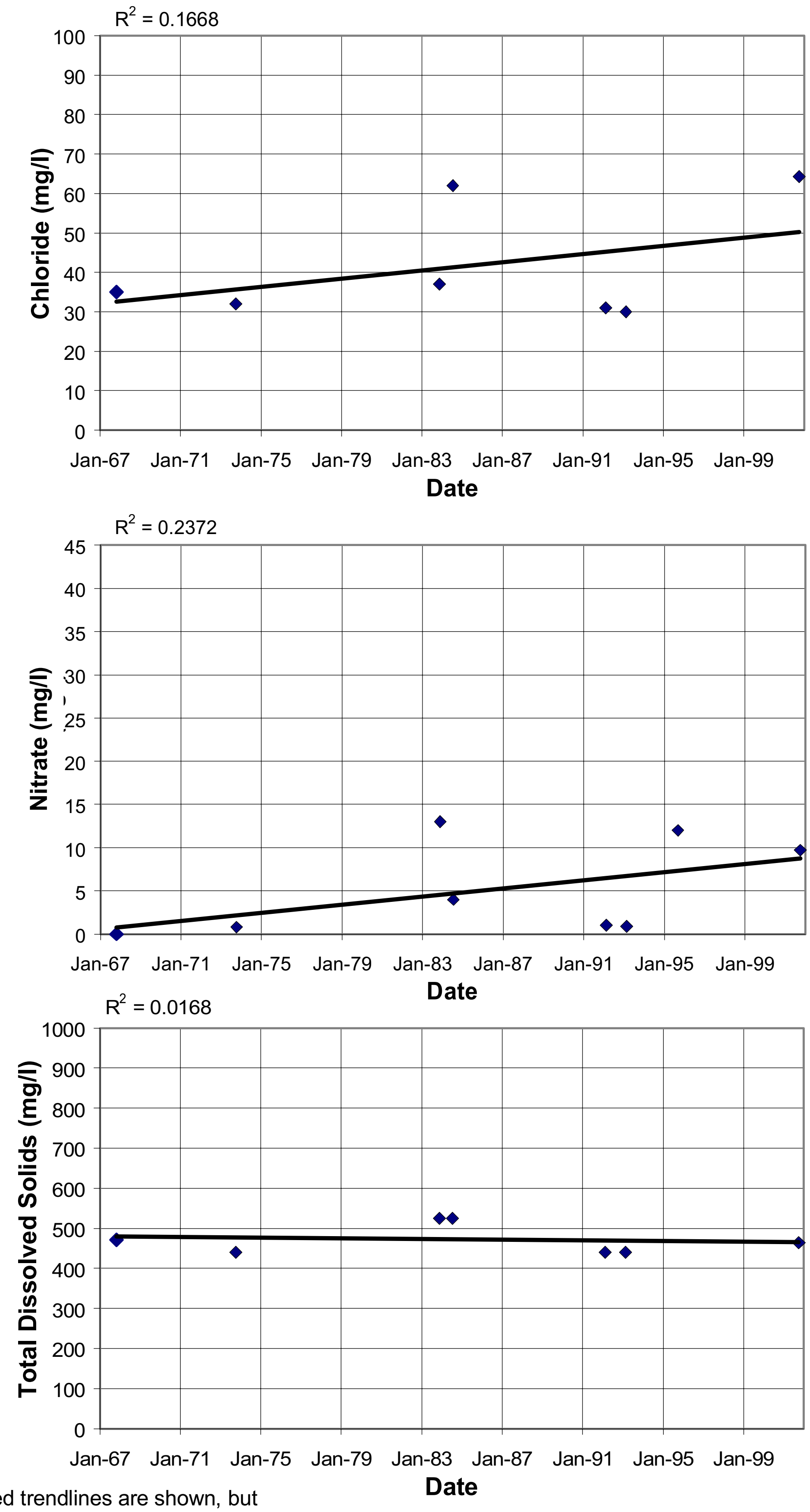


98711\1137gr01.dsf,p9

NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
26S/13E-28J01, K, L02
Estrella Area
Paso Robles Groundwater
Basin Study

26S/14E-18J01

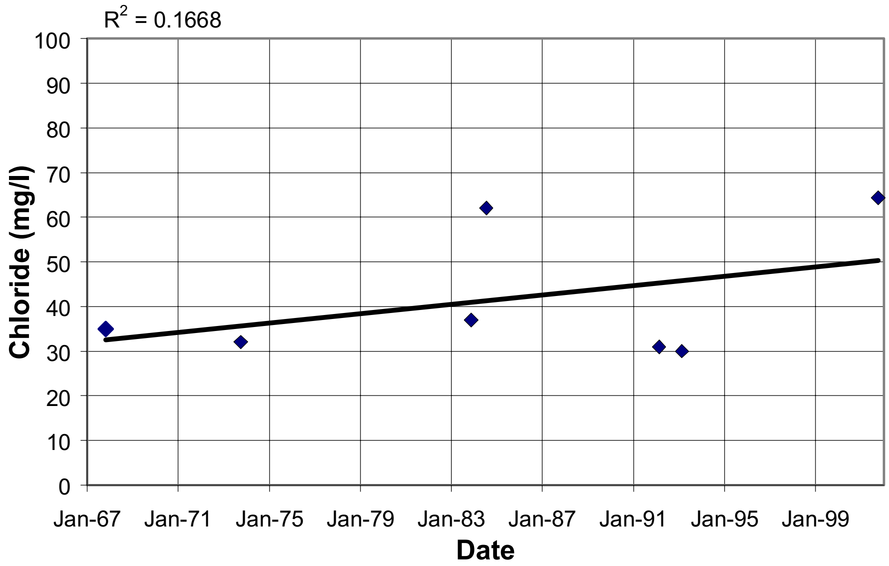


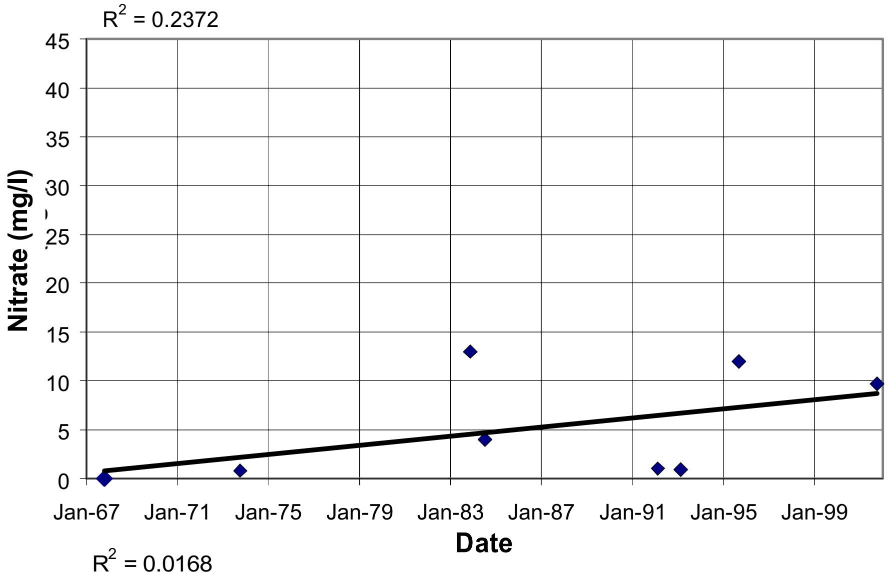
9871\1137gr01.dsf,p10

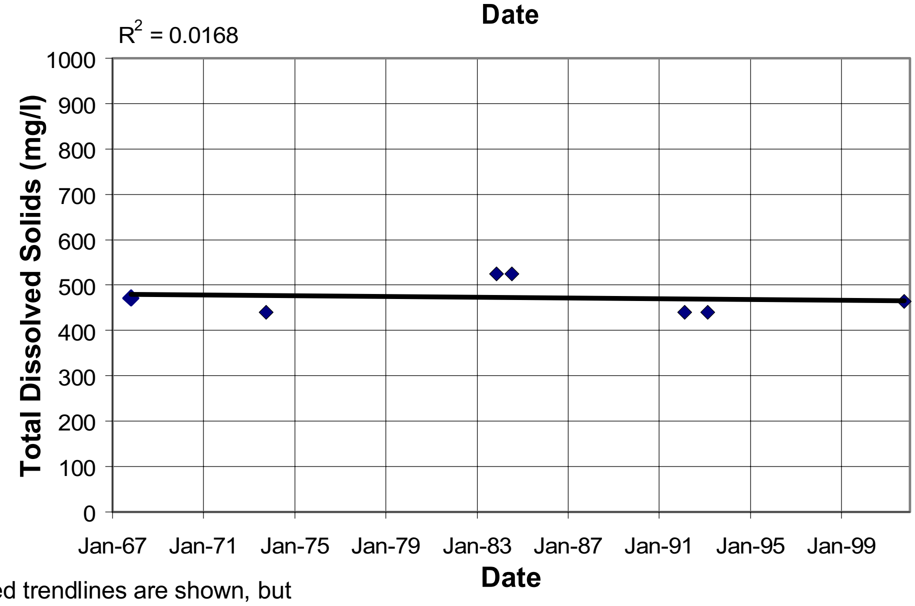
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
26S/14E-18J01
Shandon Area
Paso Robles Groundwater Basin Study

