**Response to**

# California Energy Commission Staff Data Request 55

**Dated December 5, 2002**

**In Support of the**

# Application for Certification

**For the**

# Pico Power Project

## Santa Clara, California

**02-AFC-03**

Submitted to the
California Energy Commission

Submitted by
Silicon Valley Power
City of Santa Clara

January 2003

# SOIL AND WATER RESOURCES

## Groundwater Resources

*55. Please provide additional information of the groundwater supply, including, but not limited to:*

*a) A groundwater balance;*

**Response:** The Pico Power Project (PPP) is located at 850 Duane Ave in the northern part of Santa Clara County, in the City of Santa Clara, California. The project site is situated within the Santa Clara Valley Groundwater Basin, the northern-most of three linearly interconnected groundwater basins: the Santa Clara Valley, Coyote Valley and Llagas Basins. These three groundwater basins occupy the broad, northeast-southwest trending inter-mountain valleys in the central portion of the Santa Clara County.

The Santa Clara Valley Groundwater Basin extends from Coyote Narrows at Metcalf Road in the south to the County's northern boundary at San Francisco Bay. The Diablo Mountain Range bounds the basin on the east and the Santa Cruz Mountains comprise the basin's western boundary. The Santa Clara Valley Basin is approximately 22 miles long and 15 miles wide with a surface area of approximately 225 square miles (SCVWD 2001a).

The Santa Clara Valley Groundwater Basin is divided into three hydrogeologic units: 1) the forebay, consisting of the elevated edges of the basin; 2) the upper aquifer zone; and 3) the lower aquifer zone. Within the elevated forebay area, sediments were deposited as alluvial fans from streams emanating from the mountains. These deposits consist predominantly of coarse sands and gravels with discontinuous leaky aquitards (Iwamura 1995). In the forebay area, groundwater exists primarily under unconfined conditions. Both upper and lower aquifer zones are highly stratified, containing multiple aquifers and aquitards (SCVWD 1989). Regional groundwater flow is northeast, toward San Francisco Bay.

Within the interior portion of the groundwater basin, upon which the City of Santa Clara and the PPP project site are located, fine-grained deposits are stratified and interbedded with sand and gravel aquifers. The maximum depth of these deposits exceeds 1500 feet (Iwamura 1995). Within these deposits, a continuous regional aquitard is present at depths of between 100 feet to 200 feet (Iwamura 1995). This regionally extensive aquitard separates the upper aquifer zone from the lower aquifer zone. In general, the upper aquifer zone is considered to comprise those aquifers that occur within 150 feet of ground surface. The lower aquifer zone encompasses those aquifers that are present at depths greater than 150 feet below ground surface.

**Groundwater Balance**—To maintain groundwater resources indefinitely, aquifer recharge must balance discharge. Natural aquifer recharge occurs via such processes as the infiltration of precipitation, leakage from streams, ponds and pipelines, irrigation returns and subsurface inflow into the groundwater basin from the surrounding hills. Artificial recharge occurs via planned surface water infiltration. Groundwater discharge can occur via groundwater extraction wells, as discharge into streams and saltwater bodies and via subsurface flow out of the groundwater basin. This discussion of the groundwater balance of the Santa Clara Valley Groundwater Basin focuses on groundwater extraction via supply wells and both natural recharge and artificial recharge processes.

In 2001, approximately 115,358 acre-feet of groundwater were extracted from the Santa Clara Valley Groundwater Basin (SCVWD 2002). The Santa Clara Valley Water District (SCVWD) estimates that over 99 percent (114,605 acre-feet) of the groundwater withdrawn from the basin was used to meet municipal and industrial water supply requirements. An estimated 753 acre-feet was used for agricultural water supply (SCVWD 2002). The low agricultural water demand (less than one percent of the overall basin groundwater usage) reflects the predominantly urban nature of the Santa Clara Valley.

Groundwater extraction from the Santa Clara Valley Groundwater Basin is currently balanced by both natural recharge (via the infiltration of precipitation, seepage from streams, ponds, and pipelines, irrigation return flow and seepage into the groundwater basin) and artificial recharge programs that rely upon local and imported surface water to replenish the groundwater basin. Natural and artificial recharge processes are discussed in detail in response to Question 55c, below. A summary of natural and artificial recharge volumes is provided here to address the question of groundwater balance.

Within the Santa Clara Valley Groundwater Basin, natural recharge to the principal (confined) water supply aquifer is estimated by the SCVWD using a groundwater flow model. For 2001, natural recharge to the lower confined principal water supply aquifer was estimated to be approximately 26,000 acre-feet. Through their use of artificial recharge programs, the SCVWD also estimated that the combination of in-stream recharge and infiltration via recharge ponds provided approximately 90,700 acre-feet of artificial recharge to the Santa Clara Valley Groundwater Basin in 2001 (SCVWD 2002). Consequently, for 2001, the total natural and artificial recharge to the Santa Clara Valley Groundwater Basin was estimated to be 116,700 acre-feet (SCVWD 2002).

