PERCOLATION OF SANTA CLARA RIVER FLOW WITHIN THE SANTA PAULA BASIN

Open-File Report 2013-01
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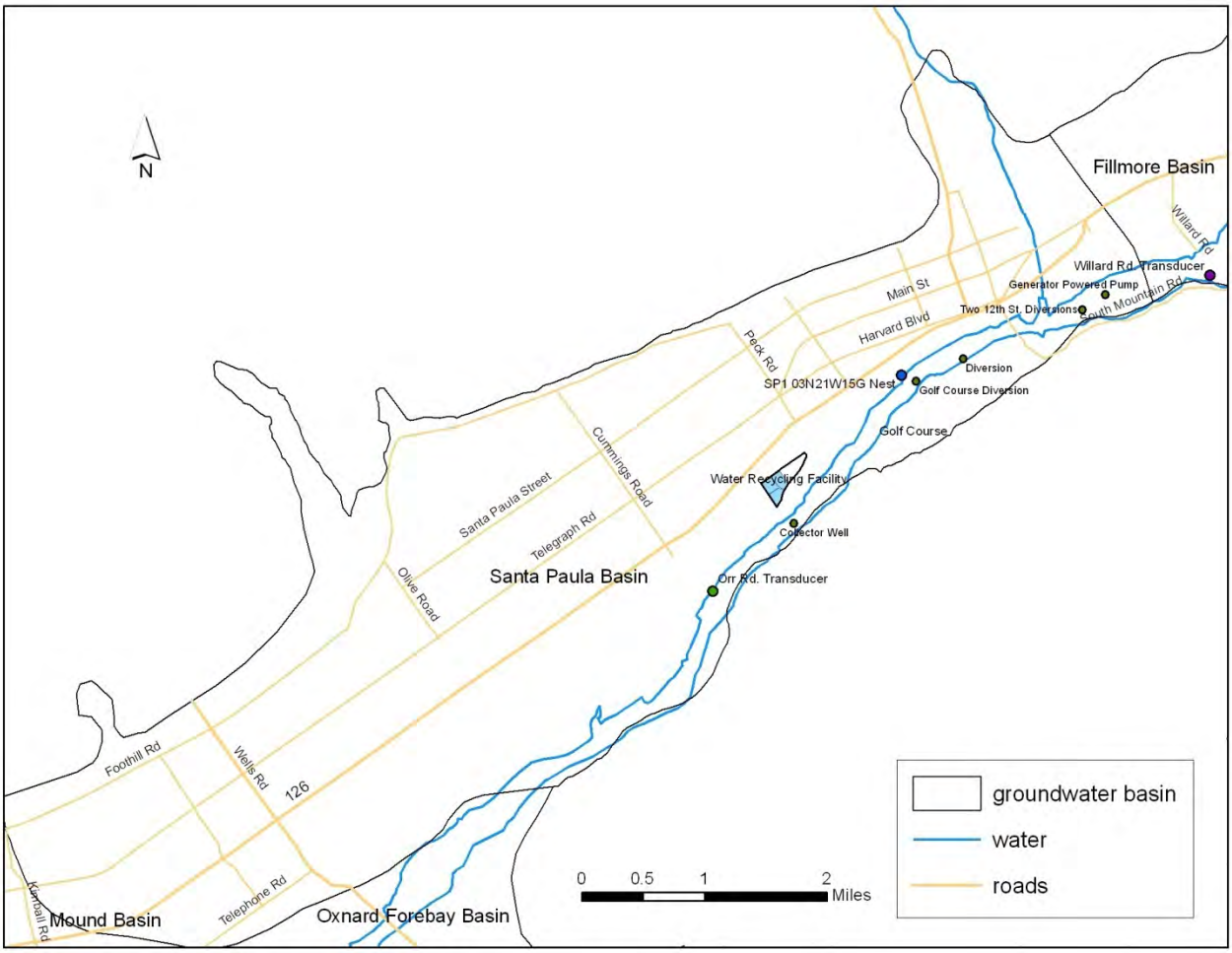

THIS REPORT IS PRELIMINARY AND IS SUBJECT TO MODIFICATION BASED UPON FUTURE ANALYSIS AND EVALUATION

PREPARED BY

GROUNDWATER DEPARTMENT

UNITED WATER CONSERVATION DISTRICT

PERCOLATION OF SANTA CLARA RIVER FLOW WITHIN THE SANTA PAULA BASIN

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UWCD OPEN-FILE REPORT 2013-01

EXECUTIVE SUMMARY / ABSTRACT

United Water Conservation District performed a study on the percolation of the Santa Clara River within the Santa Paula Basin. This study was accomplished by field investigation of the Santa Clara River during August and September of 2010 and 2011. Santa Clara River flow and stage was measured near Willard Road at the eastern end of the basin and near Orr Road in the central portion of the basin. Estimates of flow losses to diversions and to evapotranspiration (ET) by phreatophytes in the floodplain of the Santa Clara River were made in the study area. The percolation of the Santa Clara River was calculated as follows:

Percolation_(SCR) = Flow_(Willard Rd.) + Inflow_(SP Creek) - Diversions - ET - Flow_(Orr Rd.)

The data suggest that there is measurable percolation in the studied reach of the Santa Clara River, and percolation is greater when groundwater levels in the alluvial aquifer are lower. When groundwater levels are high, there may be only minimal percolation along the studied reach of the Santa Clara River. The 2011 measurements were initiated during a period of high groundwater levels, and included estimates for flow losses to diversions and evapotranspiration. Measured percolation along a 5-mile reach ranged from 8.6 cfs to slightly gaining (negative percolation values). The error bars associated with the estimates made for water diversions, evapotranspiration, and Santa Paula Creek surface water inflow into the Santa Clara River are potentially larger than the total percolation calculated during the study

Recent field measurements conducted by United Water are compared to historical data from September 1929 through September 1932 (California State Division of Water Resources, 1933). The recent data indicate there is slightly less percolation of Santa Clara River water into the Santa Paula Basin under the current study conditions than was observed in the historical data at the same time of year.

Heads in the alluvial aquifer adjacent the Santa Clara River appear to influence percolation rates along the river. Few shallow monitoring wells exist near the river and relationships between river stage and heads in the alluvial aquifer remain poorly documented. Significant effort would be required to improve upon existing percolation estimates showing a limited capacity for basin recharge (e.g. estimates of evapotranspiration). River percolation under high-flow conditions remains undetermined.

1 INTRODUCTION

United Water Conservation District (United Water) is a public agency within Ventura County, California that is charged with conserving the water of the lower Santa Clara River and its tributaries. United Water works to manage the surface water and groundwater resources within eight groundwater basins, including the Santa Paula basin (Figure 1-1).

Few detailed investigation of river percolation have been conducted in the Santa Paula basin. Most existing studies document relatively minor amounts of recharge to the basin, and have been conducted when low-flow conditions prevail in the Santa Clara River and in Santa Paula Creek. This study incorporates estimates of diversions from the river and water losses to riparian vegetation, and offers and assessment of recent dry-season conditions within the basin.

1.1 BACKGROUND

About 25,000 acre-ft of groundwater is pumped from the Santa Paula basin each year (UWCD, 2011), as reported by groundwater users to United Water. United Water's recent evaluation (UWCD, 2013) of the Santa Paula Creek flow data indicates that there is currently less percolation of Santa Paula Creek water than has been documented historically (California State Division of Water Resources, 1933). This document serves as a companion to the Santa Paula Creek study, and represents an attempt to evaluate and enhance the understanding of the percolation of Santa Clara River flow within the Santa Paula basin.

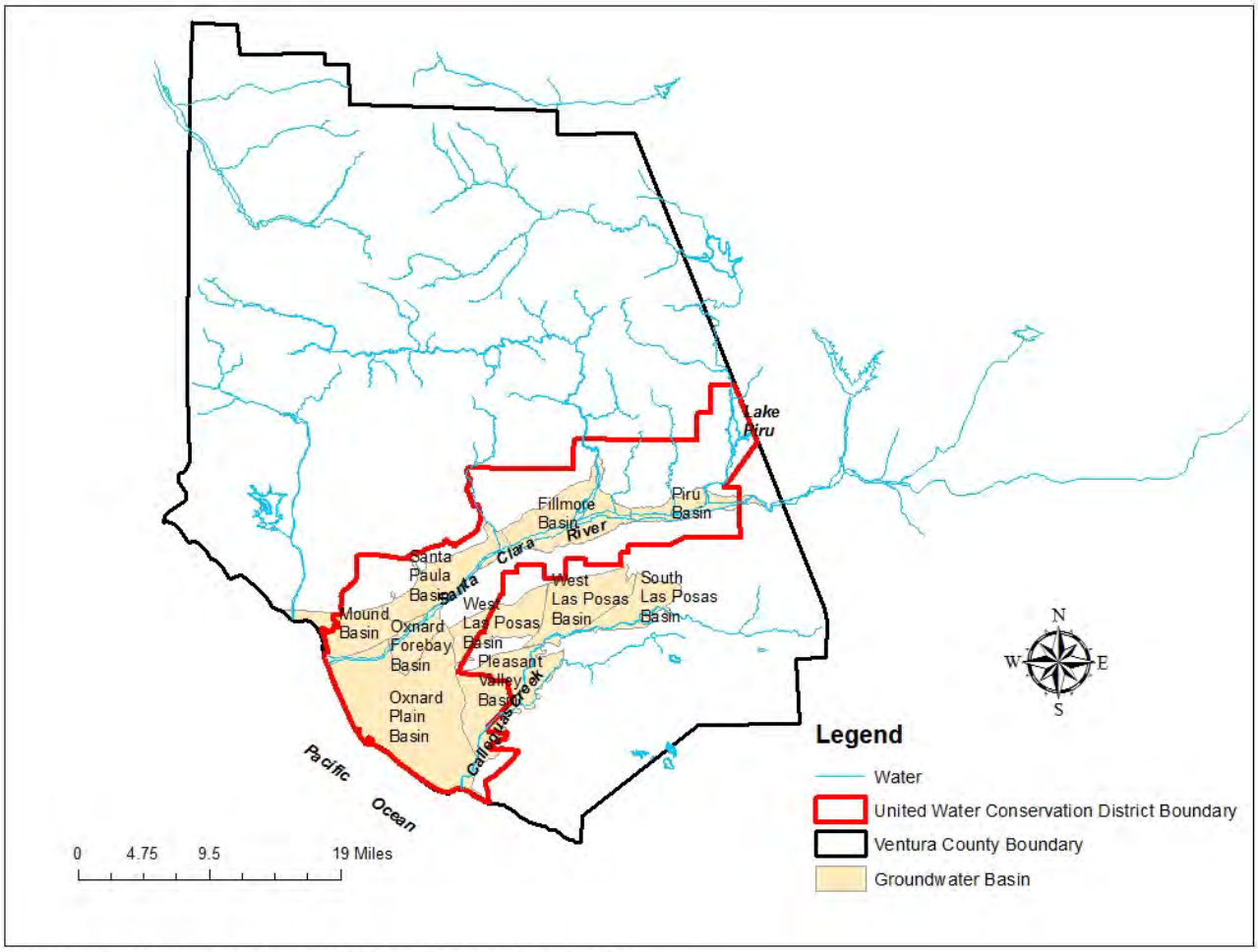

Figure 1-1: Location Map of the Santa Paula basin with respect to the other seven basins and United Water Conservation District.

1.2 GEOLOGY/HYDROGEOLOGY OF THE SANTA PAULA BASIN

The Santa Paula basin is located within the valley of the Santa Clara River. Figure 1-2 shows surface geology in the vicinity of the Santa Paula basin. The basin is bounded by the Sulphur Mountain foothills on the northwest and South Mountain on the southeast. The basin is elongated in a northeast-southwest orientation. It is approximately 10 miles long and 3.5 miles wide. The elevations of the surface of the valley fill deposits range from 130 feet above sea level (near Saticoy) to 270 feet above sea level near the City of Santa Paula. The major fresh water-bearing strata utilized for groundwater production are the San Pedro Formation and younger overlying river deposits of the Santa Clara River; alluvial fan deposits; and recent river and stream deposits (Mann, 1959).