26S/14E-35D01





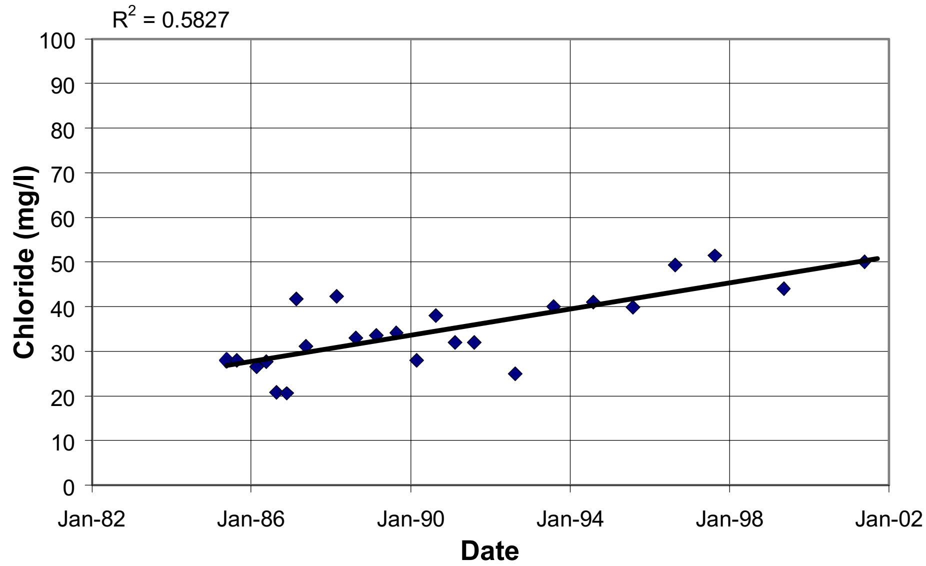


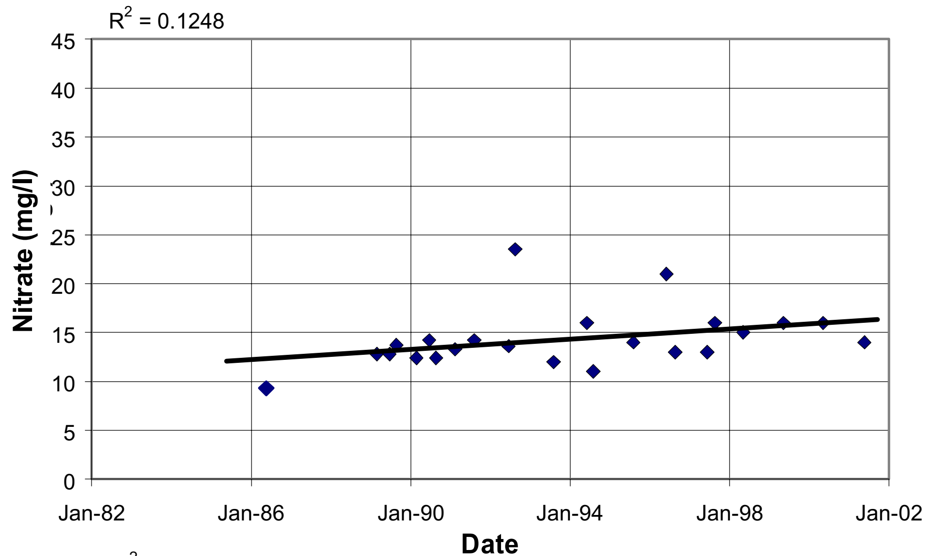
9871\1137gr01.dsf,p11

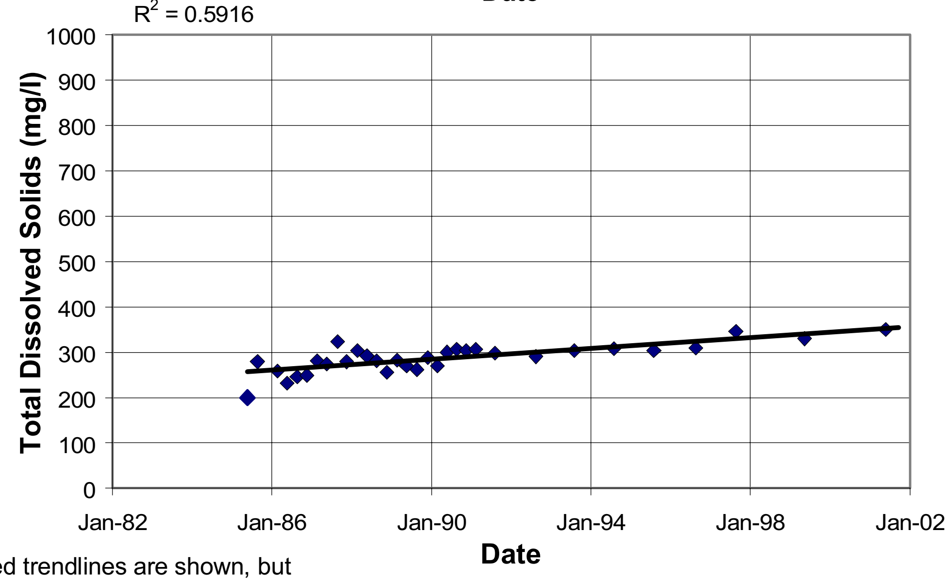
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
26S/14E-35D01
Shandon Area
Paso Robles Groundwater Basin Study

26S/15E-20B03





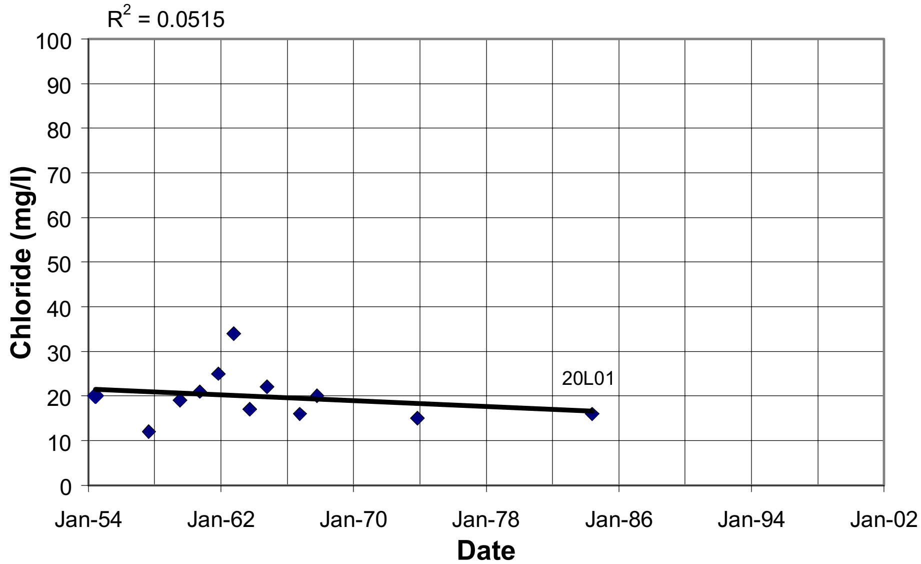


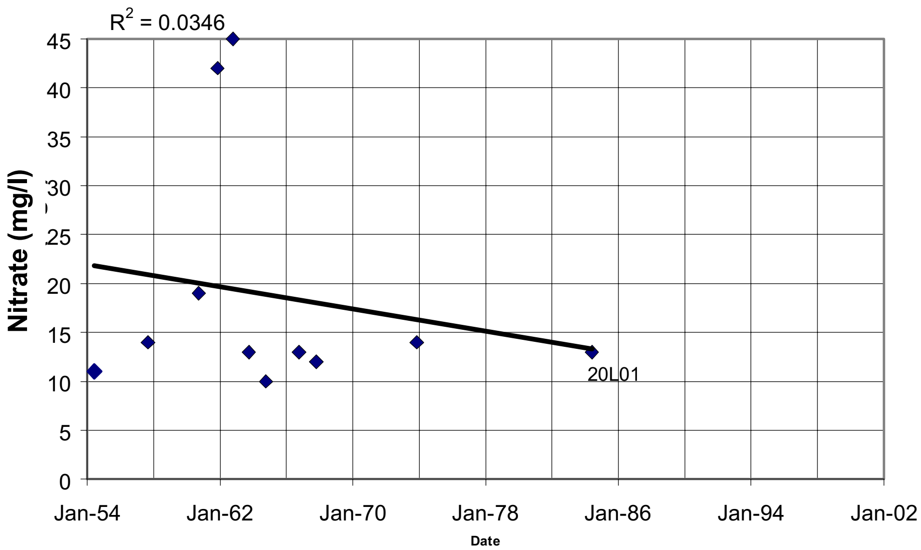
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

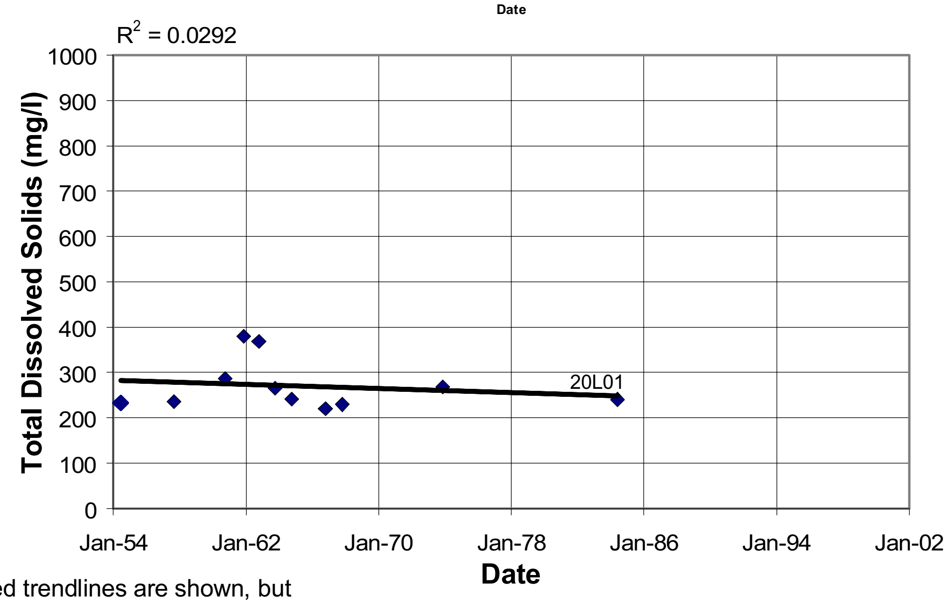
CHEMICAL HYDROGRAPHS
26S/15E-20B03
Shandon Area
Paso Robles Groundwater Basin Study

9871\1137gr01.dsf,p12

26S/15E-20L01, N01





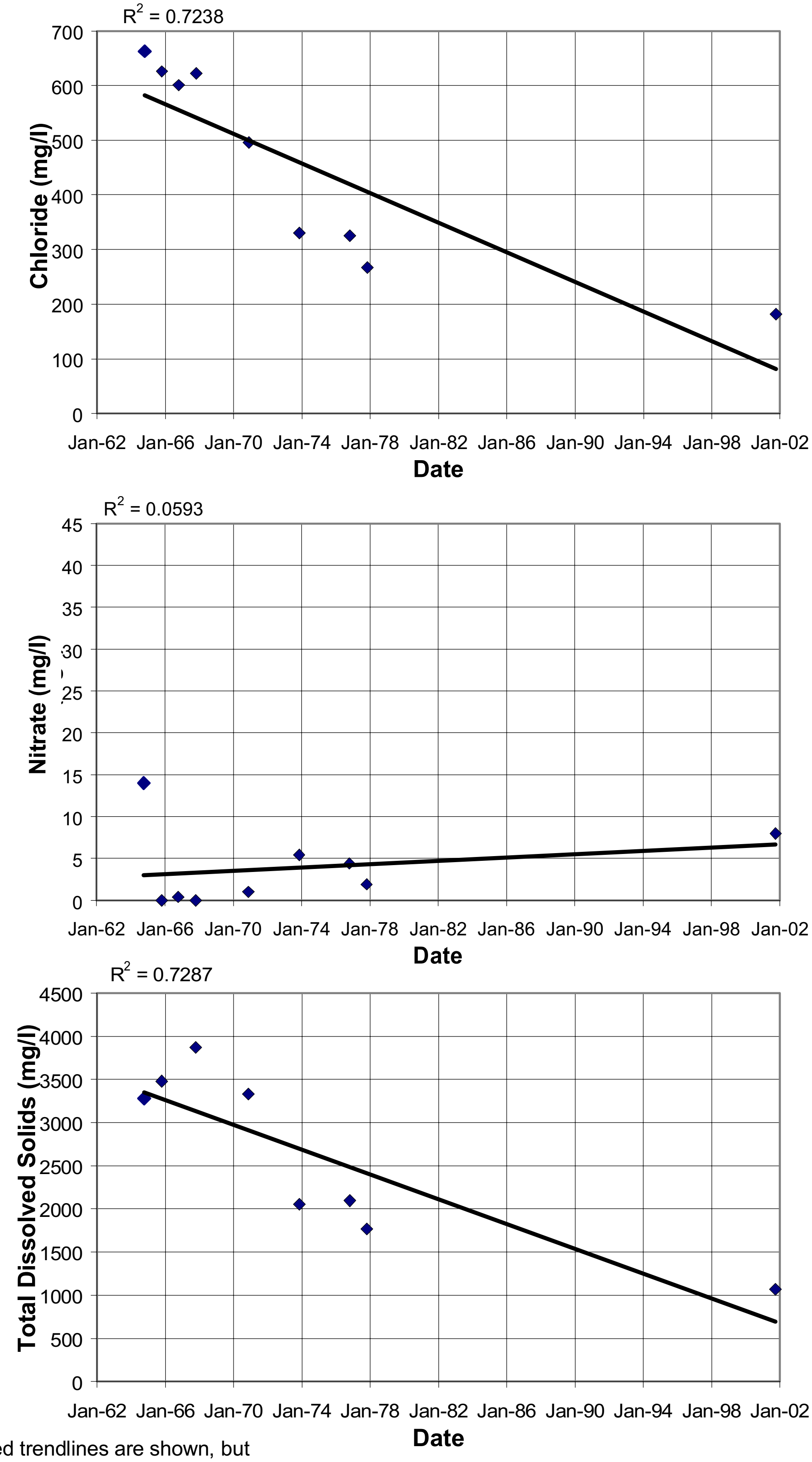


9871\1137gr01.dsf,p13

NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
26S/15E-20L01, N01
Shandon Area
Paso Robles Groundwater Basin Study