The estimated total yearly recharge of 116,700 acre-feet for 2001 exceeds the annual groundwater extraction via water supply wells (115,358 acre-feet) by 1,342 acre-feet ($4.37 \times 10^8$ US gallons). Table DR55-1 summarizes the 2001 groundwater balance for the Santa Clara Valley Groundwater Basin (SCVWD 2002).

**Table DR55-1.** Groundwater Balance Summary for Santa Clara Valley Groundwater Basin, 2001.

| Groundwater use | Volume of groundwater Extracted (acre-feet)[1,2] | Type of basin recharge | Estimated recharge volume (acre-feet)[3] |
|---|---|---|---|
| Municipal and Industrial Water Use | -114,605 | Natural Recharge | 26,000 |
| Agriculture | -753 | Artificial Recharge | 90,700 |
| Total | -115,358 | Total | +116,700 |

1. All values are reported in acre-feet. To convert to US gallons, multiply acre-feet by $3.26 \times 10^5$.
2. Groundwater extracted from the Santa Clara Valley Groundwater Basin is presented as negative number.
3. Groundwater recharge to the Santa Clara Valley Groundwater Basin is presented as a positive number.

As discussed above, the groundwater balance for the Santa Clara Valley Groundwater Basin depends upon the balance between aquifer recharge and discharge. If the volume of groundwater entering or leaving the groundwater basin is balanced, then the basin is considered to be in a steady-state condition and there is no change in aquifer storage. If a greater volume of water enters the basin than leaves, the amount of groundwater in storage is increased.

In the Santa Clara Valley Groundwater Basin, the change in storage is estimated using the groundwater flow model (SCVWD 2002). For 2001, the groundwater model calculated an annual increase in aquifer storage of 12,500 acre-feet. Groundwater model results also indicate that between 1993 through 2001, aquifer storage has increased (i.e., recharge into the basin has been greater than groundwater discharge).

*b) Current and historic groundwater elevations for the basin;*

Groundwater elevations are indicative of the balance between groundwater withdrawal and recharge and reflect how much groundwater is stored within an aquifer system at a particular point in time. Both high and low groundwater elevations can cause adverse conditions. Low groundwater elevations can lead to land subsidence and near-surface groundwater elevations can result in nuisance conditions for below ground structures and construction activities.

The SCVWD has monitored groundwater elevations in the Santa Clara Valley Groundwater Basin since 1915. Although groundwater elevation data is collected at various time intervals from 215 wells across Santa Clara County, the SCVWD collects monthly elevation data from five “index wells” located across the County’s three groundwater basins (SCVWD 2002). The index wells were selected for monitoring because they are considered representative of the general groundwater elevation trends within each basin.

Figure DR55-1 (below) illustrates the location of Santa Clara County index wells. Figure DR55-2 presents the hydrograph of the index well for the Santa Clara Valley Groundwater Basin.

