Santa Ana River Water Rights

Testimony of Dennis E. Williams

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I. Summary of Testimony

1. The project will have numerous benefits related to groundwater in the San Bernardino Basin Area (SBBA). A summary of the benefits are:

   - The project will allow Muni/Western to develop up to 200,000 acre-ft from the diversion of Santa Ana River water that would otherwise flow out of the area without being put to beneficial use. This additional water conservation will provide drought protection and less reliance on imported water.

   - Reduce liquefaction potential by keeping groundwater levels 50 ft below the land surface through optimization of recharge and extraction. This is very important in the highly urbanized SBBA which is an area that is particularly susceptible to liquefaction as it is adjacent to the San Andreas, San Jacinto and Cucamonga faults. New evidence has indicated that there is currently a build-up of strain on the southern San Andreas fault that will ultimately result in a large earthquake on both the San Andreas and San Jacinto faults (Final EIR, 2007). Keeping groundwater levels in the SBBA below 50 ft will greatly reduce the risk of liquefaction when a major earthquake does occur.

   - Assist in improving the water quality of the SBBA by accelerating clean up of the contaminant plumes. For example, it is expected that Scenario A will clean up the PCE plume (i.e., Newmark and Muscoy plumes) three years faster than if there was no project. It is also expected that Scenario A will clean up the TCE plume (i.e., Norton/Redlands-Crafton plumes) five years faster than if there was no project.

- In general, the diverted water will have overall benefits with respect to TDS and nitrate concentrations. For TDS, there would be beneficial impacts under the project scenarios in the Bunker Hill A management zone, with less than significant impacts expected in the Bunker Hill B and Lytle management zones. With respect to nitrate concentration, beneficial impacts would be anticipated for all management zones.

- The findings of my work was based on using six model scenarios that were developed and tested with an integrated groundwater and streamflow model ("groundwater model"), as well as a solute transport model. The groundwater flow model simulated groundwater levels, and direction and rate of flow. The solute transport model simulated water quality concentrations (i.e., TDS, nitrate, perchlorate, PCE and TCE). The six scenarios represent the following conditions:

  - No project,
  - Maximum capture (1,500 cfs),
  - Minimum capture (500 cfs), and
  - Most likely scenario (1,500 cfs, and takes into account Seven Oaks Accord and settlement with Conservation District).

- In addition to the groundwater flow, particle tracking and solute transport models, a subsidence model was developed to evaluate project impacts. Also, analytical models were developed to examine impacts of artificial recharge in areas outside of the SBBA.

II. Background and Qualifications

2. My name is Dennis Williams. I have over 35 years of experience in groundwater hydrology and resource management. I have directed geohydrologic investigations domestically and worldwide which include the design and supervision of construction of over 700 deep large-scale municipal and irrigation water supply wells. I have been a consultant to the United Nations and several foreign governments and am also a part-time research professor in the University of Southern California's (USC) Civil and Environmental Engineering Department where since 1980 I have taught graduate level courses in geohydrology and groundwater modeling. I am currently directing research on water-supply well design and construction at USC's geohydrologic laboratory which houses the largest sand-tank model in the world. I am the author of over 30 publications on groundwater and wells and was the principal author of the *Handbook of Groundwater Development* (John Wiley & Sons, 1990). I have provided expert witness testimony for numerous legal cases, Regional Water Quality Control Board and State Water Resources Control Board proceedings related to groundwater issues, including groundwater quality and quantities.

3. I am the founder and president of GEOSCIENCE Support Services, Inc. which was established in 1978. GEOSCIENCE is a groundwater consulting company specializing in groundwater supply, development, management and protection. GEOSCIENCE's clients include most of the major water districts and agencies in Southern California, as well as clients in South America, Europe, and the Middle East.

III. GEOSCIENCE's Role in Project

4. GEOSCIENCE has been working cooperatively with Science Applications International Corporation (SAIC) since 2002 to develop an optimized plan to divert and manage unappropriated Santa Ana River water within the Muni/Western (San Bernardino Valley Municipal Water District and Western Municipal Water District) service area (see Muni/Western Ex. 6-3).

5. In particular, GEOSCIENCE has been responsible for developing and running groundwater flow and solute transport models of the San Bernardino Basin Area (SBBA)

in support of the Santa Ana River water right applications. The purpose of the modeling was to simulate various proposed Seven Oaks Reservoir water delivery scenarios, and to evaluate the potential impact on groundwater levels and groundwater quality in the SBBA. Additionally, an evaluation of impacts from artificial recharge in basins outside of the model area but within the Muni/Western service area, as well as subsidence modeling within the SBBA were performed. Results of the groundwater flow and solute transport modeling, subsidence modeling and artificial recharge evaluation outside of the SBBA were used to support the Draft Environmental Impact Report (EIR) for the proposed water right applications.

IV. Overview of Methods Used to Evaluate Impacts to Groundwater and Surface Water

6. In order to evaluate impacts of appropriating Santa Ana River water, a number of numerical models and analytical equations were developed and utilized by GEOSCIENCE and SAIC. Models utilized by GEOSCIENCE include groundwater flow and transport model, a subsidence model and analytical solution to estimate artificial recharge outside the SBBA but within Muni/Western's service area. These models simulated predictive scenarios and impacts on surface and groundwater resources in the study area. For example, the OPMODEL, Allocation Model and groundwater models work "iteratively" in estimating deliveries to artificial recharge spreading facilities. An iterative process between these models occurs since deliveries of water to artificial recharge spreading facilities are not only limited by delivery constraints (e.g., available conveyance route capacities and absorption (recharge) capacities of spreading facilities) but also by groundwater levels and groundwater quality (e.g., location of groundwater contamination plumes in the SBBA).

7. Releases from Seven Oaks Dam were simulated using SAIC's OPMODEL. The distribution of releases from the Dam was simulated sing SAIC's Allocation Model. The River Analysis measures effects of the project diversions on downstream channel hydraulics.

8. The Operations Model, Allocation Model and River Analysis will be described in detail in Mr. Robert Beeby's testimony. The following is a brief review.

9. The Operations Model (OPMODEL) is a model developed to estimate the quantity of unappropriated Santa Ana River water available for diversion by Muni/Western. This model simulates monthly releases that could be made from Seven Oaks Dam under a set of variable conditions. These conditions are determined by a number of parameters including the following:

- Diversions by senior water rights claimants;
- Diversions by the San Bernardino Valley Water Conservation District (Conservation District);
- Releases designed to accomplish habitat restoration as prescribed by the terms of the Biological Opinion (BO) of the U.S. Fish and Wildlife Service for operation of Seven Oaks Dam; and
- Operation of Seven Oaks Dam for either flood control or a combination of flood control and seasonal water conservation storage.

10. The Allocation Model simulates the manner in which water diverted by Muni/Western would be put to beneficial use. The Allocation Model is a mechanism designed to distribute diverted water through a set of existing and proposed conveyance facilities to a set of water uses. These uses are:

- Direct use within the Muni/Western service areas;
- Groundwater recharge of the San Bernardino Basin Area (SBBA);
- Groundwater recharge outside the SBBA but within the Muni/Western service areas; and
- Water Exchange.

11. A groundwater flow model was developed, based on the existing USGS groundwater flow model, using outputs from the OPMODEL and Allocation Model. The groundwater flow and solute transport models were used to evaluate impacts on groundwater levels and quality. An analytical method was used to evaluate impacts from artificial recharge in basins outside of the model area but within the Muni/Western service area. In addition, subsidence modeling was used to determine impacts from aquifer system compaction within the SBBA.

12. The River Analysis includes a collection of analytical techniques designed to assess the changes that potential diversions by Muni/Western could have on the flow regime of the Santa Ana River. Analyses were conducted for two sets of conditions:

- Non-storm flow conditions where attention is focused on changes in instream channel flow; and
- Storm flow conditions where attention is focused on overbank flooding.

13. Subsidence modeling calculated ground surface subsidence resulting from groundwater level changes within the aquifer system. Groundwater levels predicted by the groundwater flow model were used as input to the subsidence model. The subsidence model (PRESS) predicted recoverable and non-recoverable compaction of fine-grained layers within the aquifer system.

14. To evaluate impacts of artificial recharge in areas outside of the SBBA, an analytical method was used. The method used employed Hantush’s (1967) formula for the growth and decay of groundwater mounds in response to uniform percolation. This method takes into account spreading basin geometry, hydraulic conductivity, effective porosity, percolation rates, time required for recharge, depth to groundwater and effective saturated thickness of the underlying aquifer (see Muni/Western Ex. 6-4).

V. Sources of Data

USGS Groundwater Flow Model

15. The groundwater flow model, originally developed by the USGS (Danskin et al., 2006) for the San Bernardino Basin Area (SBBA), was obtained for use in simulating various proposed Seven Oaks Reservoir water delivery scenarios. Electronic files of the USGS groundwater flow model were made available through Muni (San Bernardino Valley Municipal Water District), which cooperated with the USGS in developing the model.

16. The USGS groundwater flow model was calibrated from 1945 to 1998. For purposes of the EIR, the model was updated from 1998 – 2000. The table below summarizes some differences between the original USGS flow model and the updated model used for this study.

Table 1. Comparison between Original USGS Model and USGS Model Update Used to Develop Optimum Management Scenarios for EIR

	Item	*Original USGS Model*	*USGS Model (Updated)*
Groundwater Flow Model	Model Package	MODFLOW	same
	Areal Extent	All of the valley-fill within the Bunker Hill and Lytle Creek basins (approximately 141 square miles)	same
	Cell Size	820 ft x 820 ft (uniform)	same
	Model Grid	118 (i-direction) and 184 (j-direction)	same
	Number of Layers	2	same
	Length of Stress Period	1 year	same
	Number of Time Steps per Stress Period	100	same
	Time Step Multiplier	1.2	same
	Steady-State Calibration Year	1945	same
	Transient Calibration Period	1945 – 1998	1945 - 2000
	Relative Error[1]	4.92 percent	4.93 percent
Particle Tracking Model	Model Package	NA	MODPATH
	Number of Scenarios	NA	5
	Beginning of Model Year	NA	2001

	Item	*Original USGS Model*	*USGS Model (Updated)*
Solute Transport Model	Model Package	NA	MT3DMS
	Calibration Period	NA	1986 – 2000 (PCE and TCE)
	Relative Error	NA	8% for PCE and 9% for TCE
	Dispersivity - Longitudinal [ft]	NA	300
	Dispersivity - Transverse [ft]	NA	100
	Dispersivity - Vertical [ft]	NA	1
	Bulk Density [g/cm^3]	NA	1.9
	Sorption Distribution Coefficient [cm^3/g]	NA	0.0947 (PCE), 0.054 (TCE)
	Chemical Constituents Modeled	NA	PCE, TCE, TDS, NO_3, and Perchlorate
	Groundwater Plumes Modeled	NA	Muscoy, Newmark, Norton, and Redlands-Crafton

[1] The relative error is the standard deviation of the residuals (measured - modeled) divided by the observed range of the modeled parameter (e.g., groundwater levels or contaminant concentrations).

Update of USGS Groundwater Flow Model to 2000

17. Once the USGS model was successfully run, the years 1999 and 2000 were added to the model period as a verification[1] run. The sources of model input data required for this update are discussed below.

Streamflow Data

18. Daily streamflow data was downloaded from USGS's National Water Information System – Web Interface (NWISWeb) for stations shown in Muni/Western Ex. 6-5 through 6-14 and used in the Streamflow Package. (http://www.waterdata.usgs.gov/ca/nwis)

Precipitation Data

19. Daily precipitation data for the San Bernardino County Hospital station (#2146) was downloaded from the Water Resources Division of the San Bernardino County Flood Control to update the model Recharge Package for 1999 and 2000. (http://www.co.san-bernardino.ca.us/trnsprtn/pwg/Precip_Data/Zone_2_Precip_Stations.htm).

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[1] Verification is a process whereby the model is run using the calibrated parameter values and stresses to reproduce a second set of field data for which measurements are known.

Artificial Recharge Data

20. Monthly spreading volumes at the Santa Ana River and Mill Creek spreading grounds were provided by the San Bernardino Valley Water Conservation District (SBVWCD) for input into the model's Well Package.

21. Monthly volumes of imported water artificially recharged (i.e., State Water Project) were also provided by Muni.

Well Location Data

22. Well locations were provided by Danskin et al. (2006). The locations of wells were needed to assign model grid coordinates (ij values) for the Well Package.

Groundwater Production Data

23. Groundwater production data were obtained from the Western - San Bernardino Watermaster (as verified annual production) and used in the Well Package.

Solute Transport Models

Geologic Data

24. Elevations at the bottom of Model Layer 1 and Layer 2 (i.e., layer thickness) were defined by geophysical borehole logs and lithologic logs as well as the following documents:

- Dutcher and Garrett (1963);
- Morton (1976);
- GEOSCIENCE(1993);
- Hardt and Hutchinson (1980);
- Camp Dresser and McKee, Inc. (CDM, 1996);
- Danskin et al. (2006);
- HSI GeoTrans (1998);

- URS Greiner (1997 and 1999); and
- Wildermuth Environmental, Inc. (2000)

Groundwater Quality Data

25. Sources of tetrachloroethene (PCE), trichloroethene (TCE), perchlorate, total dissolved solids (TDS) and nitrate (as NO_3) used for transport model calibration include:

- CDM (1996);
- HSI GeoTrans (1998);
- URS (1997and 1999);
- Wildermuth Environmental, Inc. (2000);
- California DHS (2007); and
- USGS NWISWeb (2003)

Evaluation of Model Calibration

Groundwater Level Data

26. For model calibration, historical groundwater level data were obtained from Western Municipal Water District's Cooperative Well Measurement Program and NWISWeb for California (http://www.waterdata.usgs.gov/ca/nwis).

Groundwater Quality Data

27. Sources of water quality data used for transport model calibration include:

- CDM (1996);
- HSI GeoTrans (1998);
- URS (1997 and 1999);
- Wildermuth Environmental, Inc. (2000);
- California DHS (2007); and
- USGS NWISWeb (2003).

Model Scenarios

Input from Surface Water Models (OPMODEL and Allocation Model)

28. Results from the OPMODEL and Allocation Model provided the following groundwater model recharge and discharge values, for the various model scenarios, specifically:

- Releases to the Santa Ana River from the Seven Oaks Dam,
- Artificial recharge in the various artificial recharge facilities (i.e., spreading grounds), and
- Groundwater pumping and return flows from groundwater pumping.

Historical Recharge and Discharge (from 39 Year Base Period) for Model Prediction

29. In addition to the recharge and discharge values obtained from the OPMODEL and Allocation Model, other recharge and discharge terms used in the predictive groundwater model are summarized in Table 2.

Table 2. Summary of Groundwater Recharge and Discharge Terms

Description of Model Input Data		*Assumptions and Sources of Data*
Gaged Mountain Front Runoff	Release to Santa Ana River from the Seven Oaks Dam	*OPMODEL*
	Other Gaged Inflow	Historical Data (1962-2000)*
Artificial Recharge at Spreading Grounds		Allocation Model
Recharge from Underflow		Extension of Historical Trend*
Return Flow from Groundwater Pumping		Allocation Model
Recharge from Ungaged Mountain Front Runoff		Historical Data 1962-2000*
Infiltration from Direct Precipitation		Historical Data 1962-2000*
Recharge from Local Runoff Generated by Precipitation		Historical Data 1962-2000*
Groundwater Pumping		Allocation Model
Groundwater Outflow (i.e., Underflow Discharge)	Across San Jacinto Fault near Santa Ana River area	Model-Calculated
	Across Barrier E	Extension of Historical Trend*
*From updated flow model (1945-2000).		

Potential for Liquefaction

30. Liquefaction occurs as the result of both seismic activity (e.g., earthquake) and the presence of high groundwater. For most investigations, potential for liquefaction exists when groundwater is within 50 ft of the land surface (Matti and Carson, 1991; SCEC, 1999).

31. References used in determination of liquefaction potential in the SBBA include:

- Southern California Earthquake Center (SCEC), 1999. Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Liquefaction in California,

- Carson et al., 1986. Stratigraphic and geotechnical data from a regional drilling investigation in the San Bernardino Valley and vicinity, California. Open-File Report 86-225,
- Matti and Carson, 1991. Liquefaction Susceptibility in the San Bernardino Valley and Vicinity, Southern California – A Regional Evaluation. USGS Bulletin 1898.
- Topographic maps from the San Bernardino County Flood Control Department and topographic maps and digital elevation models (DEMs) from the USGS, and
- USGS, 2002. USGS CPT Data, San Bernardino County, California. http://quake.wr.usgs.gov/prepare/cpt/data/?map=sanbern (Accessed October 1, 2004).

Potential for Land Subsidence due to Groundwater Withdrawal

32. The model used to predict land subsidence as the result of the various operational scenarios in the SBBA was calibrated using land surface elevations, lithologic, elastic properties and groundwater level data from an area immediately east of the San Jacinto fault near Loma Linda.

33. The PRESS model was calibrated using historical land subsidence and groundwater level data from the City of Riverside's Raub Well #8. The Raub #8 is located in an area where subsidence was measured historically (1945 – 1968, Lofgren, 1971).

34. The geophysical borehole log for Raub #8 was obtained from the USGS to construct the lithologic log for subsidence modeling.

35. Values for virgin and elastic compressibility, and pre-consolidation were determined during the model calibration process. Vertical hydraulic conductivity values were obtained from the groundwater flow model, as well as from wells with similar lithology in the Chino Groundwater Basin.

VI. Santa Ana River Hydrology

36. In order to characterize the nature of flow in the Santa Ana River statistical parameters for various scenarios are provided. These include: the number of days of flow, flow rates, flow quantities and daily periods without flow.

37. Flow statistics are provided for:
    - Historical measured conditions,
    - No Project Condition (including the Seven Oaks Dam), and
    - Project Scenario A (maximum capture, see Section XI for scenario description).

38. Flow data for the analyses were provided by SAIC, and staff at GEOSCIENCE worked together with SAIC to generate the tables and charts that describe the nature of Santa Ana River flows on a statistical basis. Section 3.1 and Appendix A of the Draft EIR have additional statistical plots related to Santa Ana River flows.

39. Statistics on the annual number of days with flow in the Upper Santa Ana River, for each river segment, are provided in Table 3 below. Figures 1 – 3 show the number of days per water year (October 1 to September 30) that flow was recorded at each of the six river segments for each scenario. Graphs depicting the probability distribution and probability of exceedance for the number of days per water year with flow are included in Figure 4 - 6 and Figure 7 - 9, respectively.

Table 3. Upper Santa Ana River - Number of Days with Flow Statistics for Water Year 1966-67 through Water Year 1999-00

River Segment / Approximate Reach		*No. Days with Flow per Water Year*			
		Minimum	*Maximum*	*Median*	*Average*
Segment A Upstream of Seven Oaks (based on Combined Mentone Gage) Reach 6	Historical	364	366	365	365
	No Project	NA	NA	NA	NA
	Scenario A	NA	NA	NA	NA
Segment B Above Cuttle Weir (based on River Only Mentone Gage) Portion of Reach 5	Historical	65	366	356	310
	No Project	365	366	365	365
	Scenario A	365	366	365	365
Segment C Downstream of Cuttle Weir (Segment B minus WCD diversion) Portion of Reach 5	Historical	21	321	225	212
	No Project	0	300	64	93
	Scenario A	3	98	34	38
Segment D Below Mill Creek (Segment C plus Mill Creek) Portion of Reach 5	Historical	9	347	145	168
	No Project	5	302	134	160
	Scenario A	5	297	114	135
Segment E At E Street Based on E Street Gage (includes SBWRP effluent through 1995-96) Portion of Reach 4	Historical	66	366	365	348
	No Project	11	365	158	168
	Scenario A	10	365	157	159
Segment F Below RIX-Rialto Effluent Outfall Portions of Reach 4 and Reach 3	Historical	365	366	365	365
	No Project	365	366	365	365
	Scenario A	365	366	365	365

NA = not applicable
See Muni/Western Ex. 6-116 for segment and reach location
Source: USGS NWIS - Web Interface (Historical data); SAIC (No Project & Scenario A data)

40. Monthly flow rate statistics, for each river segment in the Upper Santa Ana River, are provided in Table 4 below. Graphs depicting the probability distribution and probability of exceedance are included in Figures 10 – 27, and Figures 28 – 46, respectively.

Table 4. Upper Santa Ana River - Monthly Average Flow Rate Statistics for Water Year 1966-67 to Water Year 1999-00

River Segment / Approximate Reach		*Flow Rate [cfs]*			
		Minimum	*Maximum*	*Median*	*Average*
Segment A Upstream of Seven Oaks (based on Combined Mentone Gage) Reach 6	Historical	9	1,052	48	87
	No Project	NA	NA	NA	NA
	Scenario A	NA	NA	NA	NA
Segment B Above Cuttle Weir (based on River Only Mentone Gage) Portion of Reach 5	Historical	0	1,052	7	51
	No Project	3	1,051	7	51
	Scenario A	3	419	3	12
Segment C Downstream of Cuttle Weir (Segment B - WCD diversion) Portion of Reach 5	Historical	0	995	2	33
	No Project	0	1,002	0	30
	Scenario A	0	375	0	2
Segment D Below Mill Creek (Segment C + Mill Creek) Portion of Reach 5	Historical	0	1,354	4	61
	No Project	0	1,385	3	58
	Scenario A	0	933	1	35
Segment E At E Street Based on E Street Gage (includes SBWRP effluent through 1995-96) Portion of Reach 4	Historical	0	2,096	37	93
	No Project	0	1,800	7	68
	Scenario A	0	1,589	7	54
Segment F Below RIX-Rialto Effluent Outfall Portions of Reach 4 and Reach 3	Historical	17	2,270	52	107
	No Project	70	1,695	86	142
	Scenario A	70	1,575	85	131

NA = not applicable
See Muni/Western Ex. 6-116 for segment and reach location
Source: USGS NWIS - Web Interface (Historical data); SAIC (No Project & Scenario A data)

41. Monthly flow quantity statistics, for each river segment in the Upper Santa Ana River, are provided in Table 5 below. Graphs depicting the probability distribution and probability of exceedance are included in Figures 47 – 64, and Figures 65 – 82, respectively.

Table 5. Upper Santa Ana River - Total Monthly Flow Quantity Statistics for Water Year 1966-67 to Water Year 1999-00

River Segment / Approximate Reach		*Total Flow [acre-ft]*			
		Minimum	*Maximum*	*Median*	*Average*
Segment A Upstream of Seven Oaks (based on Combined Mentone Gage) Reach 6	Historical	576	60,520	2,848	5,222
	No Project	NA	NA	NA	NA
	Scenario A	NA	NA	NA	NA
Segment B Above Cuttle Weir (based on River Only Mentone Gage) Portion of Reach 5	Historical	0	60,520	419	3,052
	No Project	167	58,389	450	3,090
	Scenario A	167	23,246	184	700
Segment C Downstream of Cuttle Weir (Segment B - WCD diversion) Portion of Reach 5	Historical	0	57,257	103	1,992
	No Project	0	55,656	0	1,793
	Scenario A	0	20,829	0	87
Segment D Below Mill Creek (Segment C + Mill Creek) Portion of Reach 5	Historical	0	77,868	222	3,644
	No Project	0	76,953	193	3,475
	Scenario A	0	51,831	68	2,096
Segment E At E Street Based on E Street Gage (includes SBWRP effluent through 1995-96) Portion of Reach 4	Historical	0	120,552	2,204	5,607
	No Project	0	103,573	443	4,064
	Scenario A	0	91,411	410	3,225
Segment F Below RIX-Rialto Effluent Outfall Portions of Reach 4 and Reach 3	Historical	1,023	139,584	3,119	6,465
	No Project	3,916	97,537	5,213	8,532
	Scenario A	3,916	90,596	5,137	7,868

NA = not applicable
See Muni/Western Ex. 6-116 for segment and reach location
Source: USGS NWIS - Web Interface (Historical data); SAIC (No Project & Scenario A data)

42. Annual Upper Santa Ana River flow quantity statistics, for each river segment, are provided in Table 6 below. Graphs depicting the probability distribution and probability of exceedance are included in Figures 83 – 85, and Figures 86 – 103, respectively.