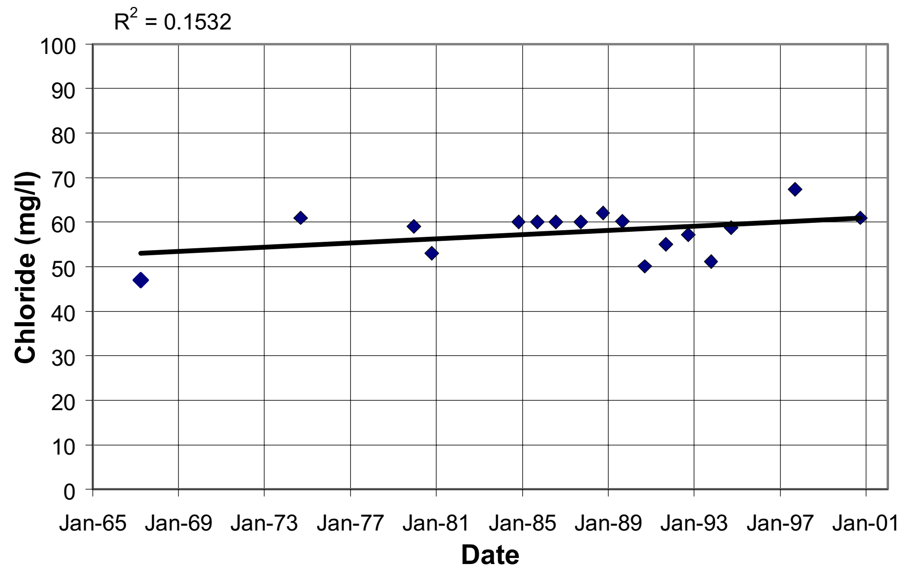
26S/15E-28Q02

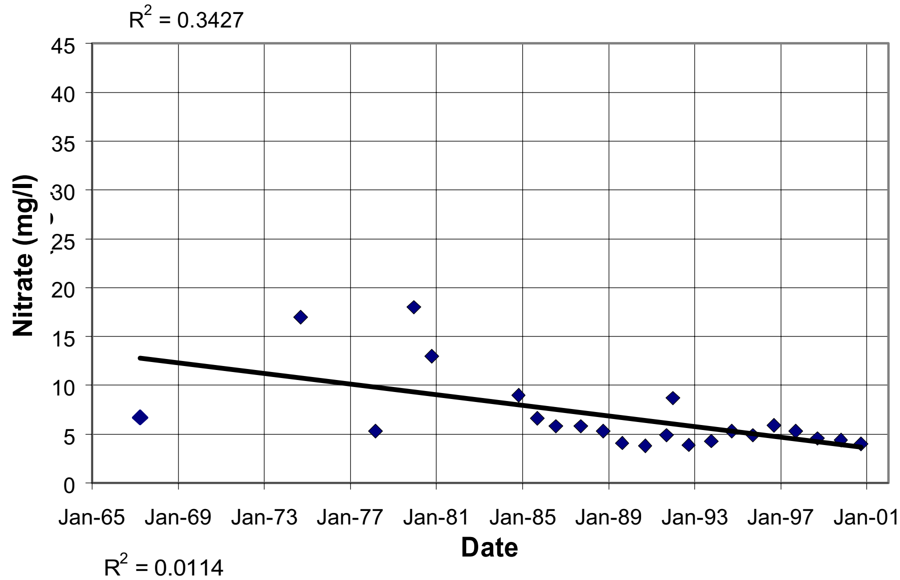


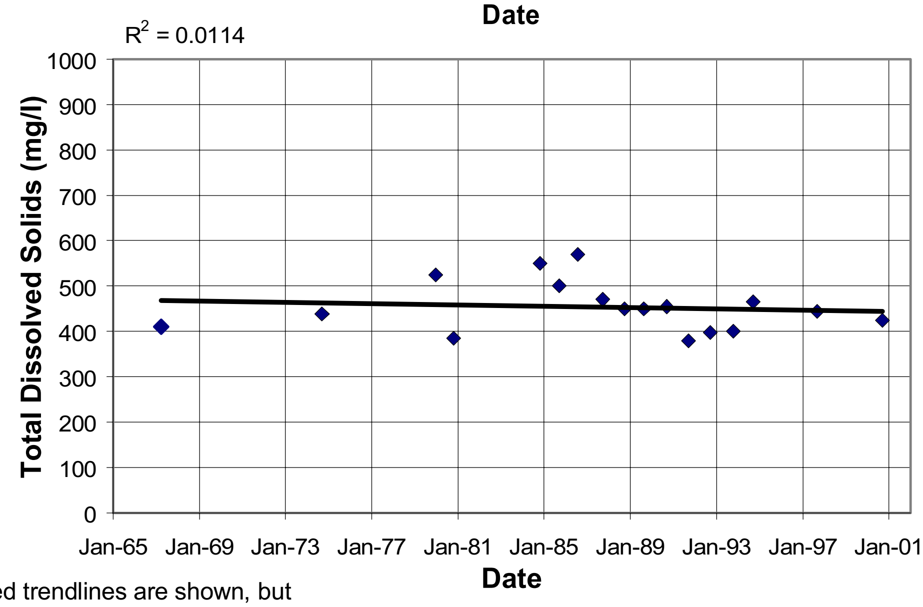
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
26S/15E-28Q02
Shandon Area
Paso Robles Groundwater Basin Study

27S/12E-2E01





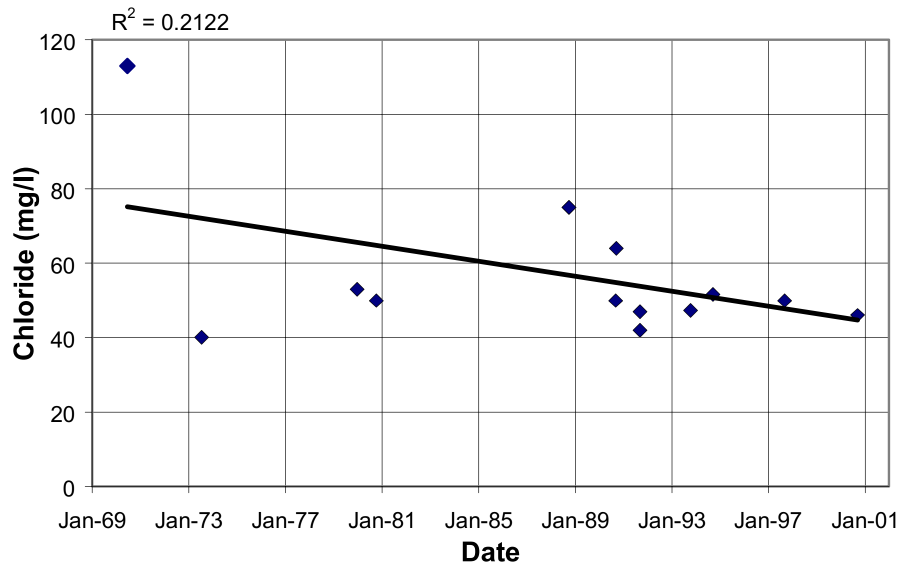


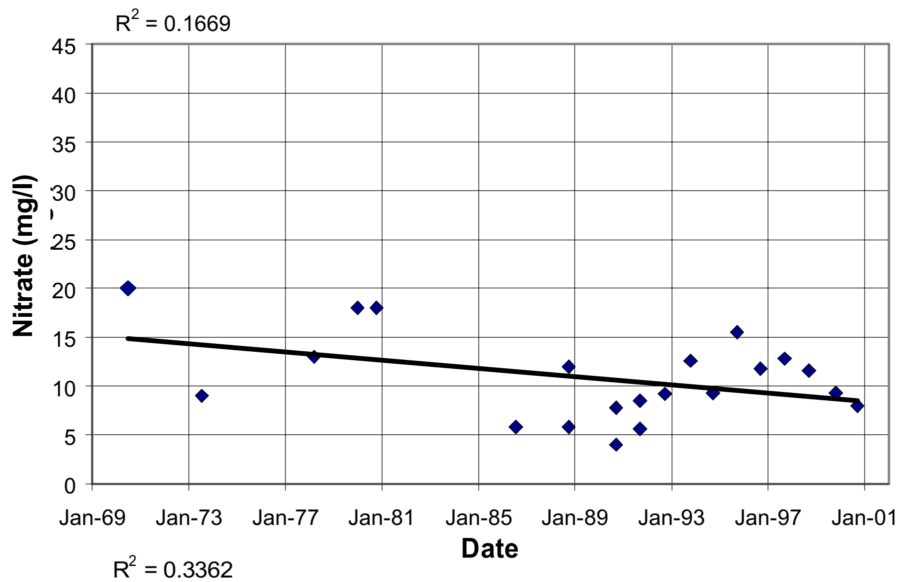
9871\1137gr02.dsf,p1

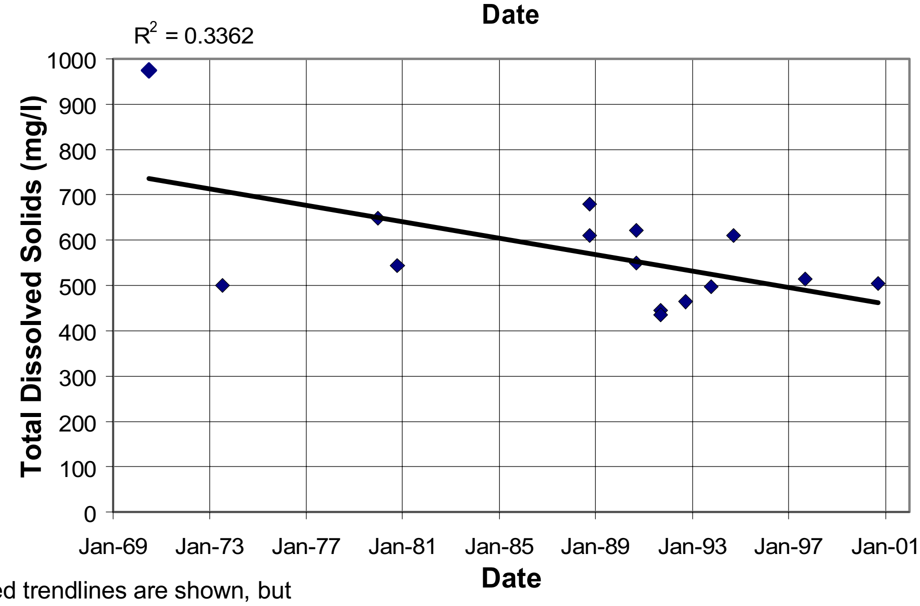
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
27S/12E-2E01
Estrella Area
Paso Robles Groundwater Basin Study