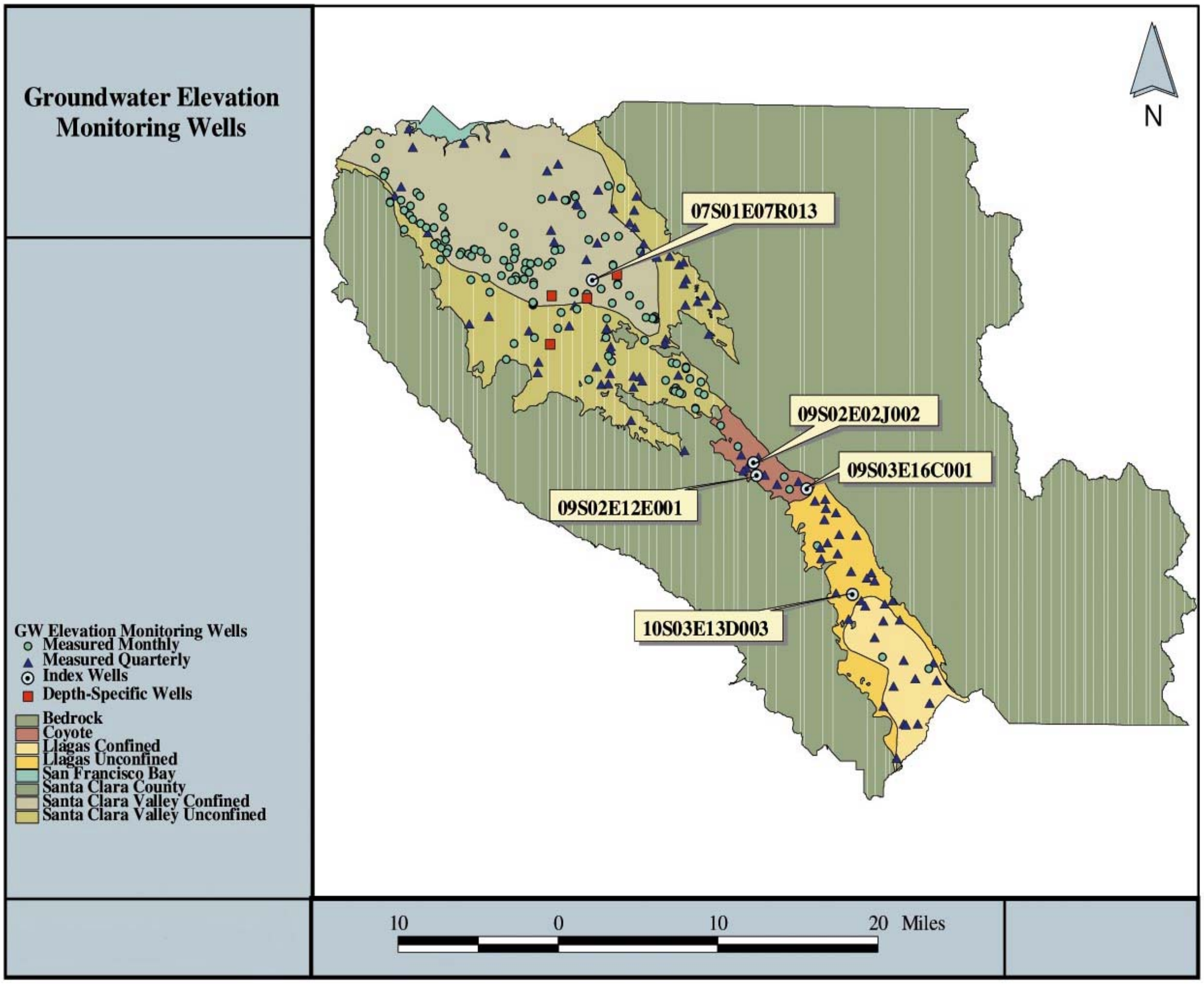


**Figure DR55-1.** Groundwater elevation monitoring wells (Source: SCVWD 2002, Figure 3-1)

As illustrated in Figure DR55-1, the index well for the Santa Clara Valley Groundwater Basin is Well 07S01E07R013. This well is located approximately 7 miles southwest of the PPP site.

As can be observed from the hydrograph for the Santa Clara Valley Groundwater Basin (Figure DR 55-2, below), the record groundwater level low in 1964 (due to below average rainfall and increased water supply demand) is clearly visible. The effects of the drought years in 1977 and 1987 are also evident and are shown by the pronounced decline in the groundwater elevation. For the 30-year period of record illustrated above, the minimum groundwater elevation of approximately -130 feet was reported in the fall of 1964. The maximum groundwater elevation within the last 25 years (excluding initial flowing artesian conditions measured in 1915-1916) was observed in the spring of 1998 (approximately 100 feet). Groundwater elevations in 2001 were approximately 20 feet below the maximum historic groundwater elevation and are over 200 feet above the minimum recorded groundwater elevations (SCVWD 2002). Groundwater levels in 2001 are also approximately 78 feet above the subsidence threshold.