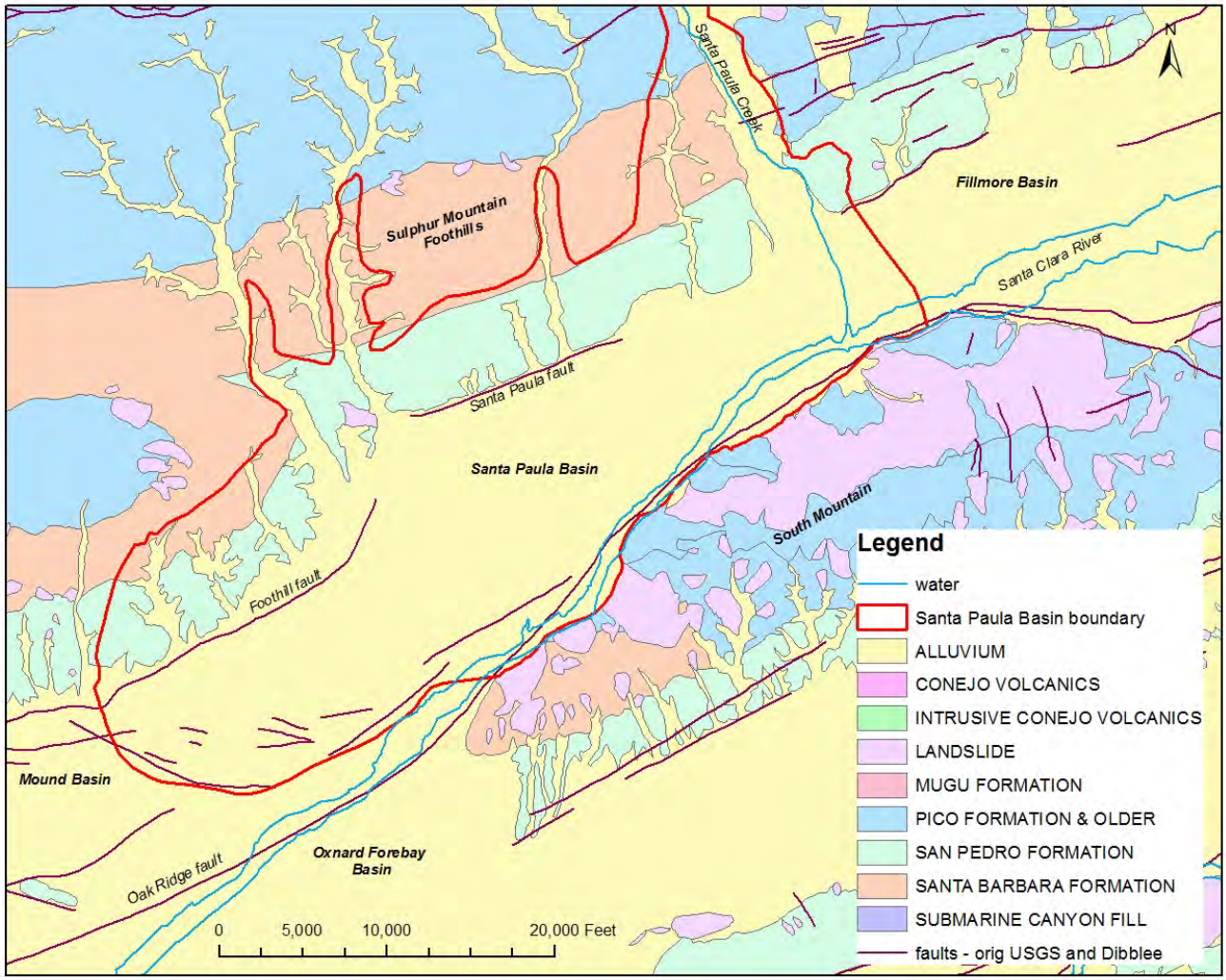

Figure 1-2: Geology Map of Santa Paula basin.

The basin sediments have been warped into a syncline that is oriented in a northeast-southwest direction. To the south, the Oak Ridge fault forms a partial barrier to groundwater movement. On the north, a portion of the aquifer represented by the San Pedro Formation is exposed in an outcrop along the Sulphur Mountain foothills. The Santa Paula basin borders the Oxnard Forebay and Mound basins on the west. To the east, the Santa Paula basin is in hydraulic connection with the Fillmore Basin. Groundwater rises and becomes surface flow in the Santa Clara River near this boundary, and substantial underflow is believed to exist.

Hydrogen and oxygen isotope data, and other recorded data, indicate that the Santa Paula basin receives recharge from the Santa Clara River (USGS, 1999). However, there is a thick clay deposit in a portion of the eastern Santa Paula basin, near the confluence of the Santa Clara River and Santa Paula Creek that likely reduces the amount of water that infiltrates to the deeper aquifers. Other sources of recharge to the Santa Paula basin include: rainfall percolation through the San Pedro Formation outcrops that are exposed along the foothills to the north, percolation of streams crossing these sediments, and underflow from the Fillmore Basin. Recharge is observed in groundwater level hydrographs, as groundwater levels in the majority of wells throughout the basin show significant seasonal variability (UWCD, 2011). During high-rainfall years, monitoring wells in

the western portion of the basin, just northwest of the Freeman Diversion, have shown artesian flow. Groundwater flow in the Santa Paula basin is generally east-to-west.

1.3 PREVIOUS INVESTIGATIONS / OTHER RELATED DATA

There have been a few previous investigations of infiltration rates along the Santa Clara River in the Santa Paula basin. Brief summaries of specific investigations are presented in this section.

1.3.1 STATE OF CALIFORNIA DEPARTMENT OF PUBLIC WORKS (1933)

The Division of Water Resources published flow data for the Santa Clara River from September 1929 through September 1932 as part of their "Bulletin No. 46: Ventura County Investigation" (1933).

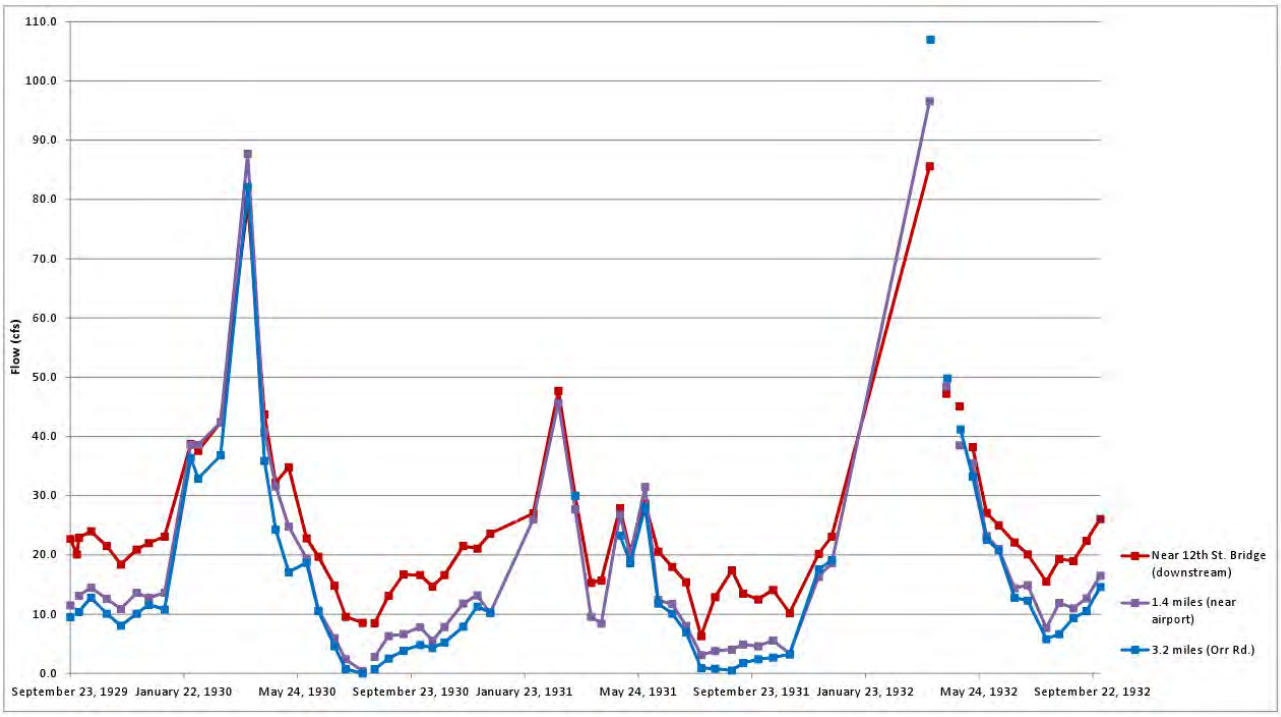

Figure 1-3: State of California Department of Public Works 1933 Bulletin No. 46 data.

The published results show there was more percolation measured during the drier months of the year when flow in the Santa Clara was lower. The historic data from near 12th Street Bridge to 3.2 miles downstream (Orr Road) shows as much as a 17.7 cfs loss between the two sites.

1.3.2 OTHER RELATED STUDIES

The USGS has studied the interactions of surface water with the groundwater in the Santa Clara River Valley (Reichard et al, 1999). The related report contains flow data for the stretch of the Santa Clara River below the diversions near 12th St. to near Orr Road. Nearly all of the reported measurements were collected during United Water's fall conservation releases in the years 1993,

1994 and 1995. The one summer measurement for low-flow conditions (7/28/1994) shows a loss of 0.2 cfs in the reach between the Santa Paula Airport and Orr Road. Other data are more variable, showing gains as high as 49 cfs and losses as great as 29 cfs. United Water was a cooperator in this study, but has little confidence in some of the reported flows. Some measurements were not collected on the same day, and others appear to document changing flow conditions associated with releases from Lake Piru.

Another report examined the affects of surface water releases to the Santa Clara River from Lake Piru in 1991, following the preceding years of drought (Densmore, 1991). The discussion and conclusions section reports, "…recharge (or diversion) within the Santa Paula basin was small and within measurement errors."

The Santa Paula Basin Experts Group prepared the 2003 Investigation of Santa Paula Basin Yield report for the Santa Paula Basin Technical Advisory Committee. The percolation of Santa Clara River flow within the Santa Paula basin was not determined. However, the report found that "The relatively rapid response of water levels to recharge indicates that seepage from stream flow is the major source of recharge to groundwater in Santa Paula Basin" (Santa Paula Basin Experts Group, 2003).

United Water owns and manages Lake Piru (see Figure 1-1). In years when water levels in the lake permit, water is released through Santa Felicia Dam into Piru Creek and conveyed to the Santa Clara River. Some of the water percolates down through the permeable stream channels as it flows towards the Freeman Diversion, providing recharge to the Piru, Fillmore, and Santa Paula groundwater basins. Table 1-1 shows the release volumes for the last 6 years, and estimates of how much water percolated into the Piru and Fillmore basins. United Water estimates the percolation by measuring flow in the Santa Clara River in strategic locations and subtracting the downstream measurement from the upstream measurement. Conservation releases from Lake Piru are typically conducted in the late summer or fall of the year.

Year	Piru	Fillmore	Total Released
2007	16,000	6,250	40,900
2008	15,900	5,000	45,500
2009	13,600	4,700	26,700
2010	14,400	4,700	33,000
2011	12,500	3,500	31,500
2012	13,600	8,600	35,200

Table 1-1: Estimated Santa Felicia Dam fall conservation releases benefit to the downstream groundwater basins (acre-ft).

The amount of surface water that percolates directly into the Santa Paula basin during the fall releases is believed to be small. The difference between the upstream and downstream flow measurements in Santa Paula basin is commonly within the plus or minus 5 percent error associated with the method used to measure the flow.

Piru basin is in hydrologic connection with Fillmore basin, which is in hydrologic connection with Santa Paula basin. The large amount of water from United Water's conservation releases that percolates into Piru and Fillmore basins eventually benefits Santa Paula basin via underflow from the Fillmore basin. Rising groundwater near the Fillmore/Santa Paula basin boundary is also higher in the period following the conservation release from Lake Piru.

2 OBJECTIVE AND APPROACH

The objective of this study was to assess current percolation rates of the Santa Clara River within the Santa Paula basin. The period of investigation was from 9 August 2011 through 8 September 2011. Historical Santa Clara River flow data was then compared to the recent Santa Clara flow data. The objective was achieved in the following ways:

- Stream gauging measurements were collected at strategic locations along the river to obtain surface flows of the Santa Clara River, from western Fillmore basin to central Santa Paula basin.

- Data from 9 August 2011 through 8 September 2011 was processed and plotted. The data was mapped using ArcGIS.

- Transducers were deployed in the Santa Clara River to document the diurnal, weekly, and general trends of the Santa Clara River stage within the time period of study. A calibration was performed to relate stage height to measured flow in the river.

- Santa Paula Creek flow rates were obtained from the USGS Santa Paula Creek gauging station 11113500 and integrated into the Santa Clara River flow calculations. The gauged flow of Santa Paula Creek is assumed to be what enters the Santa Clara River. Recent gauging has shown minimal percolation along the lower (5 mile) reach of the Santa Paula Creek.

- Withdrawals of water by diverters along the Santa Clara River were estimated and included in the calculations of the Santa Clara River flow.

- Mapping of *Arundo donax*, air photos and infield visual appraisal were used to estimate the area of Santa Clara River floodplain significantly impacted by riparian uptake. Evapotranspiration was estimated from data obtained from the California Irrigation Management Information System (CIMIS) Santa Paula Station 198 to approximate water losses in the studied area.

- Transducer and hand measurements of water levels in shallow alluvial monitoring well 03N21W15G05S (SP1-80) were compared with observed trends in the stage height (transducer) data from the Santa Clara River.

- Santa Clara River flow data from August and September 2010 (a year of near-average precipitation) were plotted and compared to 2011 Santa Clara River flow data, a year of above-average precipitation.

