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.