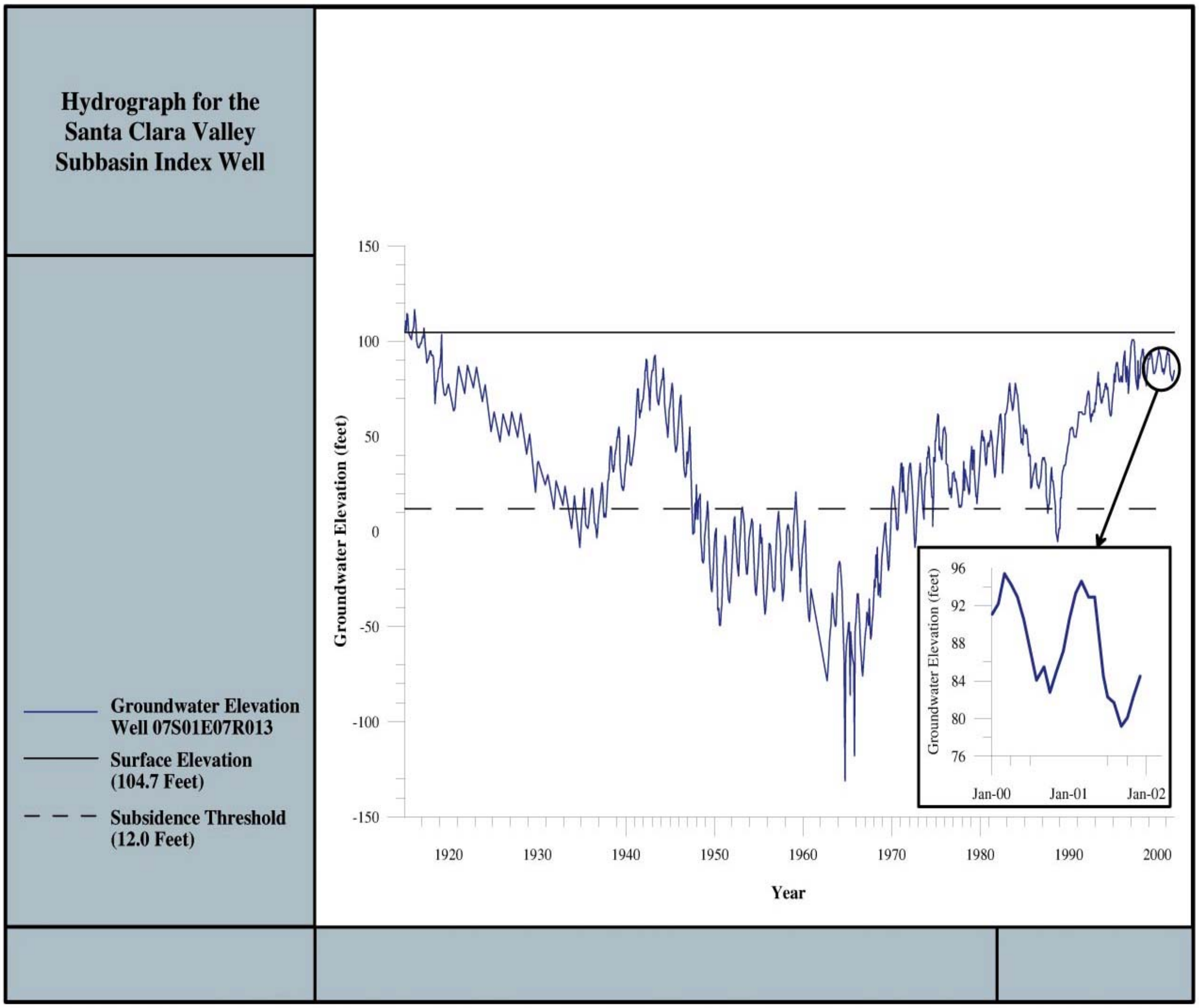


**Figure DR55-2.** Hydrograph for the Santa Clara Valley Groundwater Basin Index Well (Source: SCVWD 2002, Figure 3-2).

*c) Current, historic and projected groundwater recharge volumes;*

Recharge to the Santa Clara Valley Groundwater Basin consists of both natural groundwater recharge and artificial recharge of local surface water and imported water. Natural groundwater recharge includes recharge from rainfall, net leakage from pipelines, seepage from surrounding hills, seepage into and out of the groundwater basin, and net irrigation return flows to the basin. Artificial recharge occurs via instream recharge and percolation ponds as a part of the Santa Clara Valley Water District's (SCVWD) artificial recharge operation (Iwamura 1995).

Currently, natural recharge to the lower confined principal aquifer is in the Santa Clara Valley Groundwater Basin is calculated using a groundwater flow model. For 2001, natural recharge to the basin was estimated to be 26,000 acre-feet.

Artificial recharge programs in 2001 accounted for the infiltration of approximately 90,700 acre-feet into the Santa Clara Valley Groundwater Basin. An estimated 5,000 acre-feet were recharged via the in-stream recharge program and 40,700 acre-feet entered the basin through off-stream percolation ponds. Approximately 90 miles of stream channel comprise the in-stream recharge program. The SCVWD operates and maintains 71 recharge ponds, with a combined surface area of approximately 393 acres (2001a).

Future projected recharge volumes will be managed in accordance with water balance requirements. As of 2001, the SCVWD completed both the feasibility testing of a direct injection facility to increase artificial recharge and the construction of a full-scale injection well. The injection well has a capacity of 750 acre-feet/year and will be supplied with treated water. The SCVWD may address the potential for additional direct injection facilities in the future (SCVWD 2001b).

*d) Current and historic saltwater intrusion into the basin;*

**Current Conditions**—Saline groundwater was detected near Palo Alto as early as 1910 in the Santa Clara Valley Groundwater Basin upper shallow aquifer zone (Iwamura 1980). A chloride ion concentration of 100 milligrams/liter (mg/L) is presently used to define the leading edge of the saltwater transition zone. Using the 100-mg/L contour, an area within the upper aquifer zone encompassing 18 square miles along shoreline of San Francisco Bay has been affected by saltwater intrusion (RWQCB 2001). This zone extends west to Palo Alto, east to Milpitas and south along the Guadalupe River to the San Jose Municipal Airport. The lower aquifer zone is mostly unaffected by saltwater intrusion (RWQCB 2001). Localized areas of elevated salinity, which have been detected within the lower principal aquifer, are associated with the downward migration of saline water through improperly abandoned wells (SCVWD 2001b).

The PPP site is located between ¼-mile and ½-mile from the 100 mg/L contour line which defines the outer transition zone of saltwater intrusion within the upper aquifer zone.

**Historic Conditions**—When groundwater was first pumped from the Santa Clara Valley Groundwater Basin, water levels were at shallow depths groundwater flow in the shallow aquifer trended toward San Francisco Bay. Piezometric pressures within the principal lower confined aquifer zone were higher than those above the ground surface (resulting in flowing artesian conditions). As the demand for groundwater increased, piezometric pressures in the confined principal aquifer zone were lowered sufficiently to cause land subsidence (Iwamura 1980). The combination of shallow pumping of the shallow aquifer and land subsidence led to the reversal of hydraulic gradients in the upper aquifer and the original hydraulic gradients within the upper aquifer zone (which had trended toward the San Francisco Bay), were reversed.