Table 6. Upper Santa Ana River - Total Annual Flow Quantity Statistics for Water Year 1966-67 to Water Year 1999-00

River Segment / Approximate Reach		*Total Flow [acre-ft]*			
		Minimum	*Maximum*	*Median*	*Average*
Segment A Upstream of Seven Oaks (based on Combined Mentone Gage) Reach 6	Historical	13,434	216,327	39,157	62,664
	No Project	NA	NA	NA	NA
	Scenario A	NA	NA	NA	NA
Segment B Above Cuttle Weir (based on River Only Mentone Gage) Portion of Reach 5	Historical	280	204,837	12,170	36,623
	No Project	2,438	200,351	12,556	37,082
	Scenario A	2,172	31,302	7,421	8,397
Segment C Downstream of Cuttle Weir (Segment B - WCD diversion) Portion of Reach 5	Historical	266	169,357	4,582	23,907
	No Project	0	165,247	3,414	21,517
	Scenario A	0	20,829	0	1,045
Segment D Below Mill Creek (Segment C + Mill Creek) Portion of Reach 5	Historical	225	277,694	12,322	43,722
	No Project	64	272,576	9,333	41,706
	Scenario A	64	160,004	7,836	25,157
Segment E At E Street Based on E Street Gage (includes SBWRP effluent through 1995-96) Portion of Reach 4	Historical	11,480	320,016	34,908	67,280
	No Project	1,278	15,116	48,764	49,867
	Scenario A	1,323	227,313	14,301	38,696
Segment F Below RIX-Rialto Effluent Outfall Portions of Reach 4 and Reach 3	Historical	25,003	288,408	35,195	77,585
	No Project	54,454	314,425	76,058	102,380
	Scenario A	54,454	264,331	74,828	94,413

NA = not applicable
See Muni/Western Ex. 6-116 for segment and reach location
Source: USGS NWIS - Web Interface (Historical data); SAIC (No Project & Scenario A data)

43. Statistics on the annual number of days without flow in the Upper Santa Ana River, for each river segment, are provided in Table 7 below. Figures 104 – 106 show the number of days per water year that flow was not recorded at each of the six river segments for each scenario. Graphs depicting the probability distribution and probability of exceedance for the number of days per water year without flow are included in Figures 107 – 109 and Figures 110 – 112, respectively.

Table 7. Upper Santa Ana River - Number of Days without Flow
Statistics for Water Year 1966-67 through Water Year 1999-00

River Segment / Approximate Reach		*No. Days without Flow per Water Year*			
		Minimum	*Maximum*	*Median*	*Average*
Segment A Upstream of Seven Oaks (based on Combined Mentone Gage) Reach 6	Historical	0	2	0	0
	No Project	NA	NA	NA	NA
	Scenario A	NA	NA	NA	NA
Segment B Above Cuttle Weir (based on River Only Mentone Gage) Portion of Reach 5	Historical	0	300	9	55
	No Project	0	0	0	0
	Scenario A	0	0	0	0
Segment C Downstream of Cuttle Weir (Segment B minus WCD diversion) Portion of Reach 5	Historical	44	344	141	153
	No Project	65	366	301	272
	Scenario A	267	362	332	327
Segment D Below Mill Creek (Segment C plus Mill Creek) Portion of Reach 5	Historical	19	356	221	198
	No Project	63	360	231	206
	Scenario A	68	360	251	231
Segment E At E Street Based on E Street Gage (includes SBWRP effluent through 1995-96) Portion of Reach 4	Historical	0	299	0	17
	No Project	0	355	208	197
	Scenario A	0	356	209	206
Segment F Below RIX-Rialto Effluent Outfall Portions of Reach 4 and Reach 3	Historical	0	0	0	0
	No Project	0	0	0	0
	Scenario A	0	0	0	0

NA = not applicable
See Muni/Western Ex. 6-116 for segment and reach location
Source: USGS NWIS - Web Interface (Historical data); SAIC (No Project & Scenario A data)

VII. Project Area Geohydrology

44. The Project Area comprises Muni/Western's service areas, which includes all or portions of the groundwater basins: Bunker Hill, Lytle Creek, Rialto-Colton, Yucaipa, and San Timoteo. However, the main focus of the study was on the Bunker Hill and Lytle Basins, which collectively are referred to as the San Bernardino Basin Area (SBBA). The groundwater modeling work carried out by GEOSCIENCE was limited to the SBBA, with an analytical expression used to determine impacts from artificial recharge basins outside of the model area.

San Bernardino Basin Area

Location

45. The SBBA plays a central role in the water supply for communities within the Muni/Western service areas. The SBBA has a surface area of approximately 90,000 acres (141 square miles) and lies between the San Andreas and San Jacinto faults, as shown in Muni/Western Ex. 6-117. The basin is bordered on the northwest by the San Gabriel Mountains; on the northeast by the San Bernardino Mountains; on the east by the Banning fault and Crafton Hills; and on the south by a low, east-facing escarpment of the San Jacinto fault and the San Timoteo Badlands. Alluvial fans extend from the base of the mountains and hills that surround the valley and coalesce to form a broad, sloping alluvial plain in the central part of the valley.

46. The SBBA traditionally refers to two groundwater basins: Bunker Hill and Lytle Creek, (see Muni/Western Ex. 6-118). The Bunker Hill Groundwater Basin is further divided into sub-areas, including the Cajon, City Creek, Devil Canyon, Divide, Mill Creek, Pressure Zone, Redlands, and Reservoir sub-areas (see Muni/Western Ex. 6-119).

Geology and Aquifer System

47. The primary water-bearing formations of the SBBA are the unconsolidated sediments of older and younger alluvium and river channel material deposited and reworked by the Santa Ana River and tributaries such as Lytle Creek and Cajon Creek (Dutcher and Garrett, 1963). Near the mountain front, the unconsolidated deposits tend to be coarse-

grained and poorly sorted, becoming finer-grained and well sorted downstream. The older alluvium consists of continental, fluvial deposits, ranging in thickness from tens of feet to more than 800 ft. The younger alluvium is approximately 100 ft thick, composed mainly of floodplain deposits. The relatively recent river channel deposits are less than 100 ft thick but are among the most permeable sediments in the SBBA and contribute to large seepage losses from streams (Danskin et al., 2006).

48. Dutcher and Garrett (1963) divided the SBBA alluvial sediments into upper, middle, and lower confining members and upper, middle, and lower water-bearing members. However, the aquifer system of the SBBA is generally unconfined with water moving vertically between the multiple water-bearing layers. The confining members are more accurately described as leaky aquitards[2] of finer grained sediments.

49. The upper and middle water-bearing members provide most of the water to municipal and agricultural wells. In the central part of the SBBA, these areas are separated by as much as 300 ft of interbedded silt, clay, and sand (the middle confining member). This middle confining member produces confined conditions over the central part of the basin (referred to locally as the “confined area” or pressure zone), but thins and becomes less effective toward the margins of the basin (Dutcher and Garrett, 1963). Although the middle confining member is not as permeable as the adjacent water-bearing zones, this unit consists primarily of continuous sand and silt (not silt and clay as is found in most aquitards) and yields water to wells (Danskin et al., 2006). The lower confining and lower water-bearing member are not typically penetrated by most production wells and play a smaller role in the valley-fill aquifer, mainly due to deeper depths and generally lower permeability.

50. Three exceptions to the general presence of the leaky stratified system in the SBBA occur in the southwestern, southern, and eastern portions of the basin. The three separate water-bearing zones are not identifiable in the southwestern part of the basin, between the San Jacinto and Loma Linda faults (i.e., the Lytle Creek Basin - see Muni/Western

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[2] An aquitard is a low-permeability sedimentary unit that can store groundwater and also transmit it slowly from one aquifer to another (Fetter 1988). An aquitard is generally considered to be a barrier or partial barrier to movement of groundwater because water tends to move substantially slower through aquitards than aquifers.

Ex. 6-117 and 6-119), but are generally recognizable up to approximately four miles east of the Loma Linda Fault.

51. In part of a former marshland in the south part of the basin, between Warm Creek and the Santa Ana River, thick clay sequences in the Holocene younger alluvium result in confined to semi-confined aquifer conditions in the upper 50 to 100 ft of saturated materials. This area containing the upper confining member is referred to as the "Pressure Zone" (see Muni/Western Ex. 6-119). The upper aquitard is also absent adjacent to the San Bernardino Mountains (i.e., the "forebay"), allowing groundwater recharge from mountain stream runoff to percolate into the basin.

Groundwater Flow

52. The areal pattern of groundwater flow, from areas of recharge along the base of the mountains, to areas of discharge where the Santa Ana River crosses the San Jacinto Fault, has historically remained relatively unchanged. Groundwater elevation contours shown in Muni/Western Ex. 6-120 illustrate this flow regime in the SBBA. However, vertical groundwater movement has changed through time due to groundwater extraction and artificial recharge. Groundwater pumping has occurred from increasingly deeper depths, altering the natural vertical movement of groundwater by progressively draining deeper zones of groundwater (Danskin et al., 2006).

Recharge and Discharge

53. Percolation from gaged streams (such as the Santa Ana River, Lytle Creek, Cajon Creek, Devil Canyon Creek, East Twin Creek, Warm Creek, City Creek, Plunge Creek, and Mill Creek) is the major source of recharge in the SBBA. Recharge occurs both in the stream channels and in nearby artificial recharge basins. As a result of the highly permeable river-channel deposits and the artificial recharge operations, nearly all of the flow in the smaller gaged streams (Devil Canyon, Waterman, East Twin, Plunge, and San Timoteo creeks) is recharged to the aquifer close to the mountain front. During floods, the major streams (Santa Ana River, Mill Creek, and Lytle Creek) transmit large volumes of water over a short period, resulting in some surface water exiting the basin without contributing to groundwater recharge. Percolation from un-gaged streams and other runoff sources (i.e., streams that do not have USGS gages, or runoff from urban areas that is not gaged)

is less important than runoff in gaged streams since the total quantity of ungaged runoff is approximately one-tenth that of gaged runoff.

54. Recharge to the SBBA also results from underflow (subsurface inflow), direct infiltration of precipitation, return flow, infiltration from underground sanitary sewer lines and storm drains, and artificial recharge of imported water. Subsurface inflow to the SBBA occurs (1) across the Crafton Fault and through the poorly transmissive materials comprising the Badlands, (2) across a small section of unconsolidated deposits north of the Crafton Hills, and (3) through materials beneath the Cajon Creek and Lytle Creek channels. Underflow across the Crafton Fault and through the Badlands was defined by Dutcher and Fenzel (1972) to be approximately 6,000 acre-ft per year (acre-ft/year) for the period 1945 to 1965, and underflow beneath the creek channels was estimated by the DWR (1970) to be approximately 3,300 acre-ft/year for the period 1935 to 1960. Recharge from direct precipitation on the valley floor is generally minimal. An additional source of recharge is derived from return flow of water pumped from and used locally within the SBBA. Hardt and Hutchinson (1980) estimated return flow to be 30 percent of total extractions, except for wells that export groundwater directly out of the San Bernardino area. Artificial recharge of imported water to the SBBA began in 1972. Because of the extremely permeable sand and gravel deposits, recharge rates are high. Based on a recharge efficiency rate of 95 percent (applied water less losses), the total quantity of artificial recharge in the basin averaged approximately 7,400 acre-ft/year from 1972 to 1992. Because of the size of several of the recharge basins and exceptionally permeable material, a larger quantity of water could be imported and recharged along the base of the San Bernardino Mountains if necessary (i.e., recharge basin capacity and infiltration rates are not currently limiting the amount of imported water recharged).

55. Groundwater discharge from the SBBA occurs from (1) rising water, (2) subsurface outflow, and (3) groundwater extractions. Rising water primarily occurs in the lower reaches of Warm Creek, when nearby groundwater rises above the level of the channel bottom. The quantity of groundwater discharge into the creek for the period 1945 to 1992 was determined to be highly variable, with a maximum discharge exceeding 40,000 acre-ft/year and a minimum discharge of zero for 16 consecutive years, from 1963 to 1978 (Danskin et al., 2006). Subsurface outflow occurs across the San Jacinto Fault and

Barrier E[3] at two locations, including in the vicinity of the Santa Ana River at the Colton Narrows, and where Lytle Creek emerges from the San Gabriel Mountains, north of Barrier J (see Muni/Western Ex. 6-117). In the vicinity of the Santa Ana River at the Colton Narrows, subsurface outflow occurs in the younger alluvium. For the period 1936 to 1949, subsurface outflow in this area was estimated to range from 14,300 to 23,700 acre-ft/year (Dutcher and Garrett, 1963). Subsurface outflow north of Barrier J was estimated to be approximately 4,000 acre-ft/year, by Dutcher and Garrett (1963), and between 2,700 and 4,200 acre-ft/year during water years 1935 to 1960, by DWR (1970).

56. While stream flow and subsurface outflow contribute to basin discharge, groundwater extraction is the primary model discharge term. Extracted water is used for agricultural, municipal, and industrial purposes. Most pumping is located near major streams, including the Santa Ana River, Lytle Creek, Warm Creek, and East Twin Creek. This areal distribution of pumpage reflects the exceptionally permeable deposits that underlie stream channels and the abundant nearby recharge (Danskin et al., 2006). As the area has become urbanized, the quantity of agricultural pumpage has declined considerably, presently accounting for less than 20 percent of the gross pumpage (Danskin et al., 2006). However, overall pumpage has increased in the basin due to increased pumping for municipal and industrial purposes. Prior to 1940, gross pumpage in the basin was less than 110,000 acre-ft/year, while currently pumping has reached as high as approximately 200,000 acre-ft/year (Western–San Bernardino Watermaster, 2002).

57. Per the provisions of the Western Judgment, operational criteria with regard to the amount of water in storage, along with extractions and additions that are made on an annual basis, apply to the SBBA. The basin is maintained to not exceed the long-term natural safe yield, so that extractions made by pumping on the part of agencies with authority to do so must be replaced (or replenished) to the extent that they exceed the natural safe yield. Muni plays a critical role in these replenishment activities.

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[3] A groundwater barrier may be formed by faults transecting alluvial groundwater basins. The fault may create partial (i.e., leaky) or complete barriers to groundwater flow. It is well accepted in the groundwater industry that the barrier effect is the result of local and incomplete offsetting of gravel beds against clay beds, development of secondary clay gouge zones along the faults, and/or cementation of the gravel and sand beds immediately adjacent to the fault by deposition of carbonate minerals from rising water (Dutcher and Garrett, 1963). The barrier may have the affect of "damming" up groundwater on the upgradient side of the barrier, thereby causing differences in water levels on either side of the barrier.

<u>Groundwater Storage and Groundwater Levels</u>

58. The basin has an estimated total storage capacity of approximately 5,976,000 acre-ft (DWR, 2003).

59. Estimates are made annually of the change in groundwater volume (i.e., storage) in the SBBA by both Muni and the San Bernardino Valley Water Conservation District (Conservation District), from which a cumulative change in basin storage is calculated. The approach employed by Muni calculates the change in storage for nine sub-areas: Cajon, Devil Canyon, Lytle Creek, Pressure Zone, City Creek, Redlands, Mill Creek, Reservoir, and Divide (see Muni/Western Ex. 6-119). Calculating the change in storage for the SBBA is accomplished by summing individual values for each of the sub-areas.

60. The first change in storage calculation was completed for the years 1934-1960 by the DWR (DWR, 1970). The values were calculated using the Specific Yield Method and a mathematical model developed by TRW, Inc. (TRW, 1967). In 1980, Muni updated the change in storage calculation to include the years 1961-1980. In the early 1990s, Muni created a new change in storage model using software developed by Environmental Systems Research Institute (ESRI). In years of low precipitation, infiltration (direct from precipitation and from surface streams) decreases while groundwater extractions increase, thereby causing the cumulative storage to decrease. The trend in cumulative change in storage over the period 1934-2002 is shown in Muni/Western Ex. 6-121. The cumulative change in storage is cyclical based upon weather conditions. For example, 1934 through 1945 and 1979 through 1983 were wet periods, which produced increases in storage, while 1950 through 1966 was a dry period, resulting in decreased storage. To assist in the interpretation of Muni/Western Ex. 6-121 (and Muni/Western Ex. 6-122), an inset representing cumulative departure from average annual precipitation over the same time period is shown. These cycles are also evident in Muni/Western Ex. 6-123, which illustrates the average annual increase or decline in depth to groundwater across the entire basin.

61. The San Jacinto Fault generally runs perpendicular to the groundwater flow and acts as a partial barrier (e.g., similar to a subsurface, leaky dam) resulting in groundwater level differences across the fault. This phenomenon also contributes to the high groundwater located within the City of San Bernardino commonly referred to as the Pressure Zone.

Muni/Western Ex. 6-124 depicts depth to groundwater contours throughout the SBBA, Rialto-Colton Basin, and Yucaipa Basin, including those reflecting shallow groundwater conditions in the Pressure Zone. In the past, the groundwater level in the Pressure Zone has risen high enough to cause artesian flowing conditions[4].

62. For the basin as a whole, there can be wide fluctuations in the average depth to groundwater from year to year, with annual changes as high as approximately 40 feet (see Muni/Western Ex. 6-123). However, for the most part, annual changes register less than 20 feet (+ or -), with only six years exceeding this range. There are, however, noticeable variations in behavior across management zones.

63. The Lytle Creek Basin contains Lytle Creek with extensive headwaters in the adjacent mountain areas and a river channel comprised of deep, porous alluvial deposits. Due to the presence of Lytle Creek and its relatively small size, this management zone exhibits far greater and more extreme changes than any other management zone of the SBBA. In 40 of the 68 years, the annual average change in depth to groundwater exceeds 20 feet, with 8 years showing changes greater than 50 feet, and 3 years showing changes greater than 100 feet (see Muni/Western Ex. 6-125).

Groundwater Quality

64. Groundwater in the SBBA is generally a sodium/calcium bicarbonate type, containing equivalent amounts of sodium and calcium near the land surface and an increasing predominance of sodium in deeper parts of the valley-fill aquifer. A total dissolved solids (TDS) range of 150 to 550 milligrams per liter (mg/L), with an average of 324 mg/L, is found in public water supply wells (DWR, 2003). The water quality objectives (WQOs) for the SBBA are provided in Table 8, with the management zones locations of the SBBA shown on Muni/Western Ex. 6-126.

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[4] Condition where the groundwater level rises above the land surface in confined aquifers.

Table 8. Groundwater Quality Objectives for the SBBA[a]

Groundwater Management Zone	*Total Dissolved Solids (TDS)*	*Nitrate-Nitrogen (NO_3-N)*	*Nitrate (NO_3)*
Bunker Hill A	310	2.7	12.1
Bunker Hill B	330	7.3	32.8
Lytle Creek	260	1.5	6.7

a. All measurement units are milligrams per liter (mg/L) which is the equivalent of parts per million (ppm).
Source: SARWQCB, 2004.

65. The Office of Environmental Health Hazard Assessment (OEHHA) developed Public Health Goals (PHGs) for nitrate. These are equivalent to California's current drinking water standards of 45 parts per million (ppm) for NO_3, the equivalent of 10 ppm NO_3-N.

66. The inorganic composition of the groundwater may be affected by warm water emanating from faults and fractures in the bedrock surface underlying the aquifer. For example, concentrations of fluoride that exceed drinking water standards have limited the use of groundwater extracted near some faults and from deeper parts of the aquifer. In some public water supply wells in the SBBA, some inorganics (primary and secondary), radiological constituents, nitrates, pesticides, VOCs, and synthetic organic chemicals (SOCs) were found above the applicable MCL (see Table 9). However, all water delivered to public water users is treated prior to delivery and the quality of this water meets or is of better quality than the applicable state and Federal standards.

Table 9. Prevalence of Contaminants in SBBA Wells

Constituent	*No. Wells Sampled*	*No. Wells with a Concentration Above an MCL*
Inorganics (primary)	212	13
Radiological	207	34
Nitrates	214	34
Pesticides	211	20
VOCs and SOCs	211	32
Inorganics (secondary)	212	25

Source: DWR, 2003.

67. The SBBA is affected by five major groundwater contaminant plumes: the Redlands-Crafton, Norton Air Force Base, Muscoy, Newmark, and Santa Fe plumes. The major constituents of each plume are summarized in Table 10 and their locations shown on Muni/Western Ex. 6-127.

Table 10. Constituents in Groundwater Contamination Plumes in the SBBA

Contaminant Plume	*TCE*[a]	*Perchlorate*	*PCE*[b]	*DBCP*[c]	*VOC*[d]	*Superfund Site*
Redlands-Crafton	X	X		X		
Norton AFB	X		X			
Muscoy	X		X			X
Newmark	X		X			X
Santa Fe	X		X		X	

Notes:
a. TCE = trichloroethylene
b. PCE = tetrachloroethylene
c. DBCP = dibromochloropropane
d. VOCs = volatile organic compounds

Updated table from comments addressed in Final EIR (page 3-290)

Rialto–Colton Groundwater Basin

Location

68. The approximately 30,100-acre (47 square mile) Rialto–Colton Basin lies to the west of the SBBA. The basin is bounded on the northwest by the San Gabriel Mountains; on the northeast by the San Jacinto Fault and Barrier E; on the southeast by the Badlands; and on the southwest by the Rialto-Colton Fault (see Muni/Western Ex. 6-117 and 6-118). Except in the southeastern part of the basin, the San Jacinto and Rialto–Colton faults act as groundwater barriers that impede flow into and out of the basin (Woolfenden and Koczot, 1999).

Aquifer System and Groundwater Flow

69. The basin consists of four water-bearing units: the river channel; upper; middle; and lower. Groundwater generally moves from east to west in the river channel and upper water-bearing units. In the middle and lower water-bearing units, water moves from

northwest to southeast. Groundwater movement is affected by two internal faults, Barrier J and an unnamed fault. Water moves across Barrier J into the unfaulted part of the groundwater system. The unnamed fault is a partial barrier to groundwater movement in the middle water-bearing unit and is an effective barrier in the lower water-bearing unit (Woolfenden and Koczot, 1999).

70. Woolfenden and Koczot (1999) of the USGS used a groundwater flow model to simulate groundwater flows in the Rialto-Colton Basin with particular attention placed on the effects of artificial recharge at the Cactus Spreading and Flood Control Basins and Linden Ponds. Simulated flow patterns based on historical artificial recharge activities at the Cactus Spreading and Flood Control Basins are illustrated in Muni/Western Ex. 6-128. As indicated by the flow paths, recharged water moves in a southeasterly direction away from Cactus Spreading and Flood Control Basins toward the channel of the Santa Ana River.