- A comparison to historical percolation rates (California State Division of Water Resources, 1933) was performed to evaluate possible changes in the Santa Clara River percolation rate within the Santa Paula basin.

3 PERCOLATION INVESTIGATION, SUMMER 2011

The study elements detailed above were undertaken in late summer 2011 in an attempt to quantify river percolation in the Santa Paula basin during a period of summer low flows. Results of these efforts are detailed in this section. Selected maps and graphs are included in the following pages, while others are contained in Appendix A through D. The study was conducted when dry conditions prevailed in the watershed, and concluded when United Water initiated the fall conservation release from Lake Piru.

3.1 SANTA CLARA RIVER STREAM GAUGING DATA

Stream flow measurements were collected using Sontek® FlowTracker flow meters, following USGS standard protocols. Transects were established across the Santa Clara River where channel conditions were suitable for measurements. Flow velocity and water depth were measured at increments across the channel, allowing the calculation of river flow (see Appendix E). Photos of the Willard Rd. and Orr Rd. stream flow measurement sites are included in Appendix F.

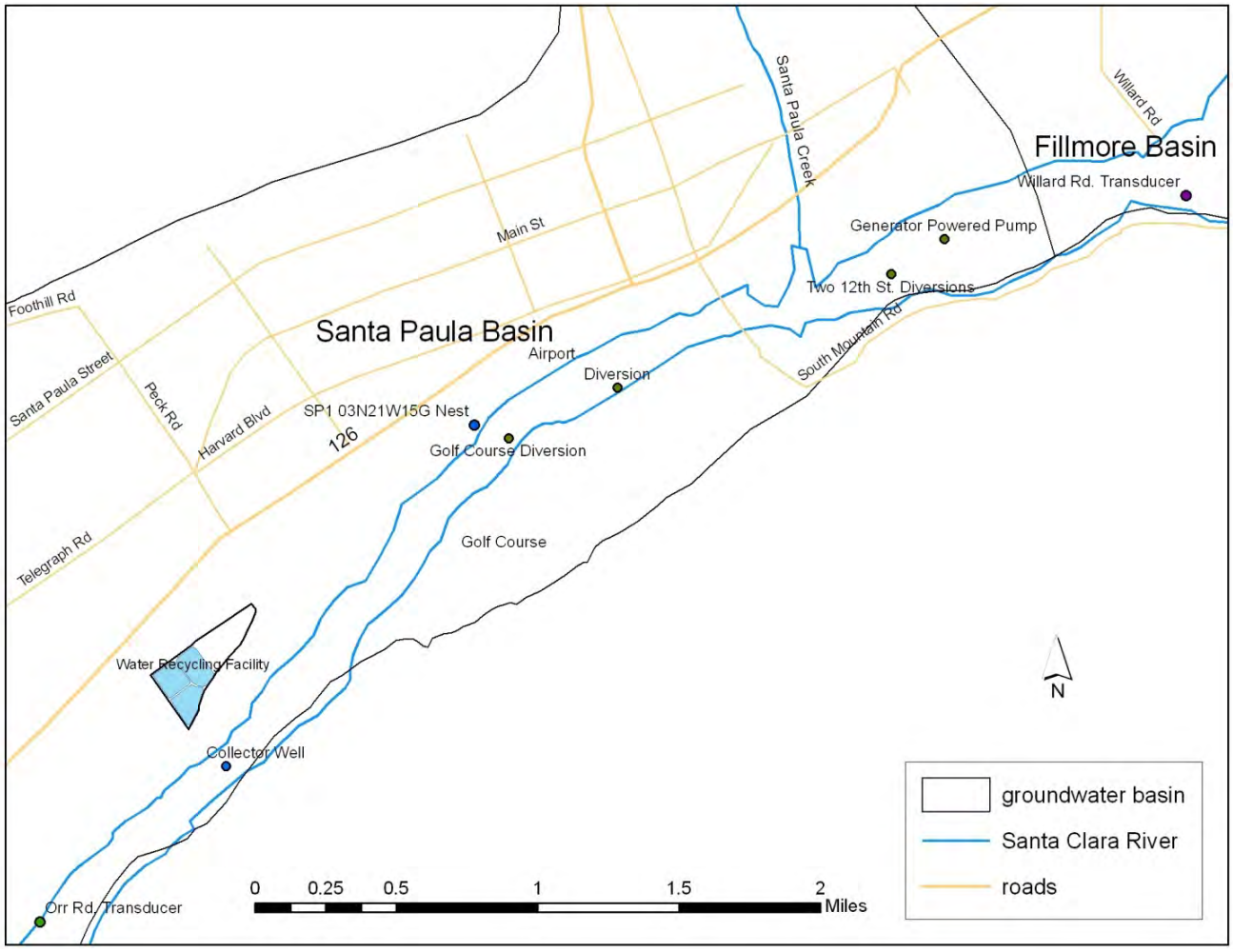

Figure 3-1: Map of the reach of the Santa Clara River investigated as part of the current study.

There is an area of rising groundwater at the Fillmore/Santa Paula basin boundary. The in-river flow measurements collected during this investigation show that the reach from near Willard Road to just above Santa Paula Creek is a region of no percolation. Measurements suggest it may have been a slightly gaining reach during the period of study, but the data is inconclusive due to the level of accuracy of the instrument. Maps of the stream gauging flow data collected from 9 August 2011 through 8 September 2011 are included in Appendix A.

Flows declined throughout the 2011 study period at both the Willard Road and Orr Road sites (Figure 3-5). At the Willard Road site, the high-flow measurement was 44.2 cfs, and the low-flow measurement was 27.8 cfs. At the Orr Road site, the high-flow measurement was 38.5 cfs, and the low-flow measurement was 23.5 cfs. The smallest measured total loss between Willard Road and Orr Road was 3.7 cfs, and the greatest was 5.8 cfs.

3.2 SANTA CLARA RIVER STAGE

Two pressure transducers were installed in the Santa Clara River. The upstream transducer was installed near Willard Road and the second transducer was installed 5.1 miles downstream (3.4 miles downstream from the 12th St. Bridge) near Orr Road. The instruments were installed where the river channel is relatively deep and narrow, allowing greater resolution of river stage. The transducers were programmed to record a measurement every 15 minutes to log changes in Santa Clara River stage over the duration of the study period. Stage data at this resolution reveals diurnal and weekly fluctuations in the Santa Clara River (Figure 3-2).

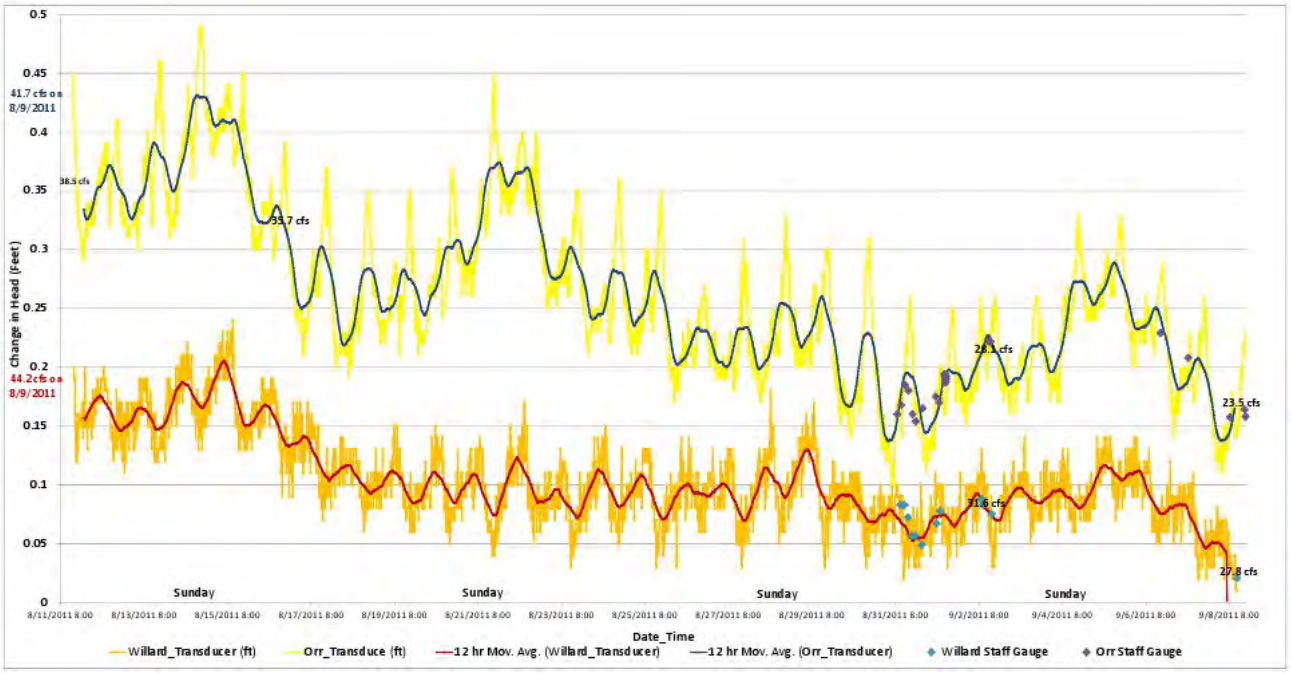

Figure 3-2: Plot of transducer data and staff gauge measurements collected at the Willard Rd. and Orr Rd sites.

Staff gauges were installed on 31 August 2011 at both sites, and monitored for 9 days to confirm the reliability of the transducer data. Barometric corrections were made to the raw transducer files.

A twelve-hour moving average was used to smooth out and fit the transducer data to the manual staff gauge measurements in order to remove chatter from the raw measurements. The transducer stage data was then correlated to the flow measurements (see Appendix B).

Stage records from both transducers show a rise in the river during the weekends, when there is likely less groundwater pumping and surface water diversions taking place in the Santa Paula and Fillmore basins. Figure 3-2 shows a distinct rise Santa Clara River stage on each Sunday at both the Willard Road and Orr Road sites.

3.3 SANTA PAULA CREEK FLOW ESTIMATE

USGS Santa Paula Creek gauging station 11113500 (at Steckel Park) average daily flow data was used to estimate how much surface water was being added to the Santa Clara River below the Willard Road site. Average daily gauge data ranged from 3.7 to 6.8 cfs. The 5 minute data showed a diurnal fluctuation as high as 3.5 cfs in Santa Paula Creek (See Appendix C). UWCD's recent evaluation (Update on the Santa Paula Creek Percolation Study, 2012) of Santa Paula Creek flow indicates that there is little percolation below Canyon Irrigation Company's Harvey Diversion.

Three stream gauging measurements were collected just above the confluence of Santa Paula Creek and the Santa Clara River (see Appendix A and Appendix C) by United Water during the study. The two measurements obtained on 2 September 2011 and 8 September 2011. The other measurement obtained on 9 August 2011 at the beginning of the study, is about 50 percent (3 cfs) lower than that given by the USGS data. The Santa Paula Creek flow plot is included in Appendix C.

The USGS gauging station is upstream from Canyon Irrigation's Harvey Diversion, so estimates of Santa Paula Creek flow reaching the Santa Clara River based on gauge data are generally thought to be high. Customer water order records provided by Canyon Irrigation show that the diversion was in operation during much of the study period. However, a number of variables affect flow on Santa Paula Creek between gauge 11113500 and the Santa Clara River Confluence. These variables include: intermittent Canyon Irrigation groundwater pumping deliveries, required diversion bypass flows, return flow to Santa Paula Creek when Canyon Irrigation's covered reservoir is full, ungauged inflow from Mud Creek below the diversion, diurnal fluctuation, and a gaining reach below the diversion (UWCD, 2013).

3.4 SOURCES OF WATER REMOVAL FROM THE SANTA CLARA RIVER

There are two significant mechanisms by which surface water is removed from the Santa Clara River as it flows from the western Fillmore basin through the central Santa Paula basin. Water diversions and evapotranspiration by riparian vegetation are the major sources of loss along this reach, and estimates of these factors are detailed below.

3.4.1 DIVERSIONS

Water diversions were identified within the studied stretch of the Santa Clara River. These include four diversions withdrawing surface water from the south bank of the Santa Clara River in the area near the 12th St. Bridge and downstream from this location. In addition, a portable diversion (trash pump) was periodically removing water from the north bank of the river at a location upstream of the 12th St. Bridge. There is also a collector well-type diversion in the studied stretch of the river (see Figure 3-3). It is not known how long the pumps in the diversions are running from day-to-day. To accommodate this uncertainty, flow data has been converted to daily averages. It is believed that the largest diversion operates continuously. A quantitative estimate of daily diversions was required to complete the Santa Clara River percolation calculations. Crop factors which estimate typical irrigation use for specific crops were used in order to estimate diversion rates from the unmetered diversions along the studied reach of the river.