The greatest inland saltwater intrusion occurred in the upper aquifer zone along Guadalupe River and Coyote Creek (RWQCB 2001). Saltwater moved upstream during high tides and recharged the upper aquifer with brackish water. Land surface subsidence aggravated the condition by allowing farther inland incursion of saltwater up the river channels.

e) *Estimated effects of pumping on saltwater intrusion, movement of saltwater or contaminated plumes, impacts to other wells and subsidence.*

To effectively respond to the question of the impact of pumping the back-up supply well, the radial drawdown associated with groundwater extraction must be calculated. Consequently, this response presents a brief overview of PPP back-up well water supply requirements, the selection of hydraulic parameters and the methodology for completing a predictive drawdown analysis prior to the discussion of pumping effects.

**Back-Up Water Supply Requirements**—As discussed in response to Data Request 53, the South Bay Water Recycling (SBWR) system is highly reliable. Services outages of a short-term duration (less than 72-hours) once or twice a year comprise actual operating conditions. To assess the realistic, but conservative, rate at which water will be extracted from the backup supply well, the following assumptions were made:

1) A 72-hour service interruption would occur during the year (during which time no recycled water would be available) which would require the use of the backup well,
2) All PPP water supply requirements would be obtained from the backup supply well (i.e., there would be no contribution from the City of Santa Clara potable water supply system), and
3) The 72-hour outage would occur during hot summer days such that the PPP would therefore require 1.26 mgd (875 gpm) to operate.

To calculate the worst-case pumping scenario and accommodate an unusual service outage, it was assumed that the back-up water supply would be required for a maximum of 45 days per year (not including catastrophic events such as an earthquake). Consequently, predictive analyses were completed using the plant water requirements for a hot summer day (1.26 mgd) over the maximum number of days per year backup water might be required (45).

Drawdown associated with the peak flow conditions of 1,250 gpm (1.8 mgd) were also calculated for a 3-day scenario (since engineering analysis confirms that peak flow would occur only one to two percent of the time, when the temperature exceeds 94 $^{o}$F). These drawdowns are less than for the 45-day continuous groundwater extraction scenario. Consequently, in the analysis and discussion later in this response uses the maximum predicted drawdown (worst-case scenario) associated with 45 days of continuous groundwater extraction.

**Determination of Transmissivity and Storativity Values**—To obtain transmissivity and storativity values for the predictive drawdown analysis, the following efforts were completed:

- Search for nearby aquifer test data from City of Santa Clara production wells completed in the confined aquifer zone

- Industry search for aquifer test data
- Discussion with Ms. Vanessa Reymers (Assistant Engineer, SCVWD) to determine transmissivity and storativity values used in the Santa Clara Valley Groundwater Basin groundwater flow model.
- Literature search, including review of Bulletin 118-1 for applicable transmissivity and storativity parameters

As a result of the above efforts, it was determined that the City of Santa Clara does not have long-term aquifer test data on file for their production wells. Short-term well test data obtained (less than 1-hour in duration) targeted pumping efficiency and was not useful in calculating aquifer transmissivity or storativity values.

The industry search uncovered Pacific Gas and Electric Company Pump Test Reports for the forebay. These data are summarized in Table DR55-2 (Todd 1987). Although data presented in Table DR55-2 represent the forebay and not the confined principal aquifer within the Santa Clara Valley Groundwater Basin, the data are useful as an indicator of the general range of observed transmissivities in the basin.

Discussion with the SCVWD confirmed that the SCVWD do not have any aquifer test data near the PPP site. Since the groundwater model for the Santa Clara Valley Groundwater Basin assigns transmissivity and storativity values on a regional basis, the SCVWD did not believe parameters used in their existing groundwater model would be applicable to the local analysis for the PPP back-up supply well.

**Table DR 55-2.** Aquifer Properties in the Santa Clara Valley Groundwater Basin Forebay

| Well Number | Discharge (gpm) | Drawdown (ft) | Specific Capacity (gpm/ft) | Transmissivity[1] (gpd/ft) |
|---|---|---|---|---|
| 1 | 1,068 | 6.5 | 164.3 | 329,000 |
| 3 | 1,043 | 7.9 | 132.0 | 264,000 |
| 4 | 1,679 | 18.0 | 93.3 | 187,000 |
| 7 | 1,361 | 32.0 | 42.5 | 85,000 |
| 9 | 970 | 3.0 | 323.3 | 647,000 |
| 10 | 1,205 | 7.4 | 162.8 | 326,000 |
| 11 | 1,158 | 6.3 | 183.8 | 368,000 |
| 12 | 1,221 | 3.5 | 348.8 | 698,000 |
| 15 | 1,444 | 5.2 | 277.6 | 555,000 |
| 16 | 1,844 | 28.7 | 64.2 | 128,000 |
| 18 | 2,108 | 58.3 | 36.1 | 72,000 |

1. Transmissivity = (2000 x Specific Capacity)

Applicable, local hydraulic parameters were obtained from the literature search and specifically, from the *California Department of Water Resources Bulletin 118-1: Evaluation of Ground Water Resources: South San Francisco Bay*. Final branch transmissivities used in the Bulletin 118-1 groundwater flow model were averaged over a 1-mile radius surrounding the PPP site to calculate a local transmissivity for the lower confined aquifer of 312,376 gpd/ft (41,858 $ft^2$/day). This transmissivity value falls within the mid range of values reported for the forebay (Table DR55-2).