Recharge and Discharge

71. Sources of recharge to the Rialto–Colton Basin are subsurface inflow from the SBBA, precipitation, imported water, seepage from the Santa Ana River and Warm Creek, and irrigation return flow (Woolfenden and Koczot, 1999). Since 1971, pumping from the basin has varied from a low of approximately 5,000 acre-ft in 1983 to a high of approximately 17,600 acre-ft in 1990. In 2000, pumping was approximately 13,000 acre-ft (Western–San Bernardino Watermaster, 2002).

Groundwater Storage and Groundwater Levels

72. The basin has an estimated total storage capacity of approximately 213,000 acre-ft. The Rialto portion of the basin accounts for approximately 120,000 acre-ft of storage, with the remaining 93,000 acre-ft within the Colton portion of the basin (DWR, 2003).

73. Water levels vary across the basin due to the presence of internal faults. For example, in the northern part of the basin, groundwater levels rise quickly following rainfall. In the 1990s, and in this northern area of the basin, it was typical for groundwater levels to vary by 50 ft in a given year (DWR, 2003). However, in the southern part of the basin, groundwater levels are more static and water levels generally varied by only 5 to 10 ft per year in the 1990s (DWR, 2003).

Groundwater Quality

74. Total dissolved solids in public water supply wells in the Rialto–Colton Basin average 264 mg/L with a range of 163 to 634 mg/L (DWR, 2003). The WQOs for the Rialto-Colton Basin are provided in Table 11.

Table 11. Groundwater Quality Objectives for the Rialto-Colton Basin[a]

Groundwater Management Zone	*Total Dissolved Solids (TDS)*	*Nitrate-Nitrogen (NO_3-N)*
Rialto	230	2.0
Colton	410	2.7

a. All Measurement units are milligrams per liter (mg/L) which is the equivalent of parts per million (ppm).
Source: SARWQCB, 2004

75. The San Jacinto Fault markedly affects the groundwater chemistry in the basin. The TDS in groundwater downstream from the San Jacinto Fault is greater than that in the surface water found in the Bunker Hill outflow area. It is also higher in dissolved solids than well water just upstream from the fault.

76. Of the 38 public water supply wells sampled, two were over the MCL for nitrates and, in three wells, secondary inorganics, VOCs, and semivolatile organic compounds (SVOCs) exceeded the MCL (Table 12). Table 12 shows that most of the wells sampled did not contain constituents over the MCL. More than 143 water wells in Riverside and San Bernardino counties now exceed 4 parts per billion (ppb) of perchlorate (CA DHS, 2007). This 4 ppb level was the former Public Health Goal (PHG) established by the Office of Environmental Health Hazard Assessment (OEHHA). The current notification level is 6 ppb (CA DHS, 2007). Within the Muni service area of the Rialto-Colton Basin, the City of Rialto, City of Colton, West Valley Water District, and the Fontana Water Company have shut down or restricted the use of a number of wells due to perchlorate contamination in the where concentrations are above 6 ppb.

Table 12. Prevalence of Contaminants in Rialto-Colton Basin Wells

Constituent	*No. Wells Sampled*	*No. Wells with a Concentration Above an MCL*
Inorganics (primary)	38	0
Radiological	40	0
Nitrates	38	2
Pesticides	40	0
VOCs and SVOCs	40	3
Inorganics (secondary)	38	3

Source: DWR, 2003.

Yucaipa Groundwater Basin

Location

77. The 25,300-acre Yucaipa Basin lies to the east-southeast of the SBBA and is bounded on the north by the San Andreas fault; on the west by Crafton Hills; on the south by the Banning Fault; and on the east by the Yucaipa Hills (see Muni/Western Ex. 6-117).

Groundwater Flow

78. Groundwater movement in the Yucaipa Basin is generally from the mountains and hills located to the north and east, in southward and westward directions. However, there are a number of faults, including the Chicken Hill Fault, Yucaipa Barrier, Casa Blanca Fault, and Gateway Barrier that influence the direction of flow on a local level. These faults cause offsets in groundwater levels by as much as 160 ft. In the western part of the basin, northeast dipping beds of the San Timoteo Formation form barriers that cause artesian conditions (DWR, 2003).

Groundwater Storage and Groundwater Levels

79. Groundwater storage capacity in the Yucaipa Basin is estimated to be between 783,000 and 1,230,000 acre-ft, and pumping from the basin for domestic and irrigation use is estimated at 13,800 acre-ft/year (DWR, 2003). Recharge to the basin is from percolation, infiltration from local overlying streams, subsurface inflow, and artificial recharge at spreading grounds. Groundwater levels have declined historically in the

Yucaipa Basin. The decline was gradual from the 1930s until increased development and associated pumping (beginning after World War II) caused more rapid declines (DWR, 2003).

Groundwater Quality

80. Most of the recent groundwater samples from the Yucaipa Basin indicate a calcium bicarbonate type groundwater (DWR, 2003), generally meeting EPA drinking water standards, with little variation across the basin. Groundwater has higher mineral concentrations, but otherwise is similar to the surface water in the area. The average TDS from public water supply wells is 322 mg/L with a range of 200 to 630 mg/L. The WQOs for the Yucaipa Basin are provided in Table 13.

Table 13. Groundwater Quality Objectives for the Yucaipa Basin[a]

Groundwater Management Zone	*Total Dissolved Solids (TDS)*	*Nitrate-Nitrogen (NO_3-N)*
Yucaipa “maximum benefit”[b]	370	5.0
Yucaipa “anti-degradation”[c]	320	4.2

a. All measurement units are milligrams per liter (mg/L) which is the equivalent of parts per million (ppm).
b. Maximum benefit means that the objectives for the management zones assure protection of beneficial uses and are of maximum benefit to the people of the State. If the Regional Board finds that the maximum benefit is not demonstrated, then the anti-degradation objectives for these water will apply.
c. Anti-degradation objectives are the historical ambient quality TDS and nitrate-nitrogen objectives. These objectives were based partly on consideration of anti-degradation requirements (State Board Resolution No. 68-16) and factors specified in Water Code Section 13241.
Source: SARWQCB, 2004

81. Table 14 contains data from wells sampled for various pollutants (DWR, 2003). MCL concentrations in most samples in the basin did not exceed the applicable standard.

Table 14. Prevalence of Contaminants in Yucaipa Basin Wells.

Constituent	*No. Wells Sampled*	*No. Wells with a Concentration above an MCL*
Inorganics (primary	43	1
Radiological	44	1
Nitrates	46	12
Pesticides	43	4
VOCs and SOCs	44	1
Inorganics (secondary)	43	4

Source: DWR, 2003

San Timoteo Groundwater Basin

__Location__

82. The 73,100-acre San Timoteo Basin is located southeast of the Bunker Hill Basin and south of the Yucaipa Basin (see Muni/Western Ex. 6-118). The Banning Fault marks the northern boundary, and the San Jacinto Fault marks the southern boundary of the San Timoteo groundwater basin (DWR, 2003) (Muni/Western Ex. 6-117). The western part of the basin is bounded by the San Jacinto Mountains and the eastern boundary is a topographic drainage divide with the Colorado River system (DWR, 2003).

__Aquifer System__

83. Alluvium, the principal water-bearing unit of the San Timoteo Basin, is thickest near the City of Beaumont and thins to the southwest, but is not present in the central portion of the basin. The San Timoteo Formation, comprised of folded and eroded alluvial deposits, is the other water-bearing unit in the basin. The total thickness of the San Timoteo Formation is estimated to be between 1,500 and 2,000 ft, but groundwater levels in the central part of the basin indicate water-bearing gravels to depths of only 700 to 1,000 ft (DWR, 2003).

__Groundwater Flow__

84. Groundwater flow, which is generally from east to west toward the SBBA, is affected by local faulting. Groundwater levels across the Banning Fault drop 100 to 200 ft to the

south. In the western part of the basin, groundwater levels drop to the south approximately 75 ft across the Loma Linda Fault and approximately 50 ft across the San Timoteo Barrier (DWR, 2003). In the northeastern part of the basin, groundwater levels drop to the south across two unnamed faults (DWR, 2003).

Recharge and Discharge

85. Recharge to the San Timoteo Basin is from the percolation of runoff carried in streams, groundwater inflow from adjacent areas, percolation of direct precipitation, and percolation of water imported for domestic or irrigation use.

Groundwater Storage and Groundwater Levels

86. The total storage capacity of alluvial deposits in the basin is estimated to be approximately two million acre-ft, which is an increase from estimated 1960 groundwater storage levels of approximately 1,570,000 acre-ft (DWR, 2003). Runoff and imported water are delivered to streambeds and spreading grounds for percolation and groundwater recharge (DWR, 2003).

87. A study of change in groundwater levels between 1933 and 1960 revealed distinctive characteristics for wells in alluvial deposits in different parts of the basin. Hydrographs for wells in centrally located San Timoteo Canyon illustrated low annual fluctuations, while wells in the northeast portion of the basin showed high annual fluctuations. Other areas showed a continual downward trend (DWR, 2003).

Groundwater Quality

88. The mineral character of groundwater beneath San Timoteo Canyon is sodium bicarbonate; calcium bicarbonate in the alluvium of Little San Gorgonio Creek; calcium bicarbonate in younger alluvium near Beaumont; and sodium bicarbonate in older deposits (DWR, 2003). Water samples from 24 public water supply wells have an average TDS content of approximately 253 mg/L, with a range of 170–340 mg/L (DWR, 2003). The WQOs for the San Timoteo Basin are provided in Table 15.

Table 15. Groundwater Quality Objectives for the San Timoteo Basin[a]

Groundwater Management Zone	*Total Dissolved Solids (TDS)*	*Nitrate-Nitrogen (NO_3-N)*
San Timoteo "maximum benefit"[b]	400	5.0
San Timoteo "anti-degradation"[c]	300	2.7

a. All measurement units are milligrams per liter (mg/L) which is the equivalent of parts per million (ppm).
b. Maximum benefit means that the objectives for the management zones assure protection of beneficial uses and are of maximum benefit to the people of the State. If the Regional Board finds that the maximum benefit is not demonstrated, then the anti-degradation objectives for these water will apply.
c. Anti-degradation objectives are the historical ambient quality TDS and nitrate-nitrogen objectives. These objectives were based partly on consideration of anti-degradation requirements (State Board Resolution No. 68-16) and factors specified in Water Code Section 13241.
Source: SARWQCB, 2004

89. Out of 27 sampled wells, one well contained secondary inorganics above the MCL (see Table 16); otherwise, no contaminants were found (DWR, 2003).

Table 16. Prevalence of Contaminants in San Timoteo Basin Wells

Constituent	*No. Wells Sampled*	*No. Wells with a Concentration above an MCL*
Inorganics (primary	27	0
Radiological	26	0
Nitrates	28	0
Pesticides	27	0
VOCs and SOCs	27	0
Inorganics (secondary)	27	1

Source: DWR, 2003

VIII. Derivation of Hydrologic Base Period

Introduction and Criteria for Base Period Selection

90. For purposes of the work performed for this testimony, the hydrologic base period is the period of time over which changes in surface and groundwater conditions were evaluated. Selection of a hydrologic base period that represents long-term hydrologic conditions was necessary prior to conducting surface water and groundwater modeling of the Santa Ana River and San Bernardino Basin Area (SBBA). In general, a hydrologic base period should have the following characteristics (Mann, 1968; Nevada Division of Water Resources, 2000):

- Average precipitation of the base period should be approximately equal to the average precipitation of the long-term record;

- Average surface water runoff of the base period should be approximately equal to the average runoff of the long-term record;

- The hydrologic base period should contain periods of wet, dry, and average hydrologic conditions;

- The hydrologic base period should be sufficiently long to contain data representative of the averages, deviations from the averages, and extreme values of the entire historical period (typically a 20- to 30-year period; Mann, 1968);

- Contain a dry trend at both the beginning and end of the period in order to minimize the difference between the amount of water in transit in the soil at either end of the base period (Nevada Division of Water Resources, 2000); and

- Be representative of recent environmental and cultural conditions (e.g., land use, extent of urbanization, urban runoff) in order to use the base period in forecasting models.

Precipitation Stations

Length of Record

91. Historical precipitation records are available from twenty stations within or immediately adjacent to the SBBA (see Muni/Western Ex. 6-129). To be consistent with the availability of other hydrologic data (e.g., groundwater pumping), the period of record for each precipitation station does not extend past Water Year 1999-2000. The length of record for each precipitation station varies widely, ranging from 29 to 117 years (see Muni/Western Ex. 6-130).

92. As indicated in Muni/Western Ex. 6-130 there are three stations (Big Bear Lake Dam, Redlands Facts and San Bernardino County Hospital) that have over 100 years of precipitation data. Due to their sufficiently long periods of records, these three stations were closely evaluated during the process of selecting a base period.

Statistics

93. Since all twenty precipitation stations had sufficiently long periods of record (i.e., more than 20 years), it was possible to evaluate hydrologic cycles for a series of potential base periods. The potential base periods selected ranged from Water Year 1944-45 - 1999-2000, to Water Year 1969-70 - 1999-2000. Water Year 1944-45 was selected as the earliest potential start of the hydrologic base period as it coincided with the start of calibration for the groundwater model. Water Year 1969-70 was selected as the latest potential base period start, as any later start would not meet the necessary criteria (i.e., sufficiently long precipitation record with periods of wet, dry and average hydrologic conditions, etc.).

94. Using historical precipitation data, the average annual precipitation at each station for the 26 potential base periods was compared against the long-term average annual precipitation for each station. The long-term average annual precipitation at each station was determined based on the 1870-1970 average annual precipitation isohyetal map for the SBBA (see Muni/Western Ex. 6-129). Muni/Western Ex. 6-131 shows each station's percentage of measured average annual precipitation for each base period vs. the long-term average annual precipitation obtained from the 1870-1970 isohyetal map. In general, there is a range between stations for the same potential base period. For

example, for the potential base period starting from 1965, the range varies from 86% at Mill Creek Intake #3 station (i.e., measured average annual precipitation for the base period was less than the average long-term precipitation obtained from the ioshyetal map) to 118% at Crestline S.E. station (i.e., measured average annual precipitation for the base period was more than the average long-term precipitation obtained from the ioshyetal map). One explanation for the variation may be due to using the 1870-1970 isohyetal map for the long-term average annual precipitation. The isohyetal map depicts lines of equal precipitation that were interpolated from various precipitation stations. Those stations were not all the same stations used in this analysis, and therefore it is not perfectly correlated with the actual station data. Muni/Western Ex. 6-132 shows the three stations with more than 100 years of record. As shown, the variation between the measured average precipitation for each of the base periods and the long-term average annual precipitation from the isohyetal map is reduced significantly.

95. As the long-term average annual precipitation using the isohyetal map ended in 1970, the long-term measured annual precipitation for available stations was also used in the analysis to evaluated more recent conditions. In this case, the average annual measured precipitation at each station for all potential base periods, was compared against the respective station's measured long-term average annual precipitation (see Muni/Western Ex. 6-133). As shown, there are variations between stations for the same potential base period. The variation between the stations for the same potential base period is reduced significantly if only the three stations with periods of record greater than 100 years are used (see Muni/Western Ex. 6-134).

Streamflow

Streamflow Data

96. The annual streamflow data at the "Combined Flow" gaging station at Mentone (11051501) was provided by SAIC. The "Combined Flow" is a combination of three gaging stations:

- SCE Canal gage (USGS No. 11049500),
- Auxiliary Diversion gage (USGS No. 11051502), and
- Mentone gage (USGS No. 11051499).

97. Flow recorded for the Combined Flow gage represents the sum of streamflow recorded in the Santa Ana River at the Mentone gage, in addition to flow that would have been in the river at this location had it not been diverted upstream for use in the SCE hydroelectric system and at other points of diversion. This combined flow is the major source of groundwater recharge for the SBBA.

__Statistics__

98. The average annual streamflow for each of the potential base periods at the Mentone "Combined" gage were compared to the gage's long-term average annual streamflow (see Muni/Western Ex. 6-135). This analysis was used to assess which base period had a streamflow that was closest the long-term streamflow.

Determining the Appropriate Hydrologic Base Period

99. From the analyses of precipitation and streamflow described above, 26 potential base periods were examined, all of which ended in Water Year 1999-2000 which would reflect recent environmental and cultural conditions. Also, Water Year 1999-2000 is the latest year for which verified groundwater pumping data were available. The starting year of potential base periods (starting year) ranged from Water Year 1944-45 to Water Year 1969-70.

100. Based on analyses of historical precipitation and streamflow, the 39-year period from October 1961 through September 2000 (Water Year 1961–62 through Water Year 1999–00) was selected as the hydrologic base period used in this study. This base period covers both wet and dry hydrologic cycles, and the average precipitation is approximately the same as the long-term average (see Muni/Western Ex. 6-136). During this period, the average annual precipitation at the San Bernardino County Hospital station, Redlands Facts station, and the Big Bear Lake Dam station was 98%, 99% and 95% of long-term average annual precipitation based on the 1870-1970 isohyetal map, respectively; and their average measured annual precipitation was 98%, 97% and 97% of long-term average measured annual precipitation, respectively. During this time period, the average annual streamflow at the Combined Mentone gage was 99% of the long-term annual average.

IX. Groundwater Models Used to Evaluate Availability of Unappropriated Water MODFLOW Groundwater Flow Model

MODFLOW Groundwater Flow Model

General Description and Purpose of Model

101. The groundwater flow model, developed by the USGS for the SBBA (Danskin et al., 2006), was adapted for purposes of this study. The USGS model uses the MODFLOW code which is a block-centered, three-dimensional, finite difference groundwater flow model developed by the USGS. The MODFLOW model used in this study is an integrated groundwater / streamflow model.

102. The purpose of the groundwater flow model was to evaluate potential impacts of various proposed Seven Oaks Reservoir water diversion scenarios on groundwater levels and quality in the SBBA. Any negative impacts shown by modeling results were used as guidelines to modify the Allocation Model's water delivery scenarios (see Section IV for brief model description). This iterative process was continued until the there were no significant negative impacts.

Use of the USGS Flow Model

103. The USGS SBBA groundwater flow model electronic files were made available through Muni, an agency which cooperated with the USGS in developing the model. The pre-processing software "Groundwater Vistas"[5] was used to construct the MODFLOW model based on the USGS's model files. The transient model calibration for the period from 1945 to 1998 was then rerun, and cumulative inflow and outflow terms compared to USGS results. To ensure that the USGS SBBA model data was appropriately transferred to GEOSCIENCE computers, peer review meetings were held with the model's author (Wes Danskin of USGS)[6].

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[5] Environmental Simulations, Inc., 2001. Groundwater Vistas, Version 3.

[6] Meetings with Wes Danskin were held on: December 19, 2002 and June 16, 2003.

104. The following sections describe the construction of the USGS groundwater flow model including the conceptual model, model cells, layers, boundary conditions, aquifer properties and model flux terms (recharge and discharge).

Conceptual Model

105. The USGS SBBA groundwater flow model is an integrated groundwater and streamflow model developed for streams and the valley-fill aquifer of the SBBA including Bunker Hill and Lytle Basins (see Muni/Western Ex. 6-137 and 6-138). The groundwater model consists of two model layers: Layer 1 contains the upper confining member and upper water-bearing zone, while Layer 2 consists of the middle and lower confining members and middle and lower water-bearing zone (see Muni/Western Ex. 6-139). Groundwater flow between the two layers is restricted by numerous fine-grained deposits in the middle confining member. Near the mountain front, the fine-grained deposits thin to extinction, and the two layers act as one. The streams crossing the model are in hydraulic continuity with the aquifers and therefore can be both influent (losing water to the aquifer) and effluent (gaining water from the aquifer). The streamflow inflow components are generated from surface runoff originating from rain events as well as water gained from aquifers. The streamflow outflow components include deep percolation to underlying aquifers and flow out of the basin. The primary sources of recharge to the model area include gaged streams, seepage from ungaged runoff, direct infiltration of precipitation, recharge from local runoff (i.e., runoff originating from precipitation), artificial recharge (of imported water and to a lesser extent, local runoff), return flow from groundwater pumping, and underflow from adjacent basins. The primary discharge terms are groundwater extraction, evapotranspiration, and subsurface outflow.

Model Cells, Layers and Time Step

106. The USGS SBBA groundwater flow model is a two-layered model that covers approximately 524 square miles and consists of 118 nodes[7] in the north-to-south direction (i-direction) and 184 nodes in the west-to-east direction (j-direction), for a total of 43,424 cells (see Muni/Western Ex. 6-137). Note that the entire model area (524 square miles) is larger than the active cells representing the groundwater basin (141 square miles).

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[7] A model "node" is the center of a model "cell." The model cells are square with a side of 820 ft. The network of model cells forms a "grid" or "mesh" covering the entire model area.

107. Each model cell represents an area of approximately 15 acres (820 ft by 820 ft).

108. The model period (i.e., length of time when model parameters may change, e.g., pumping, streamflow, etc.) is on an annual basis. These time periods are called model "stress periods". Each annual stress period is subdivided into 100 time steps which are used by the model to "step" the model forward in time. The use of small time steps increases the accuracy of model results.

Boundary Conditions

109. The SBBA is bordered on the northwest by the San Gabriel Mountains, on the northeast by the San Bernardino Mountains, on the southeast by the Crafton Fault, and on the southwest by the San Jacinto Fault (see Muni/Western Ex. 6-137).

110. The mountainous areas to the northwest and northeast represent impermeable boundaries and were assigned "no-flow" or "inactive" cells. Groundwater recharge along the mountain front was simulated using MODFLOW's Well Package. Surface inflow from streams was simulated using MODFLOW's Streamflow-Routing Package. Unconsolidated or poorly consolidated sediments southeast of the Crafton Fault (Yucaipa Basin and San Timoteo Basin), and southwest of the San Jacinto Fault (Rialto-Colton Basin and Riverside Basin), were also assigned as "no-flow" or "inactive" cells. The underflow recharge or discharge across these faults was simulated using MODFLOW's Well Package.

Aquifer Parameters

Transmissivity

111. The initial transmissivity values used by the USGS model were based on values from Hardt and Hutchinson (1980). Hardt and Hutchinson used transmissivity values calculated from specific capacity tests performed by the California DWR (1970) and modified based on model calibration. The final transmissivity values used by the USGS model are shown in Muni/Western Ex. 6-140. For Model Layer 1, the transmissivity ranges from approximately 200 to 1,000 ft^2/day (1,500 to 7,500 gpd/ft) in the Cajon Canyon area, to 23,000 ft^2/day (172,000 gpd/ft) near the center of the SBBA. For Model Layer 2, the transmissivity ranges from approximately 200 to 1,000 ft^2/day (1,500 to

7,500 gpd/ft) in the Cajon Canyon area to 43,000 ft^2/day (322,000 gpd/ft) near the center of the SBBA (see Muni/Western Ex. 6-140).

Storativity

112. The initial storativity values for Model Layer 1 (conceptualized as an unconfined aquifer) were assigned specific yield[8] values ranging from 0.04 to 0.17 based on Eckis (1934) – see Muni/Western Ex. 6-141. For the Model Layer 2, a storativity for a confined aquifer (0.0001) was assigned.

Vertical Leakance

113. Model Layers 1 and 2 are in hydraulic continuity with flow across the model layer boundary dependent upon the hydraulic head difference between the layers as well as the leakance[9]. The initial leakance values used by the USGS model were based on Hardt and Hutchinson (1980) data that were refined by model calibration. The final leakance values range from approximately 0.0001 day^{-1} in the pressure zone, to 0.03 day^{-1} near the base of the San Gabriel and San Bernardino Mountains (see Muni/Western Ex. 6-142). This distribution reflects the variations of aquitard thickness and aquitard material hydraulic conductivity.