27S/12E-9M02, M03





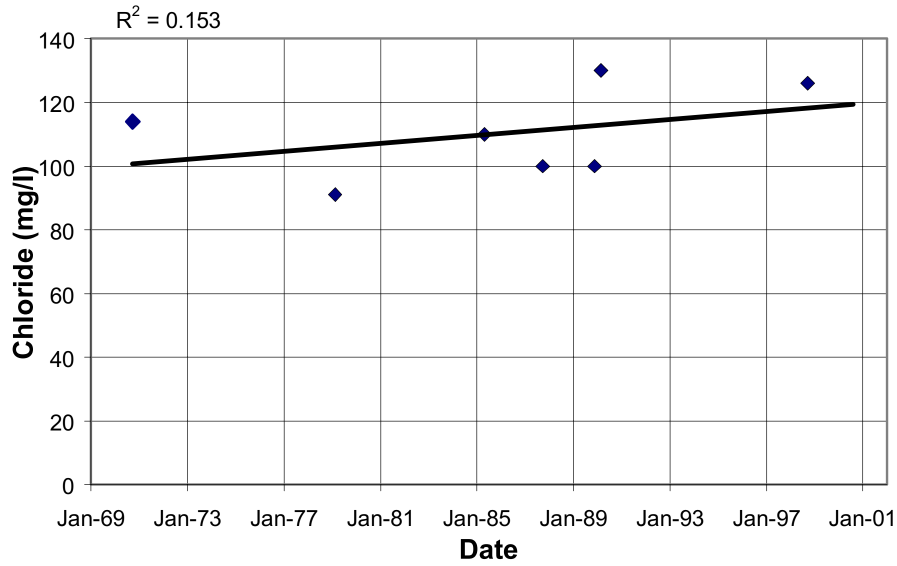


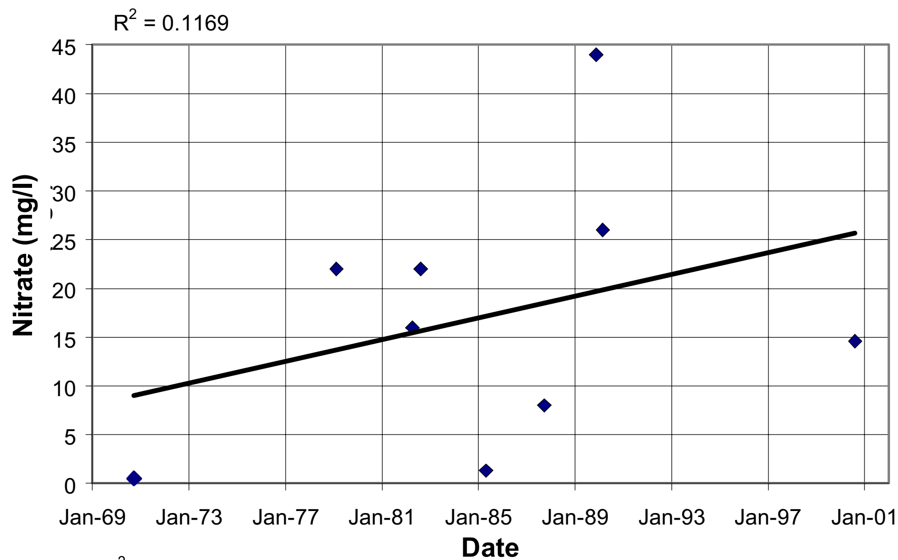
9871\1137gr02.dsf,p2

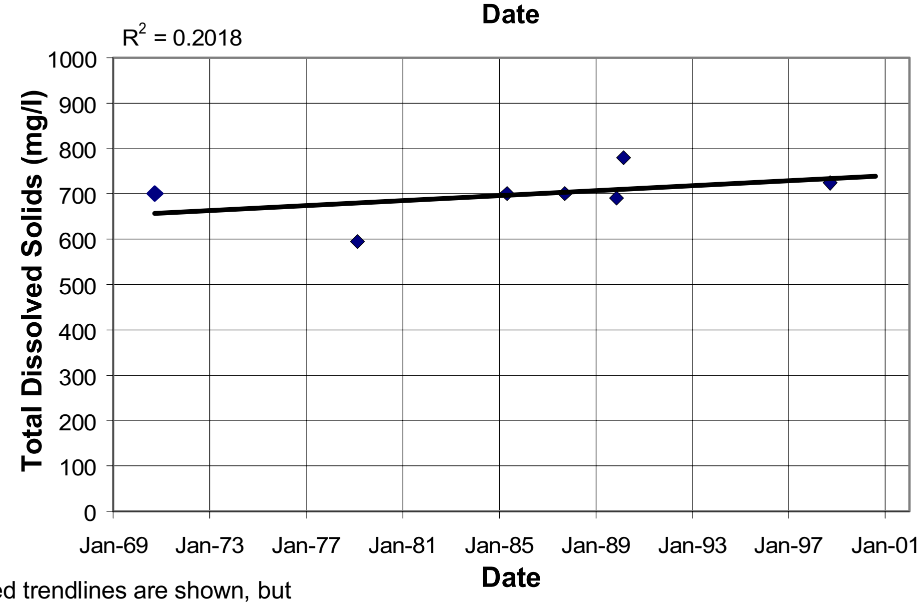
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
27S/12E-9M02, M03
Atascadero Area
Paso Robles Groundwater Basin Study

27S/12E-17R02





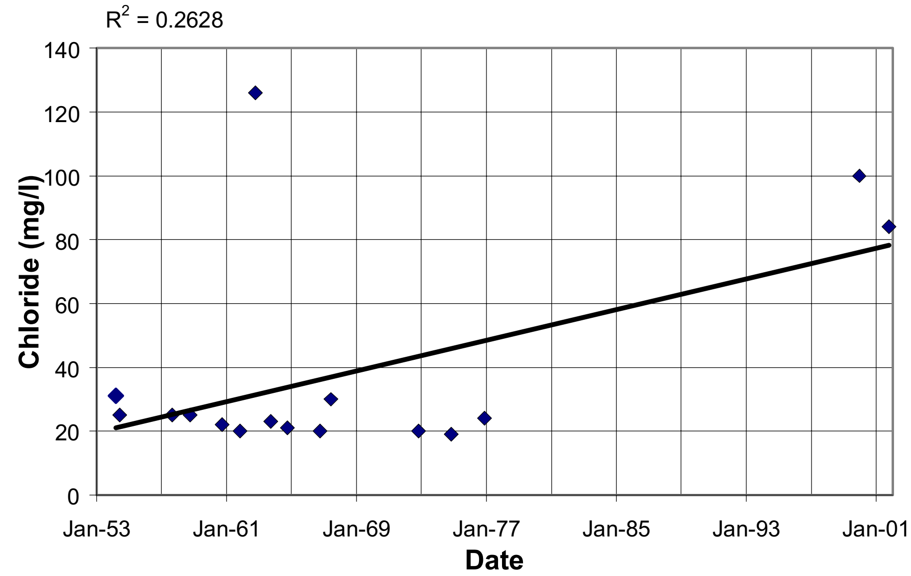


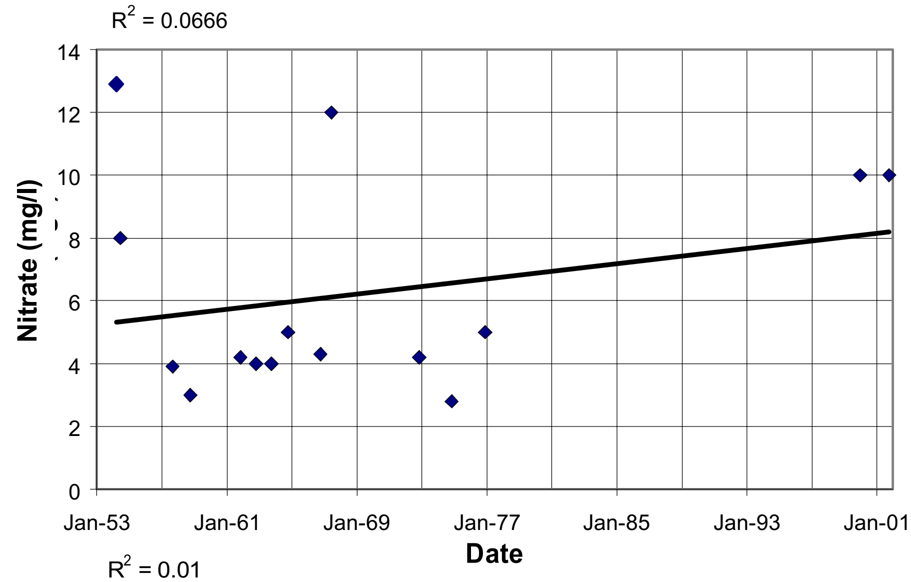
9871\1137gr02.dsf,p3

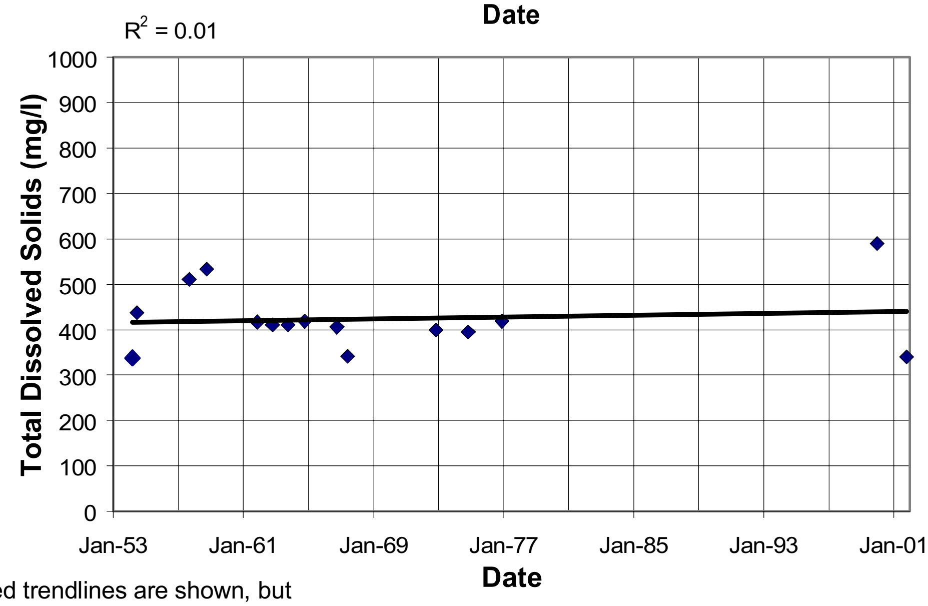
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
27S/12E-17R02
Atascadero Area
Paso Robles Groundwater Basin Study

27S/13E-9P01, 20R01, 20A, 5N





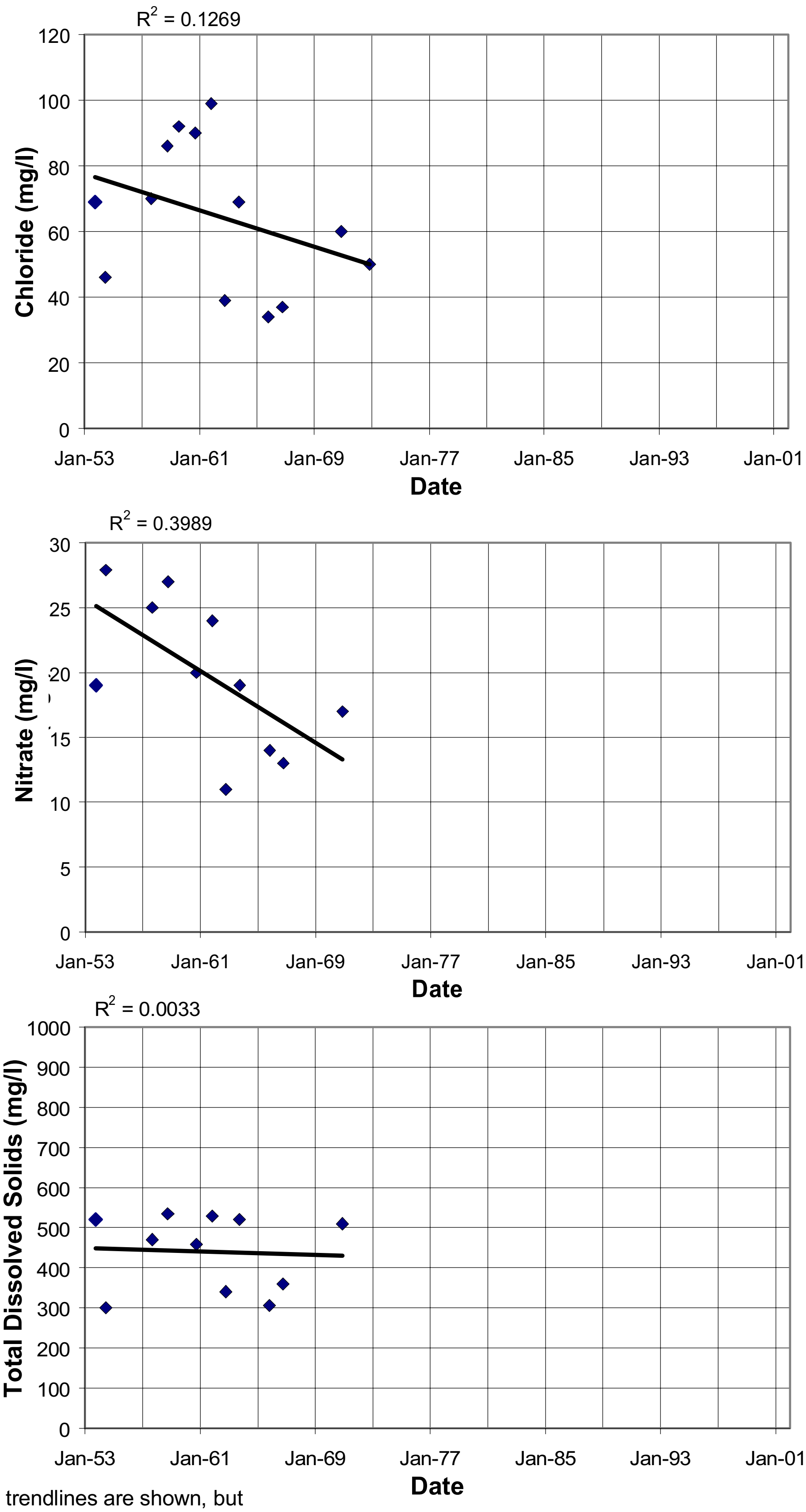


9871\1137gr02.dsf,p4

NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
27S/13E-9P01, 20R01, 20A, 5N
Creston Area
Paso Robles Groundwater Basin Study