Storativity values for a confined aquifer generally range from 0.005 to $5 \times 10^{-5}$ (Freeze and Cherry 1979). To provide a conservative estimate of storativity, a value of $1 \times 10^{-4}$ was selected for the predictive drawdown analysis.

**Predictive Radial Drawdown Analyses**—To evaluate the impact groundwater extraction on saltwater intrusion and contaminant plumes in the upper aquifer zone, wells within a 1/2-mile radius of the site and subsidence, a predictive drawdown analyses was completed. Predictive calculations were performed using the Theis nonequilibrium well equation (Equation 55-1, below) for confined aquifers. Using this equation, the drawdown at any distance can be predicted as long as the aquifer parameters of transmissivity, storativity are known.

Equation 55-1 (using well function notation):

$$h_o - h = \{Q/(4\pi T)\}\ W(u)$$

where:

$h_o - h$ = drawdown (ft)
$Q$ = constant pumping rate ($ft^3$/day)
$T$ = aquifer transmissivity ($ft^2$/day)
$W(u)$ = well function

where the argument $u$ is defined as:

$$u = \frac{r^2 S}{4Tt}$$

$r$ = radial distance from the pumping wells (ft)
$S$ = storativity (unitless)
$T$ = aquifer transmissivity ($ft^2$/day)
$t$ = time since pumping began (days)

Calculated radial drawdown with distance from PPP site was based on a worst-case scenario. Key assumptions for predictive analyses included:

1. No aquifer recharge (drought conditions).
2. Groundwater obtained solely from aquifer storage.

3. Constant groundwater extraction for the entire 3-day or 45-day period. (i.e., continuous pumping 24 hours/day, 7 days/week under defined operating conditions)
4. A transient cone of depression (continually expanding in response to pumping).

Predictive radial drawdown calculations were completed for both 3-day and 45-day constant pumping scenarios using the PPP flow requirements for a hot summer day of 1.26 mgd (875 gpm). Radial drawdown data for the 3- and 45-day pumping scenarios are graphically presented in Figure DR55-3 Appendix A (Table DR55-A1) contains the drawdown analysis results. Radial drawdown data presented represent an artesian pressure reduction in the lower confined aquifer and not dewatering (as would occur in an unconfined aquifer).

Predictive drawdowns for the greatest groundwater extraction scenario (both the 3-day and 45-day continuous pumping at 1.26 mgd) are summarized below in Table DR55-3.

**Table DR 55-3.** Summary of predicted drawdown with distance from the back-up supply well.[1]

| Radial Distance from Back-Up Water Supply Well | 3-Day Predicted Drawdown (ft) | 45-Day Predicted Drawdown (ft) |
|---|---|---|
| 50 feet | 4.02 | 5.33 |
| 250 feet | 3.44 | 4.30 |
| 500 feet | 2.99 | 3.86 |
| 1,000 feet | 2.54 | 3.42 |
| 2,640 feet (0.5 mile) | 1.92 | 2.79 |

[1]At a pumping rate of 1.26 mgd (875 gpm).

Over 3 days of continuous pumping at 1.26 mgd, drawdown is predicted to be 4.02 feet at a distance of 50 feet from the back-up supply well and less than 2 feet at a 0.5-mile distance from the well. Over 45 days of continuous pumping at 1.26 mgd, drawdown is estimated to be 5.33 feet at a 50-foot distance from the back-up well; and 2.79 feet at a distance of 0.5 mile.

It is important to note that the drawdown levels estimated above were calculated under very conservative assumptions including: 1) no aquifer recharge (drought conditions), 2) sustained groundwater extraction at a high rate (1.26 mgd), 3) water obtained solely from aquifer storage, and 4) a transient cone of depression.

**Impact of Pumping on Saltwater Intrusion and Contaminant Plumes**—The lack of a significant pressure change (less than 3 feet of drawdown under a 45-day continuous pumping scenario at a 0.5-mile radius) in the lower confined aquifer suggests that groundwater extraction from the back-up well will not induce or affect vertical gradients. Saltwater intrusion and contaminants, such as volatile organic compounds (VOCs), which may be present in the upper aquifer will not be induced to infiltrate at greater rates than may be presently occurring. This conclusion is also supported by SCVWD monitoring data which indicate that saltwater intrusion

Figure DR55-3. Radial drawdown (from Excel file).

and VOCs detected in the lower principal aquifer at below maximum contaminant levels (MCLs) likely migrated vertically via improperly abandoned wells and not primarily as a result of groundwater extraction in the lower confined aquifer (SCVWD 2001b).