Conductance for Groundwater Barriers

114. The USGS model considers several faults and groundwater barriers to be “partial” barriers to groundwater flow within the aquifer systems of the SBBA. The locations of these faults and groundwater barriers were delineated from Matti and Carson (1991) and Dutcher and Garrett (1963). The groundwater barriers were simulated in the model using the Horizontal-Flow-Barrier Package and assigning a lower hydraulic characteristic value (barrier transmissivity divided by the width of the horizontal-flow barrier) to the boundary of the barrier. The values were derived primarily by trial-and-error during the model calibration. Muni/Western Ex. 6-143 shows the model cells and final hydraulic characteristic values used for the Horizontal-Flow-Barrier Package. The smaller the hydraulic characteristic value, the greater the effectiveness of the groundwater barrier.

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[8] Equivalent to effective porosity or “drainable” porosity and essentially equal to storativity of unconfined systems.

[9] “Leakance” as defined by Hantush (1964) is the rate of flow that crosses a unit area of the interface between the main aquifer and the semi-pervious layer (i.e., “leaky layer”) if the difference between the heads at the top and bottom of the semi-pervious layer is unity.

For Model Layer 1, the hydraulic characteristic value ranges from approximately 0.03 ft/day for the northwest segment of Loma Linda Fault, to approximately 24 ft/day for the southeast segment. For Model Layer 2, the values range from approximately 0.03 ft/day for the northwest segment of Loma Linda Fault to approximately 12 ft/day for Barrier G (see Muni/Western Ex. 6-143 for barrier location).

Recharge and Discharge

115. Recharge and discharge terms (i.e., “flux” terms) in the SBBA were simulated using MODFLOW’s Streamflow-Routing Package, Recharge Package, Well Package and Evapotranspiration Package. Table 17 shows recharge and discharge terms and the associated MODFLOW package used by the USGS model.

Table 17. Recharge and Discharge Terms and Associated MODFLOW Package Used

Recharge and Discharge Flux Used on the Model		*MODFLOW Package*
Recharge	Gaged Streamflow	Streamflow-Routing
	Recharge from Ungaged Mountain Front Runoff	Well
	Imported Water	Well
	Return Flow from Groundwater Pumping	Well
	Underflow	Well
	Infiltration from Direct Precipitation	Recharge
	Recharge from Local Runoff Generated from Precipitation	Recharge
Discharge	Groundwater Pumping	Well
	Evapotranspiration	Evapotranspiration
	Gaged Streamflow	Streamflow-Routing
	Underflow	Well

Streamflow-Routing Package

116. The Streamflow-Routing Package was used to simulate the recharge and discharge of the gaged mountain front runoff through interaction between major streams and aquifers of the SBBA. Streamflow was routed down the stream channels, through Spreading Grounds and past the outflow gages near the San Jacinto Fault. A total of 56 “segments”

were identified (see Muni/Western Ex. 6-144). A stream segment is defined as the longest portion of a surface watercourse having no tributaries.

117. Segments 1, 2, 5, 17, 19, 30, 33, 35, 42 and 53 receive surface runoff from the drainage area tributary to each segment. The surface runoff inflow for these segments was based on the annual discharge of each segment's mountain front gage. These gages include Lytle Creek near Fontana (Segment 1), Cajon Creek below Lone Pine Creek near Keenbrook (Segment 2), Devil Canyon Creek near San Bernardino (Segment 5), Waterman Canyon Creek near Arrowhead Springs (Segment 17), East Twin Creek near Arrowhead Springs (Segment 19), City Creek near Highland (Segment 30), Plunge Creek near East Highlands (Segment 33), Santa Ana River near Mentone (Segment 35), Mill Creek near Yucaipa (Segment 42), and San Timoteo Creek near Redlands (Segment 53).

118. Inflow from surface runoff during the USGS calibration period 1945-1998 for each gage is shown in the Addendum as Muni/Western Ex. 6-5 through 6-14. Muni/Western Ex. 6-145 shows the total inflow from surface runoff to the SBBA. As shown, during the model calibration period (1945 to 1998), the total surface water inflow from these gages ranges from 35,900 acre-ft in 1961, to 674,000 acre-ft in 1969 with an annual average of 146,700 acre-ft/year.

119. A stream "reach" is defined as the portion of a stream segment that transects a single model grid cell. Model cells containing a portion of a stream across a corner or along an edge were generally included as reaches. Reaches were identified by their "ij" coordinates and were numbered (by segment) from their upstream to downstream (see Muni/Western Ex. 6-144. The top streambed elevation for each reach was determined based on the average surface elevation along the edge of the stream within the reach. The stream stage and the bottom elevation of the streambed were assumed to be 5 ft above and 5 ft below the top elevation of the streambed, respectively.

120. The initial streambed conductance used by the USGS model was calculated using the following equation:

$$\mathrm{CSTR} = \frac{\mathrm{KLW}}{\mathrm{M}}$$

where:

CSTR = streambed conductance, [ft^2/day]
K = vertical hydraulic conductivity of the streambed, [ft/day]
L = length of stream reach, [ft]
W = width of stream, [ft]
M = thickness of streambed, [ft]

121. During model calibration, streambed conductance was adjusted using trial-and-error until final calibration was achieved. Muni/Western Ex. 6-146 shows the streambed conductance values used for the final model calibration. During “wet” years, an increase in the width of the stream usually occurs due to amounts of streamflow overflowing the stream channels. In addition, the vertical hydraulic conductivity of the streambed increases due to the removal of fine-grained sediments by the high energy of the streamflow. Both of these result in an increase in streambed conductance. In order to account for variation of streambed conductance with time (i.e., due to wet and dry cycles), an adjustment factor was applied to the values (shown in Muni/Western Ex.6-146) for wet years, specifically 1958, 1967, 1969, 1978, 1979, 1980, 1983, 1993, 1995 and 1998. The adjustment factor ranges from 1 (unchanged) to 5 (higher conductance).

Recharge Package

122. The Recharge Package simulates regionally distributed recharge to the groundwater system as a result of precipitation. This includes infiltration from direct precipitation and recharge from local runoff generated from precipitation. The infiltration from precipitation was assumed to be approximately 1% of the long-term mean annual precipitation and to be constant from year to year. This assumption results in approximately 1,100 acre-ft/year of infiltration originating from precipitation for the SBBA. Recharge from local runoff generated from precipitation varies each year and was assumed to be 5% of the annual precipitation. During the USGS model calibration period (1945 to 1998), the recharge from local runoff generated from precipitation in the SBBA ranged from 2,000 acre-ft in 1947, to 11,800 acre-ft in 1983 with an annual average of 5,500 acre-ft/year (see Muni/Western Ex. 6-147).

123. The recharge values were areally distributed to each model cell based on the isohyetal map (see Muni/Western Ex. 6-148) representing the spatial variation of long-term average annual precipitation.

Well Package

124. Input data for the Well Package included the following:

- Recharge from Ungaged Mountain Front Runoff ;
- Artificial Recharge of Imported Water;
- Groundwater Pumping (i.e., extractions);
- Return Flow from Application of Groundwater Pumping; and
- Underflow Recharge and Underflow Discharge.

125. Recharge from ungaged mountain front runoff from the adjacent mountains and small outcrops within the SBBA was estimated based on drainage areas, streamflow in nearby basins, and measured flow in the Santa Ana River. Muni/Western Ex. 6-149 shows the model cells used to simulate recharge of ungaged mountain front runoff in the USGS model. During the model calibration period (1945 to 1998), the recharge from mountain front runoff for the SBBA ranges from 4,000 acre-ft in 1990 to 67,700 acre-ft in 1980 with an annual average of 16,200 acre-ft/year (see Muni/Western Ex. 6-150).

126. Artificial recharge of imported water was based on the historically measured imported water used for each of the spreading grounds. A recharge rate of 95% of the imported water (i.e., 5% loss) was used by the USGS model to simulate water that actually recharged the groundwater systems (Muni/Western Ex. 6-151 shows model cells used to simulate artificial recharge of imported water). During the period from 1945 to 1998, artificial recharge of imported water for the SBBA ranged from 0 acre-ft/year (artificial recharge began in 1972) to 30,400 acre-ft/year with an annual average of 2,900 acre-ft/year (see Muni/Western Ex. 6-152).

127. Groundwater extraction quantities used by the USGS model were based on measured data obtained from the Western - San Bernardino Watermaster. The amount of groundwater pumped from each well was distributed to Model Layers 1 and 2 based on the perforated interval and the hydraulic conductivity of adjacent deposits. The proportion of pumping from each well from each layer is a function of the length of the well screen in that layer

and the hydraulic conductivity of the layer. Muni/Western Ex. 6-153 shows the distribution of 762 production wells and Muni/Western Ex. 6-154 shows annual groundwater pumping for the period 1945 to 1998. As shown, annual groundwater pumping ranges from 122,900 acre-ft in 1945 to 214,000 acre-ft in 1961 with an annual average of 175,100 acre-ft/year.

128. For the purposes of the model, return flow from groundwater pumping was assumed to be that quantity of pumped groundwater which returns to the aquifer as a result of agricultural, domestic and municipal uses. Return flow was assumed to be 30% of total extraction except for wells that export groundwater directly out of the SBBA. Previous reports (Hardt and Hutchinson, 1980) estimated that return flow from these sources was equivalent to 30% of the applied water, considering the permeability of the soil and volume of applied water. Wells used for export were assumed to have 0 to 3% (pipe losses) return flow. The return flow was assumed to recharge Model Layer 1 in the same cell as the pumping wells, assuming that groundwater was applied in the nearby vicinity of the pumping well. As shown in Muni/Western Ex. 6-155, the annual return flow from groundwater pumping ranges from 20,100 acre-ft in 1945 to 37,000 acre-ft in 1961 with an annual average of 28,300 acre-ft/year for the period from 1945 to 1998.

129. Recharge from underflow to the SBBA occurs across the Crafton Fault. Muni/Western Ex. 6-156 shows the model cells used to simulate this recharge. The amount of annual recharge from underflow used by the USGS model ranged from 3,800 acre-ft to 6,800 acre-ft with an annual average of 5,100 acre-ft/year for the period from 1945 to 1998 (see Muni/Western Ex. 6-157). Groundwater outflow from the SBBA occurs across the San Jacinto Fault and Barrier E. Muni/Western Ex. 6-156 also shows the model cells used to simulate the groundwater outflow. The amount of subsurface outflow in the USGS model ranges from 2,900 acre-ft to 14,100 acre-ft with an annual average of 6,100 acre-ft/year for the period from 1945 to 1998 (see Muni/Western Ex. 6-158).

Evapotranspiration Package

130. The Evapotranspiration Package simulates the effects of plant transpiration and direct evaporation in removing water from the saturated zone. Data on maximum evapotranspiration rate, evapotranspiration surface, and extinction depth are required inputs to the model.

131. A maximum evapotranspiration rate of 38 in./year was used in the USGS model based on Hardt and Hutchinson (1980). Extinction depth was estimated to be 15 ft (Lee, 1912; Robinson, 1958; and Sorenson et. al., 1991). Based on the depth to water, the evapotranspiration rate linearly decreased from 100% at the surface to 0% at the extinction depth of 15 ft. Evapotranspiration is assumed to occur whenever the water level is above the extinction depth.

USGS Model Calibration (1945 – 1998)

132. The method of calibration used by the USGS model was the standard "history matching" technique using both steady state and transient calibration. Steady-state calibration was carried out for the year 1945 and transient calibration for the period 1945 to 1998. Model-generated groundwater levels were compared with measured levels for wells in the SBBA. Adjustments in hydrogeologic parameters were then made within acceptable limits until a satisfactory match was obtained. Model-calculated recharge and discharge terms were also compared to estimated and measured recharge and discharge terms.

133. For model calibration, historical groundwater level data for 43 wells within the SBBA were obtained from the USGS website and compared with model-generated groundwater levels. In general, the pattern of the model-generated and measured levels are similar in that the model appears to capture the long- and short-term temporal trends in groundwater levels in most parts of the basin (see Muni/Western Ex. 6-159). Muni/Western Ex. 6-160 is an "X-Y" plot showing comparisons of measured and model-generated groundwater levels. The relative error (i.e., standard deviation of the groundwater level residuals[10] divided by the observed head range; Zheng and Bennett, 2002). The relative error for the USGS calibration period (1945 – 1998) is approximately 5%. Common modeling practice considers that a good fit exists between historical and model-predicted data if the relative error is less than 10% (Spitz and Moreno, 1996; and Environmental Simulations, Inc. 1999). The USGS model also provided a good match with the gaged surface runoff within the SBBA (see Muni/Western Ex. 6-161).

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[10] "Residual" = measured – modeled

Model Update

134. In addition to re-running the USGS model original calibration (1945 – 1998), the model was updated to 2000 by adding the years 1999 and 2000 to the 1945-1998 calibration period. The year 2000 is the most recent year for which verified groundwater production data were available at the time of preparing the Draft EIR. Another purpose of the updated model run was to validate the USGS flow model by comparing model generated values with measured values for the 1998 – 2000 period. In addition, the most recent model-generated groundwater elevations (i.e., 2000) were used as initial (i.e., starting) elevations for future model scenarios. This avoids errors that may be introduced from hand contouring (i.e., constructing initial groundwater elevations for the start of model runs).

135. Annual values of recharge and discharge were based on measured data or estimated for the two years (1999-2000) using the same methods as described in the section on Recharge and Discharge. During the model verification period (1999-2000), the relative error of the model-generated groundwater levels was 6% (see Muni/Western Ex. 6-162). For the entire updated calibration period (1945 – 2000), the relative error was 4.93%. Both statistics are well below the generally accepted calibration criteria of 10%.

Model Sensitivity

136. As part of the development of the USGS SBBA groundwater flow model, sensitivity analysis was performed (Danskin et. al., 2006). The analysis involved observing the relative change in model output caused by a change in model inputs.

137. Recharge from streams and pumping from wells were found to have the greatest influence on the model output. Variations in the quantity or spatial distribution of these actions create important changes in groundwater levels, and simulated recharge and discharge (Danskin et. al., 2006).

138. Transmissivity and storage coefficients of the valley-fill aquifer are of lesser importance. However, faults and groundwater barriers within the simulated area are critical in maintaining groundwater levels in the former marshland southwest of Norton Air Force Base (Danskin et. al., 2006).

139. Head-dependant relations used to approximate both evapotranspiration and stream-aquifer interactions have a controlling influence on the model. These relations reduce fluctuations in hydraulic heads by adjusting the quantity of simulated recharge or discharge. The sensitivity analysis demonstrated that seemingly static hydraulic heads may mask substantial changes in groundwater flow rates, especially in the former marshland southwest of Norton Air Force Base (Danskin et. al., 2006).

140. Increased streambed conductance during years with unusually high runoff was found to be very important in providing sufficient recharge to match groundwater levels following 1965. Temporary constant values tested as part of the sensitivity analysis produced groundwater levels as much as 100 ft lower by the end of the 54-year simulation period (1945 – 1998). Return flow from water pumped was found to be a significant component of the water budget. Reducing return flow from 30 to 15 percent of gross groundwater production at selected wells resulted in groundwater levels as much as 50 ft lower than measured, even in the former marshland southwest of Norton Air Force Base (Danskin et. al., 2006).

Model Scenarios

141. Scenarios representing a No Project condition and various project conditions were run using the updated groundwater flow model. Section XI describes details of each of the six model scenarios developed.

142. The updated USGS flow model along with subsidence and analytical methods were used to determine project impacts on:

- Groundwater levels,
- Groundwater storage,
- Groundwater quality,
- Liquefaction potential,
- Subsidence potential, and
- Impacts of spreading outside of the SBBA.

MODPATH Model

General Description and Purpose of Model

143. In order to assist in evaluating potential impacts of proposed projects on remediation (i.e., cleanup) efforts, groundwater flow paths were evaluated using a particle tracking model (MODPATH). MODPATH is a post-processing package developed to compute three dimensional flow paths (i.e., particle tracking) using output from the groundwater flow model. MODPATH uses a semi-analytical particle-tracking scheme that allows an analytical expression of the particle's[11] flow path to be obtained within each finite-difference grid cell. Particle paths are computed by tracking particles from one cell to the next until the particle reaches a boundary, an internal sink/source, or satisfies some other termination criterion.

144. MODPATH does not take into account dispersion, retardation or half-life decay. The results of MODPATH simply provide an indication of the direction and rate of groundwater flow using hydraulic heads and aquifer properties from the flow model.

Development of the MODPATH Model

145. In addition to model input data used by MODFLOW, MODPATH requires data on model layer elevations and effective porosity[12]. Elevations at the bottom of Model Layer 1 and Layer 2 were defined by geophysical borehole logs and lithologic logs as well as the following documents:

- Dutcher and Garrett (1963);
- Morton (1976);
- GEOSCIENCE (1993);
- Hardt and Hutchinson (1980);
- Camp Dresser & McKee Inc. (CDM, 1996);
- Danskin et. al., (2006);
- HSI GeoTrans (1998);
- URS (1997 and 1999); and
- Wildermuth Environmental, Inc. (2000).

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[11] A "particle track" would represent the flow path taken by groundwater through model time and influenced by any relevant recharge or discharge component (e.g., pumping or spreading).

[12] Also equivalent to specific yield.

146. Elevations at the bottom of Model Layer 1 and Layer 2 are shown in Muni/Western Ex. 6-163 and 6-164, respectively. Model layer thicknesses are presented in Muni/Western Ex. 6-165 and 6-166.

147. Effective porosity values in Model Layer 1 were assumed to be the same as the specific yields in Model Layer 1 (see Muni/Western Ex. 6-141). Effective porosity values for Model Layer 2 were assumed to be 80% of the values for Model Layer 1 (personal communication with Wes Danskin of USGS, 2003).

Use of MODPATH Model Scenarios

148. Results from the MODFLOW flow model simulations for each model scenario were used in conjunction with MODPATH. Particle-tracking was simulated using particles released at spreading grounds and at the leading edges of the Muscoy/Newmark PCE plume and the Redlands-Crafton TCE plume at the beginning of model year 2001.

Solute Transport Models

General Description and Purpose of Model

149. The purpose of the solute transport models was to evaluate potential impact of the various scenarios on existing plumes and chemical constituents such as PCE, TCE, TDS, nitrate and perchlorate. Solute transport modeling was carried out using MT3DMS[13], a modular three-dimensional multi-species transport model. The solute transport model requires data from the groundwater flow model (e.g., seepage velocities and flow directions). The flow in and out of each model cell is read by MT3DMS and used to track concentrations of PCE, TCE, TDS, nitrate, and perchlorate advectively and dispersively, applying retardation to the species if needed. For purpose of this study, the PCE transport model was used to simulate the migration of the Muscoy and Newmark plumes and the TCE transport model was used to simulate the movement of the Norton and Redlands-Crafton plumes.

150. For PCE and TCE, a linear isotherm equation was used to model the equilibrium-controlled linear sorption processes that occur in the aquifers. The retardation factor is a

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[13] U.S. Army Corps of Engineers, 1999. MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide.

function of aquifer parameters and the sorption distribution coefficient, which may be written as:

$$R = 1 + \frac{\rho_b}{\theta} Kd$$

where:

R = Retardation Factor,
ρ_b = Bulk Density of Aquifer Materials, [g/cm^3]
θ = Effective Porosity,
Kd = Sorption Distribution Coefficient, [cm^3/g]

151. For TDS, nitrate and perchlorate, the linear isotherm was not used, as the retardation factor for these constituents was assumed to be one. A retardation factor of 1 means that the solute is conservative (i.e., will not retarded) and travels at the same seepage velocity as the groundwater. A retardation factor greater than 1 means that the solute is retarded by chemical adsorption to the aquifer materials and travels slower than the groundwater. Hydrodynamic dispersion is quantified by dispersivity. Longitudinal dispersivity is the aquifer property which describes the amount that a solute plume spreads in the direction of flow. Transverse (or lateral) dispersivity describes the amount of spreading or dynamic dispersion perpendicular or transverse to the flow direction.

152. Although other chemicals are present in the contaminant plumes within the SBBA, PCE and TCE are the principal contaminants in the Muscoy/Newmark and Norton AFB plumes, respectively. Most of the other chemicals are either below their respective Maximum Contaminant Limit or are reaction byproducts of either PCE or TCE. For the purpose of this model, it was assumed that neither PCE nor TCE degrades significantly in groundwater.

Development of Transport Models

153. In addition to the aquifer parameters used for the MODFLOW and MODPATH models, the solute transport model requires the following data to simulate transport of chemical constituents: longitudinal, transverse, and vertical dispersivities, bulk density of the aquifer material, and the sorption distribution coefficient.

154. These parameters were determined during model calibration for both PCE and TCE. Table 18 summarizes the final values.

Table 18. Summary of Solute Transport Model Parameters

Model Parameters		*Units*	*PCE*	*TCE*	*TDS*	*Nitrate*	*Perchlorate*
Dispersivity	Longitudinal	[ft]	300	300	300	300	300
	Transverse	[ft]	100	100	100	100	100
	Vertical	[ft]	1	1	1	1	1
Bulk Density		[g/cm^3]	1.9	1.9	-	-	-
Sorption Distribution Coefficient		[cm^3/g]	0.0947	0.054	-	-	-

155. Using an average effective porosity of 0.09, which approximates the average effective porosity in the region of the PCE and TCE plumes (see Muni/Western Ex. 6-141), the retardation factors for PCE and TCE were calculated as 3.0 and 2.1, respectively.

Transport Model Calibration

156. Solute transport model calibration was performed for PCE and TCE for the period from 1986 to 2000. This time period was chosen based on the amount of data available for these years. The solute transport models were initially calibrated using a parameter estimation technique (PEST[14]) in which dispersivities, sorption distribution coefficients, and mass loading of continued sources were varied within acceptable limits. In addition, calibration also consisted of conventional trial-and-error history matching techniques to best fit the model-generated plumes to observed concentrations at wells. Sources of water quality data used for transport model calibration include CDM, 1996; HSI GeoTrans, 1998; URS, 1997-1999; Wildermuth Environmental, Inc., 2000; California DHS, 2007; and USGS NWISWeb, 2003.

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[14] Watermark Numerical Computing and Waterloo Hydrogeologic, 2000. Visual PEST – Model-Independent Parameter Estimation.

Initial Conditions

157. The initial concentrations used to calibrate the PCE and TCE transport models were derived from 1986 measured concentrations (see Muni/Western Ex. 6-167 and 6-168). Due to the limited quantity of measured PCE and TCE data available for 1986, PCE and TCE concentrations measured between 1987 and 1996 were also used.

Sinks and Sources

158. The MT3DMS transport model required concentrations to be specified for each of the sinks and sources used in the flow model. The PCE and TCE models required inputs of dissolved contaminants to simulate point sources where the dissolution of adsorbed contaminants continues in source areas. All other sources of recharge identified in the flow model were considered to contribute no PCE or TCE. All sinks (i.e., areas of discharge) were considered to have the same PCE and TCE concentration as that occurring in the same model cell (i.e., equal to the aquifer concentration).