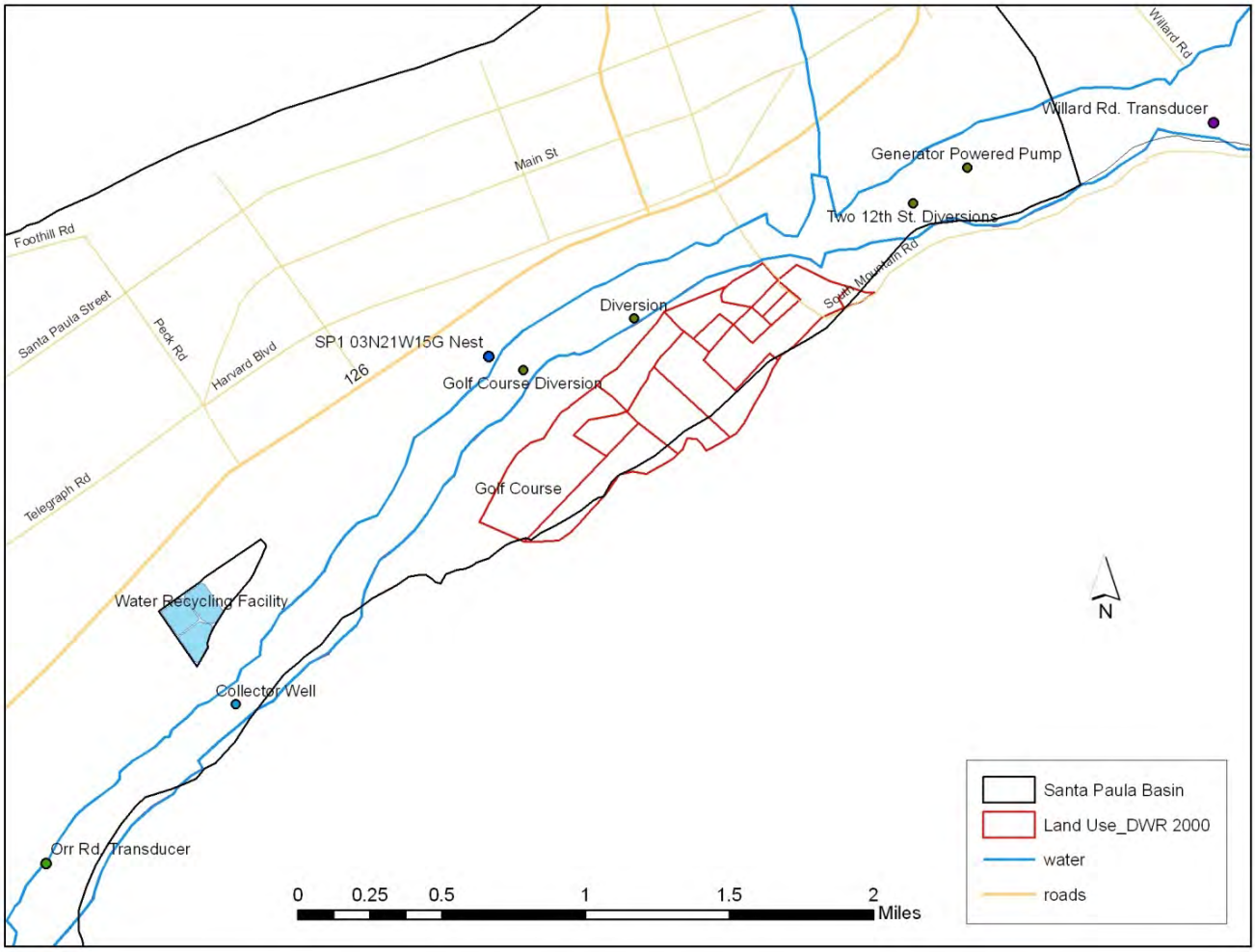

Figure 3-3: Map of the sources of water diversion along the Santa Clara River in the Santa Paula basin.

The Department of Water Resources (2001) made estimates of irrigated crop acres and water use in 2001 for the Santa Clara Valley. United Water also has a table of water demands that are used for estimating water use on unmetered properties within its district. Water usage estimates by the two agencies range from 2.5 to 3.3 ft/yr for subtropical orchards, 4.5 to 9.0 ft/yr for alfalfa, and 4.4 to

10.0 ft/yr for pasture. Lemons, oranges, avocados, row crops, and golf course turf exist in the areas being irrigated by water diverted from the Santa Clara River, with irrigation water applied by various methods.

For the purposes of the current study, a low estimate of 3 ft/yr (2.8 cfs) was used to approximate the amount of water being diverted by the four diversions on the south bank of the Santa Clara River. The diversions on the south bank were the only diversions included in the percolation calculation. The plot of the estimate (see Appendix C) takes into account the higher than average irrigation demand during the warm summer months when flows were measured.

A land use survey conducted by the Department of Water Resources (2000) provided the acreage under irrigation adjacent to the south bank of the Santa Clara River (outlined in red, Figure 3-3). United Water's ArcGIS was used to sum the land area under irrigation, which totals 475.2 acres.

It was assumed that surface water was not being diverted from the Santa Clara River on Sundays; the estimated weekly water use was applied to Monday through Saturday of each week during the study (see Appendix C). Flow measurements were made in a few of the diversion channels (see Appendix A). Such measurements were infrequent and did not include all existing diversions.

3.4.2 EVAPOTRANSPIRATION

Recent mapping of *Arundo donax* in the Santa Clara Valley (California Invasive Plant Council, 2011), in conjunction with air photos and infield visual appraisal were used to estimate the area of river bottom significantly impacted by riparian uptake along the studied reach of the Santa Clara River (see Figure 3-4). The estimated area of dense riparian vegetation was found to be 592 acres using ArcGIS.

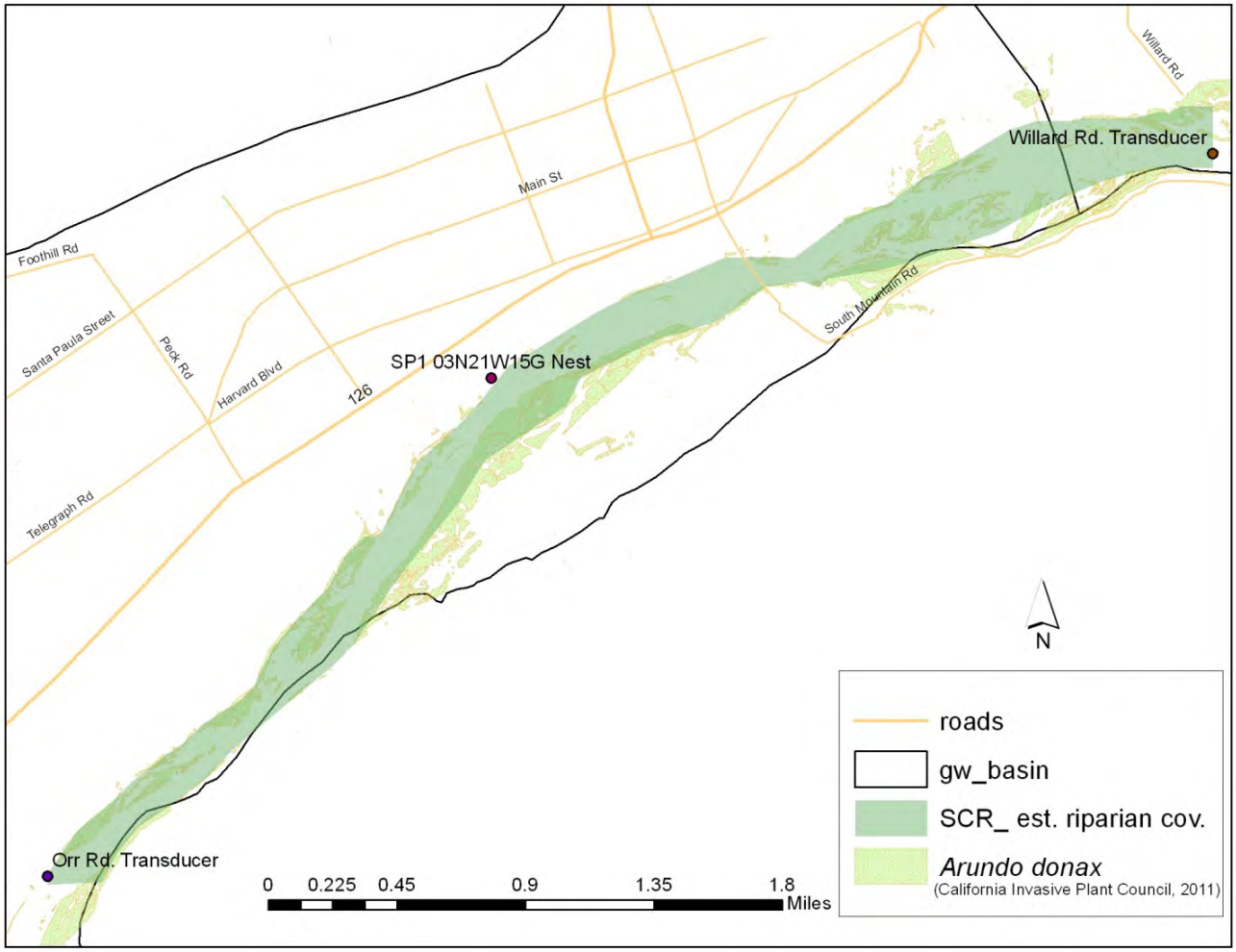

Figure 3-4: Map of Riparian influence along the Santa Clara River.

California Irrigation Management Information System (CIMIS) Santa Paula Station 198 was used to estimate daily evapotranspiration (http://wwwcimis.water.ca.gov/cimis/data.jsp). CIMIS uses a modified Penman equation to calculate evapotranspiration for standardized grasses. Total surface area was adjusted to an estimated 50 percent coverage. The adjusted surface area for riparian vegetation was then applied to the CIMIS daily evapotranspiration data to provide what is thought to be a low estimate of the daily evapotranspiration of the Santa Clara River within the studied reach. The calculated daily average evapotranspiration during the study period ranged from 1.1 cfs to 2.7 cfs, based on CIMIS information. Estimated transpiration of Santa Clara River water by riparian plants (under various plant coverage totaling 30%, 50%, and 70%) is included in Appendix C.

Published values of evapotranspiration by Arundo were also considered. One recent study estimates water use by *Arundo donax* to be 24 ft/yr, and 4 ft/yr for native vegetation (California Invasive Plant Council, 2011). Assuming *Arundo donax* takes up 24 ft/yr and there is 50 percent Arundo coverage in the area of riparian vegetation, estimated from air photos and infield visual appraisal, Arundo uptake is 9.8 cfs. This calculated loss is near the maximum loss of flow observed in the study area once surface water diversions are subtracted and inflow from Santa Paula Creek is added. The CIMIS estimates for ET by riparian plants were used instead of these published ET values for Arundo.

3.5 PERCOLATION WITHIN THE SANTA CLARA RIVER CHANNEL

Percolation in the river reach under investigation was assumed to be what was not diverted or lost through evapotranspiration. Inputs to the reach are the average daily flow at the Willard Road site and the daily flow from Santa Paula Creek. Losses include the estimated diverted surface water and evapotranspiration, such that:

Percolation_(SCR) = Flow_(Willard Rd.) + Inflow_(SP Creek) - Diversions - ET - Flow_(Orr Rd.)

Paired flow measurements from the downstream site were made approximately three hours later to account for travel time of water flowing from the Willard Road site to the Orr Road site. The above calculation yields an estimate of daily percolation of Santa Clara River water along the studied reach of the Santa Clara River under the conditions of the study period. Results over the period of study are shown graphically in Figure 3-5. Error bars of 5% are shown for the gauging measurements near Orr Road (blue lines). Error bars of 5% are also shown for flows near Willard Road (with the 5% error estimates calculated on measured flow, before these flows were adjusted for inputs and losses). Estimates of the compounded errors are also shown in Figure 3-5, which suggest maximum percolation to the Santa Paula basin potentially ranged from approximately 6 to 11 cfs during the 2011 study period.

The flow values presented on Figure 3-5 are mostly flow estimates based on stage of the river as recorded by pressure transducers at the Willard Road and Orr Road sites, with the Willard Road flows adjusted for inputs and losses along the studied reach. Gauged flow measurements are noted on Figure 3-2. Flows are presented in this way so that estimated percolation can be plotted as the difference in measured flow at either end of the reach.

