Orange County Water District

Technical Memorandum

Date: June 25, 2021

To: Jason Dadakis, P.G., C.HG., Executive Director of Water Quality & Technical Resources

From: Li Li, Senior Hydrogeologist;

Subject: Recycled Water Retention Time Buffer Area Analysis for GWRSFE-GWRS Recharge at Lower Santa Ana River and Lower Santiago Creek

1 Introduction

The Orange County Water District (OCWD) is evaluating the feasibility to recharge purified recycled water into the lower reach of the Santa Ana River (SAR) from Carbon Creek Diversion to Orangewood Avenue, and the lower reach of the Santiago Creek from Hart Park to the lower SAR, as shown in Figure 1.

With the Groundwater Replenishment System Final Expansion (GWRSFE) Project, additional recharge capacity of GWRS water is desired beyond the existing facilities (Talbert Barrier injection, Mid-Basin Injection; Kraemer, Miller, Miraloma, and La Palma Basins) permitted to recharge purified recycled water, and the previously proposed and model-analyzed Burris, Riverview, and Santiago Basins and Santiago Creek (Burris-Riverview Basins and Santiago System) (OCWD, 2021). These recently proposed and analyzed sites which have historically been used primarily for SAR storm water recharge, as well as to dewater Santiago Basins during non-storm seasons. The SAR from Carbon Creek Diversion to Ball Road has been used primarily for SAR base flow and storm flow recharge. The SAR from Ball Road to Orangewood Avenue and the lower reach of the Santiago Creek were only used for incidental recharge of storm flow runoff when available.

The purpose of this Technical Memorandum is to summarize the groundwater modeling results of subsurface retention times for the purposes of establishing the required primary buffer areas within which potable extraction is prohibited and secondary buffer areas within which potable extraction is restricted, and to recommend monitoring well locations required by regulations (California Code of Regulations [CCR] Title 22 §60320.226).

2 Model Description

The OCWD basin-wide groundwater flow model (Basin Model) was used for this evaluation. The Basin Model was developed, calibrated, and utilized by OCWD to manage the Orange

County groundwater basin (Basin). The Basin Model has proven to be a good representation of actual Basin groundwater levels over the years.

The Basin Model is a transient numerical groundwater flow model using the widely-accepted United States Geological Survey (USGS) MODFLOW (Harbaugh and McDonald, 1996) code. The Basin Model accounts for spatial variations in aquifer properties as well as monthly variations in the volume of applied recharge, groundwater production, and boundary conditions along the edges of the model domain. Additional information regarding Basin hydrogeology and construction of the Basin Model can also be found in Section 3 of the OCWD Groundwater Management Plan 2015 Update (http://www.ocwd.com/media/3622/groundwatermanagementplan2015update_20150624.pdf).

In conjunction with the MODFLOW-based Basin Model, the USGS particle tracking code MODPATH (Pollock, 1994) was used to visualize groundwater flow paths and estimate groundwater travel times. OCWD has used MODPATH for both the California Environmental Quality Act (CEQA) evaluations and the DDW-approved subsurface retention time assessments required under CCR Title 22 §60320.200 General Requirements, §60320.208 Pathogenic Microorganism Control, and §60320.224 Response Retention Time (RRT) for the currently-permitted Talbert Barrier, Kraemer Basin, Miller Basin, Miraloma Basin, La Palma Basin, Mid-Basin Injection (MBI), as well as the future Burris-Riverview Basins and Santiago System projects (OCWD, 2021). The GWRS Independent Advisory Panel has also repeatedly endorsed this modeling approach (NWRI, 2021).

3 Model Assumptions

This simulation was set up under the same assumptions used in the evaluation for Burris-Riverview Basins and Santiago System (OCWD, 2021), except that GWRS water was also recharged in lower SAR and lower Santiago Creek. It includes existing facilities, including the four additional Mid-Basin injection wells in Centennial Park, GWRSFE, a new GWRS Pipeline outlet to Burris Basin, from which GWRS water can be delivered to Riverview Basin, Santiago Basins and Santiago Creek, and lower Santiago Creek. GWRS recharge in the lower SAR can occur either via maintenance discharges from Kraemer, Miller, Miraloma, and/or La Palma Basins as a part of cleaning and related activities or more directly via a future turnout to be constructed between the GWRS Pipeline and the lower SAR.

Detailed model assumptions for this predictive simulation are listed below:

1. The simulation was carried out for a 9-year simulation period. This was equivalent to the length of the original 1990-1999 transient model calibration period. Also, 9 years was found to be sufficiently long for the recharge-induced water level changes to stabilize.
2. Accumulated overdraft (volume of empty storage below a full basin condition) was maintained at approximately 200,000 AF over the simulation duration; this represents a higher basin storage condition under which the diversion of GWRS flows for recharge to both the Burris-Riverview Basins and Santiago System and lower SAR and lower Santiago Creek is most likely to occur.
3. Projected average hydrology was assumed: 52,000 AFY SAR base flow recharge; 51,600 AFY SAR storm flow recharge (Wildermuth, 2014);

Unmeasured or incidental recharge was subdivided amongst the various components such as areal recharge from precipitation, recharge along the mountain-front boundaries of the Basin, and winter unmeasured storm flow recharge in the SAR and Santiago Creek. These components were kept the same throughout the 9-year simulation.