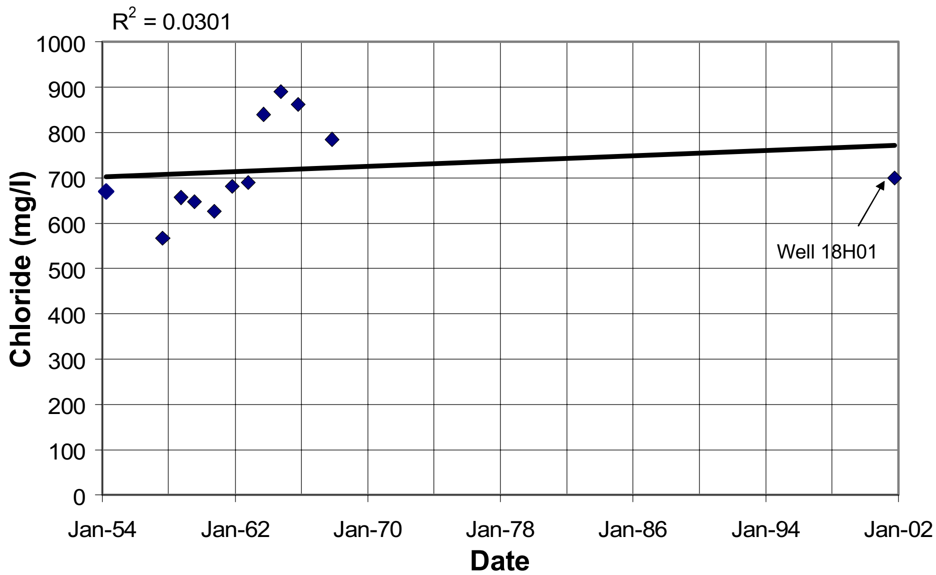
27S/13E-36R01

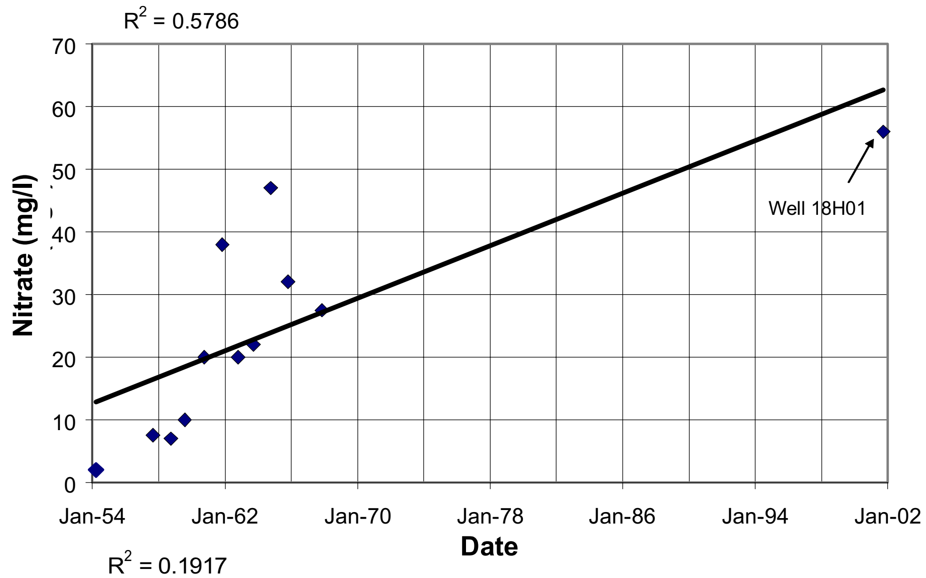


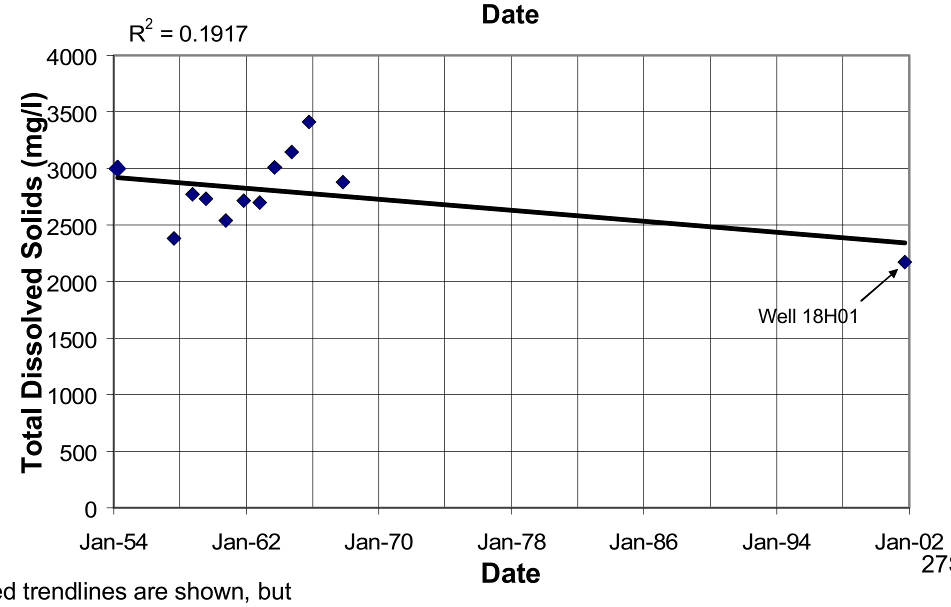
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
27S/13E-36R01
Creston Area
Paso Robles Groundwater Basin Study

27S/15E-13A01, 16E-18H01



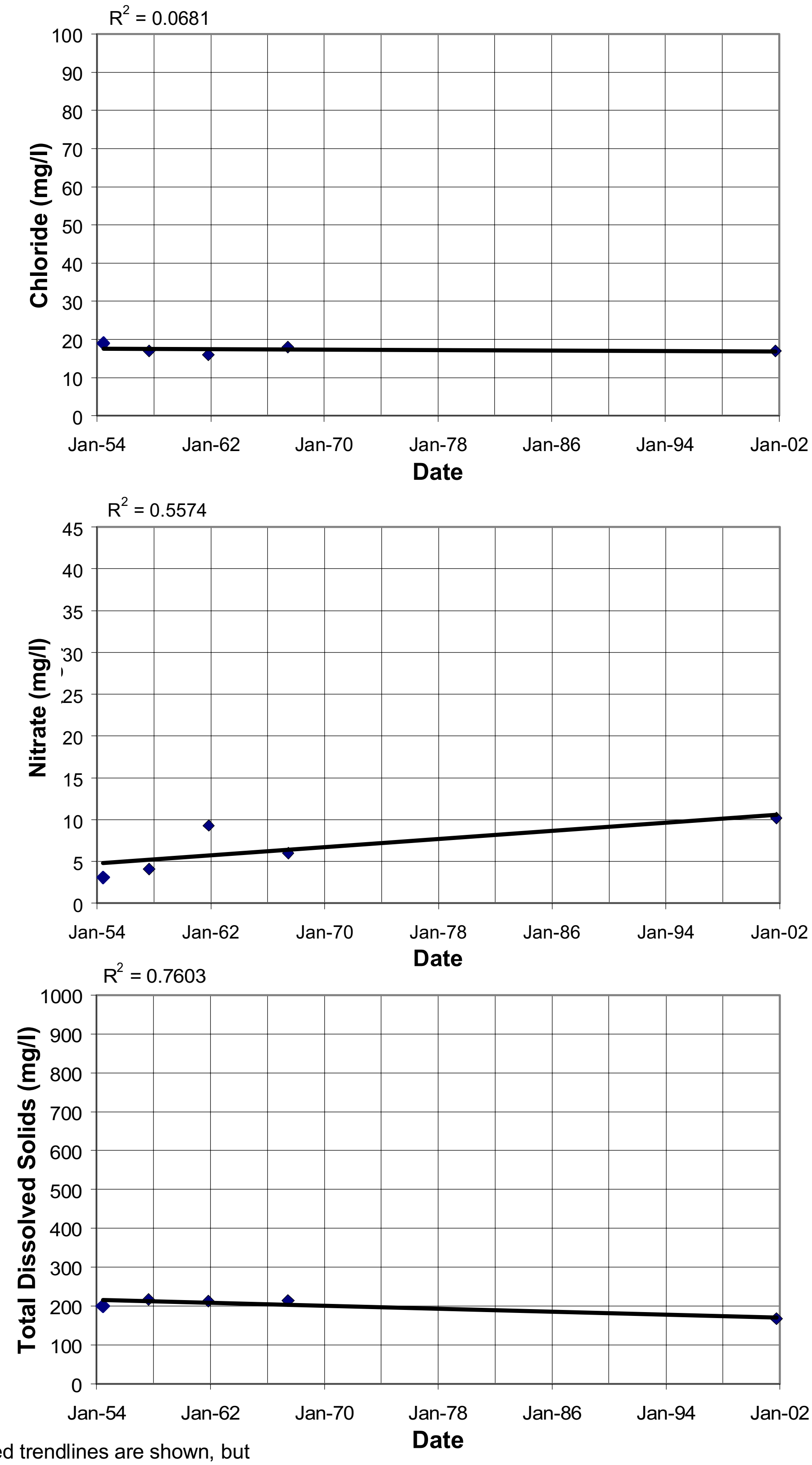




NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
27S/15E-13A01, 16E-18H01
San Juan Area
Paso Robles Groundwater Basin Study