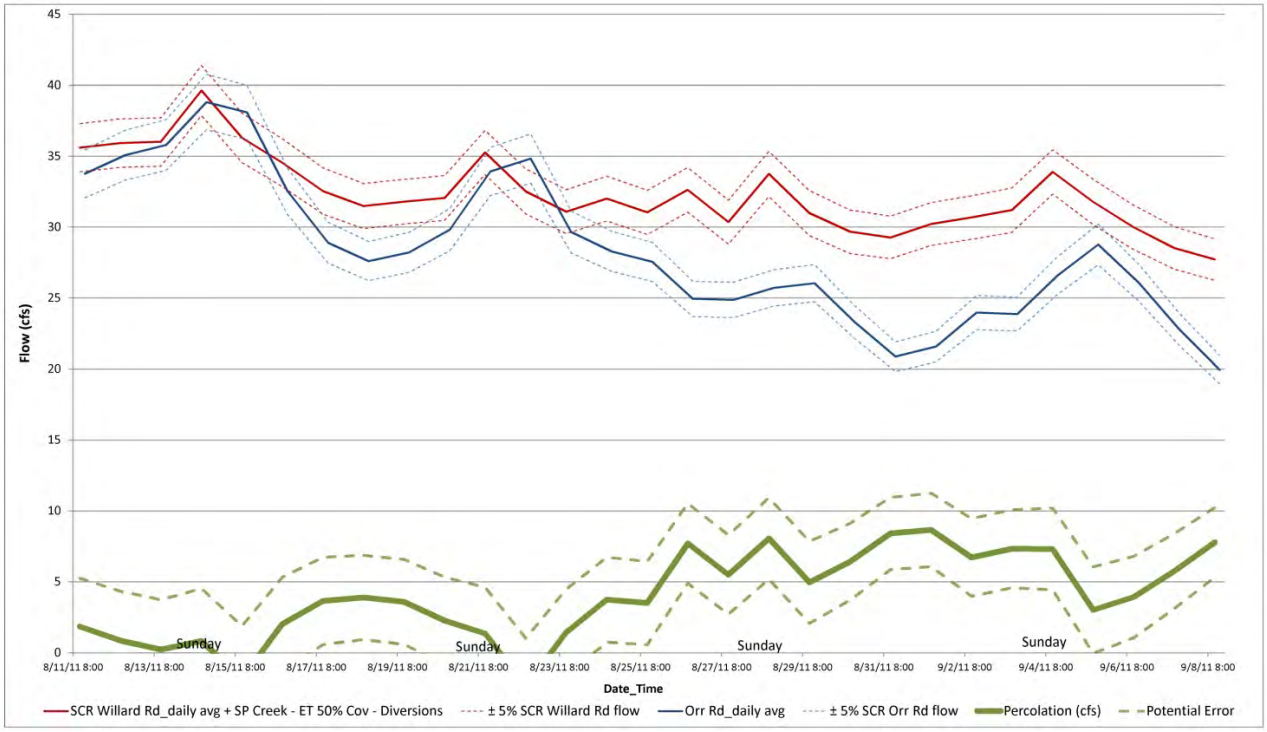

Figure 3-5: Percolation of the Santa Clara River within the stretch studied from near Willard Rd. to near Orr Rd.

The average percolation of the Santa Clara River during the 2011 study period was estimated to be 4.0 cfs. The maximum daily average percolation was 8.6 cfs and the minimum was -2.3 cfs (gaining reach).

If the dry-season percolation rates found in this current study are projected out over a one-year period, the minimum percolation is 0 acre-ft/yr, and the maximum is 6,226 acre-ft/yr. Extrapolated values are based on very limited data both spatially and temporally, and may not accurately represent conditions from season to season or year to year.

	Min (cfs)	**Max** (cfs)
Willard Rd. flow	25.7	40.6
Santa Paula Creek flow	2.6	8.8
Diversions	2.8	
Evapotranspiration	1.1	2.7
Orr Rd. flow	21.8	43.2
Percolation	**-2.3**	**8.6**

Table 3-1: Summary of the variables and their minimum and maximum values used in calculating the percolation of the Santa Clara River during the studied period.

3.6 POTENTIAL SOURCES OF ERROR

Several potential sources of error are identified in this section:

- A plus or minus 5 percent (of measured flow) measurement error is assumed to be inherent to the FlowTracker flow meter and methods used for the collection of the in-stream flow data (see error bars, Figure 3-5). USGS standards for flow gauging were followed.

- Dry season tailwater is uncommon among irrigated orchards, with the likely exception of furrows. The majority of furrow irrigated orchards discharge tailwater downstream of the Orr Rd. stream flow measurement site.

- USGS Santa Paula Creek gauging station 11113500 data was used to estimate how much water was being added to the Santa Clara River below the Willard Road site. The USGS gauging station is upstream of the Harvey diversion, so estimates based on this data are assumed to be high, since it is unknown when the Harvey Diversion was being operated and how much water was being removed.

- A low estimate of 3 ft/yr of applied water was used to assign the amount of water being diverted daily by the four diversions on the southern bank of the Santa Clara River. It is assumed that there is no return flow to the Santa Clara River from the diverted water. The water removed by the collector well and portable diversion (trash pump) operating intermittently on the north bank of the Santa Clara River was not quantified or included in the calculations. If quantified, these diversions would lower the river percolation calculated in this study.

- The Santa Paula Water Recycling Facility discharge to percolation ponds near the Santa Clara River (see Figure 3-1) was not included in the percolation calculations. The underflow

from the percolation ponds into the Santa Clara River could not be calculated with certainty due to the multiple variables associated with such a calculation. If discharge to the Water Recycling Facility percolation ponds migrates through the alluvial aquifer and contributes flow to the Santa Clara River, the percolation rates in the study would be estimated a little low. If the treated wastewater moves downward or away from the river and serves as recharge to the shallow alluvium, it may help explain why there is an observed lower percolation when comparing the 2011 data to the 2010 and the 1930s data. Discharge from the Santa Paula WRF averages approximately 3 cfs.

- Evapotranspiration estimates accounting for water loss across the study area is known to be imprecise. Precise measurements of riparian plant coverage, density, health, identification of species present, and water uptake by individual species water was beyond the scope of the current study. An underestimation of evapotranspiration would increase the amount of percolation calculated in the study, while an overestimation of ET would decrease the calculated percolation rate.

4 SANTA CLARA RIVER GAUGING, SUMMER 2010

Stream gauging measurements collected in August and September of 2010 are summarized in this section. The 2010 field investigation was less detailed than that conducted in 2011, consisting of river gauging but no stage measurements. The 2010 field investigation consisted of Santa Clara River flow measurements on four days in August and September. At the Willard Road site, the high flow measurement was 26.1 cfs, and the low flow measurement was 21.1 cfs. At the Orr Road site, the measured flow ranged from a high of 22.4 cfs and a low of 11.8 cfs. The least (total) loss in flow between Willard Road and Orr Road was 3.7 cfs, and the greatest was 12.6 cfs.

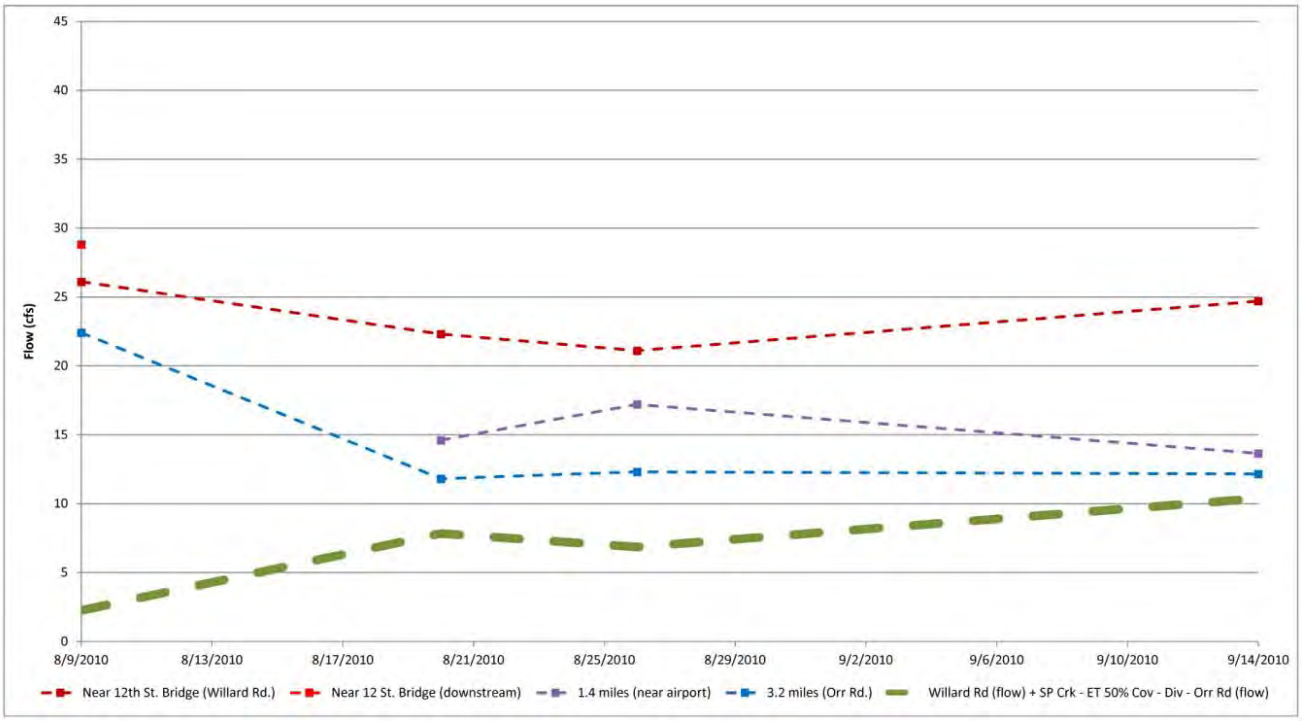

Figure 4-1: Santa Clara River Data: 9 August 2010 through 14 September 2010.

Flow measurements from summer 2010 show a similar pattern to those recorded in 2011, with percolation within the Santa Paula basin increasing over the period of study. Diversion rates were assumed to be the same as those estimated for 2011. Riparian vegetation was also assumed to be the same, and CIMIS estimated of potential ET were used for the 2010 study period.

5 WATER LEVELS IN THE ALLUVIAL AQUIFER

The "SP1" multiple-completion monitoring well is located roughly between the Willard Road and Orr Road sites (see Figure 3-1 and Appendix F) on the north bank terrace of the Santa Clara River (approximately at the midpoint of the studied reach). SP1 is 2.4 miles upstream (up gradient) from the Orr Road site. There are 5 piezometers in this nested site, with perforated intervals in both deposits of the San Pedro Formation and younger alluvial deposits. The shallowest of these piezometers, State Well Number 03N21W15G05S, has a perforated interval from 60 to 80 feet below ground surface. The electrical log indicates a thick clay from 100 feet to 225 feet below ground surface. The next deeper piezometer in the SP1 nest is perforated below this clay. During the current study period, groundwater elevations were about 25 feet deeper in the four SP1 completions perforated below the clay, compared to the piezometer perforated above the clay. Water levels are routinely 10 to 30 feet deeper in the zones beneath the clay. Head differences between the shallow well and the deeper wells indicate that the clay isolates the shallow alluvial aquifer from the deeper aquifers at this location.

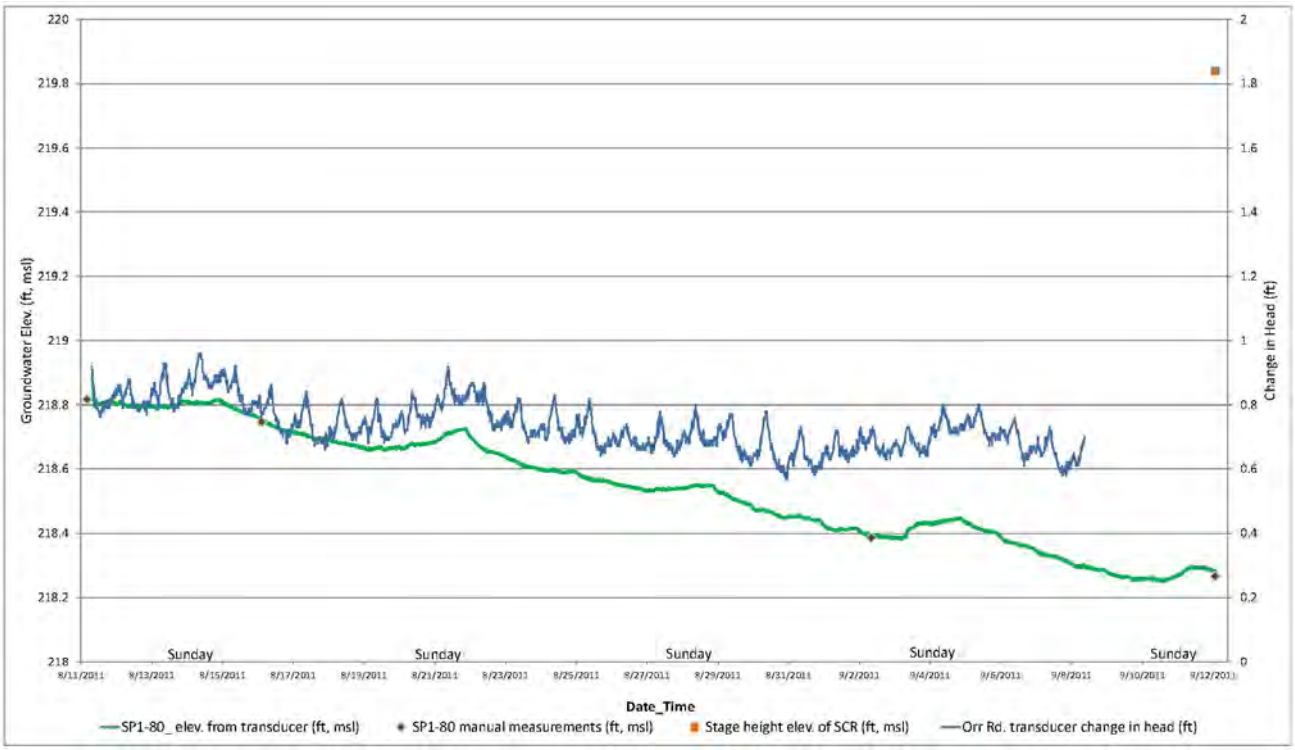

Figure 5-1: Monitoring piezometer: 03N21W15G05S (SP1-80) groundwater elevation data overlain with changes in Santa Clara River head above the Orr Rd. transducer from 11 August 2011 through 12 September 2011.