Actual measured monthly recharge volumes from SAR flows, GWRS water, and imported water were adjusted and assigned to each OCWD recharge facility in the Anaheim and Orange Forebay areas. Monthly recharge adjustments were based on the statistical monthly water supply assumptions, but all recharge facilities were kept below their respective maximum operational capacities. Burris, Riverview, Santiago Basins and Santiago Creek were assumed to be recharged at or above the 90^{th} percentile of their historical monthly recharge rate over the last 10 years for all months as the worst-case scenario (i.e., causing the highest anticipated groundwater velocities). GWRS water was assumed to recharge into all currently permitted basins, i.e., Miraloma, La Palma, Kraemer, and Miller Basins, as well as previously-proposed Burris, Riverview, Santiago Basins, and Santiago Creek above Hart Park. All basins mentioned above except Miraloma and La Palma basins can also recharge water from other sources other than GWRS. Miraloma and La Palma basins can recharge sources other than GWRS water, but for operational reasons are dedicated to GWRS water recharge only. See item #10 below for lower Santiago Creek and lower SAR recharge values used.

4. The simulation used actual WY 2012-13 (July - June) groundwater production as a starting point. During WY 2012-13, there was no coastal pumping transfer or other large-scale pumping shifts. Therefore, it was a good representation of the overall pumping distribution reflecting actual seasonal demand in different areas of the Basin. Only existing active production wells were simulated (no planned, proposed, or future wells). Minor adjustments were made to include new production wells installed after 2013 and eliminate wells that were permanently removed from service after 2013 or wells that will not be used in the future. Within the project area, production well O-19 was added, and production wells O-3 and O-15 were removed from the simulation. The production data was then repeated for each of the nine years of the simulation.

5. The simulation is balanced, i.e., total water into the Basin equals total water out. Basin storage was kept relatively constant.

   The annual production amount was adjusted to maintain a balanced (negligible Basin storage change) condition. The adjustments were only applied to large system production wells excluding the water quality improvement wells. There are several wells in City of Tustin, City of Irvine, and Mesa Water District that receive treatment as a part of water quality projects (e.g., removal of salts, nitrates, and amber tint). The production amounts from these wells are limited by well capacities, treatment plant capacities, and/or by agreements between the participating agencies and OCWD. Therefore, typical production rates were used for these wells and kept unchanged during the simulation. Production from small system or domestic wells, or irrigation wells, was also kept unchanged at a selected typical rate matching that of WY 2012-13.

   During each production adjustment, total water demand from each producer was considered as the upper pumping limit. Pumping capacity for existing production wells was not considered a limitation for simulated production. The final adjusted total annual Basin production was 352,000 AF.

6. Actual recharge at the Talbert Barrier during WY 2011-12 (July - June) was used. In WY 2011-12, the Talbert Barrier injection rates (20,736 AF) were considered to be representative of typical injection operations under a low accumulated overdraft ("high basin") condition and were sufficient to maintain protective elevations; these conditions represent the periods when the likelihood of using lower SAR and lower Santiago Creek to recharge recycled water is higher. The Basin accumulated overdraft in WY 2011-12 was approximately 179,000 AF. This injection condition was repeated for the nine-year duration of the simulation. This is a conservative assumption, as the likelihood of having a high basin condition for a consecutive 9 years is low.
7. 65,000 AFY Metropolitan Water District (MWD) imported water for Forebay recharge.
8. GWRSFE capacity of 134,000 AFY distributed as follows:
    a. Talbert Barrier: 20,736 AFY
    b. Mid-Basin injection wells (MBI-1 through MBI-5): 8,400 AFY
    c. Kraemer/Miller/Miraloma/La Palma/Burris/Riverview/Santiago Basins/Lower SAR/Santiago Creek: 104,864 AFY (not including MWD & SAR water).
9. Modeled monthly recharge rates for Burris-Riverview Basins and the Santiago System, including GWRS, SAR and MWD water, are at or above the 90th percentile of their historical monthly recharge rates over the last 10 years. The resulting annual total recharge for Burris-Riverview Basins and the Santiago System was at or slightly above the annual historical high over the last 10 years since no cleaning downtime was assumed in this evaluation. The modeled annual total recharge for each component of Burris-Riverview Basins and the Santiago System were as follows, with the historical maximum recharge over the last 10 years listed in parentheses:
    a. Burris Basin: 17,136 AF (13,523 AF)
    b. Riverview Basin: 3,252 AF (3,152 AF)
    c. Santiago Basins: 57,000 AF (40,206 AF)
    d. Santiago Creek above Hart Park: 6,480 AF (4,628 AF)
10. The modeled recharge rate for lower Santiago Creek below Hart Park was based on the percolation test conducted in 2012 (OCWD, 2012). This testing indicated that lower Santiago Creek from Hart Park to Interstate 5 has a higher recharge capacity than the reach from Interstate 5 to the confluence with the SAR, primarily due to the narrowness of the creek below Interstate 5 as well as the presence of imported fill underlaying the creek bed in this area. The SAR from Carbon Creek Diversion to Ball Road has been operated by OCWD for recharging the Basin, and the historical maximum recharge rate was assumed for this simulation. The SAR from Ball Road to Orangewood Avenue has relatively low recharge rates possibly due to geological conditions in this area; a conservative recharge rate estimated by Forebay Operations staff was assumed. Observations by Forebay Operations staff indicate that recharge rates in the SAR below Ball Road are inversely affected by the volume of water within Burris Basin, i.e., a high amount of recharge in Burris Basin results in low recharge from the lower SAR below Ball Road. Therefore, assuming both a 90th percentile recharge rate at Burris Basin and

a high recharge rate for the lower SAR below Ball Road is a conservative assumption. The modeled annual total recharge for each component were as follows:

a. SAR from Carbon Creek Diversion to Ball Rd: 35,760 AF
b. SAR from Ball Road to Orangewood Avenue: 10,800 AF
c. Santiago Creek from Hart Park to Interstate 5: 5,760 AF
d. Lower Santiago Creek from Interstate 5 to the lower SAR: 2,160 AF

4 Modeling Results

4.1 Current Buffer Area Requirements

Current State of California's regulations regarding Groundwater Replenishment Reuse Projects (GRRPs) requires the establishment of both primary and secondary boundaries (i.e., buffer areas); the primary boundary is the traditional area in which the construction of new drinking water wells is restricted, while the secondary boundary is a zone of potential controlled potable well construction, within which the operation of future new wells may extend which could subsequently affect the primary boundary, thereby requiring further study and potential mitigating activities prior to potable well construction. Monitoring wells along the flow path to the nearest production well are also required. The specific requirements for these boundaries are found in the state's Title 22 regulations §60320.200 General Requirements, §60320.208 Pathogenic Microorganism Control, and §60320.224 Response Retention Time (RRT). The requirements for selecting monitoring wells are found in Title 22 §60320.226 Monitoring Well Requirements.