159. The amount of contaminant introduced to the model was varied iteratively to match observed concentrations. The PCE input was simulated using mass-loading of dissolved PCE located at the Muscoy Source and the Newmark Source areas. Based on calibration, PCE mass-loading began at a rate of 4 g/day[15] for the Muscoy Source and the Newmark Source in 1986. It decreased linearly to a rate of 3.5 g/day and 2 g/day in 2000 for the Muscoy and the Newmark Source areas respectively (see Muni/Western Ex. 6-169). The TCE input was located in the northeastern part of the Norton plume. The concentration of the TCE input was estimated initially based on the observed data in the Norton plume area. The amount of TCE introduced into the model is shown in Muni/Western Ex. 6-170.

Transport Model Calibration Results

160. The model-generated PCE MCL plume boundary for selected years is shown in Muni/Western Ex. 6-171 (Model Layer 1) and Muni/Western Ex. 6-172 (Model Layer 2). In general, the model-generated MCL plume boundary closely matches the MCL plume boundary contoured from observed data. The model-generated TCE MCL plume boundary is shown in Muni/Western Ex. 6-173 (Model Layer 1) and Muni/Western Ex.

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[15] grams/day

6-174 (Model Layer 2). The model-generated migration rate of the TCE plume agrees with the rate estimated from observed data as can be seen by comparing the observed TCE measurements over time with movement of the MCL plume boundary.

161. In order to evaluate the accuracy of the transport model calibration, PCE and TCE concentrations from the final calibration run were compared to measured data at selected wells (see Muni/Western Ex. 6-175 and 6-176). In most of the wells, measured and model-generated PCE and TCE concentrations display similar trends.

162. Histograms of PCE and TCE residual concentrations (measured concentrations less model-generated concentrations) are shown in Muni/Western Ex. 6-177 and 6-178, respectively. The histograms show a bell shape with most of the residual concentrations in the range of +/- 5 µg/L. The model relative error[16] was 8% and 9% for PCE and TCE concentrations, respectively, indicating an acceptable model calibration. It is common modeling practice to consider a relative error of less than 10% to be a good fit (Spitz and Moreno, 1996; and Environmental Simulations, Inc., 1999).

Use of Transport Model Scenarios

163. After calibrating the PCE and TCE transport models, the predictive flow models were used to provide input to the predictive transport models. The transport model prediction runs consisted of 39 annual stress periods from October 2000 through September 2039. The transport model was run for each of the predictive flow model scenarios:

1) No Project Condition,
2) Scenario A,
3) Scenario B,
4) Scenario C, and
5) Scenario D.

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[16] Relative error is the standard deviation of the water quality residuals divided by the observed range.

Initial Conditions

164. Concentrations obtained from PCE and TCE model calibration results were used as initial concentrations for the predictive transport model scenarios and are shown in Muni/Western Ex. 6-179 and 6-180.

165. As the distributions of TDS and nitrate concentrations were strongly heterogeneous, a different approach was used to establish initial conditions for these constituents. The model area was divided into several equal concentration zones and each zone assigned the average of concentrations observed in the year 2000 within the zone. These zones are shown in Muni/Western Ex. 6-181 and 6-182. The transport model was then run using the same groundwater flow model used in the PCE and TCE calibration, but with initial conditions determined by the equal concentration zones and source-sink concentrations assigned as described in the following section. The purpose of these model runs was to generate “smooth” initial TDS and nitrate concentrations for the predictive transport models from the equal concentration zones (see Muni/Western Ex. 6-183 and 6-184).

166. Initial concentrations for the perchlorate transport model were derived from observed concentrations in the year 2000, and are shown in Muni/Western Ex. 6-185.

Source and Sink Concentrations

PCE and TCE

167. In the PCE model, the amount of mass-loading in the source area was assumed to decrease linearly by extending the trend of 1986-2000 (see Muni/Western Ex. 6-169) until all sources were exhausted. In the PCE calibration model, the mass-loading of solute simulated the mobilization of PCE adsorbed to aquifer materials at the source area of PCE contamination and was necessary to match observed data. The linear trend of mass-loading was continued into the future to continue the simulation of PCE desorbing from aquifer materials. The TCE model, however, did not contain any additional sources of TCE other than the initial concentrations, and concentrations at all TCE sources dropped to zero by the end of model calibration period[17]. Based on available historic data, it was assumed that no potential future sources of TCE would exist. All sinks used concentrations found in the aquifer at the cell in which the sinks are located.

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[17] Concentrations of PCE and TCE at other sources in the model were considered to be zero.

TDS and Nitrate

168. The sources for TDS and nitrate input concentrations were specified according to the flow input source defined in the flow model. The sources of flow into the model are described under the section on Recharge and Discharge, and a summary of the source type and the TDS and nitrate concentrations used is shown in Table 19. Source concentrations were specified either based on Santa Ana River and SWP water concentrations, or based on the equal concentration zones described above in the Initial Conditions section.

Table 19. Assumptions for TDS and Nitrate Concentrations

Flow Source	*Source Type*	*Concentration Used*
Direct Infiltration from Precipitation	Recharge	Same as ambient water quality
Recharge from Local Runoff Generated by Precipitation	Recharge	Same as ambient water quality
Artificial Recharge	Recharge	Flow-weighted average of recharge water source concentrations (Santa Ana River or SWP)
Recharge from Ungaged Mountain Front Runoff	Well	Same as ambient water quality
Return Flow from Groundwater Pumping	Well	Same as ambient water quality
Underflow Recharge	Well	Same as ambient water quality

169. The concentrations of TDS and nitrate used to represent Santa Ana River and SWP water were determined from an average of all available sampling data from those sources (Table 20).

Table 20. TDS and Nitrate Concentrations for Santa Ana River and SWP Water

Constituent	Units	*Artificial Recharge Water*	
		Santa Ana River[1]	*State Water Project*[2]
TDS	[mg/L]	232	282
Nitrate (as NO_3)	[mg/L]	5.7	3.1

1 Determined from USGS Water Quality database.
2 Determined from historic State Water Project water quality records.

Perchlorate

170. It was assumed that there were no additional sources of perchlorate other than the initial concentrations. Little information is available regarding the perchlorate plume source; therefore, only reported perchlorate concentrations were used to delineate the plume. All sinks used concentrations found in the aquifer in the cell in which they were located.

Subsidence Model

Description of Model

171. As a part of this project, subsidence modeling has been completed in association with the No project Condition and the four different Project scenarios (A through D), using the groundwater flow model and the PRESS subsidence model (Predictive Relations between Effective Stress and Subsidence). The PRESS model is a modified version of a program called COMPACT, which was initially developed by Helm for one-dimensional simulation of aquifer system compaction, in Pixley, California (Helm, 1975). Revisions were made in 1979-1980 by the Harris-Galveston Coastal Subsidence District (Espey, Huston & Associates, Inc., 1979), which included changes in format, plotting and input/output routines. Specifically, the modifications allow for multiple aquifers and simplification of input preparation. Similar to Espey, Huston & Associates, Inc., Fugro-McClelland (Southwest), Inc. also used the PRESS code to simulate land-subsidence for the Harris-Galveston Coastal Subsidence District in 1997 (Kasmarek and Robinson, 2004). The COMPACT code, that the PRESS code was based on, has been tested against the U.S. Geological Survey Interbed-Storage Package (another program used to simulate aquifer compaction) and found to be very similar (Leake and Prudic, 1991).

172. The PRESS model computes ground surface subsidence resulting from a given change in potentiometric head within a system of aquifers. Both the virgin (non-elastic) and rebound (elastic) compressibilities of the clay layers (aquitards) are taken into account when estimating total subsidence.

173. The program uses the one-dimensional Terzaghi consolidation theory with some simplification of parameters to relate a time history of potentiometric head changes to a time history of subsidence. The total ground surface subsidence, as a function of time, is computed by summing up the individual subsidence occurring in each clay layer. Calibration of the model to historically measured subsidence using observed changes in potentiometric head for a given lithology allows prediction of future subsidence.

Model Input Parameters

174. Water level impacts were simulated at City of Riverside Raub Well #8 (“Raub #8”), located on the southeast corner of Waterman and Orange Show Road. This well was selected from a collection of SBBA wells with recorded geophysical borehole logs, because it is located in the Pressure Zone nearest to the area of maximum historic subsidence (Fife et al., 1976) and had the largest cumulative thickness of clay layers. An idealized lithologic log for Raub #8 was constructed from the short normal resistivity geophysical log (see Muni/Western Ex. 6-186). Clay layers and their thicknesses were identified and six compacting intervals were approximated. The values virgin compressibility, elastic compressibility, and pre-compaction stress were determined during the calibration process. Vertical hydraulic conductivity was chosen from calibrated values from wells similar in lithology, but located in the Chino Groundwater Basin.

175. The PRESS model is able to simulate two controlling aquifers by specifying potentiometric head at three places in the total alluvial thickness. The change in potentiometric surface over time (drawdown) is specified for the upper and lower aquifers and for the bottom of the alluvial thickness. This drawdown over time is the PRESS “loading function”. The loading function used was the drawdown generated in layers 1 and 2 of the MODFLOW model at the Raub #8 well for the updated model calibration period (1945-2000) and each of the MODFLOW model scenarios (2001-

2039). The drawdown loading functions for the MODFLOW model layers 1 and 2 are illustrated in Muni/Western Ex. 6-187 and 6-188.

Model Calibration

176. The properties of the compaction intervals including virgin compressibility, elastic compressibility, and pre-compaction stress were determined by and trial-and-error parameter estimation procedure. The model was calibrated to measured subsidence of 1.3 feet occurring from the period from 1943 to 1968-1969 at a location immediately east of the San Jacinto fault near Loma Linda, as measured by the Coast and Geodetic Survey (Lofgren, 1971). Muni/Western Ex. 6-189 shows that the modeled subsidence in 1969 matches the measured subsidence of 1.3 feet.

X. Methods Used to Evaluate Impacts of Spreading Outside of Model Area

Analytical Method

177. To evaluate impacts of artificial recharge in areas outside of the model area (due to surface spreading), an analytical method was used. As these recharge areas are outside of the groundwater flow model area, groundwater level responses to recharge could not be predicted using the model. As such, an alternative method was used to predict groundwater mounding. The analytical method used was the Hantush equation, which estimates the growth and decay of groundwater mounds in response to uniform percolation (Hantush, 1967).

178. The analytical method was applied to three artificial recharge areas designated by the Allocation Model that lie outside of the groundwater model domain, specifically:
   - Cactus Spreading Ground (in Rialto-Colton Basin)
   - Wilson Spreading Ground (in Yucaipa Basin)
   - Garden Air Creek Spreading Ground (in San Timoteo Basin)

179. In his 1967 paper, Hantush presents an analytical expression for changes in groundwater elevation at any distance from the center of a rectangular spreading basin subject to uniform percolation. Assumptions used to derive the analytical expression assume that the underlying aquifer is homogeneous, isotropic, and effectively of infinite areal extent, the formation parameters are constant, and the constant rate of deep percolation relative to the horizontal hydraulic conductivity is small such that vertically downward percolation is almost entirely refracted in the direction of the slope of the water table. The Hantush equation requires the following inputs:

   - The length and width of the spreading ground areas,
   - The uniform percolation rate,
   - The time required for recharge,
   - The depth to groundwater and effective saturated thickness of the underlying aquifer, and
   - The horizontal hydraulic conductivity and effective porosity of the underlying aquifer.

180. For each spreading ground area, estimates of the above parameters were obtained from the following sources:

- Matusak, 1979. Preliminary Evaluation of State Water Project Groundwater Storage Program, Bunker Hill – San Timoteo – Yucaipa Basins,
- Moreland, 1972. Artificial Recharge in the Upper Santa Ana Valley, Southern California. U.S. Geological Survey Open-File Report,
- Wildermuth Environmental, Inc. (2000). TIN/TDS Study – Phase 2A of the Santa Ana Watershed Development of Groundwater Management Zones – Final Technical Memorandum. Prepared for TIN/TDS Task Force. Dated July 2000, and
- Woolfenden and Koczot, 1999. Numerical Simulation of Ground-Water Flow and Assessment of the Effects of Artificial Recharge in the Rialto-Colton Basin, San Bernardino County, California. U.S. Geological Survey Water-Resources Investigations Report.

Rialto-Colton Model

181. Muni/Western obtained a copy of a groundwater model of the Rialto-Colton Basin prepared by the USGS (Woolfenden and Koczot, 1999). The USGS Rialto-Colton model is a MODFLOW model which also has MODPATH (particle tracking) capability. This model was used in the analysis to evaluate potential water quality impacts of the projects within the Rialto-Colton basin.

182. The USGS Rialto-Colton Basin groundwater flow model is an integrated streamflow and groundwater model developed for streams and the water-bearing units of the Rialto-Colton Basin. The groundwater model consists of four model layers. These layers represent the river-channel deposits and the upper, middle, and lower water-bearing units.

183. The four-layered model covers approximately 195 square miles and consists of 90 nodes[18] in the north-to-south direction (i-direction) and 90 nodes in the west-to-east direction (j-direction), for a total of 32,400 nodes. Each model cell represents an area of

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- [18] A model "node" is the center of a model "cell". The model cells are square with a side of 820 ft. The network of model cells forms a "grid" or "mesh" covering the entire model area.

approximately 15 acres (820 ft by 820 ft). The model was calibrated to transient conditions for the period 1945 to 1996 with an annual stress period.

184. The USGS Rialto-Colton model simulations were run for the period from 2001 to 2035 under a No Project Condition and Scenario A. Hydrologic conditions for 1962-1996 were assumed to represent the future conditions for 2001-2035. No spreading occurs at Cactus Spreading and Flood Control Basins under the No Project Condition. Spreading under Scenario A ranges from zero to 18,953 acre-ft in 2008 (i.e., hydrologic year 1969), with the total spreading being 118,916 acre-ft (average of 3,398 acre-ft/yr) during the period from 2001-2035. MODPATH particle-tracking was simulated using particles released at the northwestern and southeastern edges of the Rialto-Colton perchlorate plume at the beginning of model year 2001.

XI. Description of Model Scenarios

185. Model scenarios used for the modeling effort are summarized in this testimony, but are described in more detail in Mr. Robert Beeby's testimony.

186. In addition to future hydrologic conditions and other natural events, there are four major parameters that influence the amount of water available for appropriation by Muni/Western. The manner of their combination results in a range of potential diversions, such as:

1. Diversions by senior water rights claimants;
2. Diversions by the Conservation District;
3. Releases of Santa Ana River surface water from Seven Oaks Dam to accommodate habitat restoration as called for in the BO issued by the USFWS; and
4. Operation of Seven Oaks Dam for both flood control and seasonal water conservation storage.

187. The amount of unappropriated Santa Ana River surface water available for diversion in any given year depends on the values of these parameters. A number of model simulations reflecting combinations of these parameters were developed to determine the range of potential quantities of unappropriated Santa Ana River surface water. After all diversions are made, including those of Muni/Western, any Santa Ana River surface water not diverted is assumed to flow down the river. Table 21 lists each of these parameters and the values they can assume in the model simulations.

Table 21. Parameters Used in Model Simulations

Parameter	*Parameter Type*	*Value in Model*
1. Diversions by senior water rights claimants	Variable	Historical diversions claimants or Diversion of up to 88 cfs
2. Diversions by the Conservation District	Variable (assuming a maximum diversion rate of 300 cfs)	Historical diversions Conservation District or Licensed right of up to 10,400 acre-ft/year
3. Environmental Habitat Releases	Variable	1,000 cfs for 2 days at a 6-month minimum interval when water is available or Other habitat treatment (high-pressure water)
4. Seasonal Water Conservation Storage within Seven Oaks Reservoir	Variable	Dam operated for flood control within Seven Oaks Reservoir or Dam operated for both flood control and seasonal water conservation storage

188. As shown in Muni/Western Ex. 6-373, 16 different simulations are possible through the different combinations of these four basic parameters. With completion of Phase I of the Plunge Pool Pipeline, Santa Ana River water is diverted at the Cuttle Weir at a maximum rate of 500 cfs and conveyed to (1) the Foothill Pipeline, (2) the Santa Ana River Crossing (SARC) Pipeline, and (3) the Santa Ana River Spreading Grounds. Upon completion of Phases II and III of the Plunge Pool Pipeline and its connection to the Inland Feeder Pipeline, up to a maximum of 1,500 cfs of Santa Ana River water could be diverted. Where appropriate, especially in the analysis of surface water and groundwater resources, impacts associated with diversions of either of these quantities of Santa Ana River water are analyzed. In this way, potential impacts to the environment have been bounded on the upper and lower limits, and impacts associated with the diversion of quantities of water between these two volumes have been assessed.

189. Under each of the Project simulations, the amount of unappropriated Santa Ana River water captured with a maximum diversion rate of 1,500 cfs would be as shown in Muni/Western Ex. 6-374. With a maximum diversion rate of 500 cfs, the corresponding

quantities of Santa Ana River water captured by Muni/Western would be as shown in Muni/Western Exhibit 6-375.

190. Of the 16 scenarios, five were carried forward for detailed analyses as part of the EIR, namely:

1. No Project Condition. Conditions representative of No Project conditions are: (1) historical diversions by senior water rights claimants; (2) historical diversions by the Conservation District; (3) environmental restoration with releases from Seven Oaks Dam; and (4) no seasonal water conservation storage at Seven Oaks Dam. The No Project Condition is similar to Scenario 10 shown in Muni/Western Ex. 6-373, except no diversions would be made by Muni/Western.

2. Project Scenario A. Scenario 15 in Muni/Western Ex. 6-374 represents the maximum potential appropriation by Muni/Western at a diversion rate of 1,500 cfs and is the result of assuming: (1) historical diversions by senior water rights claimants; (2) licensed diversions by the Conservation District; (3) environmental restoration without releases from Seven Oaks Dam; and (4) seasonal water conservation storage at Seven Oaks Dam.

3. Project Scenario B. Scenario 15 in Muni/Western Exhibit 6-375 represents the maximum potential appropriation by Muni/Western at a diversion rate of 500 cfs and is the result of assuming: (1) historical diversions by senior water rights claimants; (2) licensed diversions by the Conservation District; (3) environmental restoration without releases from Seven Oaks Dam; and (4) seasonal water conservation storage at Seven Oaks Dam.

4. Project Scenario C. Scenario 2 in Muni/Western Ex. 6-374 represents the minimum potential appropriation by Muni/Western at a diversion rate of 1,500 cfs and is the result of assuming: (1) diversions up to 88 cfs by senior water rights claimants; (2) historical diversions by the Conservation District; (3) environmental restoration with releases from Seven Oaks Dam; and (4) no seasonal water conservation storage at Seven Oaks Dam.

5. Project Scenario D. Scenario 2 in Muni/Western Exhibit 6-375 represents the minimum potential appropriation by Muni/Western at a diversion rate of 500 cfs and is the result of assuming: (1) diversions up to 88 cfs by senior water rights claimants; (2) historical diversions by the Conservation District; (3) environmental restoration with releases from Seven Oaks Dam; and (4) no seasonal water conservation storage at Seven Oaks Dam.

191. An additional scenario was developed after the Draft EIR was completed. The Most Likely Scenario represents the potential appropriation by Muni/Western at a diversion rate of 1,500 cfs and is the result of assuming: (1) settlement with Conservation District; (2) historical diversions by senior water rights claimants (includes Seven Oaks Accord); (3) environmental restoration with releases from Seven Oaks Dam; and (4) with seasonal water conservation storage at Seven Oaks Dam.

192. Table 22 presents the allocation assumptions used for each scenario.

Table 22. Assumptions for Model Scenarios

	WCD Spreading			*Senior Water Right Diversion*		*Habitat Release*		*Muni/Western Diversion*			*Seasonal Water Conservation Storage*
								Plunge Pool	*Cuttle Weir*		
								1500 cfs	*500 cfs*		
Model Scenario	*Historical*	*Licensed*	*Settlement with Conservation District*	*Historical*	*88 cfs*	*Habitat Release*	*Other Habitat Treatment**	*Diversion Rate*	*Diversion Rate*	*No*	*Yes*
No Project Condition	x			x		x				x	
Scenario A (maximum capture)		x		x			x	x			x
Scenario B		x		x			x		x		x
Scenario C	x				x	x		x			
Scenario D (minimum capture)	x				x	x			x		
Most Likely Scenario			x	x		x		x			x

*Less than 100 acre-ft in the 39-year period

Source: See Appendix A of DRAFT EIR: Surface Water Hydrology for details, and Sections 6.2.5.3.1 through 6.2.5.3.3 of the DRAFT EIR

193. Results from the OPMODEL and Allocation Model provided the following groundwater model recharge and discharge values, for the various model scenarios:

- Releases to Santa Ana River from the Seven Oaks Dam,
- Artificial recharge in the spreading grounds, and
- Groundwater pumping and return flow from groundwater pumping.

194. Table 23 presents the allocation of Santa Ana River water for the model scenarios. As shown, Muni/Western's potential project capture ranges from 10,272 acre-ft/year to 27,042 acre-ft/year.

Table 23. Summary of Allocation of Santa Ana River Water
Annual Average from 2001 - 2039
(Units in acre-ft/year)

Allocation of Santa Ana River Water		*No Project Condition*	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*	*Most Likely Scenario*
Seven Oaks Dam Releases	Undiverted Santa Ana River	20,704	0	1,317	0	734	210
	Habitat Release	915	0	0	712	712	915
	Turnback to Santa Ana River	0	0	536	0	426	0
(Not Included in the Groundwater Model)	Diversion by Senior Water Rights	26,619	26,619	26619	29,646	29,361	26,619
Artificial Recharge	Santa Ana River Spreading Grounds (by WCD)	10,384	4,961	4,961	10,217	10,217	9,489
	Santa Ana River Spreading Grounds (by Senior Water Rights)	0	0	0	6,474	6,759	0
	Airport Spreading Grounds (by Senior Water Rights)	0	0	0	203	203	0
(Not Included in the Groundwater Model)	Reservoir Evaporation	144	144	156	82	82	144

Allocation of Santa Ana River Water	*No Project Condition*	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*	*Most Likely Scenario*
Total Used Before Muni/Western Diversion	58,766	31,724	33,589	47,334	48,494	37,377
Synthesized Santa Ana River Flow above SCE Diversion	58,766	58,766	58,766	58,766	58,766	58,766
Muni/Western Potential Capture	**0**	**27,042**	**25,177**	**11,432**	**10,272**	**21,389**

Releases to Santa Ana River from the Seven Oaks Dam

195. Releases to the Santa Ana River from the Seven Oaks Dam were based on the results from OPMODEL. As shown in Table 23, for the No Project Condition, the Seven Oaks Dam releases included, on average, 20,704 acre-ft/year of undiverted Santa Ana River water, 915 acre-ft/year of habitat release and zero turnback to Santa Ana River for an average annual total of 21,619 acre-ft/year during the period 2001-2039. For scenarios A and C, both undiverted Santa Ana River water and turnback to Santa Ana River were computed to be zero. The amount of undiverted Santa Ana River water is 734 acre-ft/year for Scenario D and 1,317 acre-ft/year for Scenario B. The amount of turnback to Santa Ana River water is 426 acre-ft/year for Scenario D and 536 acre-ft/year for Scenario B. Habitat release was determined to be zero for both Scenarios A and B (less than 100 acre-ft in 39 years from other habitat treatment), and averaged 712 acre-ft/year for both Scenarios C and D. Muni/Western Ex. 6-376 summarizes the annual Seven Oaks Dam releases for each scenario.