The reference point elevation (the top of the outer casing) of well SP1 was used to survey the stage of the river near the well site. It was found that the elevation of groundwater in SP-80 was 1.6 feet below the height of the river surface on 12 September 2011. Figure 5-1 demonstrates that water levels in well SP1-80 correspond with the observed weekend fluctuations in stage height in the river. The weekly pattern is likely produced by less agricultural groundwater pumping and surface water diversions taking place in the Santa Paula and Fillmore basins during the weekends.

The river stage and alluvial groundwater elevations plotted in Figure 5-1 allow the observation that groundwater elevations in well SP1-80 are dropping faster than the river stage during 2011 study period. Estimated percolation increased during the later portion of the study period, suggesting that groundwater elevations in the alluvial aquifer near the river may influence percolation rates along this reach of the Santa Clara River.

River flows and the water levels in SP1-80 were lower in 2010 (see appendix D) than they were in 2011. Water levels in SP1-80 were about 2.3 feet lower in late summer 2010 than they were throughout the 2011 study period. Estimates of river percolation were slightly higher in 2010 than they were in the following year, suggesting groundwater elevations in the shallow alluvial aquifer near the Santa Clara River may be a variable influencing river percolation rates in the Santa Paula basin. However, heads in this aquifer are not highly variable, and assuming the diversion rates and riparian coverage were the same (applying 2010 CIMIS estimates of potential ET) as those estimated for 2011, the estimated percolation was 2.3 cfs to 10.5 cfs in the 2010 (average year) and -2.3 cfs to 8.6 cfs in the 2011 (wet year) estimates.

6 FINDINGS AND CONCLUSIONS

Based on the results of this study and comparison with historical data, United Water offers the following conclusions:

- The historic data (California State Division of Water Resources, 1933) shows low flows between the Orr Road and Willard Road sites during the same time of year as the current 2011 study. There is as much as a 16.9 cfs loss between these two sites in the historic data. The base flows near the 12th St. Bridge in the current 2011 study are over twice that recorded in the historic study during the same time of year, and are a reflection of relatively high water levels in the Fillmore basin.

- Apparent percolation in the 1933 DWR study was similar to that documented at the same time of year in 2010.

- The 2010 field investigation was less detailed than the 2011 study, consisting of Santa Clara River flow gauging but not stage measurements. The least measured loss between Willard Road and Orr Road in 2010 was 3.7 cfs, and the greatest is 12.6 cfs. Measured river losses were slightly higher in summer 2010 than in summer 2011.

- After accounting for inputs (Santa Paula Creek) and losses (diversions and riparian ET) flow and stage measurements dating from 9 August 2011 through 8 September 2011 indicate

there was maximum percolation of 8.6 cfs and minimum percolation of -2.3 cfs of Santa Clara River surface flow in the eastern Santa Paula basin between Willard Road and Orr Road.

- Available data suggest that surface water infiltration in this reach of the Santa Clara River is limited, both currently and historically. Several variables (e.g., evapotranspiration, diversions for irrigation, interaction with the alluvial aquifer) remain difficult to quantify.

- Comparison of the 2010 and 2011 measurements suggest that there is slightly more percolation in the studied stretch of the Santa Clara River in 2010, when groundwater elevations recorded in well SP1-80 were lower. In the 2011 study period, more river percolation was observed when heads in the alluvial aquifer were lower.

- The error bars associated with the assumptions made for water diversions, evapotranspiration, Santa Paula Creek surface water inflow into the Santa Clara River, and the omission of the Santa Paula Water Recycling Facility discharge to its percolation ponds are larger than the total percolation calculated for the Santa Clara River reach under investigation.

- River percolation under high-flow conditions remains undetermined, and channel conditions make high-flow measurements difficult to obtain. Higher percolation rates would be anticipated when flood flows inundate wider areas within the floodplain, although the length of inundation is generally limited to a maximum or a few days per year.

- Additional studies could remove some uncertainty from percolation estimates within the Santa Paula basin, but existing studies have sufficiently demonstrated that percolation potential within the Santa Paula basin is less than speculations from earlier studies.

7 REFERENCES

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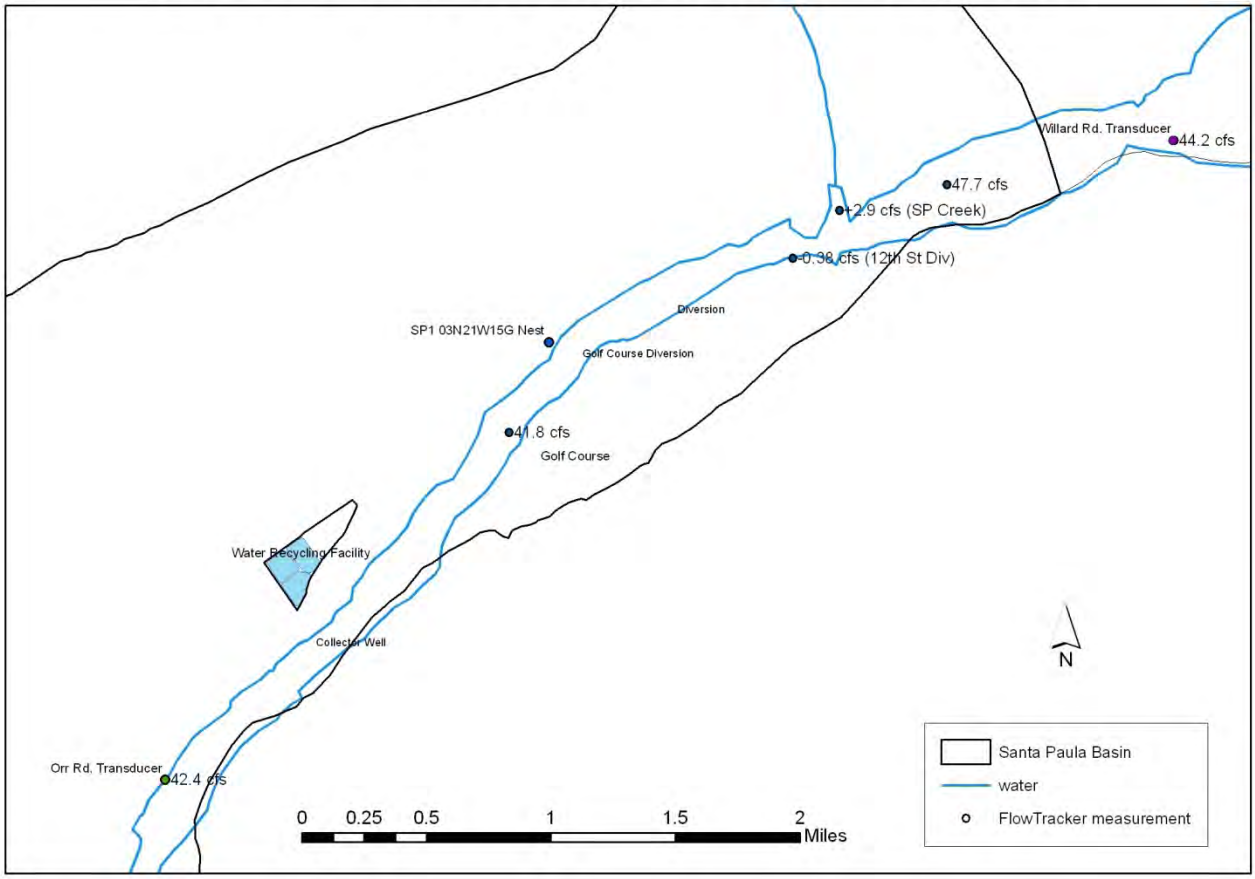
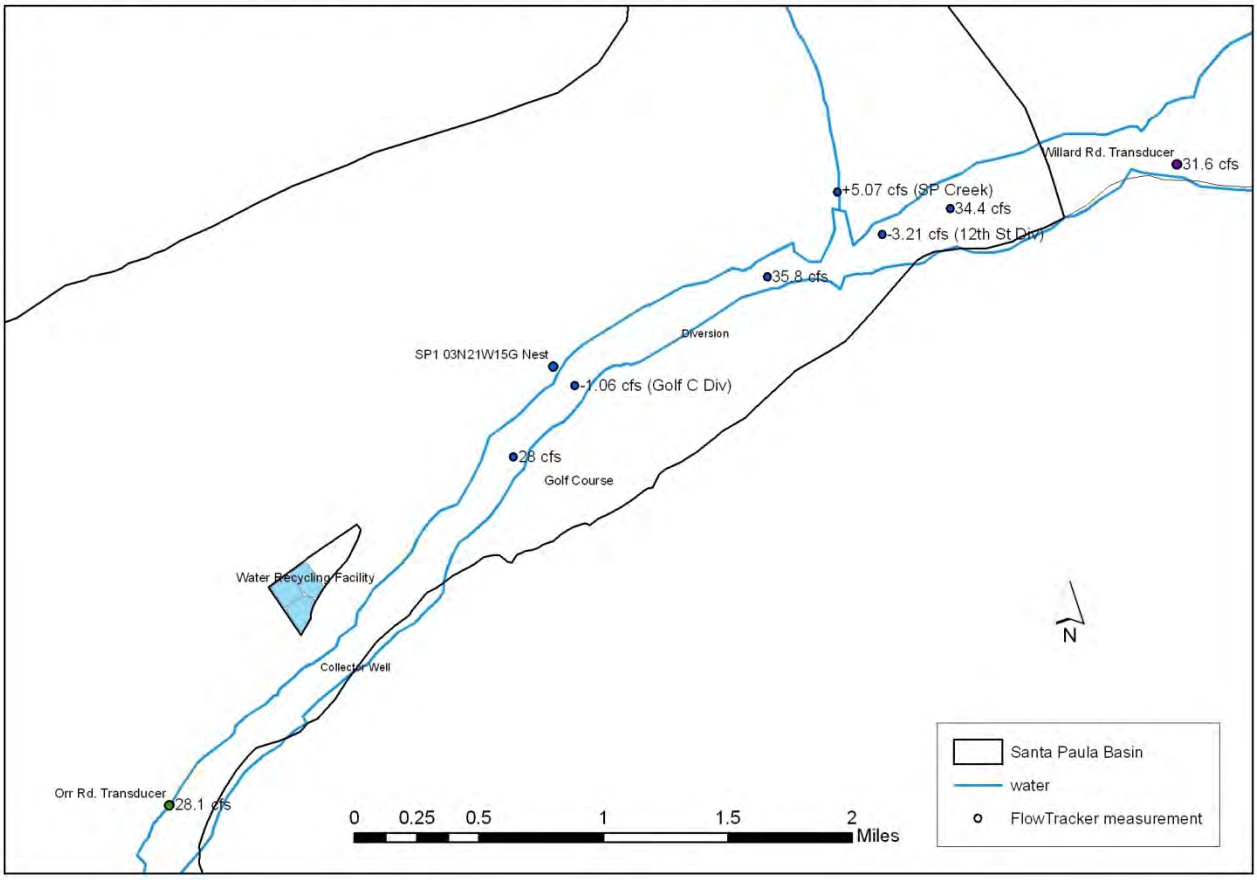
APPENDIX A – STREAM GAUGING MEASUREMENTS: AUGUST AND SEPTEMBER 2011