An eight-month primary and a ten-month secondary boundary have been developed for this evaluation using the OCWD Basin Model, which correspond to 4- and 5-log virus removal, respectively, via subsurface retention using the 50% safety factor for numerical models resulting in 0.50 log virus log reduction credit per month stated in the state's Title 22 Table 60320.208.

4.2 Modeling Approach

The particle tracking code MODPATH was used in conjunction with MODFLOW to estimate the underground retention time. An effective porosity of 0.25 was assigned to aquifer layers; this value represents the lower end of the 0.25 – 0.40 range for unconsolidated sand and gravel deposits comprising the study area aquifers (Freeze and Cherry, 1979: Table 2.4). Lower values of effective porosity result in greater groundwater velocities when hydraulic conductivity and gradient are held constant (i.e., greater velocity is required move the same volume of water through a lower porosity medium).

In order to estimate the shortest residence time to any active drinking water wells in the vicinity and the farthest estimated extent of the eight-month and ten-month buffer areas, reasonably high recharge rates were used as described in the model assumptions listed above. Particles were assigned laterally along the lower SAR and lower Santiago Creek, and vertically at the bottom of each area.

4.3 Particle Tracking Results

Lower SAR

The result of the MODPATH simulation (Figure 2) for the lower SAR shows that the simulated groundwater flow paths were generally consistent with the observed groundwater gradient and hydrogeologic conditions; groundwater flows primarily westward in the Shallow Aquifer and to the south/southwest in the Principal Aquifer. Particles were released along the bottom of the SAR. Recharge in the northern portion of the lower SAR migrated to the west, southwest or northwest within the Shallow Aquifer, and then migrated vertically downward to the Principal Aquifer due to a mergence zone where the intervening aquitard between the Shallow and Principal aquifers is largely absent. From this mergence zone area, groundwater flow within the Principal Aquifer is to the south/southwest.

There are several production wells downgradient from the lower reach of the SAR, including City of Anaheim production well A-46, two small system production wells (ABBY-A and NOBL-O) and Pacific Scientific (PSCI) remediation wells. A-46 is screened in the Principal Aquifer. As shown in Figure 2, particles reaching A-46 in the Principal Aquifer originated from recharge into the upper portion of the lower SAR and travelled southwest or northwest within the Shallow Aquifer and then migrating vertically downward in the aforementioned mergence zone to the Principal Aquifer and then flowed south/southwest to A-46 in approximately 2,781 to 3,186 days. The small system production well NOBL-O is also screened in the Principal Aquifer but is only used for industrial and irrigation purposes, not domestic or potable uses. Particles released from the uppermost portion of the lower SAR travelled towards the south in the Shallow Aquifer and then migrated down to the Principal Aquifer through the mergence zone and reached well NOBL-O in approximately 221 to 889 days. The production well ABBY-A is screened in the Shallow Aquifer. Particles released from the southern portion of the lower SAR travelled southwestward and reached well ABBY-A in approximately 753 to 876 days. The PSCI remediation wells are all screened in the Shallow Aquifer. Particles released from the middle portion of the lower SAR travelled towards the west and reached these wells in approximately 426 to 450 days. Nearby industrial well MKSSN-A is screened in the Principal Aquifer, but no particles arrived at this well.

Five existing OCWD monitoring wells along the lower reach of the SAR are proposed to fulfill the state's GRRP monitoring requirements (CA Title 22 §60320.226), including four in the Shallow Aquifer (OCWD-BP5, OCWD-BP3, AM-19, and AM-19A) and one in in the Principal Aquifer (AM-27). Wells AM-21A in the Shallow Aquifer and AM-21 in the Principal Aquifer will also be monitored voluntarily, but are not proposed as compliance wells due to lack of accessibility. Both AM-21A and AM-21 are located within a busy road and require substantial traffic controls in order to safely monitor. A schematic North-South cross-section along the SAR showing local geology, well locations and well screens (Figure 3) are used to demonstrate that these wells are located along the flow path towards production well A-46 both in the Shallow Aquifer and in the Principal Aquifer. Please also refer to Figure 11-7 of April 2021 GWRSFE Title 22 Engineering Report (same as Figure 3 within Appendix 5-A of same report) for a West-East Cross-Section showing modeled flow paths from Burris Basin (adjacent to lower SAR) to A-46, which are representative of flow paths between the northern portion of the lower SAR and A-46.

Lower Santiago Creek

The result of the MODPATH simulation (Figure 4) for the lower Santiago Creek shows that the simulated groundwater flow paths were generally consistent with the observed groundwater gradient and hydrogeologic conditions; groundwater flows primarily southwestward in the Shallow Aquifer. Particles were released along the bottom of Santiago Creek and remained in the Shallow Aquifer within the project area. Based on the available borehole logs in this area, a laterally continuous competent aquitard exists between the Shallow and Principal aquifers in this area. Therefore, simulated recharge along lower Santiago Creek into the Shallow Aquifer did not migrate down into the Principal Aquifer within the project area during the nine-year model simulation and may not reach the Principal Aquifer even with an extended model simulation due to the laterally continuous aquitard which thickens to the southwest.