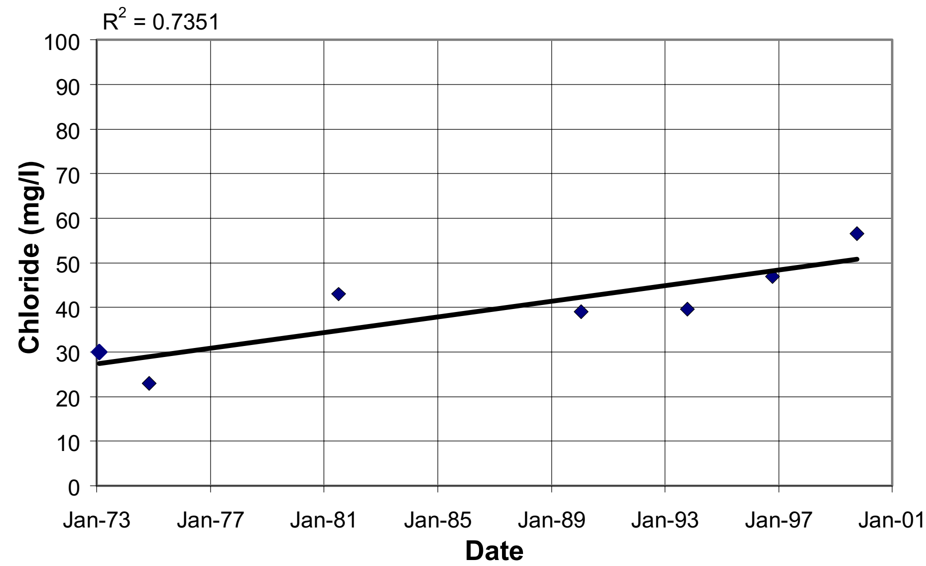
27S/15E-35F01

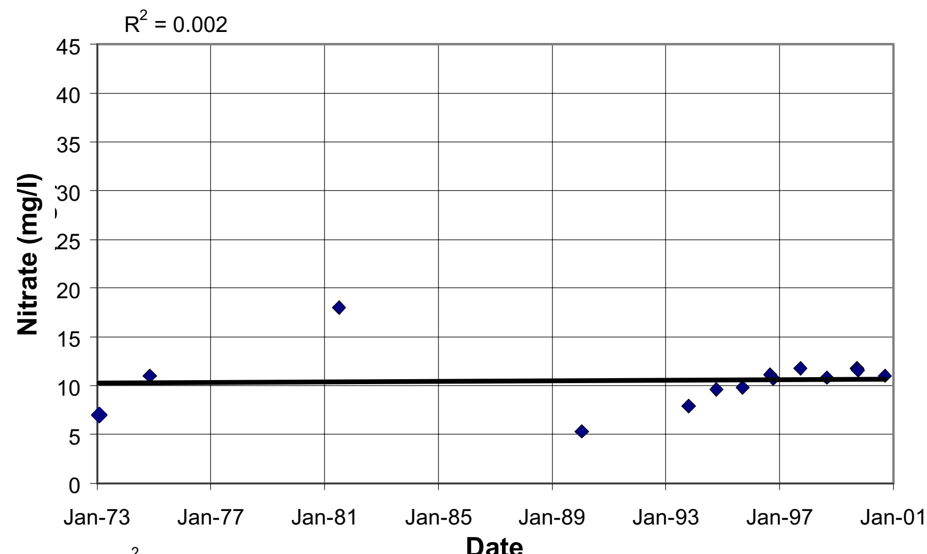


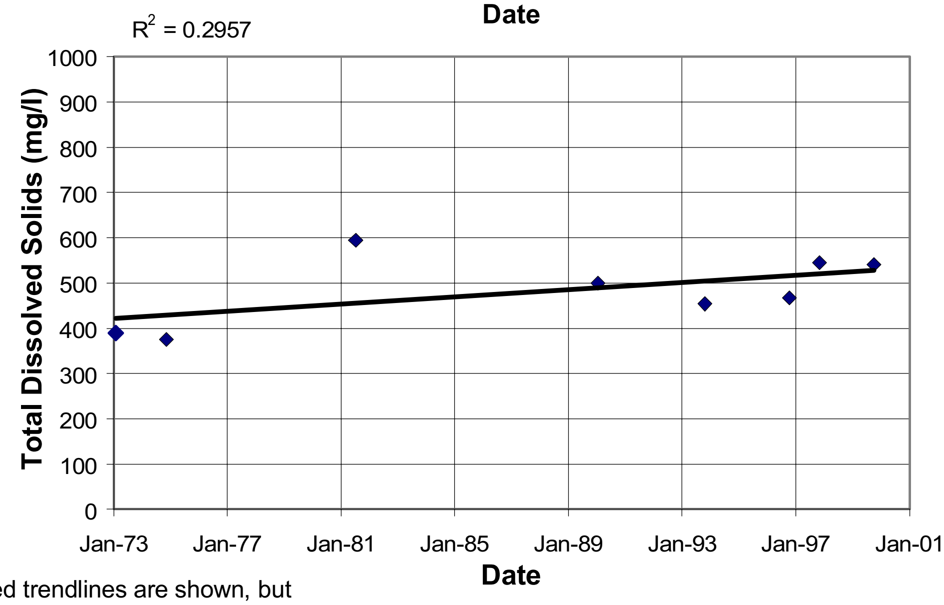
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
27S/15E-35F01
San Juan Area
Paso Robles Groundwater Basin Study

28S/12E-10A03







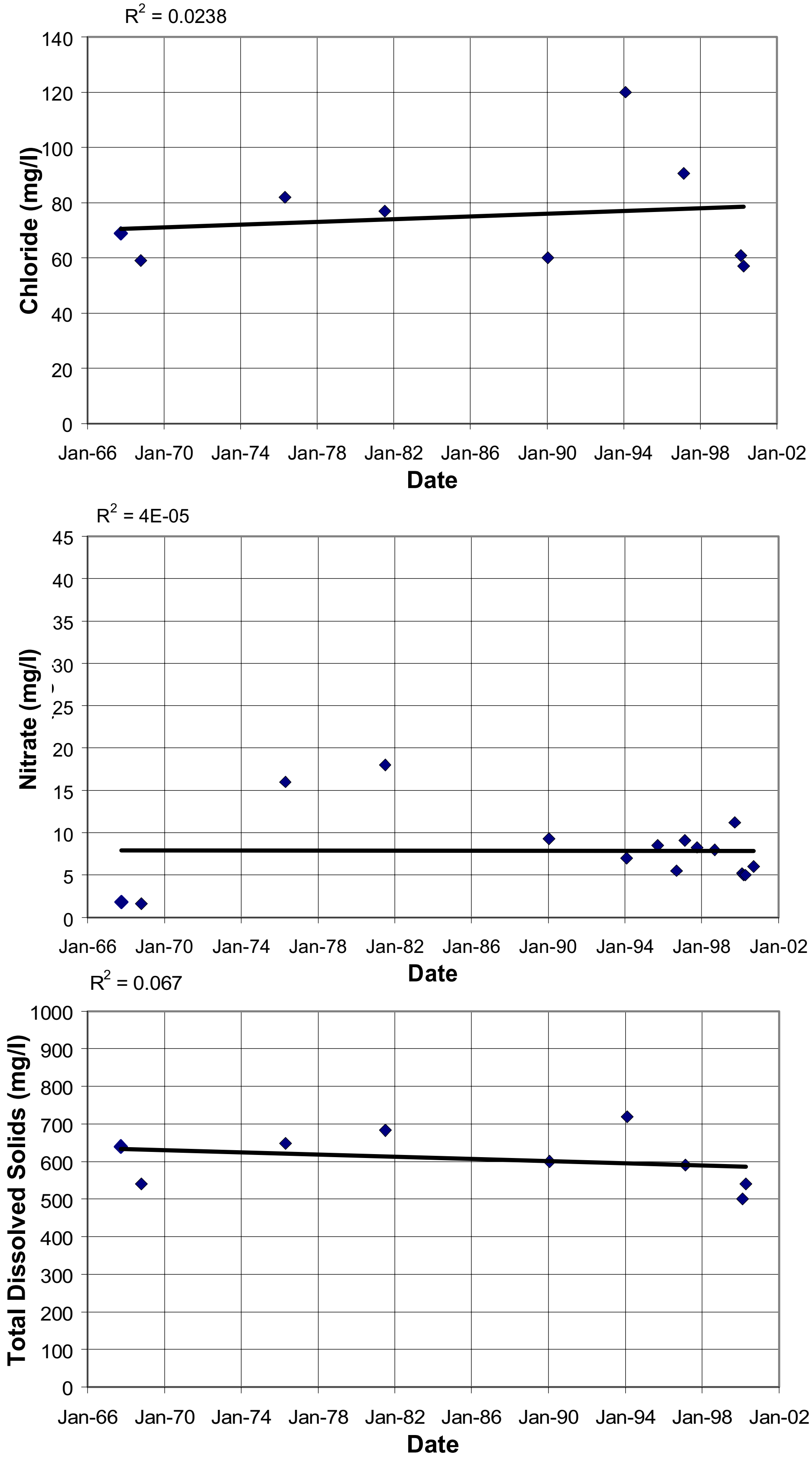
9871\1137gr02.dsf,p8

NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
28S/12E-10A03
Atascadero Area
Paso Robles Groundwater
Basin Study

Project No. 98-71-1137

28S/12E-11N06, N07



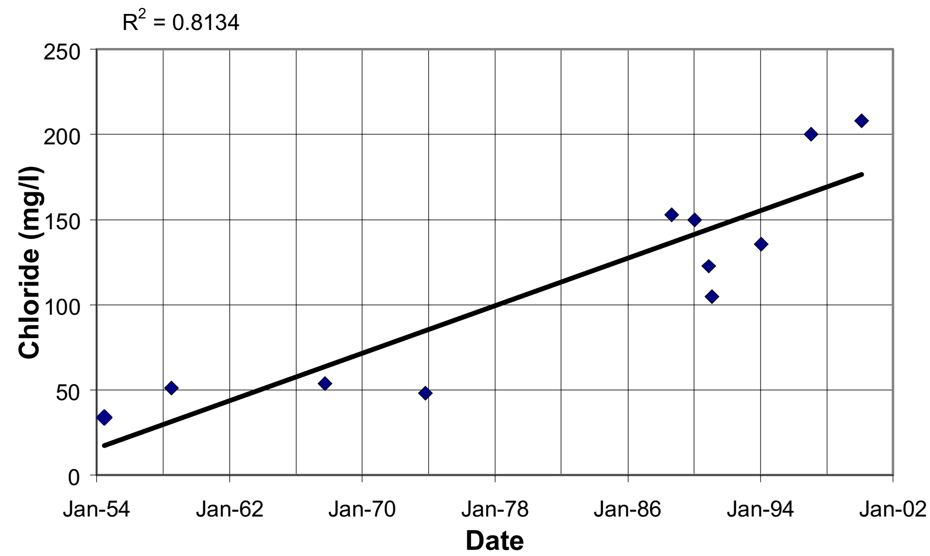
9871\1137gr02.dsf,p9

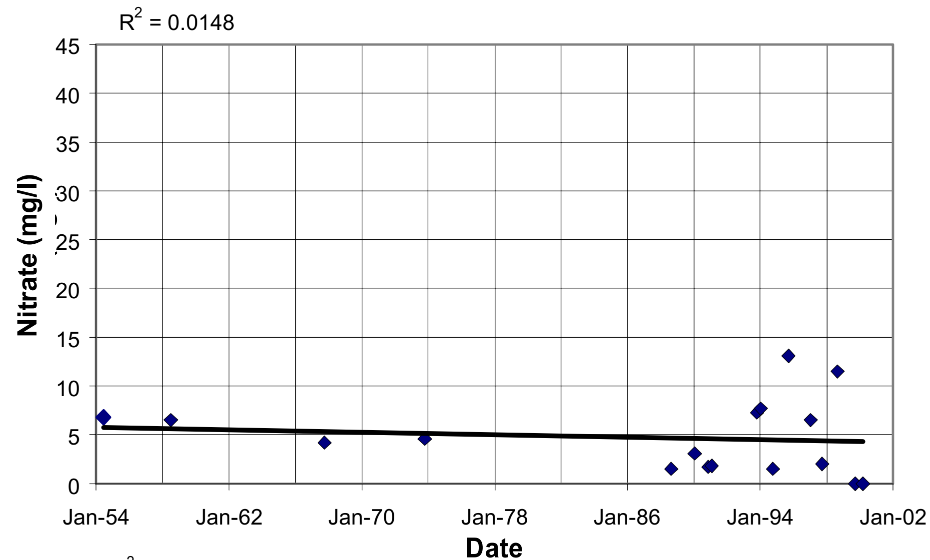
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

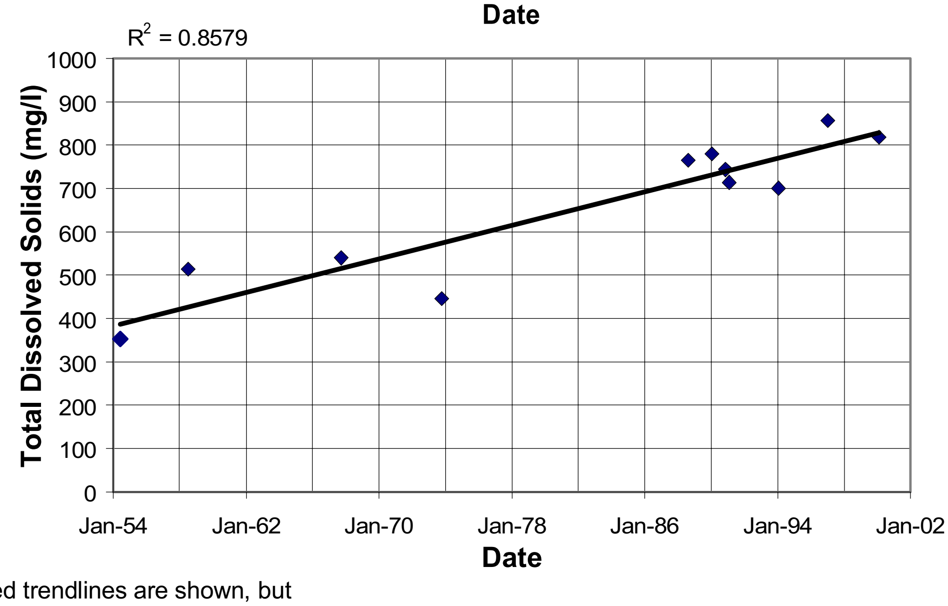
CHEMICAL HYDROGRAPHS
28S/12E-11N06, N07
Atascadero Area
Paso Robles Groundwater Basin Study