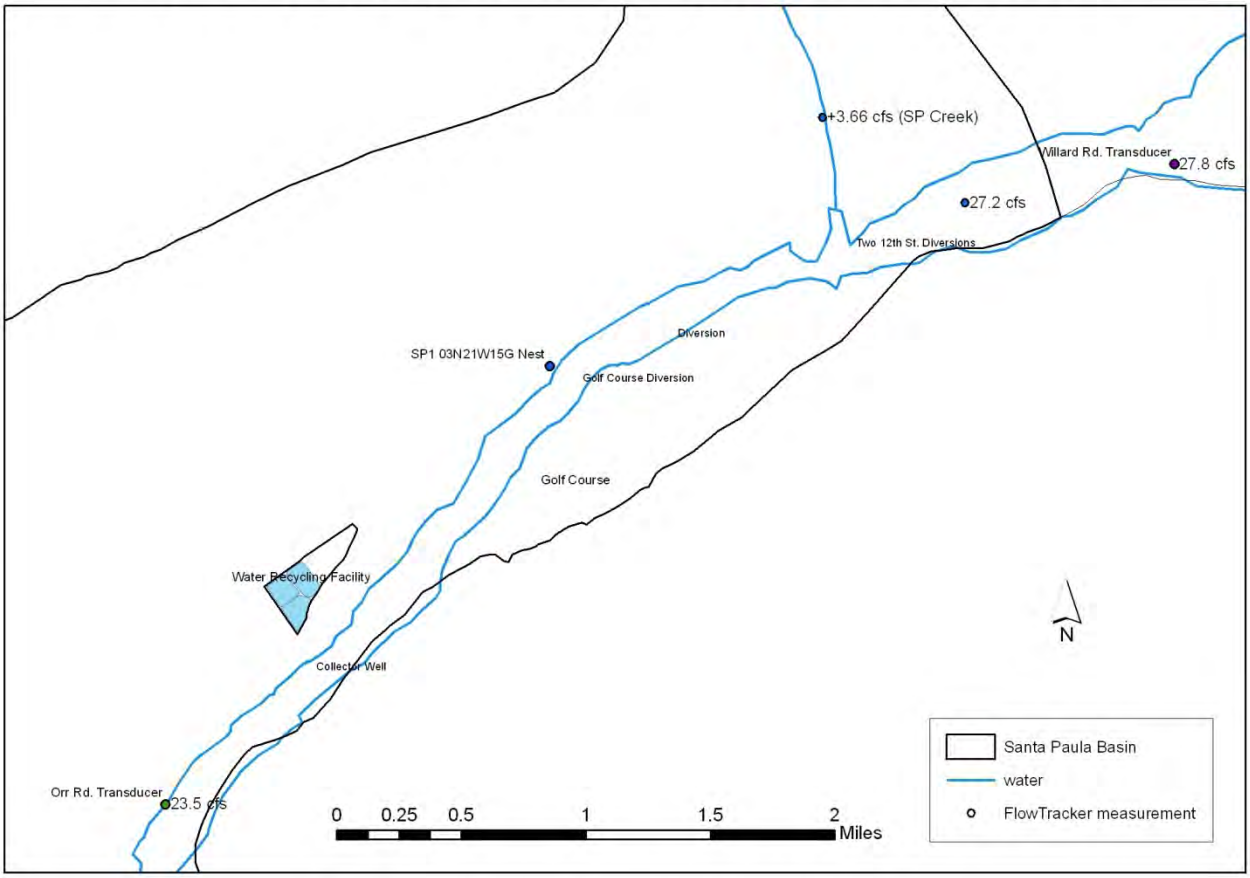
Santa Clara River Flow Measurements: 9 August 2011



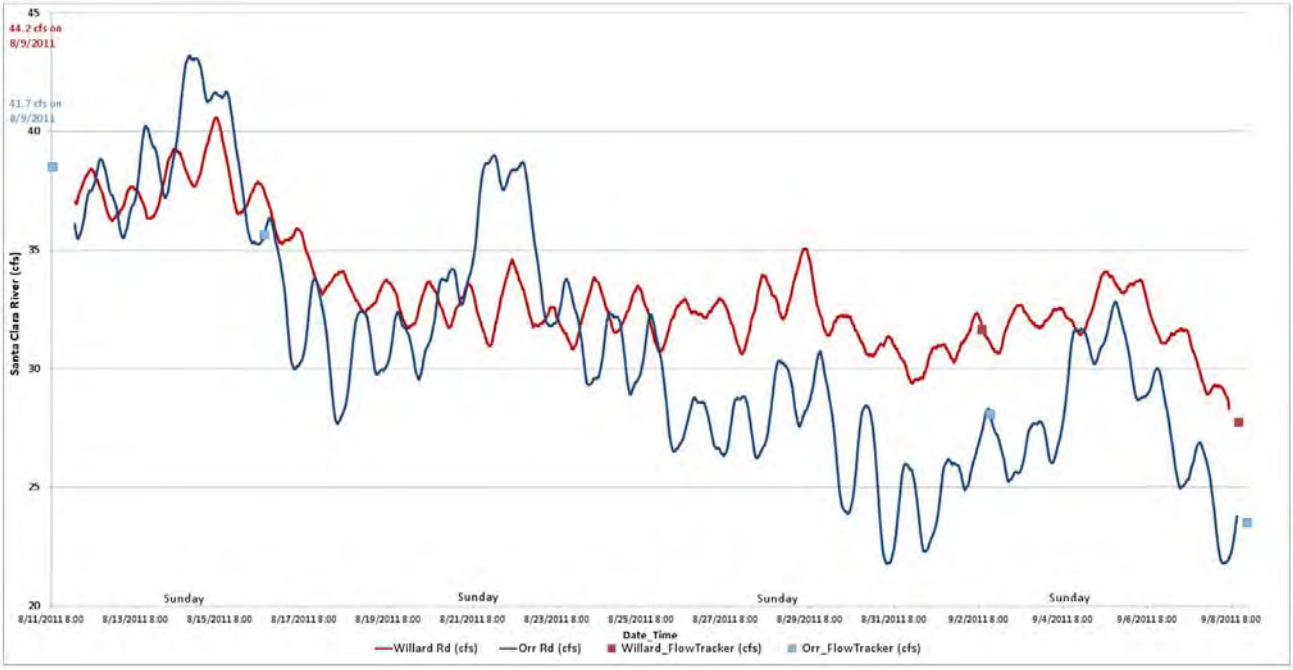
Santa Clara River Flow Measurements: 2 September 2011

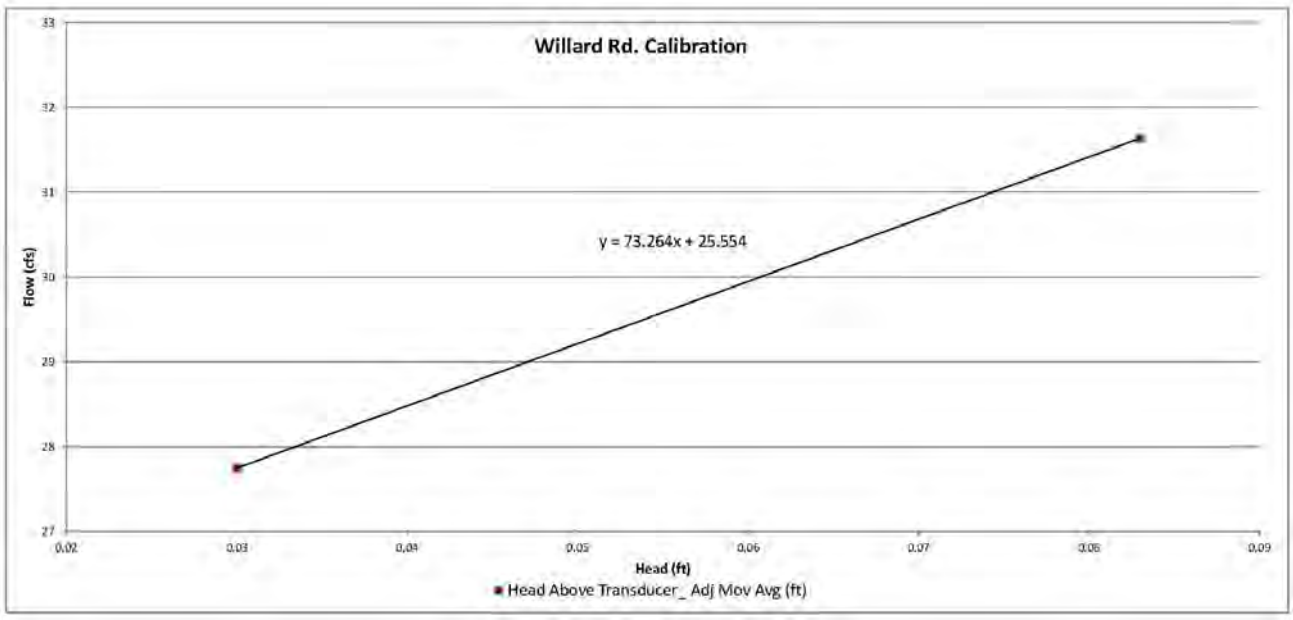


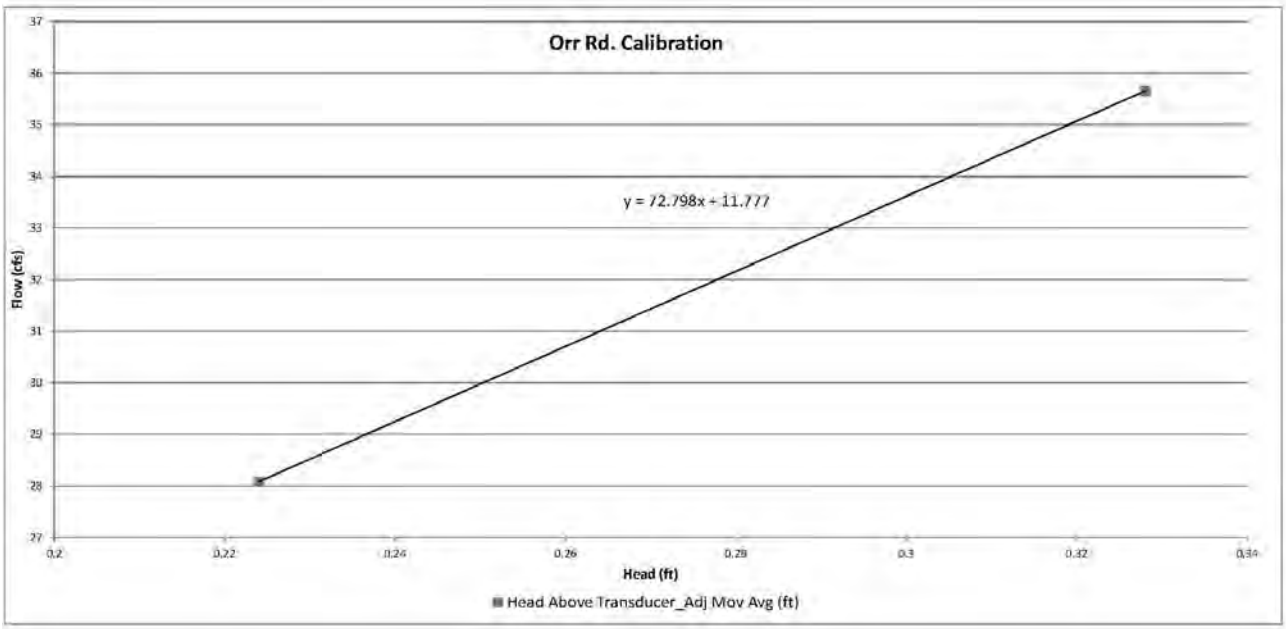
Santa Clara River Flow Measurements: 8 September 2011



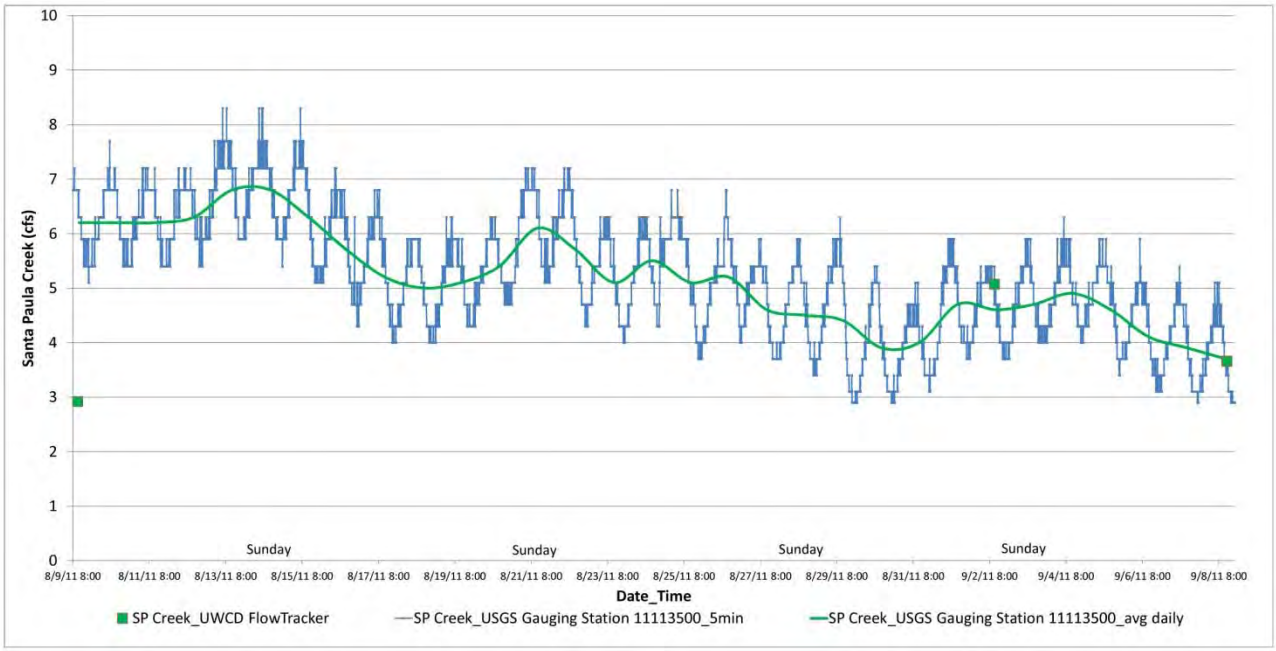
APPENDIX B – SANTA CLARA RIVER 12 HOUR MOVING AVERAGE TRANDUCER DATA FLOW PLOT AND CALIBRATION