There are several production wells in the vicinity of the lower Santiago Creek, including City of Santa Ana large system production wells SA-18, SA-24, SA-36, and SA-39, City of Santa Ana standby large system production wells SA-27 and SA-28, and one small system well RVGC-SA. These large system production wells (SA-18, SA-24, SA-27, SA-28, SA-36, and SA-39) are all screened in the Principal Aquifer and were not impacted by recharge in the lower reach of the Santiago Creek. Well RVGC-SA is screened in the Shallow Aquifer and located downgradient from Santiago Creek. Particles released from the west downstream end of Santiago Creek travelled towards the southwest and arrived at this well in approximately 601 to 1,006 days.

Two existing wells (OCWD monitoring well SCS-11, which includes two casings SCS-11/1 and SCS-11/2, and RVGC-SA) are proposed to fulfill the state's GRRP monitoring requirements (CA Title 22 §60320.226). SCS-11/1 and RVGC-SA are screened in the Shallow Aquifer and SCS-11/2 is screened in the Principal Aquifer; all three well points are located along the flow path of particles released from Santiago Creek (Figure 4).

A summary of the simulated arrival time to the production wells discussed above is presented in Table 1. The domestic or potable production well with earliest arrival downgradient of each recharge area is highlighted in bold.

Table 1: Simulated Arrival Time at Selected Production Wells

Particle Release Area	Production Well	Well Use	Aquifer	Simulated Arrival Time (days)
Lower SAR	ABBY-A	Irrigation	Shallow	753-876
	PSCI wells	Remediation	Shallow	426-450
	NOBL-O	Industrial & Irrigation	Principal	221-889
	A-46	**Potable**	**Principal**	**2,781-3,186**

Particle Release Area	Production Well	Well Use	Aquifer	Simulated Arrival Time (days)
Lower Santiago Creek	RVGC-SA	Irrigation	Shallow	601-1,006
	SA-16,18,24,27, 28,29,33,35 36,38,39,41	Potable	Principal	No arrival within 3,285-day simulation

4.4 Buffer Areas

Primary and secondary buffer areas for the lower Santa Ana River and lower Santiago Creek were generated using the model-derived particle locations at eight and ten months, respectively, after they were released, as shown in Figure 5 and Figure 6. From these figures, there are no existing potable production wells within either the primary or secondary buffer areas.

5 References

Freeze, R.A. and Cherry, J.A., 1979. *Groundwater* (No. 629.1 F7).

Harbaugh, A.W., and McDonald, M.G., 1996. *User's Documentation for MODFLOW-96, An Update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model: U.S. Geological Survey, Open-File Report 96-485.*

National Water Research Institute, *Meeting 17 Panel Report, Review of the Orange County Water District's Groundwater Replenishment System, Based on an Independent Advisory Panel Meeting – October 29-30, 2020.* Submitted January 6, 2021.

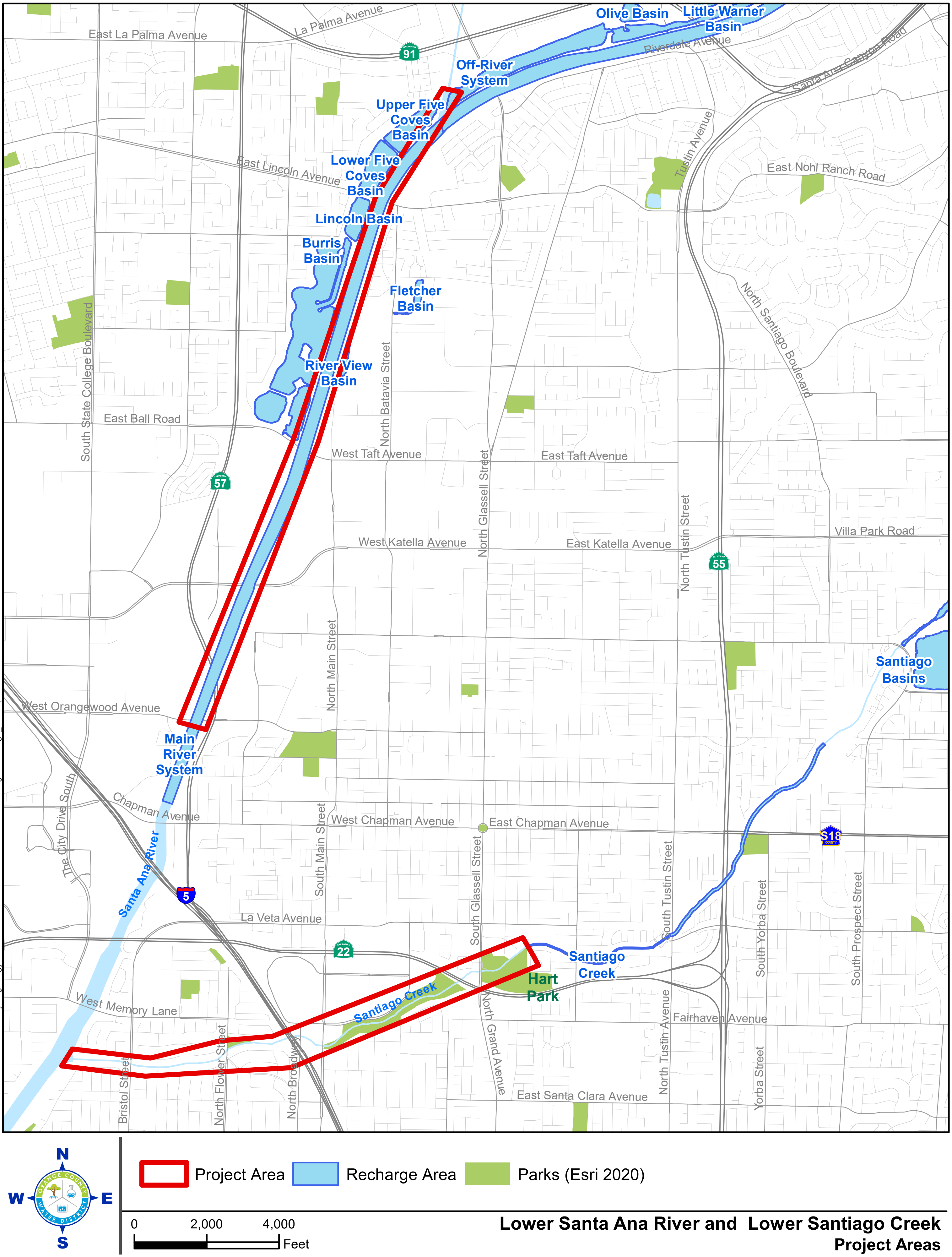
Orange County Water District, 2012. Technical Memorandum, Potential Recharge Capacity of Lower Santiago Creek. June 7, 2012.

