

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° to 3° 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° 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° to 5° (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° to 3° (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°. 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.