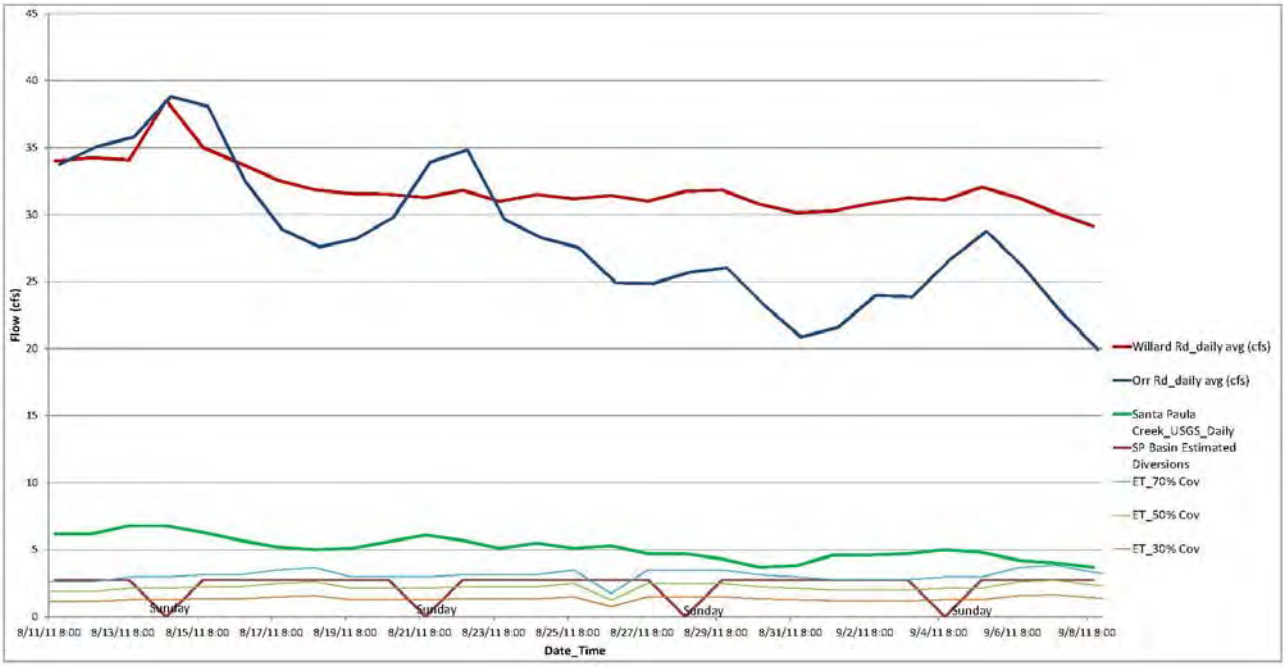




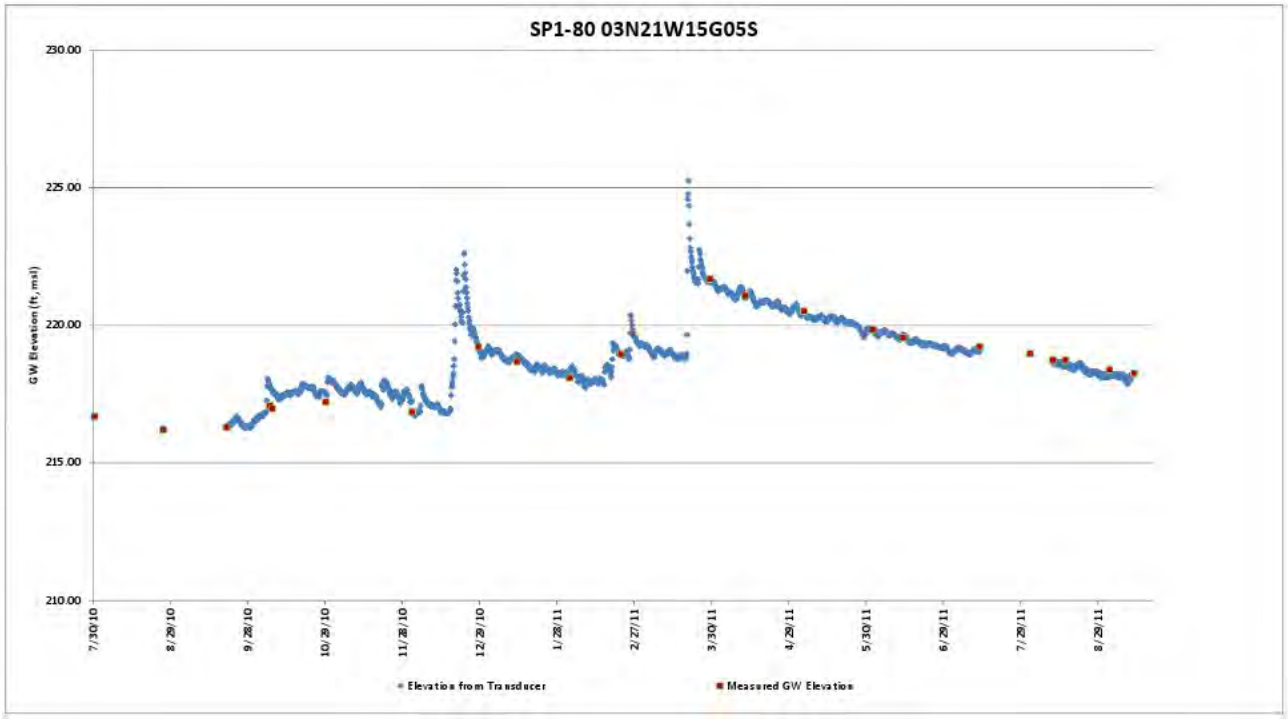

Orr Rd. Calibration
y = 72.798x + 11.777
Flow (cfs)
37
36
35
34
33
32
31
30
29
28
27
0.2
0.22
0.24
0.26
0.28
0.3
0.32
0.34
Head (ft)
Head Above Transducer_Adj Mov Avg (ft)

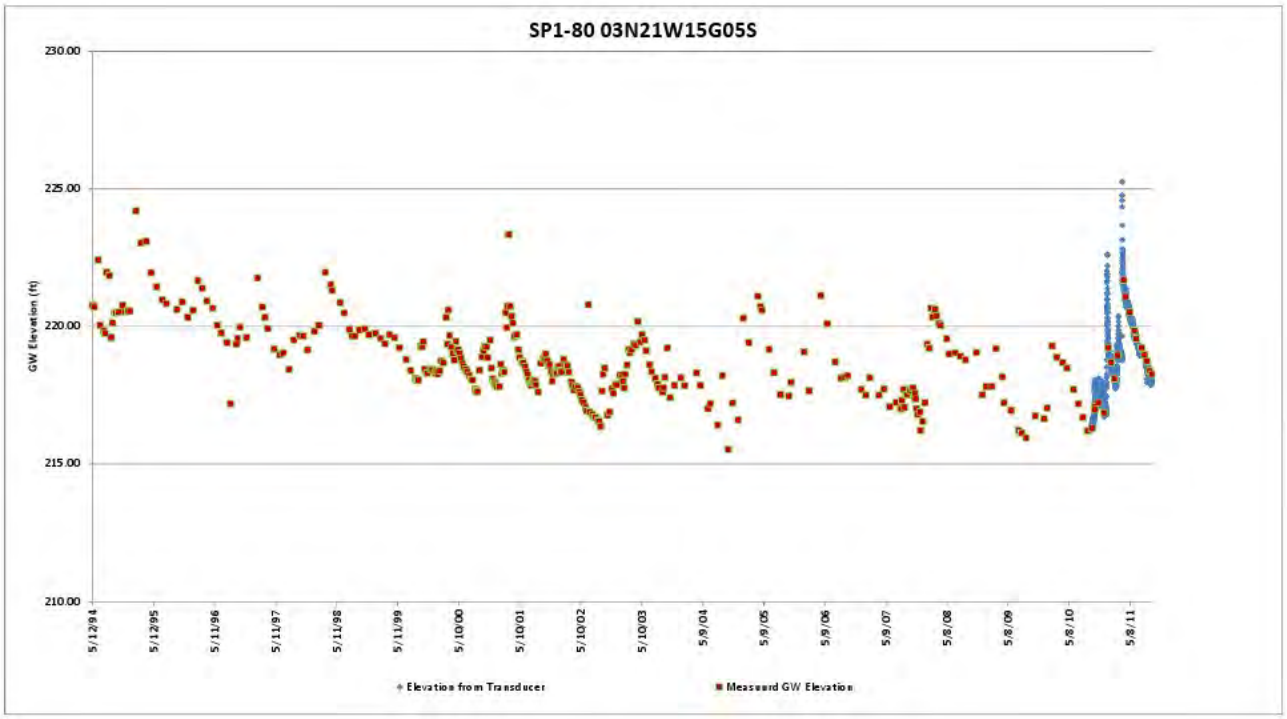
APPENDIX C – COMPONENTS OF THE SANTA CLARA RIVER PERCOLATION CALCULATIONS





APPENDIX D – MONITORING WELL: 03N21W15G05S (SP1-80)





APPENDIX E – SANTA CLARA RIVER FLOW MEASUREMENT DATA

Date	Location	Flow (cfs)	Width (ft)	Mean Vel (ft/s)	Max depth (ft)	Mean Depth (ft)	# Stations
8/9/2010	Willard Rd	26.08	24.0	1.32	1.10	0.82	25
8/9/2010	below 12th St bridge	28.8					
8/9/2010	Orr Rd	22.37	33.0	1.13	1.00	0.60	34
8/20/2010	Willard Rd	22.33	23.0	1.19	1.10	0.81	24
8/20/2010	near airport	14.63	18.0	1.20	1.00	0.68	19
8/20/2010	Orr Rd	11.84	31.0	0.91	0.70	0.42	32
8/26/2010	Willard Rd	21.11	24.0	1.20	1.00	0.73	25
8/26/2010	near airport	17.25	19.0	1.44	0.80	0.63	20
8/26/2010	Orr Rd	12.33	31.0	1.08	0.70	0.37	32
9/14/2010	Willard Rd	24.74	21.0	1.07	1.90	1.11	22
9/14/2010	near airport	13.64	22.0	1.97	0.90	0.58	23
9/14/2010	Orr Rd	12.15	24.0	1.20	0.70	0.42	25
8/9/2011	Willard Rd	44.17	19.0	1.70	1.98	1.36	22
8/9/2011	above 12th St bridge	47.74					
8/9/2011	near airport	41.83	27.0	2.44	0.90	0.63	28
8/9/2011	Orr Rd	41.66	25.0	1.86	1.49	0.90	26
8/9/2011	Orr Rd	43.09					
8/11/2011	Orr Rd	38.20	25.0	1.75	1.52	0.87	26
8/11/2011	Orr Rd	38.70	23.0	1.63	1.70	1.04	24
8/16/2011	Orr Rd	35.66	24.5	1.73	1.42	0.84	26
9/2/2011	Willard Rd	31.64	19.0	1.38	1.85	1.20	24
9/2/2011	above 12th St bridge	34.37					
9/2/2011	below 12th St bridge	35.812					
9/2/2011	near airport	28	25.0	1.90	0.80	0.58	26
9/2/2011	Orr Rd	28.08	25.0	1.46	1.40	0.77	26
9/8/2011	Willard Rd	27.75	17.0	1.32	1.79	1.24	21
9/8/2011	above 12th St bridge	27.15	27.0	1.32	0.99	0.59	30
9/8/2011	Orr Rd	23.50	22.0	1.42	1.30	0.75	23

Santa Clara River stream flow measurements collected using Sontek® FlowTracker flow meters.

APPENDIX F – SELECTED PHOTOS

MONITORING WELL: 03N21W15G05S (SP1-80) on alluvial terrace overlooking the Santa Clara River channel.

Santa Clara River and diversions from 12st Bridge in Santa Paula looking upstream.

Santa Clara River stream flow measurement site near Orr Rd. looking downstream.

Santa Clara River stream flow measurement site near Willard Rd. looking downstream.

Alluvial Terrace above the Santa Clara River floodplain looking oblique downstream.