Orange County Water District, 2021. Technical Memorandum, Recycled Water Retention Time Buffer Area Analysis for GWRSFE– Proposed GWRS Recharge at Burris & Santiago Areas. March 10, 2021.

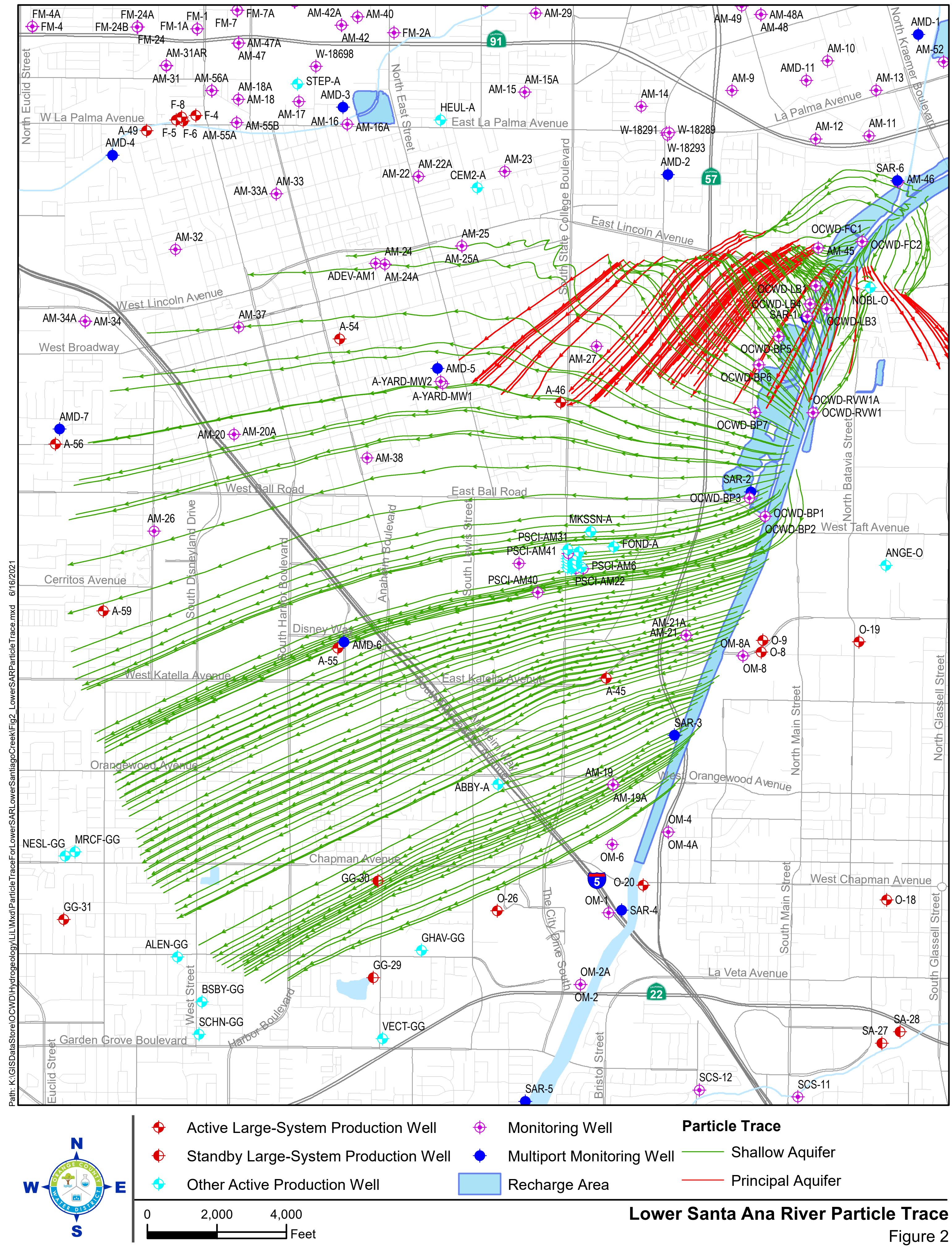
Pollock, D.W., 1994. *User's Guide for MODPATH/MODPATH-PLOT, Version 3: A particle tracking post-processing package for MODFLOW, the U. S. Geological Survey finite difference ground-water flow model: U.S. Geological Survey Open-File Report 94-464.*