Artificial Recharge at Spreading Grounds

196. The amount of artificial recharge from spreading grounds was based on results from the Allocation Model. During the development of water delivery scenarios, the Allocation Model and the groundwater model worked iteratively to determine reasonable deliveries to spreading grounds. The iterative process was necessary since deliveries of water to spreading grounds are not only limited by delivery constraints (e.g., available conveyance route capacities and absorptive capacities of spreading facilities), but also by groundwater levels and the impact to groundwater contamination plumes. Water delivery scenarios in the Allocation Model were modified by a series of iterations that considered high

groundwater levels in the Pressure Zone and interference with remediation efforts in the contaminant plume areas (determined using the groundwater model).

197. Annual artificial recharge at each spreading ground for the period 2001-2039 for each model scenario is shown in Muni/Western Ex. 6-377 through 6-381. Table 24 summarizes (by scenarios) average annual artificial recharge applied at each spreading ground during the period 2001-2039.

Table 24. Summary of Average Annual Artificial Recharge, 2001-2039 (Units in acre-ft/year)

Spreading Grounds	*No Project Condition*	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*	*Most Likely Scenario*
Santa Ana River	10,384	4,961	5,411	16,691	16,976	10,134
Mill Creek	0	468	718	406	499	439
City Creek	0	3,956	2,116	45	254	3,628
Patton	372	484	482	361	357	400
Waterman	7,813	12,320	13,551	9,474	8,671	10,464
East Twin Creek	6,332	10,274	11,108	7,971	7,533	8,696
Badger	1,403	2,200	1,990	1,503	1,806	1,774
Devil Canyon/ Sweetwater	3,227	4,622	3,514	3,657	3,821	3,961
Lytle Creek	2,785	4,848	3,640	3,825	4,065	4,178
Total	**32,316**	**44,133**	**42,530**	**43,933**	**43,982**	**43,674**

Source: See Appendix A of DRAFT EIR: Surface Water Hydrology for details.

198. Artificial recharge at the Santa Ana River spreading grounds for the No Project Condition was estimated to be 10,384 acre-ft/year based on historical spreading by the WCD. This amount increased to 16,691 and 16,976 acre-ft/year for Scenarios C and D, respectively. Artificial recharge for Scenarios C and D was comprised of spreading by the WCD and Senior Water Rights Claimants. It decreased to 4,961 and 5,411 acre-ft/year for

Scenarios A and B. Artificial recharge for Scenarios A and B was largely comprised of spreading by the WCD, which was estimated based on the WCD's licensed diversions.

199. For both Scenarios A and B, artificial recharge increased at spreading grounds other than Santa Ana River compared to the No Project Condition. For Scenario B, these increases ranged from 110 acre-ft/year (at the Patton Spreading Grounds) to 5,738 acre-ft/year (at the Waterman Spreading Grounds). For Scenario A, the increases ranged from 112 acre-ft/year at the Patton Spreading Grounds, to 4,507 acre-ft/year at the Waterman Spreading Grounds. For both Scenarios C and D, artificial recharge varied at spreading grounds other than Santa Ana River compared to the No Project Condition. For Scenario C, the changes in spreading ranged from a decrease of 11 acre-ft/year (at the Patton Spreading Grounds) to an increase of 1,661 acre-ft/year (at the Waterman Spreading Grounds). For Scenario D, the changes in spreading ranged from decrease of 15 acre-ft/year at the Patton Spreading Grounds, to increase of 1,280 acre-ft/year at the Lytle Creek Spreading Grounds.

<u>Groundwater Pumping and Return Flow from Groundwater Pumping</u>

200. Table 25 shows the estimated annual Non-Plaintiffs' and Plaintiffs' groundwater pumping for each model scenario during the period 2001-2039. The pumping value assigned to each well in a particular year was based on the amount pumped in the year 2000 multiplied by the ratio of the total projected pumping for that particular year[19]. The total projected groundwater pumping for each of the model scenarios was based on results from the Allocation Model.

201. Muni/Western Ex. 6-382 summarizes the average annual groundwater pumping used for the model scenarios.

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[19] For example, for a well pumped 1,000 gpm in 2000, the ratio of the total projected pumping for 2020 to the total pumping in 2000 is 1.11 (an increase of 11%). Pumping for this well in 2020 would be 1,110 gpm (1110 = 1.11 x 1000).

Table 25. Average Annual Groundwater Pumping, 2001 to 2039 (Units in acre-ft/year)

Type of Groundwater Pumping	*No Project Condition*	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*	*Most Likely Scenario*
Non-Plaintiffs	169,140	169,140	169,140	166,439	166,439	169,140
Plaintiffs	64,348	67,442	66,960	67,216	66,981	66,621
Total	233,488	236,582	236,100	233,655	233,420	235,761

Source: See Appendix A of DRAFT EIR: Surface Water Hydrology for details on Scenarios A – D and No Project Condition.

202. The Non-Plaintiffs' groundwater pumping for the No Project Condition and both Scenarios A and B was estimated to be 169,140 acre-ft/year. For both Scenarios C and D the Non-Plaintiffs' groundwater pumping was estimated to be approximately 2,701acre-ft/year less than that for the No Project Condition, owing to the additional diversion of Senior Water Rights Claimants. For all four project scenarios, modeled increases in groundwater pumping by Plaintiffs ranged from 2,612 acre-ft/year to 3,094 acre-ft/year relative to the No Project Condition. This estimate was based on the Plaintiffs' existing right to export from the SBBA. The Plaintiffs' right to export was adjusted based on four items:

1) Plaintiffs' portion of the diverted Santa Ana River water delivered outside the SBBA (but not exchanged),
2) Plaintiffs' portion of the Conservation District replenishment adjustment,
3) Plaintiffs' portion of the diverted Santa Ana River water delivered to the SBBA, and
4) Plaintiffs' portion of the estimated change in natural river recharge based on Santa Ana River water diversions under each project scenario in comparison to the No Project Condition.

203. Return flow from groundwater pumping was assumed to be 30% of the total amount of groundwater extracted except for wells that export groundwater directly out of the SBBA. Wells used for export were assumed to have a 0% to 3% return flow. The return flow was assumed to recharge Model Layer 1 in the vicinity of the wells. These assumptions are the same as the assumptions used by the USGS for the model calibration period from 1945-1998.

XII. Ability to Place Diverted Water to Reasonable and Beneficial Use

No Project Condition

<u>Groundwater Levels – No Project Condition</u>

204. Groundwater elevation contours for the No Project Condition in the years 2000 (model initial conditions), 2005, 2010, 2015, 2016 (lowest levels), 2020, 2022 (highest levels), 2025, 2030, 2035, and 2039 (end of model simulation) are shown in Muni/Western Ex. 6-190 for Model Layer 1 and Muni/Western Ex. 6-191 for Model Layer 2. In general, model-generated groundwater flow is similar to historical directions with groundwater flowing west from the Santa Ana River and Mill Creek Spreading Grounds, and southeast from the Lytle Creek and Cajon Creek (i.e., flowing to the Pressure Zone area). Water level fluctuations reflect hydrological wet and dry cycles. For example, a change in groundwater level of 50 ft to 100 ft occurs in the Pressure Zone between model years 2016 (equivalent to 1977 – end of a dry year cycle) and 2022 (end of a wet cycle, historical year 1983; also see Muni/Western Ex. 6-190).

<u>Groundwater Storage – No Project Condition</u>

205. The overall water budgets for each of the model runs were compiled to evaluate the SBBA groundwater model and to obtain changes in groundwater storage. The inflow terms for the model include recharge to groundwater from gaged streamflow, artificial recharge, local runoff generated by precipitation, infiltration from direct precipitation, return flow from groundwater pumping, ungaged mountain front runoff and underflow. The outflow terms consist of evapotranspiration, groundwater pumping, and underflow. The difference between the total inflow and total outflow is the change in groundwater storage. The annual groundwater budget for the No Project Condition is shown in Muni/Western Ex. 6-383. Table 26 and Muni/Western Ex. 6-192 summarize the average annual groundwater budgets for the period 2001-2039.

206. Groundwater storage in the SBBA declines 3,324 acre-ft/year during the period 2001 through 2039 under the No Project Condition.

Table 26. Average Annual Groundwater Budgets, 2001-2039 (Units in acre-ft)

Flux Terms		*No Project Condition*	*Scenario A*	*Scenario D*	*Most Likely Scenario*
Inflow	Recharge from Gaged Streamflow	139,517	131,022	128,253	130,637
	Artificial Recharge at Santa Ana River Spreading Grounds	10,384	4,961	16,976	10,134
	Artificial Recharge at Other Spreading Grounds	21,932	39,172	27,006	33,539
	Recharge from Local Runoff Generated by Precipitation	5,627	5,627	5,627	5,627
	Infiltration from Direct Precipitation	1,137	1,137	1,137	1,137
	Return Flow from Groundwater Pumping	39,575	39,614	39,037	39,604
	Recharge from Ungaged Mountain Front Runoff	17,820	17,820	17,820	17,820
	Underflow Recharge	2,997	2,997	2,997	2,997
	Total Inflow	**238,989**	**242,350**	**238,853**	**241,495**
Outflow	Evapotranspiration	5,822	6,314	5,903	6,216
	Groundwater Pumping	233,488	236,582	233,420	235,761
	Underflow Discharge	3,003	2,860	2,904	2,864
	Total Outflow	**242,313**	**245,756**	**242,227**	**244,841**
Change in Groundwater Storage (Total Inflow – Total Outflow)		**-3,324**	**-3,406**	**-3,374**	**-3,346**

Source: Groundwater flow model for various scenarios.

Liquefaction Potential – No Project Condition

207. Liquefaction typically occurs in recent (Holocene to late Pleistocene) deposits of silt, sand, and gravel. Most liquefaction occurs where the depth to groundwater is less than 50 ft; this depth is traditionally considered adequate for most investigations of liquefaction potential (SCEC, 1999). Soil liquefaction is a major cause of damage during earthquakes. For purposes of this testimony, areas with depth to groundwater of less than 50 ft in the Pressure Zone were evaluated.

208. Areas where depth to groundwater less than or equal to 50 ft below the land surface were delineated using the groundwater model. For the No Project Condition, these areas are shown in Muni/Western Ex. 6-190 for selected years. The estimated acreages for each year are also shown in these figures for the entire SBBA as well as the Pressure Zone (not including the river channels). For the No Project Condition, the cumulative total area of potential liquefaction in the Pressure Zone during the period 2001 through 2039 is approximately 32,184 acres. Yearly acreages for the No Project Condition are shown on Muni/Western Ex. 6-193 and 6-194.

Subsidence Potential – No Project Condition

209. The modeled subsidence for all scenarios is shown in Muni/Western Ex. 6-189. During the period from 2001 through 2039, the No Project Condition had 0.35 ft of subsidence at the location of Raub #8 with an average subsidence rate of 0.0083 ft/year. Table 27 summarizes the total subsidence and average subsidence rate at the location of Raub #8 during the period 2001 through 2039 for each model scenario.

Table 27. Total Subsidence and Average Subsidence Rate at the Location of Raub Well #8, 2001-2039

Scenario	*Total Subsidence [ft]*	*Average Subsidence Rate [ft/year]*
No Project	0.35	0.0083
Scenario A	0.62	0.0158
Scenario D	0.43	0.0108

Project Scenario A (Maximum Capture)

Groundwater Levels – Scenario A

210. Groundwater flow directions and general patterns of fluctuations for Scenario A are similar to the No Project Condition (see Muni/Western Ex. 6-195 and 6-196).

211. Differences in groundwater levels between the No Project Condition and Scenario A are shown in Muni/Western Ex. 6-197 (Model Layer 1) and Muni/Western Ex. 6-198 (Model Layer 2). Model-generated groundwater levels for Scenario A are higher in the

northwestern portion of the SBBA and the northwestern portion of the Pressure Zone, reflecting the increase in artificial recharge at the Waterman, East Twin Creek, Badger, Devil Canyon/Sweetwater, and Lytle Creek Spreading Grounds. Groundwater levels are lower in most portions of the Pressure Zone and the eastern portion of the SBBA due to the diversion of Santa Ana River water (i.e., the diversion prevents deep percolation in a portion of the Santa Ana River channel reach).

212. Hydrographs at selected wells and spreading grounds for the No Project Condition and Scenario A are shown in Muni/Western Ex. 6-199 through 6-223. These hydrographs show the temporal variations in the groundwater levels reflecting the hydrologic conditions, artificial recharge and groundwater pumping assumed for the scenarios.

<u>Groundwater Storage – Scenario A</u>

213. The annual groundwater budget for the Scenario A is shown in Muni/Western Ex. 6-384. Table 26 and Muni/Western Ex. 6-224 summarize the average annual groundwater budgets for the period 2001-2039.

214. As shown in Table 26, the primary change in groundwater budgets between the No Project Condition and Scenario A is recharge from gaged streamflow. For the No Project Condition, the average annual recharge from gaged streamflow is 139,517 acre-ft/year. For Scenario A, groundwater recharge from streamflow would be reduced by approximately 8,495 acre-ft/year (139,517-131,022 = 8,495), due to the diversion of the Santa Ana River water. For the No Project Condition, a portion of the 20,704 acre-ft/year undiverted Santa Ana River water would recharge the groundwater basin.

215. Muni/Western Ex. 6-225 shows the inflow and outflow terms as a percentage of the total groundwater budget and average annual change in groundwater storage for Scenario A as compared to the No Project Condition.

Groundwater Quality – Scenario A

Particle Tracking

216. Paths traveled by particles in Scenario A were compared to paths traveled for particles under the No Project Condition (see Muni/Western Ex. 6-226 through 6-244). In general, groundwater flow directions are similar to the No Project Condition, but the rate of groundwater flow differs. The differences are due primarily to increased hydraulic gradients as the result of artificial recharge.

217. For Scenario A, groundwater flows slightly faster in the northwestern portion of the SBBA than it does for the No Project Condition (i.e., the particles travel greater distances in the same amount of time; see Table 28). This reflects increased artificial recharge at Waterman, East Twin Creek, Badger, Devil Canyon/Sweetwater and Lytle Creek Spreading Grounds, which steepens local hydraulic gradients and therefore increases rates of flow. In the southeastern portion of the SBBA, groundwater flow is slightly slower for Scenario A than for the No Project Condition, due to the diversion of Santa Ana River water.

Table 28. Seepage Velocity Determined by MODPATH Model under Different Model Scenarios (units in ft/day)

Area	*No Project Condition*	*Scenario A*	*Scenario D*
Northwest area encompassing Devil Canyon/Sweetwater, Badger, Waterman, East Twin Creek Spreading Grounds (Model Layer 1)	2.7	3.5	3.4
Southeast area encompassing Santa Ana River, Mill Creek, and Patton Spreading Grounds (Model Layer 1)	5.1	4.8	5.0
PCE Plume Front (Muscoy-Newmark) (Model Layer 2*)	1.9	1.9	1.9
TCE Plume Front (Redlands-Crafton) (Model Layer 1)	1.8	1.8	1.8
* Major plume is in Model Layer 2.			

218. Groundwater flow from the fronts of plumes in the Pressure Zone is similar to flow for the No Project Condition and its direction is similar. Because the increases in seepage velocity occur mainly upgradient of contaminant plumes, they are not expected to interfere with the operation of existing remediation systems. In fact, increasing the rate of groundwater flow upgradient of the contaminant plumes will actually aid in the remediation efforts, as the upgradient portion of the plume would be "pushed" by the increased flow velocities resulting from steeper hydraulic gradients in the vicinity of the spreading grounds.

Solute Transport Models

PCE – Scenario A

219. Results for the PCE transport model are shown in Muni/Western Ex. 6-245 and 6-246. These figures show the modeled MCL plume (i.e., 5 µg/L) boundary of the Newmark and Muscoy PCE plumes for Scenario A compared to that of the No Project Condition. The PCE plume boundary dissipates more quickly (by three years) as a result of increased artificial recharge at spreading basins upgradient of the plumes (see Muni/Western Ex. 6-247 for screenshot of animated movement of PCE from 2001 through 2039 – the animation file is part of the testimony presentation, and Muni/Western Ex. 6-248). These spreading grounds include Lytle Creek, Devil Canyon/Sweetwater, East Twin, and Waterman Spreading Grounds in the northwestern portion of the SBBA.

220. The plume size in Scenario A is smaller than the plume sizes of the No Project Condition (see model years 2030, 2035 and 2039 in Muni/Western Ex. 6-245 and 6-246). Scenario A also shows greater reduction in plume sizes than Scenario D. At the Lytle Creek, Devil Canyon/Sweetwater, East Twin, and Waterman Spreading Grounds there is a 59% increase in artificial recharge from Scenario A compared to the No Project Condition.

TCE – Scenario A

221. Results for the TCE transport model are shown in Muni/Western Ex. 6-249 and 6-250. These figures show the modeled MCL plume (i.e., 5 µg/L) boundary of the Norton and Redlands-Crafton TCE plumes for each of the project scenarios compared to that of the No Project Condition. The TCE plume boundary dissipates more quickly (by five years)

as a result of increased artificial recharge at spreading basins upgradient of the Norton plume and increased pumping from the Pressure Zone by Plaintiffs (see Muni/Western Ex. 6-251 for screenshot of animated movement of PCE from 2001 through 2039 – the animation file is part of the testimony presentation, and Muni/Western Ex. 6-252).

222. The TCE plume boundary disappears earliest in Scenario A as shown where the plume boundary has disappeared entirely by 2035 (see Muni/Western Ex. 6-249 and 6-250). There is a 58% increase in artificial recharge at the spreading grounds at the northwestern part of the SBBA over that of the No Project Condition for Scenario A. In addition, there is an increase in pumping from Plaintiffs by 3,094 acre-ft/year for Scenario A relative to the No Project Condition.

TDS – Scenario A

223. Total dissolved solids (TDS) concentrations from the solute transport model were examined for the No Project Condition and Scenario A. The average TDS concentration for the SBBA compared to the No Project Condition was calculated by determining the differences in cell-by-cell model concentration at the end of model simulation between the project scenario and the No Project Condition. A weighted average of the differences was then calculated based on the aquifer thickness and specific yield. For Scenario A, the weighted average of the difference in TDS concentration for the SBBA between the No Project Condition and the project scenario is +0.75 mg/L (see Table 29).

Table 29. Average of the Difference in TDS Concentration for the SBBA from No Project Condition - 2039

Model Scenario	*Weighted Average of Difference from No Project [mg/L]*
A	+0.75
D	-0.21

224. The differences in TDS concentration between the No Project Condition and project scenarios resulted from the different amounts of SWP spreading, Santa Ana River spreading, Santa Ana River channel percolation, and groundwater pumping.

225. Model-generated TDS concentration at the 25 index wells and nine spreading grounds for project scenarios and were compared to the No Project Condition and are shown in Muni/Western Ex. 6-253 through 6-286. Most of these wells are deep and show TDS concentrations from Model Layer 2. These wells are isolated and buffered from the TDS changes in Layer 1 and therefore show infrequent variation and little difference between scenarios. TDS at index well IW-14 decreases the most in response to high volumes of low TDS Santa Ana River water applied to spreading grounds at Devil Canyon/Sweetwater, Waterman, and East Twin Creek Spreading Grounds for Scenario A (see Muni/Western Ex. 6-266). Deep wells near the upper reaches of the Santa Ana River region, including IW-17 (see Muni/Western Ex. 6-269) maintain fairly constant, low TDS concentrations as a result of recharge from the Santa Ana River or high quality, low TDS artificial recharge at the Santa Ana River or Mill Creek Spreading Grounds for the No Project Condition and all project scenarios. Deep wells in the Pressure Zone, such as IW-11 (see Muni/Western Ex. 6-263) and IW-12 (Muni/Western Ex. 6-264), show less change with time than wells in the central basin area, but outside the Pressure Zone.

226. Model-generated TDS concentration at the spreading grounds for the project scenarios compared to the No Project Condition is also shown in Muni/Western Ex. 6-278 through 6-286. TDS concentrations at Patton, East Twin Creek, and Waterman Spreading Grounds change most frequently in response to annual fluctuations of low TDS recharge water from either the SWP or Santa Ana River. The ambient, groundwater TDS concentration in these areas is generally high and the applied high quality recharge water dilutes the existing conditions during periods of high recharge. TDS concentrations at the Santa Ana River and Mill Creek Spreading Grounds are generally constant since recharge water is generally the same concentration as the ambient conditions. Differences in TDS concentrations between model scenarios at spreading grounds are principally a result of the frequency and amount of low TDS recharge water allocated to each scenario.

227. To analyze water quality impacts at the basin scale, the average concentration level for TDS was projected for the end of the model simulation in future year 2039. These levels are shown in Table 30 for each of the management zones within the SBBA.

Table 30. Average TDS Levels at the End of Model Simulation (Year 2039)

Water Quality Objective(WQO)	*TDS, mg/L*			
Groundwater Management Zone	*SWRCB WQO*	*No Project Condition*	*Scenario A*	*Scenario D*
Bunker Hill A	310	355	347	351
Difference from WQO		*45*	*37*	*41*
Difference from No Project		*NA*	*-8*	*-4*
Bunker Hill B	330	262	267	263
Difference from WQO		*-68*	*-63*	*-67*
Difference from No Project		*NA*	*6*	*2*
Lytle	260	211	213	213
Difference from WQO		*-49*	*-47*	*-47*
Difference from No Project		*NA*	*2*	*1*

228. There would be beneficial impacts under all Project scenarios in Bunker Hill A under the current WQOs as compared to the No Project Condition. Less than significant impacts could be expected in the Bunker Hill B and Lytle management zones (see Table 30).

229. The differences in TDS concentration between Project scenarios and the No Project Condition result, in large part, from differences in the amounts of SWP spreading, Santa Ana River spreading, Santa Ana River channel percolation, and groundwater pumping.

230. Most of the 25 index wells (see Muni/Western Ex. 6-287 for locations) used for this analysis are deep and TDS concentrations vary little among scenarios. TDS at index well IW14 (Leroy Street Well), illustrated in Muni/Western Ex. 6-288, decreases the most in response to high volumes of low TDS Santa Ana River water applied to spreading grounds at Devil Canyon/Sweetwater, Waterman, and East Twin Creek spreading

grounds under Project Scenario A. Deep wells near the upper reaches of the Santa Ana River region, including IW17 (Well 32) shown in Muni/Western Ex. 6-289, maintain fairly constant, low TDS concentrations as a result of recharge from the Santa Ana River or high quality, low TDS artificial recharge at the Santa Ana River or Mill Creek spreading grounds for the No Project Condition and all Project scenarios. Deep wells in the Pressure Zone, such as IW11 (Raub 1) illustrated in Muni/Western Ex. 6-290, and IW12 (Lower Kelly) shown in Muni/Western Ex. 6-291, demonstrate less change with time than wells in the intermediate section of the SBBA, but outside the Pressure Zone.

231. Projected TDS concentrations at Patton, East Twin Creek, and Waterman spreading grounds change most frequently in response to annual fluctuations of low TDS recharge water from either the SWP or Santa Ana River. The ambient groundwater TDS concentration in these areas is generally high and the applied high quality recharge water dilutes the existing concentrations during periods of high recharge. TDS concentrations at the Santa Ana River and Mill Creek spreading grounds are generally constant since recharge water generally has the same concentration level as the ambient conditions. Differences in TDS concentrations between Project scenarios at spreading grounds are principally a result of the frequency and amount of low TDS recharge water allocated in each scenario.