**Impacts of Pumping to Other Wells—**At the request of the City of Santa Clara, a well search within a 0.5 mile radius of the site was completed by the SCVWD on December 27, 2002. SCVWD well search results are presented in Appendix B (Table DR55-B1). A brief summary of results is discussed below. The location of all wells within a 0.5-mile radius of the site completed at depths greater than 100 feet below ground surface are shown on Figure DR55-4. The SCVWD database search identified 371 wells within a ½ mile radius of the PPP site. Of these wells, 284 are listed as "destroyed." Another 22 are listed as "abandoned," leaving 65 wells listed as "active." Of the active wells within the database, only three are listed as being completed at depths of greater than 100 feet below ground surface (Well 06S01W34A004, Well 06S01W26N015 and Well 06S01W34H048). Another well (Well 06S01W35F001) is listed as a water producing well associated with paper processing, although its depth and completion information are not available. An additional six wells were listed as groundwater extraction wells with no accompanying construction information. While the depth for these wells is not known, these groundwater extraction wells are most likely associated with the former on-site remediation (groundwater pump and treat) performed at the Owens-Corning site in the shallow aquifer. However, for completeness, their location is also shown on Figure DR 55-4.

In summary, it appears that four (4) wells are situated in the lower principal aquifer within 0.5-mile of the PPP site. A yield of 1,339 gpm was reported for Well 06S01W34A004. This well is listed as a water producing well completed at 672 feet below ground surface for fiberglass manufacturing and is, therefore, likely associated with the Owens-Corning Fiberglass facility at 960 Central Expressway.

Well 06S01W34H048, identified as a groundwater monitoring well, is completed at 102 feet below ground surface. This well may also be associated with remedial activities at the Owens-Corning facility as it appears to be located in close proximity to the former groundwater extraction wells on the site. Well 06S01W26N015 is described as a cathodic protection well with a depth of 120 feet. The RWQCB (2001) noted that there are many cathodic protection wells in the San Francisco Bay area.

The four wells completed in the lower confined aquifer are located at approximately 2,640 feet (0.5 mile) from the PPP site. The most significant wells are those that continue to be associated with groundwater production at depth: Well 06S01W34A004 (672 ft below ground surface) and potentially Well 06S01W35F001 (no depth available). Based upon the predictive drawdown calculations completed, under the 3-day and 45-day predictive drawdown analysis, these wells would experience an additional 2 to 3 feet of drawdown as a result of pumping of the back-up supply well.

Figure DR55-4. Wells within 0.5 miles.

Given that the 2001 groundwater elevations for the Santa Clara Valley Groundwater Basin were approximately 20 feet below the maximum historic groundwater elevation and aquifer storage within the principal aquifer has been increasing since 1993, the impact of 2 to 3 feet of additional drawdown on the two production wells described above does not represent a significant pressure change for the lower confined aquifer. It is highly improbable that the predicted increase in drawdown caused by one to two 3-day PPP pumping events per year would impact the water supply yield of these wells.

**Subsidence**—Land subsidence was first noticed in the Santa Clara Valley in 1919 in San Jose (SCVWD 2001b). With a confined aquifer, subsidence occurs when groundwater pumping reduces artesian pressures. The reduction in artesian pressures causes increased loading on the intragranular aquifer skeleton and this, in turn, can cause compaction and subsequent land subsidence. Most compaction in sands and silts occurs within a few years after the reduction of artesian pressure (Walton 1970). Subsidence also depends upon the subsurface lithology and upon the magnitude and duration of artesian pressure decline.

A period of time is required for fine-grained sediments to compact and adjust complete to a decline in artesian pressures. Terzaghi (1943) noted that time required for complete compaction is proportional to the square of the thickness of the sediments.

The SCVWD currently monitors land subsidence across the Santa Clara Valley Groundwater Basin. Through the introduction of imported water and the SCVWD's artificial recharge program, the rate of inelastic land subsidence in the basin has been reduced to less than 0.01 ft per year since the early 1970s (SCVWD 2002). Compaction recorders (extensometers) were installed in 1960 by the United States Geological Survey (USGS) in two 1,000-foot boreholes in the centers of the historical subsidence sites in Sunnyvale and San Jose. Figure DR55-5 presents the network of compaction monitoring performed by the SCVWD.

The predicted radial drawdown at a 0.5-mile radius from the PPP site for the 3-day and 45-day pumping events are 1.92 and 2.79 feet, respectively (Table DR55-3). The magnitude of these predicted changes in pressure will not be able to induce land subsidence. Additionally, 2001 groundwater elevation monitoring (Table DR55-2, above), indicates that groundwater levels and storage were near historical high levels and were well above the subsidence threshold for the basin.