Wildermuth Environmental Inc., 2014. *Prado Basin Daily Discharge Estimates for 2021 and 2071 Using the Wasteload Allocation Model.*

FIGURES

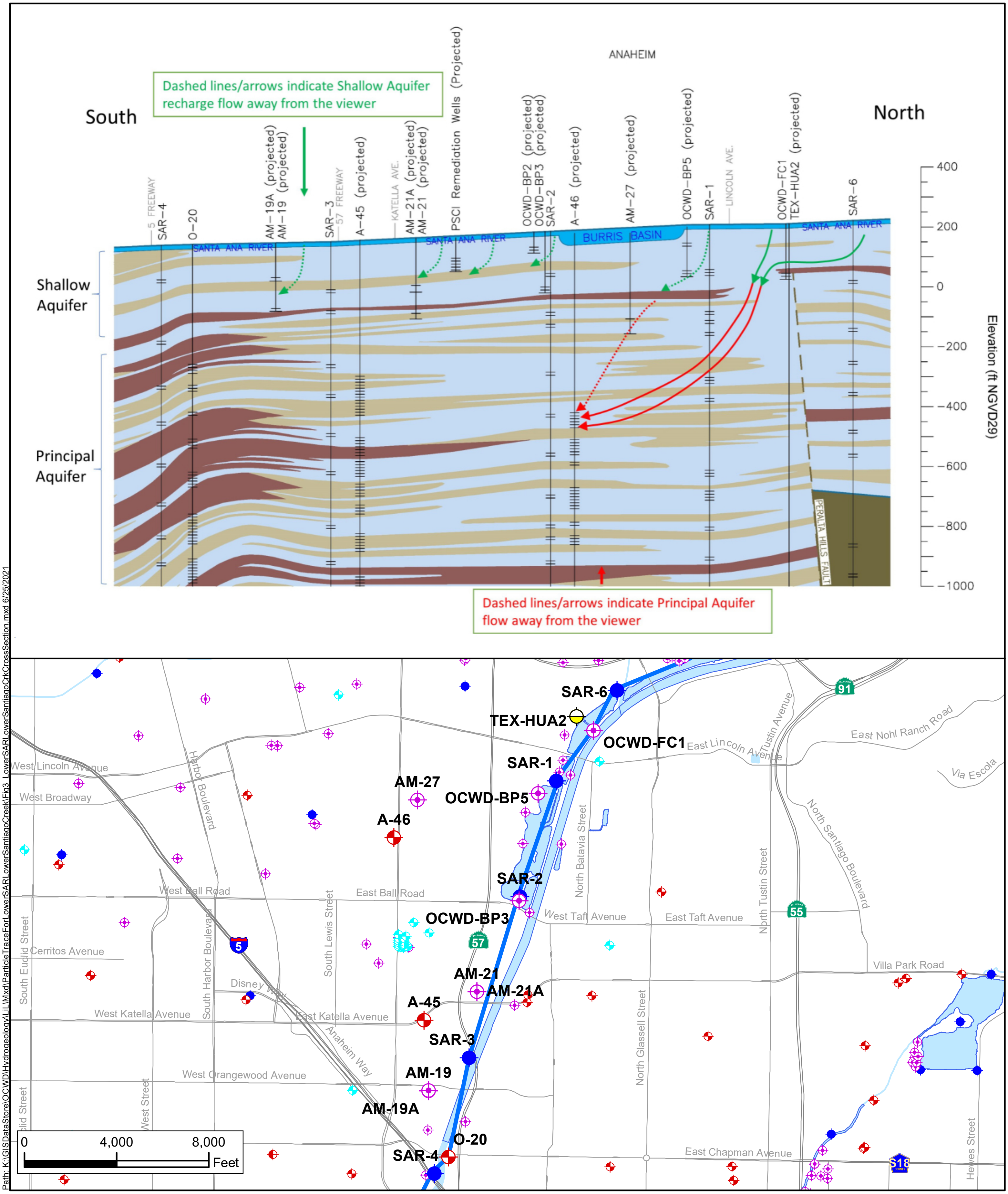


Lower Santa Ana River and Lower Santiago Creek
Project Areas
Figure 1



Lower Santa Ana River Particle Trace

Figure 2



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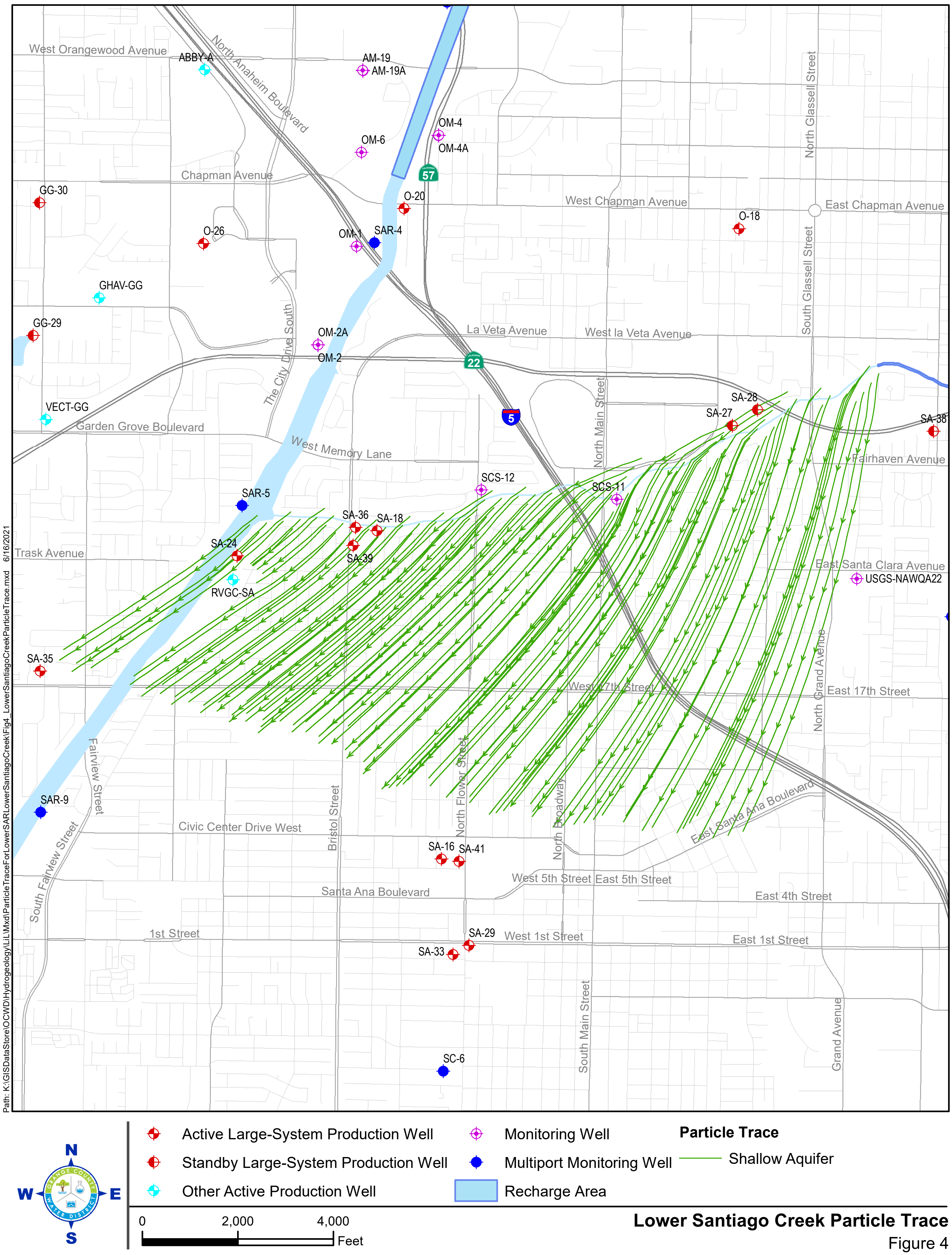