232. Under all Project Scenarios A and D, and when considering current WQOs, the most frequent impacts are beneficial with 50 percent or more of all impact determinations falling in this category (see Table 31). Significant impacts would be experienced in no more than 10 percent of all instances. Locations with significant impacts cluster in Bunker Hill A with beneficial impacts clustered in Bunker Hill B and Lytle Creek management zones.

Table 31. Frequency of Impact Determinations for TDS

	Impact Determination based on Water Quality Objective		
Project Scenario	*% Significant*	*% Less than Significant*	*% Beneficial*
A	10	40	50
D	9	39	52

Nitrate – Scenario A

233. For Scenario A, the average nitrate (as NO_3) concentration for the SBBA compared to the No Project Condition was calculated using the same method described above for TDS. The weighted average of the difference in nitrate (as NO_3) concentration for the SBBA between the No Project Condition and Scenario A was -0.49 mg/L (see Table 32).

Table 32. Average of the Difference in Nitrate (as NO_3) Concentration for the SBBA from No Project Condition – 2039

Model Scenario	*Weighted Average of Difference from No Project [mg/L]*
A	-0.49
D	-0.19

234. The minor difference in nitrate (as NO_3) concentration between the No Project Condition and the project scenarios resulted from differences in SWP spreading, Santa Ana River spreading, Santa Ana River channel percolation, and groundwater pumping.

235. Model-generated nitrate (as NO_3) concentrations at the 25 index wells and nine spreading grounds for the project scenarios compared to the No Project Condition are shown in Muni/Western Ex. 6-292 through 6-325. As with the TDS concentrations, the deep wells show infrequent variation and little difference between scenarios and deep wells near the upper reaches of the Santa Ana River region maintain fairly constant, low nitrate concentrations as a result of recharge. Deep wells in the Pressure Zone, such as IW-11 and IW-12 show a steady decline in nitrate concentrations as high quality groundwater recharged at the spreading grounds gradually migrate to the Pressure Zone. The largest difference among deep wells between scenarios was observed at IW-16, which shows a decline in nitrate concentration at the end of the model period under the No Project Condition, while in Scenario A it resumes its initial high concentration after a brief decline (see Muni/Western Ex. 6-307). This occurs as a result of increased recharge of

high-quality, low nitrate Santa Ana River or SWP water at the Waterman, East Twin Creek, and Patton Spreading Grounds that push high nitrate groundwater from the Warm Creek region towards IW-18.

236. Model-generated nitrate (as NO_3) concentrations at spreading grounds for the project scenarios to the No Project Condition are shown in Muni/Western Ex. 292 through 6-325. As with TDS concentrations, frequent fluctuations at Waterman, Devil Canyon/Sweetwater, and Patton Spreading Grounds occurred in response to applied recharge water. Differences in nitrate (as NO_3) concentrations between model scenarios at spreading grounds are principally a result of the frequency and amount of low Nitrate recharge water allocated to each scenario.

237. For nitrate concentration levels, beneficial impacts would be anticipated for all management zones under current WQOs (see Table 33).

Table 33. Average Nitrate Concentration Levels at the End of Model Simulation (Year 2039)

Water Quality Objective	*Nitrate (NO_3), mg/L*			
Groundwater Management Zone	*SWRCB WQO*	*No Project Condition*	*Scenario A*	*Scenario D*
Bunker Hill A	12.1	12.3	10.3	11.4
Difference from WQO		*0*	*-2*	*-1*
Difference from No Project		*NA*	*-2*	*-1*
Bunker Hill B	32.8	10.2	10.5	10.4
Difference from WQO		*-23*	*-22*	*-22*
Difference from No Project		*NA*	*0*	*0*
Lytle	6.7	3.8	3.9	3.8
Difference from WQO		*-3*	*-3*	*-3*
Difference from No Project		*NA*	*0*	*0*

238. Under Project Scenarios A and D, when considering current WQOs, the most frequently occurring impacts are beneficial with 60 percent or more of all impact determinations falling in this category (Table 34). Significant impacts would be experienced in no more

than 4 percent of all instances. Locations with significant impacts cluster in Bunker Hill A, with beneficial impacts concentrated throughout the Bunker Hill B management zone.

Table 34. Frequency of Impact Determinations for Nitrate

	Impact Determination based on Water Quality Objective		
Project Scenario	*% Significant*	*% Less than Significant*	*% Beneficial*
A	2	35	63
D	4	36	60

Perchlorate – Scenario A

239. Results for the perchlorate transport model are shown in Muni/Western Ex. 6-326 and 6-327. These figures compare the modeled 6 µg/L plume boundary of the Redlands-Crafton plume for Scenario A to that of the No Project Condition. The plume takes slightly longer to dissipate in Scenario A than in Scenario D (see model year 2020 in Muni/Western Ex. 6-327 and 6-363, and Muni/Western Ex. 6-328). This is because more recharge occurs in the Santa Ana River in the No Project Condition or in the Santa Ana River and Mill Creek Spreading Grounds in Scenario D as compared to Scenario A.

<u>Liquefaction Potential – Scenario A</u>

240. Areas where depth to groundwater less than or equal to 50 ft below the land surface were delineated using the groundwater model. These areas are shown on Muni/Western Ex. 6-195 for selected years. The estimated acreages for each year are also shown on Muni/Western Ex. 6-195 for the entire SBBA as well as the Pressure Zone (not including the river channels). Yearly acreages are shown on Muni/Western Ex. 6-193 and 6-194. Differences in areas of potential liquefaction between Scenario A and the No Project Condition are shown on Muni/Western Ex. 6-329 for future year 2016 (hydrologic year 1977 – lowest groundwater level) and future year 2022 (hydrologic year 1983 – highest groundwater level). Muni/Western Ex. 6-330 is a screenshot of an animated sequence showing the changing areas of potential liquefaction over the predictive period (the animation file is part of the testimony presentation).

241. For Scenario A, there is a general reduction in the total area of potential liquefaction within the Pressure Zone area (not including river channels) when compared to the No Project Condition.

242. For Scenario A, the area of potential liquefaction in the Pressure Zone is substantially reduced during the wettest years of the hydrologic cycle compared to the No Project Condition. The area reduces to 7,533 acres for Scenario A with a total cumulative reduction in potential liquefaction area of 24,651 acres (77%).

243. Scenario A has more years where no potential liquefaction area (within the Pressure Zone) occurs as compared to the No Project Condition. For the No Project Condition, no potential liquefaction area occurs in 13 years of the 39-year model period (approximately 33% of the time; see Muni/Western Ex. 6-194). The number of years when no potential liquefaction area occurs increases to 26 years (67% of the time) for Scenario A. This is equal to an approximately 100% increase in the number of years of no potential liquefaction.

Subsidence Potential – Scenario A

244. The modeled subsidence for all scenarios is shown in Muni/Western Ex. 6-189. During the period from 2001 through 2039, the No Project Condition had 0.35 ft of subsidence at the location of Raub #8 with an average subsidence rate of 0.0083 ft/year. Scenario A had 0.62 ft of subsidence at the same location with an average subsidence rate of 0.0158 ft/year. There was a difference of 0.27 ft of subsidence between the No Project Condition and Scenario A. Table 35 summarizes the total subsidence and average subsidence rate at the location of Raub #8 during the period 2001 through 2039 for each model scenario.

Table 35. Total Subsidence and Average Subsidence Rate at the Location of Raub Well #8, 2001-2039

Scenario	*Total Subsidence [ft]*	*Average Subsidence Rate [ft/year]*
No Project	0.35	0.0083
Scenario A	0.62	0.0158
Scenario D	0.43	0.0108

245. It is important to note that the model-predicted subsidence was based on limited data on measured historical subsidence and parameters related to subsidence calculations (e.g., virgin and elastic compressibilities). Installation of extensometers to monitor the aquifer systems responding to the groundwater level changes can significantly enhance the ability of subsidence prediction.

Impacts of Spreading Outside of Model Area – Scenario A

Rialto-Colton Groundwater Basin (Cactus Spreading Grounds)

246. The Cactus Spreading Grounds are located in the approximate center of the Rialto-Colton Basin. The maximum amount of water allocated to the Cactus Spreading Grounds (from the Allocation Model) is 0 for the No Project Condition, and 18,953 acre-ft for Scenario A (see Muni/Western Ex. 6-385). Table 36 summarizes parameters used in the calculations of the groundwater mounds.

247. The maximum groundwater mound height was estimated to be 48 ft, near the center of the Cactus Spreading Grounds. Areas with a rise in groundwater level greater than 10 ft are approximately 3,400 acres for Scenario A (see Muni/Western Ex. 6-331). These recharge amounts did not cause the groundwater levels to rise to within 50 ft of the land surface.

248. Using the USGS Rialto-Colton groundwater flow model and particle tracking, Scenario A results indicates that the project will not substantially affect the flows of groundwater contaminants within the Rialto-Colton basin. Specifically, as shown in Muni/Western Ex. 6-332, the modeling shows that there are no substantial areas that would become

contaminated under the Project condition as compared to the No Project Condition. The impact of the Project appears to increase the velocity of groundwater flows rather than to change the direction of such flows. Therefore, the Project would have a less than significant impact groundwater conditions in the Rialto-Colton basin.

Table 36. Parameters Used to Hantush Equation
Cactus Spreading Grounds

Parameter	*Value*
Total Basin Area	46 acres
Rectangular Basin Width[20]	500 ft
Rectangular Basin Length	4,000 ft
Land Surface Elevation	1,400 ft amsl
Initial Groundwater Elevation	1,200 ft amsl
Bedrock Elevation	550 ft amsl
Saturated Thickness	650 ft
Hydraulic Conductivity	374 gpd/ft^2
Effective Porosity	0.15
Total Recharge Volume	13,217 acre-ft (Scenario D) 18,953 acre-ft (Scenario A)
Duration of Recharge	144 days (Scenario D) 206 days (Scenario A)
Recharge Rate	2 ft/day
Maximum Recharge Mound Height	144 days (Scenario D) – 45 ft 206 days (Scenario A) – 48 ft

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[20] For purposes of the groundwater mound height calculation, it was assumed that the total spreading basin area was approximated by a rectangle having the same area.

Yucaipa Groundwater Basin (Wilson Spreading Grounds)

249. The Wilson Spreading Grounds are located in the center of the Yucaipa Basin. The maximum amount of water allocated to the Wilson Spreading Grounds by the Allocation Model is zero for the No Project Condition and 2,154 acre-ft for all project scenarios (see Muni/Western Ex. 6-385). Table 37 summarizes the parameters for the calculations of the groundwater mound height using the Hantush Equation.

Table 37. Parameters used in Hantush Equation
Wilson Spreading Grounds

Parameter	*Value*
Total Basin Area	34 acres
Rectangular Basin Width	650 ft
Rectangular Basin Length	2,275 ft
Land Surface Elevation	2,850 ft amsl
Initial Groundwater Elevation	2,700 ft amsl
Bedrock Elevation	2,250 ft amsl
Saturated Thickness	450 ft
Hydraulic Conductivity	66 gpd/ft^2
Effective Porosity	0.15
Total Recharge Volume	2,154 acre-ft
Duration of Recharge	63 days
Recharge Rate	1 ft/day
Maximum Recharge Mound Height	76 ft

250. Results from the analytical Hantush Equation are shown as groundwater mound height contours for Scenario A (see Muni/Western Ex. 6-331). The maximum groundwater mound height was estimated to be 76 ft, near the center of the Wilson Spreading Grounds. Areas with a rise in groundwater level greater than 10 ft are approximately

400 acres for Scenario A. These recharge amounts did not cause the groundwater levels to rise to within 50 ft of the land surface.

San Timoteo Groundwater Basin (Garden Air Creek Spreading Ground)

251. The Garden Air Creek Spreading Grounds are located in the San Timoteo Groundwater Basin. The maximum amount of water allocated to the Garden Air Creek Spreading Grounds by the Allocation Model is zero for the No Project Condition and 5,745 acre-ft for all the project scenarios (see Muni/Western Ex. 6-385). Table 38 summarizes the parameters for the calculations of the groundwater mound height using the Hantush Equation.

Table 38. Parameters used in Hantush Equation
Garden Air Creek Spreading Grounds

Parameter	*Value*
Total Basin Area	26 acres
Rectangular Basin Width	566 ft
Rectangular Basin Length	2,000 ft
Land Surface Elevation	2,360 ft amsl
Initial Groundwater Elevation	2,200 ft amsl
Bedrock Elevation	1,800 ft amsl
Saturated Thickness	400 ft
Hydraulic Conductivity	224 gpd/ft^2
Effective Porosity	0.15
Total Recharge Volume	5,745 acre-ft
Duration of Recharge	221 days
Recharge Rate	1 ft/day
Maximum Recharge Mound Height	38 ft

252. Results from the analytical Hantush Equation are shown as groundwater mound height contours for Scenario A (see Muni/Western Ex. 6-331). The maximum groundwater mound height was estimated to be 38 ft, near the center of the Garden Air Creek Spreading Grounds. Areas with a rise in groundwater level greater than 10 ft are approximately 930 acres for all four project scenarios. These recharge amounts did not cause the groundwater levels to rise to within 50 ft of the land surface.

Project Scenario D (Minimum Capture)

Groundwater Levels – Scenario D

253. Groundwater flow directions and general patterns of fluctuations for Scenario D are similar to the No Project Condition (see Muni/Western Ex. 6-333 and 6-334).

254. Differences in groundwater levels between the No Project Condition and Scenario D in selected years are shown in Muni/Western Ex. 6-335 (Model Layer 1) and Muni/Western Ex. 6-336 (Model Layer 2).

255. Hydrographs at selected wells and spreading grounds for the No Project Condition and Scenario D are shown in Muni/Western Ex. 6-199 through 6-223. These hydrographs show the temporal variations in the groundwater levels reflecting the hydrologic conditions, artificial recharge and groundwater pumping assumed for the scenarios.

Groundwater Storage – Scenario D

256. The annual groundwater budget for the Scenario D is shown in Muni/Western Ex. 6-386. Table 26 and Muni/Western Ex. 6-337 summarize the average annual groundwater budgets for the period 2001-2039.

257. As shown in Table 26, the primary change in groundwater budgets between the No Project Condition and Scenario D is recharge from gaged streamflow. For the No Project Condition, the average annual recharge from gaged streamflow is 139,517 acre-ft/year. For Scenario D, the groundwater recharge from streamflow would be reduced by approximately 11,264 acre-ft/year (139,517-128,253 = 11,264), due to the diversion of

the Santa Ana River water. For the No Project Condition, a portion of the 20,704 acre-ft/year undiverted Santa Ana River water would recharge the groundwater basin.

258. Muni/Western Ex. 6-338 shows the inflow and outflow terms as a percentage of the total groundwater budget and average annual change in groundwater storage for Scenario D as compared to the No Project Condition.

<u>Groundwater Quality – Scenario D</u>

Particle Tracking

259. Paths traveled by particles in the four Project scenarios were compared to paths traveled for particles under the No Project Condition (see Muni/Western Ex. 6-339 through 6-357). In general, groundwater flow directions are similar under the four Project scenarios and the No Project Condition, but the rate of groundwater flow differs. The differences are due primarily to increased hydraulic gradients as the result of artificial recharge.

260. For Scenario D, groundwater flow rates are slightly faster in the northwestern portion of the SBBA and slower in the southeastern portion of the SBBA in comparison to the No Project Condition, reflecting the diversion of Santa Ana River water. The magnitude of these differences is less than that observed between Scenario A and the No Project Condition.

261. Groundwater flow from the fronts of plumes in the Pressure Zone is similar to flow for the No Project Condition and its direction is similar. Because the increases in seepage velocity occur mainly upgradient of contaminant plumes, they are not expected to interfere with the operation of existing remediation systems. In fact, increasing the rate of groundwater flow upgradient of the contaminant plumes may actually aid in the remediation efforts, as the upgradient portion of the plume would be "pushed" by the increased flow velocities resulting from steeper hydraulic gradients in the vicinity of the spreading grounds.

Solute Transport Models

PCE – Scenario D

262. Results for the PCE transport model are shown in Muni/Western Ex. 6-358 and 6-359. These figures show the modeled MCL plume (i.e., 5 µg/L) boundary of the Newmark and Muscoy PCE plumes for Scenario D compared to that of the No Project Condition. In Scenario D, the PCE plume boundary dissipates more quickly as a result of increased artificial recharge at spreading basins upgradient of the plumes. These spreading grounds include Lytle Creek, Devil Canyon/Sweetwater, East Twin, and Waterman Spreading Grounds in the northwestern portion of the SBBA.

263. The plume sizes for Scenario D are smaller than the plume sizes of the No Project Condition (see model years 2030, 2035 and 2039 in Muni/Western Ex. 6-358 and 6-359). Scenario D has 20% more artificial recharge at these spreading grounds than the No Project Condition.

TCE – Scenario D

264. Results for the TCE transport model are shown in Muni/Western Ex. 6-360 and 6-361. These figures show the modeled MCL plume (i.e., 5 µg/L) boundary of the Norton and Redlands-Crafton TCE plumes for each of the project scenarios compared to that of the No Project Condition. The TCE plume boundary dissipates more quickly as a result of increased artificial recharge at spreading basins upgradient of the Norton plume and increased pumping from the Pressure Zone by Plaintiffs.

265. The plume sizes for Scenario D are smaller than the plume sizes of the No Project Condition (see model years 2035 and 2039 in Muni/Western Ex. 6-360 and 6-361). The reduction of plume sizes for Scenario D is less than the reduction for Scenario A. Scenario D has 20% more artificial recharge at these spreading grounds than the No Project Condition.

TDS – Scenario D

266. Total dissolved solids (TDS) concentrations from the solute transport model were examined for the No Project Condition and Scenario D. The average TDS concentration

for the SBBA compared to the No Project Condition was calculated by determining the differences in cell-by-cell model concentration at the end of model simulation between the project scenario and the No Project Condition. A weighted average of the differences was then calculated based on the aquifer thickness and specific yield. For Scenario D, the weighted average of the difference in TDS concentration for the SBBA between the No Project Condition and the project scenario is +0.21 mg/L (see Table 29).

267. The differences in TDS concentration between the No Project Condition and project scenarios resulted from the different amounts of SWP spreading, Santa Ana River spreading, Santa Ana River channel percolation, and groundwater pumping.

268. Model-generated TDS concentrations at the 25 index wells and nine spreading grounds for project scenarios and were compared to the No Project Condition and are shown in Muni/Western Ex. 6-253 through 6-286. Most of these wells are deep and show TDS concentrations from Model Layer 2. These wells are isolated and buffered from the TDS changes in Layer 1 and therefore show infrequent variation and little difference between scenarios. Deep wells near the upper reaches of the Santa Ana River region, including IW-17 (see Muni/Western Ex. 6-269) maintain fairly constant, low TDS concentrations as a result of recharge from the Santa Ana River or high quality, low TDS artificial recharge at the Santa Ana River or Mill Creek Spreading Grounds for the No Project Condition and all project scenarios. Deep wells in the Pressure Zone, such as IW-11 (see Muni/Western Ex. 6-263) and IW-12 (Muni/Western Ex. 6-264), show less change with time than wells in the central basin area, but outside the Pressure Zone.

269. Model-generated TDS concentration at the spreading grounds for the project scenarios compared to the No Project Condition is also shown in Muni/Western Ex. 6-278 through 6-286. TDS concentrations at Patton, East Twin Creek, and Waterman Spreading Grounds change most frequently in response to annual fluctuations of low TDS recharge water from either the SWP or Santa Ana River. The ambient, groundwater TDS concentration in these areas is generally high and the applied high quality recharge water dilutes the existing conditions during periods of high recharge. TDS concentrations at the Santa Ana River and Mill Creek Spreading Grounds are generally constant since recharge water is generally the same concentration as the ambient conditions. Differences in TDS

concentrations between model scenarios at spreading grounds are principally a result of the frequency and amount of low TDS recharge water allocated to each scenario.

270. To analyze water quality impacts at the basin scale, the average concentration level for TDS was projected for the end of the model simulation in future year 2039. These levels are shown in Table 30 for each of the management zones within the SBBA.

Nitrate – Scenario D

271. For Scenario D, the average nitrate (as NO_3) concentration for the SBBA compared to the No Project Condition was calculated using the same method described in the section above for TDS. The weighted average of the difference in nitrate (as NO_3) concentration for the SBBA between the No Project Condition and Scenario A was -0.19 mg/L (see Table 32).

272. The minor difference in nitrate (as NO_3) concentration between the No Project Condition and the project scenarios resulted from differences in SWP spreading, Santa Ana River spreading, Santa Ana River channel percolation, and groundwater pumping.

273. Model-generated nitrate (as NO_3) concentrations at the 25 index wells and nine spreading grounds for the project scenarios compared to the No Project Condition are shown in Muni/Western Ex. 6-292 through 6-325. As with the TDS concentrations, the deep wells show infrequent variation and little difference between scenarios and deep wells near the upper reaches of the Santa Ana River region maintain fairly constant, low nitrate concentrations as a result of recharge. Deep wells in the Pressure Zone, such as IW-11 and IW-12 show a steady decline in nitrate concentrations as high quality groundwater recharged at the spreading grounds gradually migrate to the Pressure Zone. The largest difference among deep wells between scenarios was observed at IW-16, which shows a decline in nitrate concentration at the end of the model period under the No Project Condition. This occurs as a result of increased recharge of high-quality, low nitrate Santa Ana River or SWP water at the Waterman, East Twin Creek, and Patton Spreading Grounds that push high nitrate groundwater from the Warm Creek region towards IW-18.

274. Model-generated nitrate (as NO_3) concentrations at spreading grounds for project scenarios to the No Project Condition are shown in Muni/Western Ex. 6-292 through 6-299. As with TDS concentrations, frequent fluctuations at Waterman, Devil Canyon/Sweetwater, and Patton Spreading Grounds occurred in response to applied recharge water. Differences in nitrate (as NO_3) concentrations between model scenarios at spreading grounds are principally a result of the frequency and amount of low Nitrate recharge water allocated to each scenario.

275. For nitrate concentration levels, beneficial impacts would be anticipated for all management zones under current WQOs (see Table 33).

Perchlorate – Scenario D

276. Results for the perchlorate transport model are shown in Muni/Western Ex. 6-362 and 6-363. These figures compare the modeled 6 μg/L plume boundary of the Redlands-Crafton plume for Scenario D to that of the No Project Condition. The plume advances and disappears fastest in the No Project Condition and Scenario D, but takes slightly longer to disappear in Scenarios A (see model year 2020 in Muni/Western Ex. 6-363 and 6-327). This is because more recharge occurs in the Santa Ana River in the No Project Condition or in the Santa Ana River and Mill Creek Spreading Grounds in Scenario D as compared to Scenario A.

Liquefaction Potential – Scenario D

277. Differences from the No Project Condition compared to Scenario D are that the area of potential liquefaction in the Pressure Zone is reduced during wet years (see Muni/Western Ex. 6-364). The cumulative total area of potential liquefaction in the Pressure Zone for the No Project Condition during the period 2001 through 2039 is approximately 32,184 acres. The area of potential liquefaction reduced to 16,825 acres for Scenario D. This amounted to a reduction of 15,359 acres for Scenario D (or a reduction of areas subjected to potential liquefaction of 48% (15,359/32,184)).

278. Scenario D has more years where no potential liquefaction area (within the Pressure Zone) occurs as compared to the No Project Condition. For the No Project Condition, no

potential liquefaction area occurs in 13 years of the 39-year model period (approximately 33% of the time; see Muni/Western Ex. 6-194). The number of years when no potential liquefaction area occurs increases to 18 years (46% of the time) for Scenario D. This is equal to an approximately 38% increase in the number of years of no potential liquefaction.