Project No. 98-71-1137

28S/12E-14K01





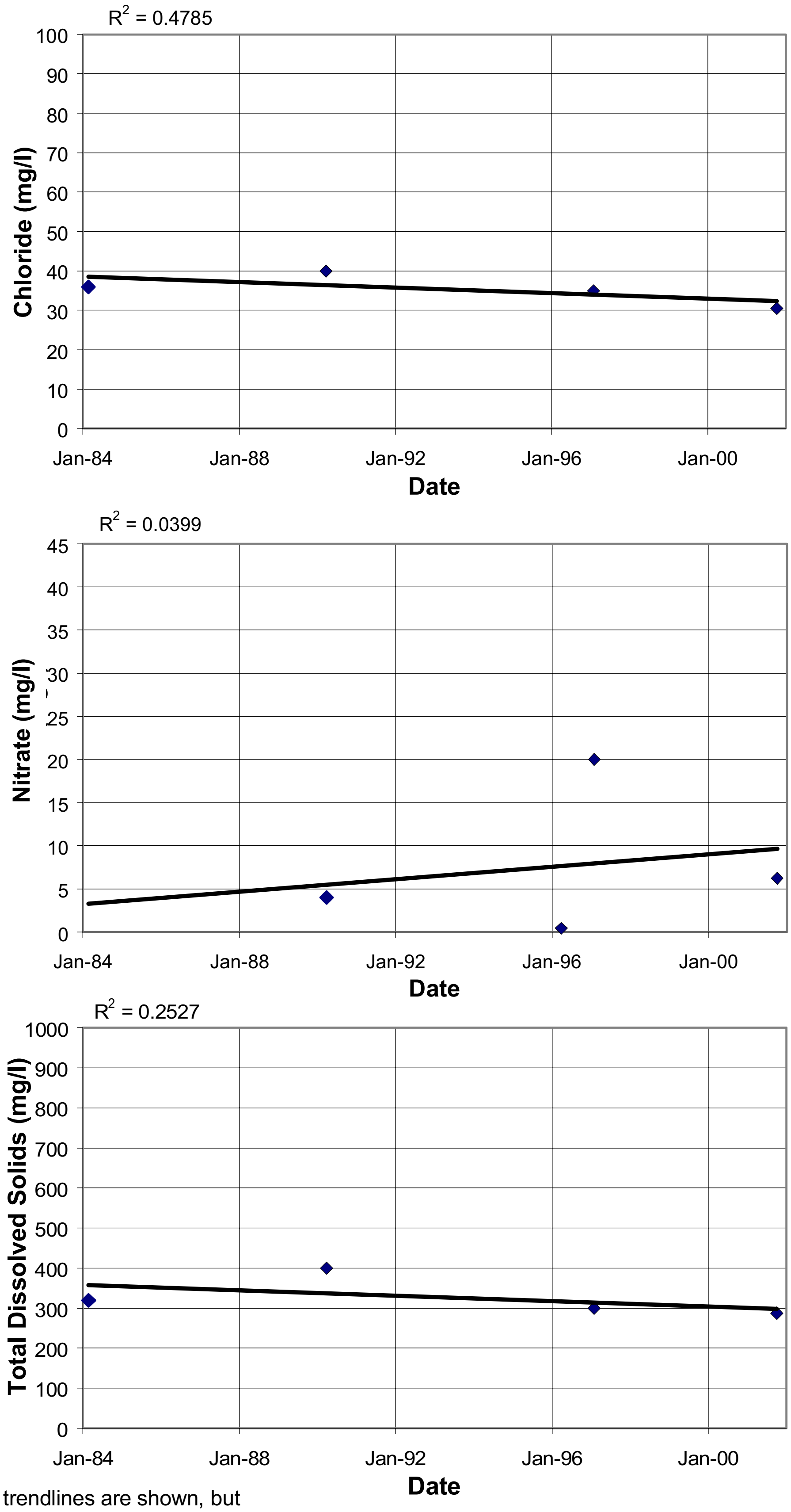


9871\1137gr02.dsf,p10

NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
28S/12E-14K01
Atascadero Area
Paso Robles Groundwater Basin Study

28S/13E-1K01, K02



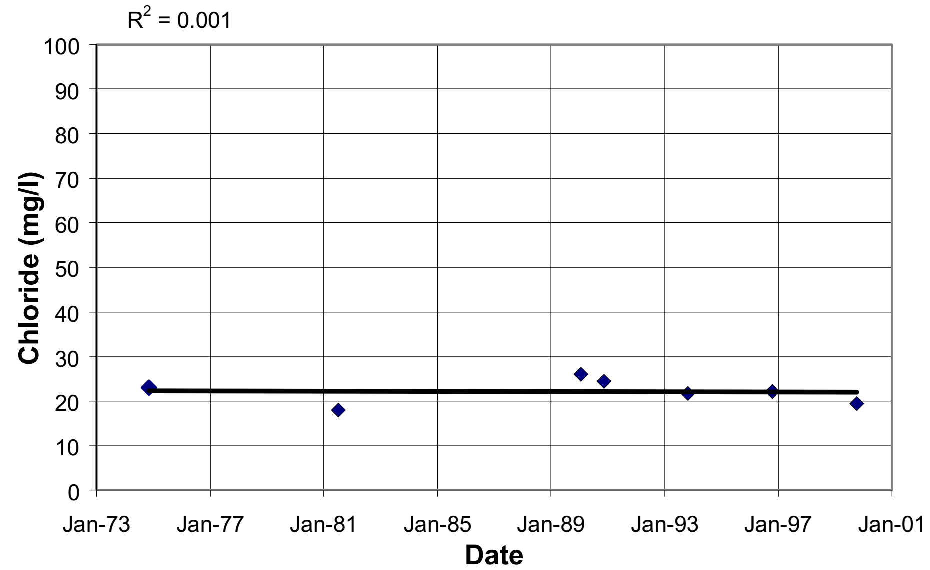
9871\1137gr02.dsf,p11

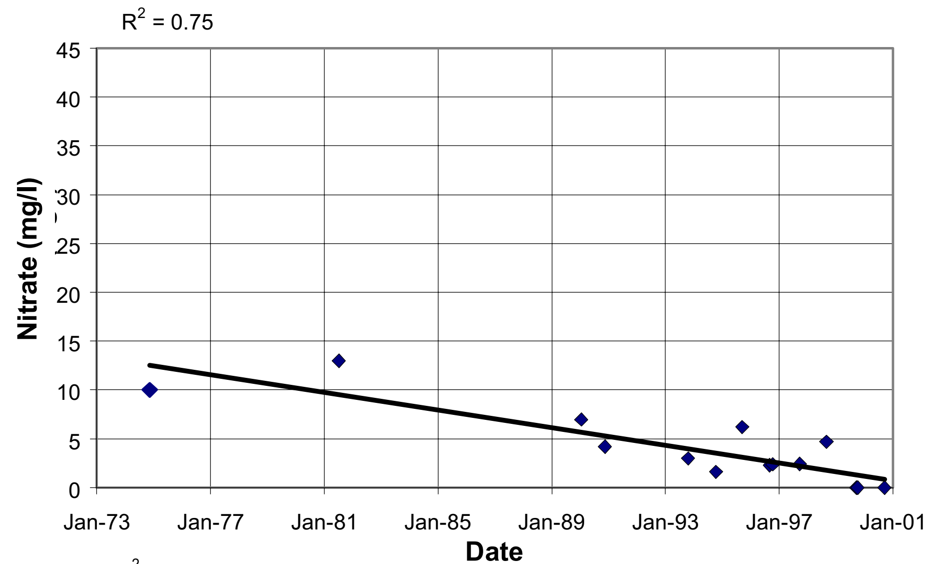
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

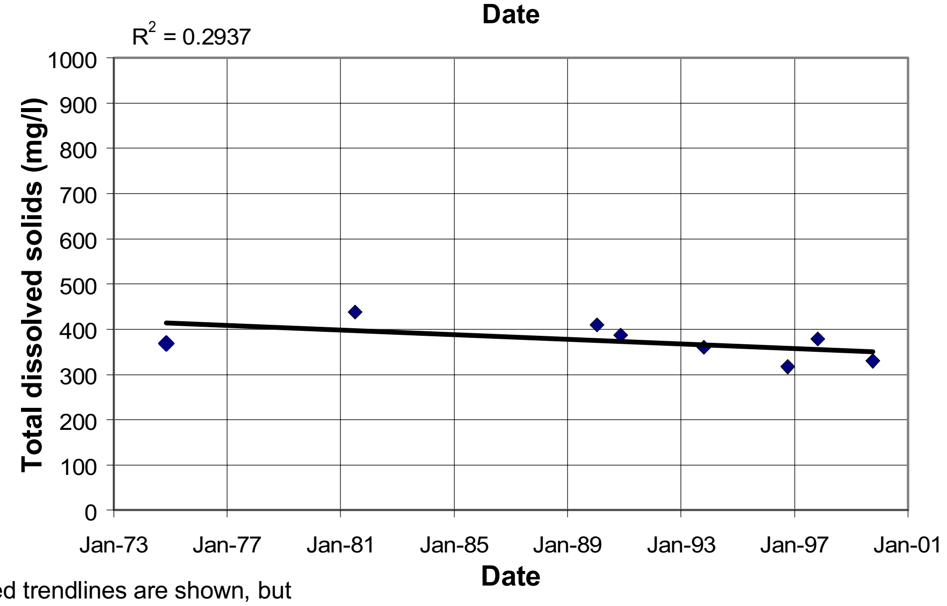
CHEMICAL HYDROGRAPHS
28S/13E-1K01, K02
Creston Area
Paso Robles Groundwater
Basin Study