- Active Large-System Production Well
- Monitoring Well
- Multiport Monitoring Well
- Oil Well
- Standby Large-System Production Well
- Other Active Production Well
- Cross Section

Particle Trace

- Shallow Aquifer
- Principal Aquifer

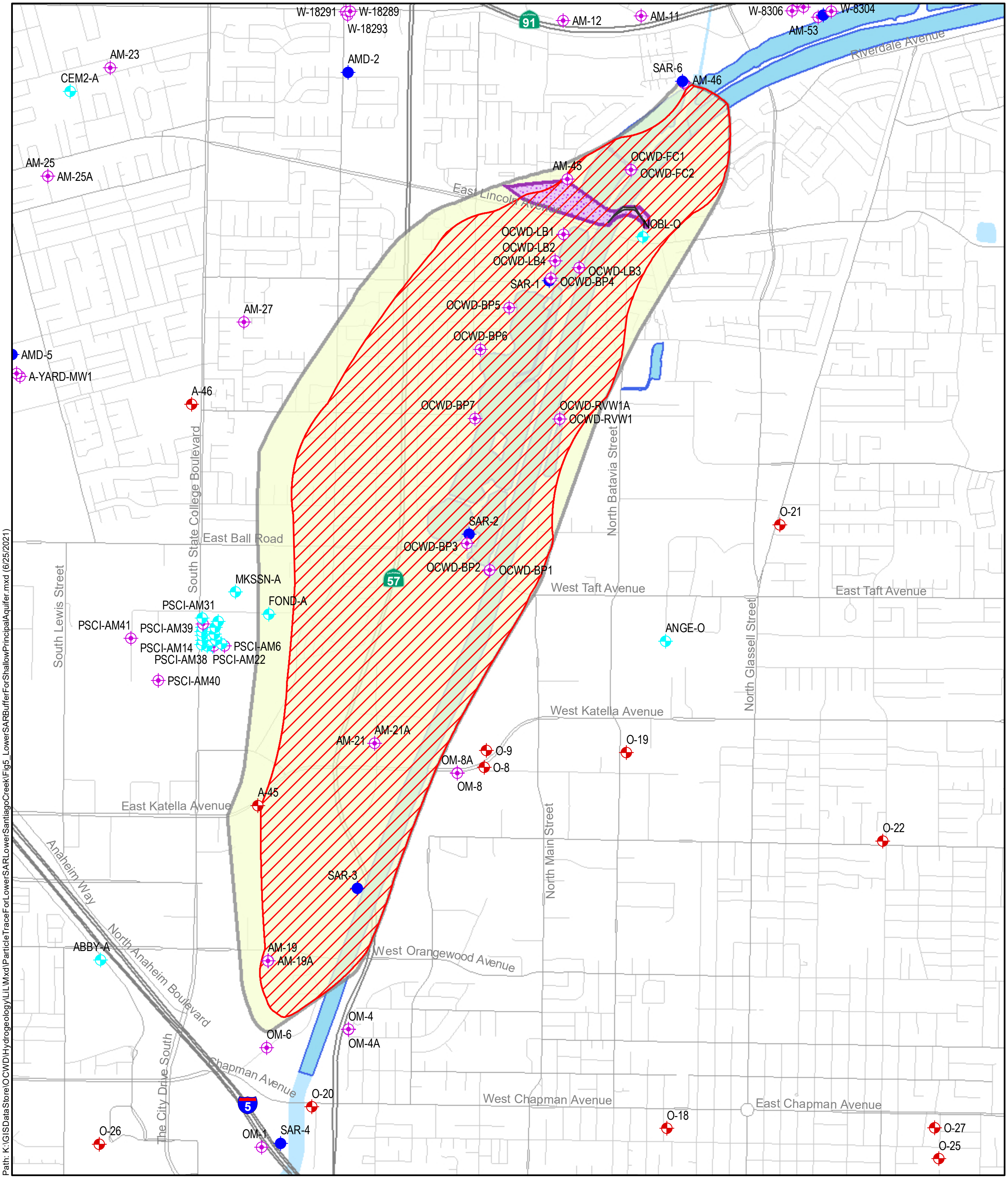
Lower Santa Ana River and Lower Santiago Creek Geologic Cross-Section