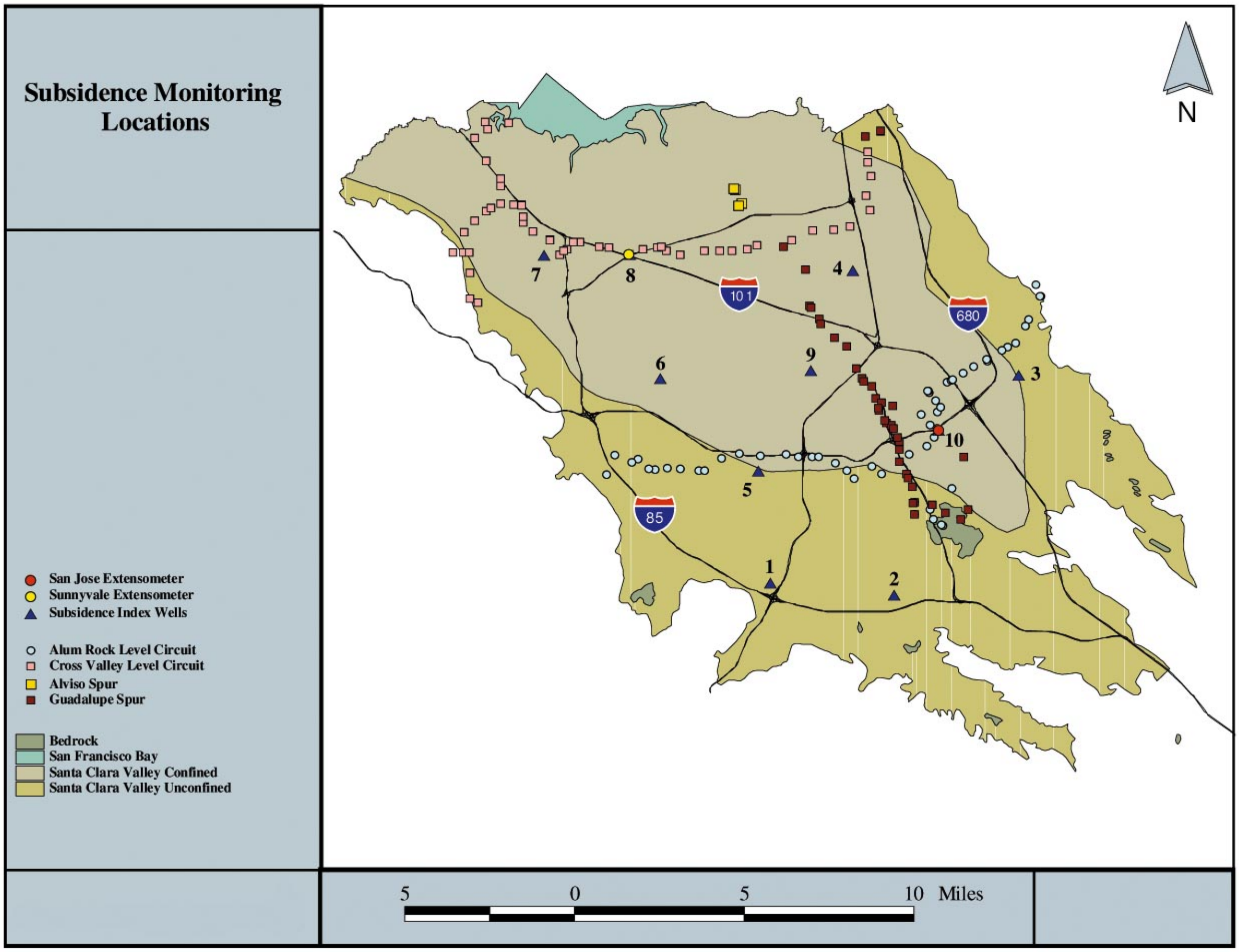


**Figure DR 55-5.** SCVWD Subsidence Monitoring Locations (Source: SCVWD 2002, Table 4-1)

## REFERENCES CITED


RWQCB. 2001. A Comprehensive Groundwater Protection Evaluation for South San Francisco Bay Basins, Draft for Stakeholder Review. Prepared by the Groundwater Committee of the California Regional Water Quality Control Board, San Francisco Bay Region. December 2001.

Freeze and Cherry. 1979. Groundwater. Prentice-Hall, NJ. 604 pp.

Iwamura, T.I.. 1980. Saltwater Intrusion Investigation in the Santa Clara County Baylands Area, California. Santa Clara Valley Water District Report, September, 1980.

——. 1995. Hydrogeology of the Santa Clara and Coyote Valleys Groundwater Basins, California in E.M. Anderson, D.W., Bruising, A.B., eds., 1995, *Recent Geologic Studies in the San Francisco Bay Area*: Pacific Section S.E.P.M.,Vol 76, p. 173-192.

Santa Clara Valley Water District (SCVWD). 1989. Standards for the Construction and Destruction of Wells and Other Deep Excavations in Santa Clara County. Santa Clara Valley Water District Publication, Revised June 1989.

——. 2001a. Santa Clara Valley Water District, Urban Water Management Plan. Developed by the Santa Clara Valley Water District, April 2001.

——. 2001b. Santa Clara Valley Water District Groundwater Management Plan. Santa Clara Valley Water District, San Jose, California. July 2001.

——. 2002. Santa Clara Valley Water District, 2001 Groundwater Conditions. Developed by the Santa Clara Valley Water District, July 2001.

Terzhaghi and Peck. 1948. Soil Mechanics in Engineering Practice. John Wiley & Sons, Inc., New York. 664 pp

Todd. 1987. Final Report, "Groundwater Management in Santa Clara Valley." David Keith Tood, Consulting Engineers, Inc., Berkeley, California. April 1987.

Walton, W.C. 1970. Groundwater Resource Evaluation. McGraw-Hill, New York. 664 pp.

# APPENDIX A

# TABLE DR55-A1
# RADIAL DRAWDOWN ANALYSIS

# APPENDIX B

# TABLE DR55-B1
# WELL SEARCH RESULTS