Project No. 98-71-1137

28S/13E-31F02





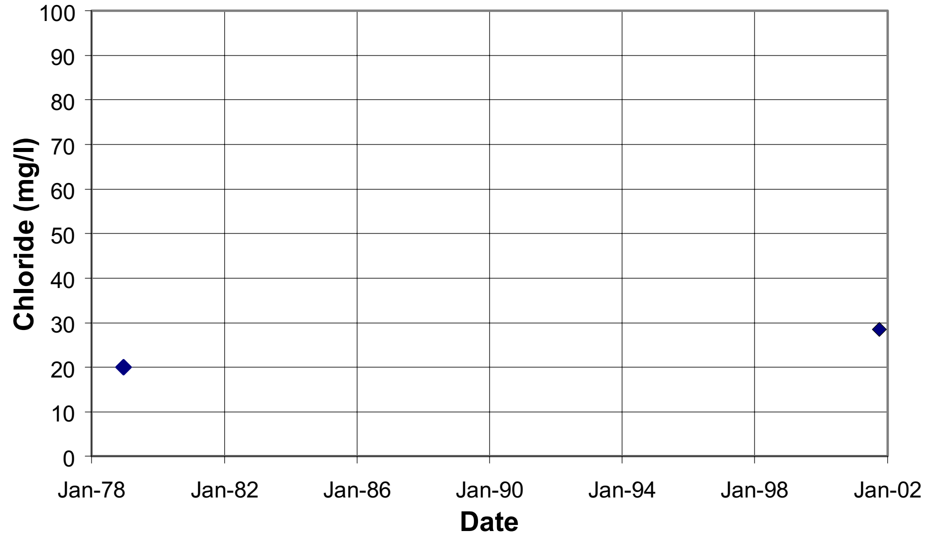


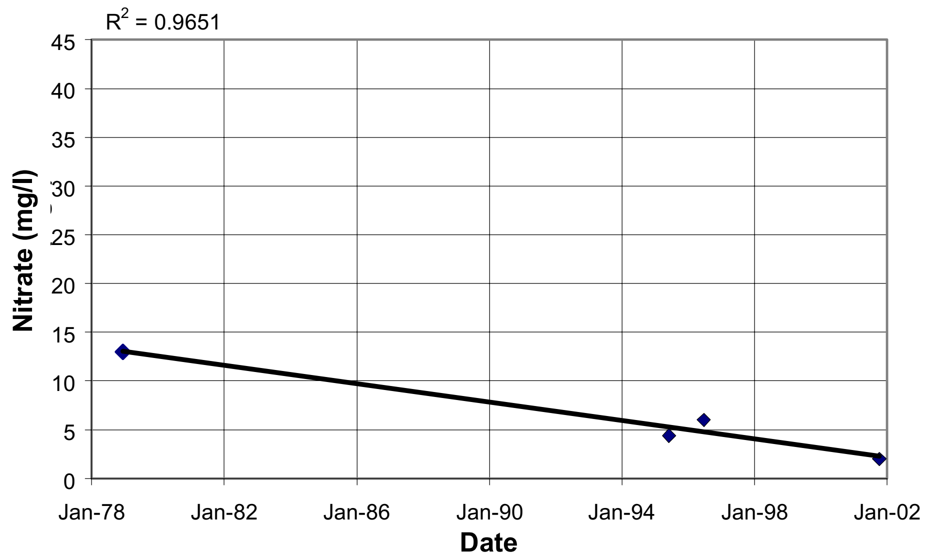
9871\1137gr02.dsf,p12

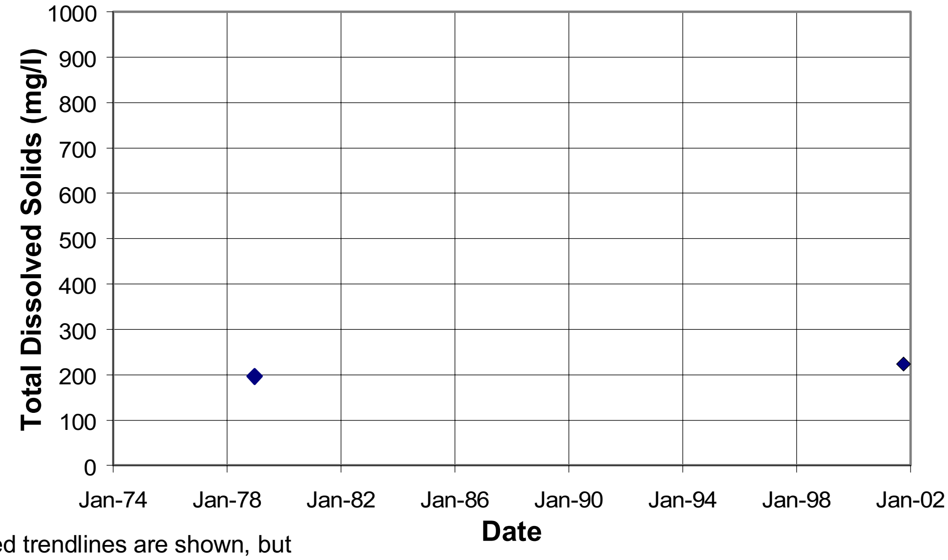
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
28S/13E-31F02
Atascadero Area
Paso Robles Groundwater Basin Study

28S/13E-36A





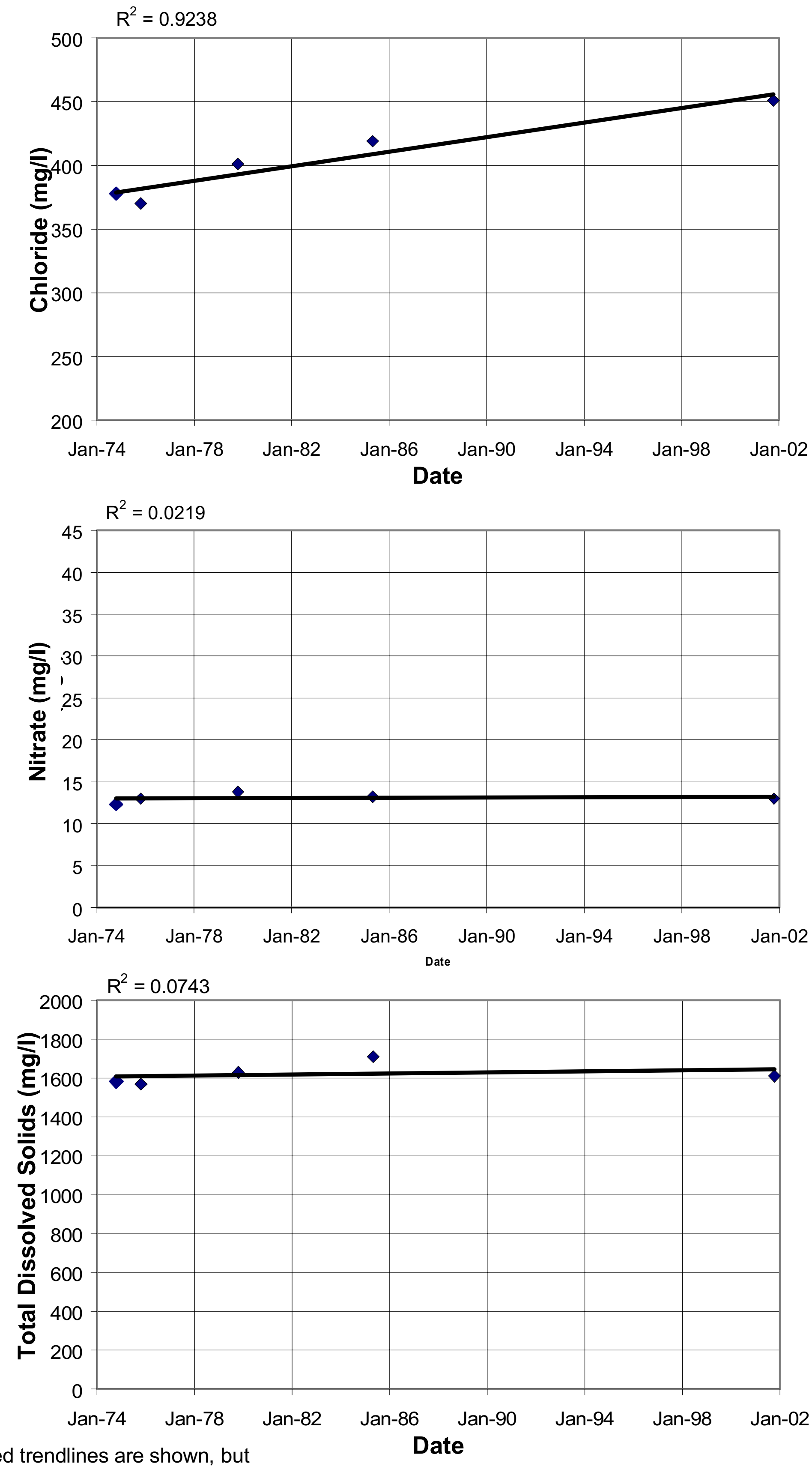


9871\1137gr02.dsf,p13

NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
28S/13E-36A
Creston Area
Paso Robles Groundwater Basin Study

28S/15E-21G, G02

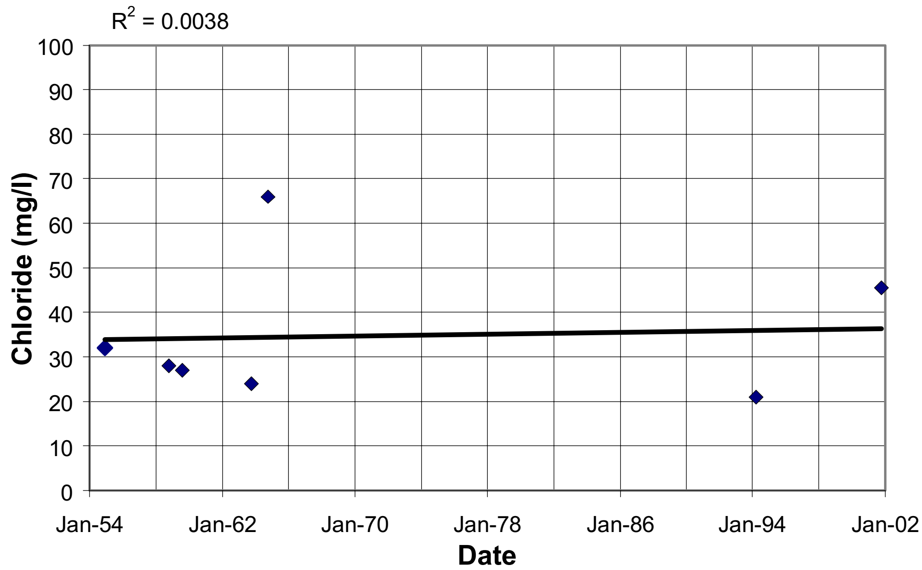


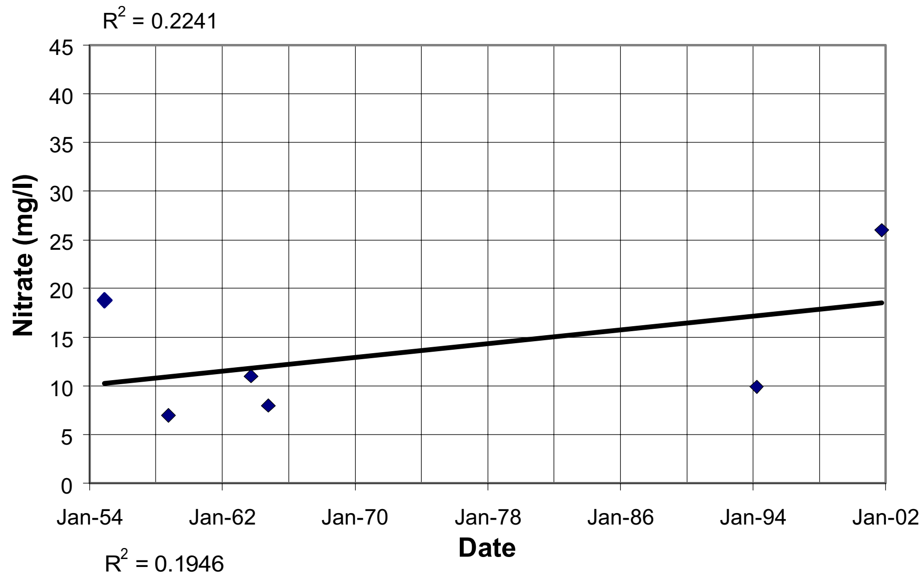
9871\1137gr02.dsf,p14

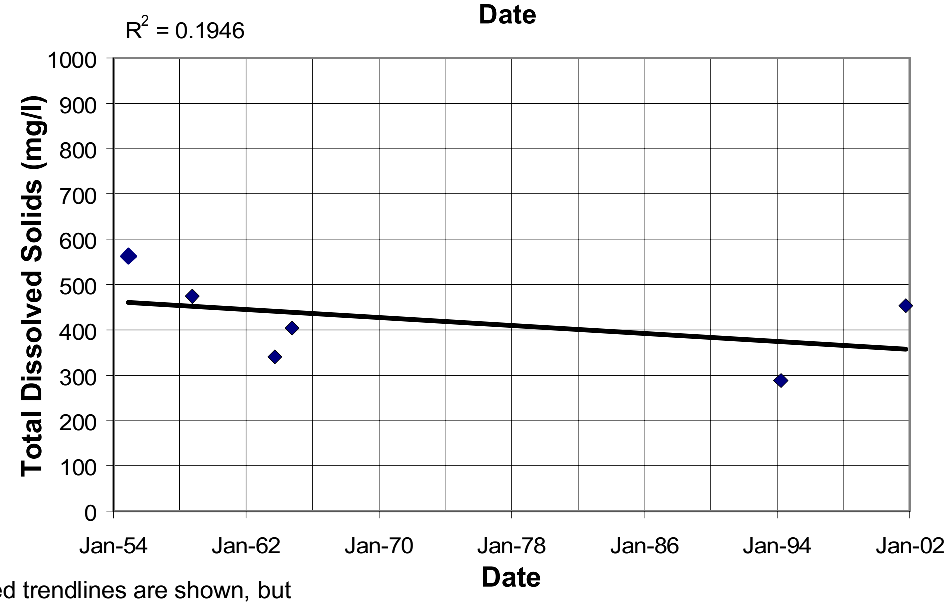
NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
28S/15E-21G, G02
Shandon Area
Paso Robles Groundwater
Basin Study

28S/16E-14N01







9871\1137gr02.dsf,p15

NOTE: The calculated trendlines are shown, but they may not be real trends. See text for discussion of trends at this well.

CHEMICAL HYDROGRAPHS
28S/16E-14N01
San Juan Area
Paso Robles Groundwater Basin Study