Figure 3



Lower Santiago Creek Particle Trace

Figure 4



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Active Large-System Production Well
Other Active Production Well
Monitoring Well
Multiport Monitoring Well
Recharge Area

Particle Trace Buffer Area

Primary Buffer

Shallow

Principal

Secondary Buffer

Shallow

Prinicpal

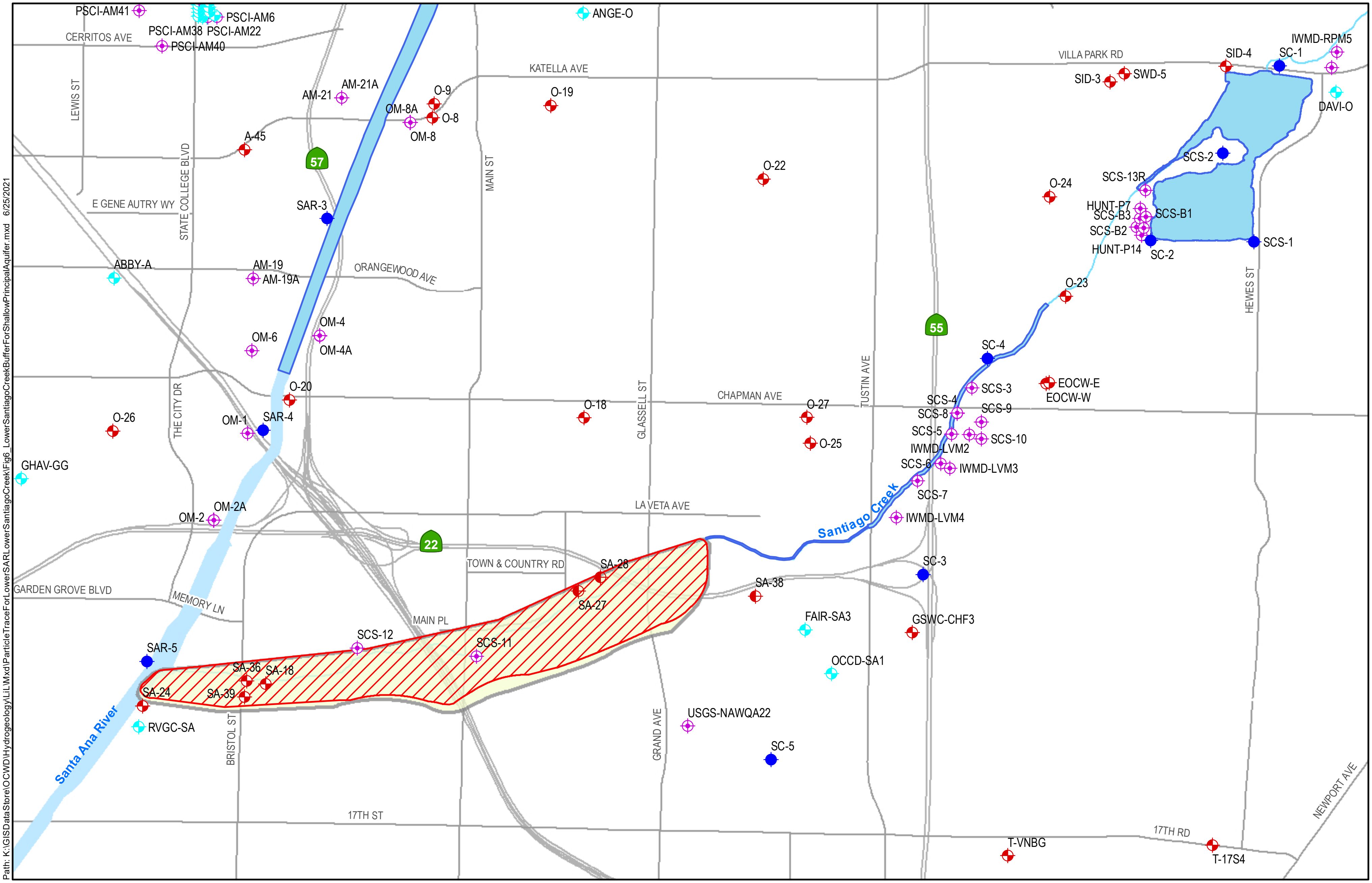
N W E S

0 2,000 4,000 Feet

Lower Santa Ana River

Primary & Seconday Buffer Areas in Shallow & Principal Aquifers

Figure 5



Active Large-System Production Well
Standby Large-System Production Well
Other Active Production Well
Monitoring Well
Multiport Monitoring Well
Recharge Area

Particle Trace Buffer Area

Primary Buffer
Shallow

Secondary Buffer
Shallow

N
W E
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0 2,000 4,000 Feet

Lower Santiago Creek
Primary & Seconday Buffer Areas in Shallow & Principal Aquifers
Figure 6

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