Subsidence Potential – Scenario D

279. The modeled subsidence for all scenarios is shown in Muni/Western Ex. 6-189. During the period from 2001 through 2039, the No Project Condition had 0.35 ft of subsidence at the location of Raub #8 with an average subsidence rate of 0.0083 ft/year. Scenario D had 0.43 ft of subsidence at the same location with an average subsidence rate of 0.0108 ft/year. There was a difference of 0.08 ft of subsidence between the No Project Condition and Scenario D.

Impacts of Spreading Outside of Model Area – Scenario D

Rialto-Colton Groundwater Basin (Cactus Spreading Grounds)

280. The Cactus Spreading Grounds are located in the approximate center of the Rialto-Colton Basin. The maximum amount of water allocated to the Cactus Spreading Grounds (from the Allocation Model) is 0 for the No Project Condition and 13,217 acre-ft for Scenario D (see Muni/Western Ex. 6-384). Table 36 summarizes parameters used in the calculations of the groundwater mounds.

281. Results from the analytical Hantush Equation are shown as groundwater mound height contours for Scenario D (see Muni/Western Ex. 6-365). The maximum groundwater mound height was estimated to be 48 ft, near the center of the Cactus Spreading Grounds. Areas with a rise in groundwater level greater than 10 ft are approximately 2,400 acres for Scenario D. These recharge amounts did not cause the groundwater levels to rise to within 50 ft of the land surface.

Yucaipa Groundwater Basin (Wilson Spreading Grounds)

282. The Wilson Spreading Grounds are located in the center of the Yucaipa Basin. The maximum amount of water allocated to the Wilson Spreading Grounds by the Allocation

Model is zero for the No Project Condition and 2,154 acre-ft for all project scenarios (see Muni/Western Ex. 6-385). Table 37 summarizes the parameters for the calculations of the groundwater mound height using the Hantush Equation.

283. Results from the analytical Hantush Equation are shown as groundwater mound height contours for Scenario D (see Muni/Western Ex. 6-365). The maximum groundwater mound height was estimated to be 76 ft, near the center of the Wilson Spreading Grounds. Areas with a rise in groundwater level greater than 10 ft are approximately 400 acres for Scenario D. These recharge amounts did not cause the groundwater levels to rise to within 50 ft of the land surface.

San Timoteo Groundwater Basin (Garden Air Creek Spreading Ground)

284. The Garden Air Creek Spreading Grounds are located in the San Timoteo Groundwater Basin. The maximum amount of water allocated to the Garden Air Creek Spreading Grounds by the Allocation Model is zero for the No Project Condition and 5,745 acre-ft for all the project scenarios (see Muni/Western Ex. 6-384). Table 38 summarizes the parameters for the calculations of the groundwater mound height using the Hantush Equation.

285. Results from the analytical Hantush Equation are shown as groundwater mound height contours for Scenario (see Muni/Western Ex. 6-365). The maximum groundwater mound height was estimated to be 38 ft, near the center of the Garden Air Creek Spreading Grounds. Areas with a rise in groundwater level greater than 10 ft are approximately 930 acres for all four project scenarios. These recharge amounts did not cause the groundwater levels to rise to within 50 ft of the land surface.

Most Likely Scenario (Incorporates Seven Oaks Accord and Settlement with Conservation District)

<u>Groundwater Levels – Most Likely Scenario</u>

286. Groundwater flow directions and general patterns of fluctuations for the Most Likely Scenario are similar to the No Project Condition (see Muni/Western Ex. 6-366 and 6-367).

287. Differences in groundwater levels between the No Project Condition and the Most Likely Scenario in selected years are shown in Muni/Western Ex. 6-368 (Model Layer 1) and Muni/Western Ex. 6-369 (Model Layer 2).

288. Hydrographs at selected wells and spreading grounds for the No Project Condition and the Most Likely Scenarios from the Draft EIR are shown in Muni/Western Ex. 6-199 through 6-223. These hydrographs show the temporal variations in the groundwater levels reflecting the hydrologic conditions, artificial recharge and groundwater pumping assumed for the scenarios.

Groundwater Storage – Most Likely Scenario

289. The annual groundwater budget for the Most Likely Scenario is shown in Muni/Western Ex. 6-387. Table 26 and Muni/Western Ex. 6-370 summarize the average annual groundwater budgets for the period 2001-2039.

290. As shown in Table 26, the primary change in groundwater budgets between the No Project Condition and the Most Likely Scenario is recharge from gaged streamflow. For the No Project Condition, the average annual recharge from gaged streamflow is 139,517 acre-ft/year. For the Most Likely Scenario, the groundwater recharge from streamflow would be reduced by approximately 8,880 acre-ft/year (139,517-130,637 = 8,880), due to the diversion of the Santa Ana River water. For the No Project Condition, a portion of the 20,704 acre-ft/year undiverted Santa Ana River water would recharge the groundwater basin.

291. Muni/Western Ex. 6-371 shows the inflow and outflow terms as a percentage of the total groundwater budget and average annual change in groundwater storage for the Most Likely Scenario as compared to the No Project Condition.

Liquefaction Potential – Most Likely Scenario

292. Differences from the No Project Condition compared to the Most Likely Scenario is that the area of potential liquefaction in the Pressure Zone is reduced during wet years (see Muni/Western Ex. 6-372). The cumulative total area of potential liquefaction in the Pressure Zone for the No Project Condition during the period 2001 through 2039 is

approximately 32,184 acres. The area of potential liquefaction is reduced to 10,728 acres for the Most Likely Scenario. This amounted to a reduction of 21,456 acres for the Most Likely Scenario (or a reduction of areas subjected to potential liquefaction of 67% (21,456/32,184)).

293. The Most Likely Scenario has more years where no potential liquefaction area (within the Pressure Zone) occurs as compared to the No Project Condition. For the No Project Condition, no potential liquefaction area occurs in 13 years of the 39-year model period (approximately 33% of the time; see Muni/Western Ex. 6-194). The number of years when no potential liquefaction area occurs increases to 23 years (59% of the time) for the Most Likely Scenario. This is equal to an approximately 77% increase in the number of years of no potential liquefaction.

Maximum Amounts Recharged at Spreading Grounds

<u>Maximum Amount Spread during the 39 Year Predictive Period</u>

294. Muni/Western Ex. 6-388 summarizes the annual amounts of water that could be recharged in spreading basins both within and outside of the SBBA (within Muni/Western's service area) for Scenarios A, D and the Most Likely Scenario. From this table, the maximum amount that could be spread in one year is approximately 131,000 acre-ft (using 1992-93's hydrology).

295. Using Scenario A (which takes into account maximum diversions), the maximum amount of water that could be spread within Muni/Western's service area over the 39 year predictive period at each of the spreading grounds is listed in Table 39.

Table 39. Maximum Scenario A Spreading vs. Recorded Peak (Hydrologic Year 1980) Scenario A Spreading

	Facility Name	*Maximum Spreading – Scenario A*		*Spreading in 1980 Hydrologic Year (Model Year 2019) Scenario A [acre-ft]*
		Amount [acre-ft]	*Hydrologic Year(s)*	
Inside SBBA	Devil Canyon and Sweetwater Basins	9,800	1972	2,600
	City Creek Spreading Grounds	35,000	1993	0
	Patton Basin	724	1978 to 1979, 1993 to 1996, 1998	374
	Waterman Basins	21,719	1978 to 1979, 1985, 1993 to 1995, 1998	8,820
	East Twin Creek Spreading Grounds	17,375	1978 to 1979, 1985, 1993 to 1995, 1998	8,190
	Badger Basins	2,896	1978 to 1980, 1993 to 1996, 1998	2,896
	Lytle Basins	10,000	1974	1,260
	Santa Ana River Spreading Grounds	10,400	1967, 1970, 1971	10,126
	Mill Creek Spreading Grounds	7,176	1993	0
	Total	**115,090**		**34,266**
Outside SBBA	Cactus Spreading and Flood Control Basins	18,953	1969	10,483
	Wilson Basins	2,154	1969	1,797
	Garden Air Creek	5,745	1969	4,793
	Total	**26,852**		**17,073**

See DRAFT EIR Figure 3.2-1 for spreading ground locations
Source: SAIC

Maximum Possible Spreading

296. The maximum amount of water that could possibly be recharged at the spreading grounds within Muni/Western's service area (excluding the Santa Ana River spreading grounds) based on absorptive capacity provided by SAIC is approximately 178,000 acre-ft (see Table 40).

Table 40. Groundwater Recharge Facilities

		Conveyance Used to Serve Facility	*Recharge Facility Characteristics*[a]					
Facility Name	*Owner or Operator*	*Turnout Name & Capacity (cfs)*	*Active Recharge Facility Area*[b] *(acres)*	*Percolation Rate*[c] *(ft/day)*	*Monthly Capacity (acre-ft)*	*Absorptive Capacity used in Allocation Analysis*[d] *(cfs)*	*Maximum Possible Annual Spreading*[e] *(acre-ft)*	*Groundwater Basin (and Management Zone) Recharged*[f]
Santa Ana River Spreading Grounds	Conservation District	Foothill Pipeline Santa Ana Low Flow (288)	60 [h]	1.5	3,060	50 [i]	36,203	SBBA (Bunker Hill B)
Devil Canyon and Sweetwater Basins	SBCFCD [f]	Foothill Pipeline Sweetwater (37)	30	1.5	1,350	23	16,654	SBBA (Bunker Hill A)
Lytle Basins	Lytle Creek Water Conservation Association	Fontana Power Plant Constructed drainage channel	Variable	1.5	Variable	30 [k]	21,722	SBBA (Lytle Creek)
City Creek Spreading Grounds	SBCFCD	Foothill Pipeline City Creek (60)	75	1.5	3,375	57	41,272	SBBA (Bunker Hill B)
Patton Basin	SBCFCD	Foothill Pipeline Patton (12)	3	0.3	27	1	724	SBBA (Bunker Hill B)

Table 40. Groundwater Recharge Facilities

		Conveyance Used to Serve Facility	*Recharge Facility Characteristics*[a]					
Facility Name	*Owner or Operator*	*Turnout Name & Capacity (cfs)*	*Active Recharge Facility Area*[b] *(acres)*	*Percolation Rate*[c] *(ft/day)*	*Monthly Capacity (acre-ft)*	*Absorptive Capacity used in Allocation Analysis*[d] *(cfs)*	*Maximum Possible Annual Spreading*[e] *(acre-ft)*	*Groundwater Basin (and Management Zone) Recharged*[f]
Waterman Basins	SBCFCD	Foothill Pipeline Waterman (135)	120	0.5	810	30[j]	21,722	SBBA (Bunker Hill A)
East Twin Creek Spreading Grounds	SBCFCD	Foothill Pipeline Waterman (135)	32	1.5	225	24[1]	17,378	SBBA (Bunker Hill A)
Badger Basins	SBCFCD	Foothill Pipeline Badger (22)	15	0.5	225	4	2,896	SBBA (Bunker Hill A)
Mill Creek Spreading Grounds	SBVWCD	Greenspot Pipeline Mill Creek Spreading (50)	26	1.5	1,170	20	14,481	SBBA (Bunker Hill B)
Cactus Spreading and Flood Control Basins	SBCFCD	San Gabriel Valley Municipal Water District Lytle Pipeline Lower Lytle Creek (55)	46	1.5	2,070	35	25,342	Rialto-Colton
Wilson Basins	SBCFCD	East Branch Extension Wilson Basins (30)	12	1	360	6	4,344	Yucaipa Basin

Table 40. Groundwater Recharge Facilities

		Conveyance Used to Serve Facility	*Recharge Facility Characteristics*[a]					
Facility Name	*Owner or Operator*	*Turnout Name & Capacity (cfs)*	*Active Recharge Facility Area*[b] *(acres)*	*Percolation Rate*[c] *(ft/day)*	*Monthly Capacity (acre-ft)*	*Absorptive Capacity used in Allocation Analysis*[d] *(cfs)*	*Maximum Possible Annual Spreading*[e] *(acre-ft)*	*Groundwater Basin (and Management Zone) Recharged*[f]
Garden Air Creek	Muni	East Branch Extension Garden Air Creek (16)	n/a	n/a	n/a	16	11,585	San Timoteo Basin
Total for All Spreading Grounds, excluding Santa Ana River Spreading Grounds							*178,120*	

a. Values are from tabulation on map contained in Water Right Application by Muni and Western to appropriate water from the Santa Ana River or by engineering evaluation of spreading grounds.
b. Recharge facility area is the geographical extent of each basin that can be inundated for recharge.
c. Estimated percolation rate. This is the estimated rate at which water can percolate into the ground through the basin, expressed in feet per day. The values used have generally been computed from the annual recharge capacity tabulated on the application map. These rates are typically about one-half of the percolation rates presented by the United States Geological Survey (Moreland, 1972). The use of the smaller percolation rates is reasonable in that this Project would involve longer-term percolation rates that are typically smaller than short-term rates.
d. The estimated absorptive capacity for each site is computed by multiplying the basin area by the estimated percolation rate. Results are expressed in cubic feet per second (cfs) and used in the Allocation Model in acre-feet per month.
e. Average Annual Spreading is calculated from Absorptive Capacity x 24 hours x 365 days
f. Note that there may be flow out of the management zone or basin identified. For example, a report by GEOSCIENCE Support Services, Inc. (1992) estimated that only 36 percent of the water recharged in the upper Lytle Creek area remains in the Lytle management zone, while most of it flows to the Rialto–Colton Basin.
g. San Bernardino County Flood Control District.
h. Recharge facility area of 60 acres used, based on analysis of 1995 aerial photographs. However, the application map shows an area of 448 acres, which includes the borrow pit area for Seven Oaks Dam, possibly usable for recharge.
i. Santa Ana River Spreading Grounds were assigned 50 cfs because of shared use of this facility.
j. Available absorptive capacity of Lytle Basins is assigned 30 cfs per month for use in the Allocation Model because of groundwater recharge targets; however, it has a higher estimated absorptive capacity of 97 cfs.
k. Available absorptive capacity for the Waterman Spreading Ground was assigned 30 cfs per month in the Allocation Model based on historical recharge rates. This would require use of 54 acres of the total site of 165 acres.

l. Available absorptive capacity for the East Twin Creek Spreading Grounds was assigned 24 cfs per month in the Allocation Model based on historical recharge rates. This would require use of 32 acres of the total site of 144 acres.

XIII. Findings

297. Table 41 below summarizes the major findings of the groundwater flow and solute transport modeling, subsidence modeling and analytical methods.

Table 41. Summary of Findings

Scenario	*Potential Liquefaction*	*PCE Plume*	*TCE Plume*	*Perchlorate Plume*	*Basin Water Quality (TDS &NO3)*	*Potential Subsidence*	*Change in Basin Storage*	*Impacts of Spreading Outside SBBA*
Scenario A (Maximum Capture 1500 cfs)	77% Less than No Project	Dissipates More Rapidly	Dissipates More Rapidly	Dissipates Slightly Slower	Minimal Change (<1 mg/L)	Slightly more than No Project	Minimal Change	Groundwater levels do not rise within 50 ft of land surface
Scenario D (Minimum Capture 500 cfs)	48% Less than No Project	Dissipates More Rapidly	Dissipates More Rapidly	Dissipates Approx the Same	Minimal Change (< 1mg/L)	Slightly more than No Project	Minimal Change	Groundwater levels do not rise within 50 ft of land surface
Most Likely Scenario (1500 cfs, Conservation District Settlement & Senior Water Rights)	67% Less than No Project	NA	NA	NA	NA	Slightly more than No Project	Minimal Change	Groundwater levels do not rise within 50 ft of land surface

XIV. References

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XV. List of Exhibits

Exhibit No.	Original Figure Number	Title	Original Location	Modification
6-1		Testimony of Dennis E. Williams Santa Ana River Water Rights		
6-2		Resume of Dennis E. Williams		
6-3	2.1-1	Santa Ana River Watershed, Gaging Stations, and Muni/Western Service Area	DRAFT EIR – Main Report	
6-4		Analytical Method – Hantush (1967)	New figure	
6-5	B 1	Annual Streamflow at Lytle Creek near Fontana Gaging Station 1945-1998	DRAFT EIR – Appendix B (Addendum)	
6-6	B 2	Annual Streamflow at Cajon Creek below Lone Pine Creek near Keenbrook Gaging Station 1945-1998	DRAFT EIR – Appendix B (Addendum)	
6-7	B 3	Annual Streamflow at Devil Canyon Creek near San Bernardino Gaging Station 1945-1998	DRAFT EIR – Appendix B (Addendum)	
6-8	B 4	Annual Streamflow at Waterman Canyon Creek near Arrowhead Springs Gaging Station 1945-1998	DRAFT EIR – Appendix B (Addendum)	
6-9	B 5	Annual Streamflow at East Twin Creek near Arrowhead Springs Gaging Station 1945-1998	DRAFT EIR – Appendix B (Addendum)	
6-10	B 6	Annual Streamflow at City Creek near Highland Gaging Station 1945-1998	DRAFT EIR – Appendix B (Addendum)	
6-11	B 7	Annual Streamflow at Plunge Creek near East Highlands Gaging Station 1945-1998	DRAFT EIR – Appendix B (Addendum)	
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6-13	B 9	Annual Streamflow at Mill Creek near Yucaipa Gaging Station 1945-1998	DRAFT EIR – Appendix B (Addendum)	
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Exhibit No.	Original Figure Number	Title	Original Location	Modification
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Exhibit No.	Original Figure Number	Title	Original Location	Modification
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Exhibit No.	Original Figure Number	Title	Original Location	Modification
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6-99		Upper Santa Ana River - Probability of Exceedance for Annual Flow Quantity, Water Year 1966-67 to Water Year 1998-1999, No Project Condition Segment D: Below Mill Creek (Portion of Reach 5)	New figure	
6-100		Upper Santa Ana River - Probability of Exceedance for Annual Flow Quantity, Water Year 1966-67 to Water Year 1999-2000, No Project Condition Segment E: At E-Street Based on E-Street Gage (Portion of Reach 4)	New figure	
6-101		Upper Santa Ana River - Probability of Exceedance for Annual Flow Quantity, Water Year 1966-67 to Water Year 1999-2000, No Project Condition Segment F: Below RIX-Rialto Effluent Outfall (Portion of Reach 3 and Reach 4)	New figure	
6-102		Upper Santa Ana River - Probability of Exceedance for Annual Flow Quantity, Water Year 1966-67 to Water Year 1999-2000, Project Scenario A Segment B: Above Cuttle Weir (Portion of Reach 5)	New figure	

Exhibit No.	Original Figure Number	Title	Original Location	Modification
6-103		Upper Santa Ana River - Probability of Exceedance for Monthly Total Volumes, Water Year 1966-67 to Water Year 1999-2000, Project Scenario A Segment C: Downstream of Cuttle Weir (Portion of Reach 5)	New figure	
6-104		Upper Santa Ana River - Probability of Exceedance for Annual Flow Quantity, Water Year 1966-67 to Water Year 1998-1999, Project Scenario A Segment D: Below Mill Creek (Portion of Reach 5)	New figure	
6-105		Upper Santa Ana River - Probability of Exceedance for Annual Flow Quantity, Water Year 1966-67 to Water Year 1999-2000, Project Scenario A Segment E: At E-Street Based on E-Street Gage (Portion of Reach 4)	New figure	
6-106		Upper Santa Ana River - Probability of Exceedance for Annual Flow Quantity, Water Year 1966-67 to Water Year 1999-2000, Project Scenario A Segment F: Below RIX-Rialto Effluent Outfall (Portion of Reach 3 and Reach 4)	New figure	
6-107		Upper Santa Ana River - Number of Days without Flow per Water Year, Historical Data Water Year 1966-67 to Water Year 1999-00	New figure	
6-108		Upper Santa Ana River - Number of Days without Flow per Water Year, No Project Condition Data For Water Year 1966-67 to Water Year 1999-00	New figure	
6-109		Upper Santa Ana River - Number of Days without Flow per Water Year, Project Scenario A Water Year 1966-67 to Water Year 1999-00	New figure	
6-110		Upper Santa Ana River – Annual Number of Days without Flow Probability Distribution, Historical Data Water Year 1966-67 to Water Year 1999-00	New figure	
6-111		Upper Santa Ana River – Annual Number of Days without Flow Probability Distribution, No Project Condition, Water Year 1966-67 to Water Year 1999-00	New figure	
6-112		Upper Santa Ana River – Annual Number of Days without Flow Probability Distribution, Project Scenario A, Water Year 1966-67 to Water Year 1999-00	New figure	
6-113		Upper Santa Ana River - Probability of Exceedance for Days without Flow per Water Year, Historical Data Water Year 1966-67 to Water Year 1999-00	New figure	
6-114		Upper Santa Ana River - Probability of Exceedance for Days without Flow per Water Year, No Project Condition, Water Year 1966-67 to Water Year 1999-00	New figure	
6-115		Upper Santa Ana River - Probability of Exceedance for Days without Flow per Water Year, Project Scenario A Water Year 1966-67 to Water Year 1999-00		
6-116	3.1-6	Santa Ana River, Tributaries, Reaches, and Segment Indicators	DRAFT EIR – Main Report	X
6-117	3.2-2	San Bernardino Basin Area (SBBA)	DRAFT EIR – Main Report	

Exhibit No.	Original Figure Number	Title	Original Location	Modification
6-118	3.2-1	Groundwater Basins and Recharge Facilities	DRAFT EIR – Main Report	
6-119	3.2-3	San Bernardino Basin Area (SBBA): Sub-Areas	DRAFT EIR – Main Report	
6-120	3.2-4	San Bernardino Basin Area (SBBA) Groundwater Elevation Contours – 1994	DRAFT EIR – Main Report	
6-121	3.2-5	Cumulative Change in Groundwater Storage for the SBBA, WY 1934-35 to WY 2001-02	DRAFT EIR – Main Report	
6-122	3.2-12	Groundwater Level Hydrographs for Selected Wells in the Pressure Zone Sub-Basin , 1934-35 to 2001-02	DRAFT EIR – Main Report	
6-123	3.2-6	Average Change in Depth to Groundwater in the SBBA	DRAFT EIR – Main Report	
6-124	3.2-7	San Bernardino Basin Area (SBBA) Depth to Groundwater in 1991	DRAFT EIR – Main Report	
6-125	3.2-8	Average Change in Depth to Groundwater in the Lytle Creek Basin	DRAFT EIR – Main Report	
6-126	3.2-10	SARWQCB Management Zone Boundaries	DRAFT EIR – Main Report	Was Proposed, Now Current
6-127	3.12-1	Known Contamination Plumes and Sites	DRAFT EIR – Main Report	
6-128	3.2-13	Simulated Flow Pattern (1982-2027) with Historical Recharge in Cactus Basin	DRAFT EIR – Main Report	
6-129		Annual Precipitation Isohyetal and Precipitation Stations	New figure	
6-130		Length of Record for Precipitation Stations	New figure	
6-131		Station Base Period vs. Percentage of San Bernardino County Flood Control District Long-Term Average Annual Precipitation (1870-1970 Isohyetal Map)	New figure	
6-132		Station Base Period vs. Percentage of San Bernardino County Flood Control District Long-Term Average Annual Precipitation (1870-1970 Isohyetal Map) Precipitation Stations with 100+ Years of Available Data	New figure	
6-133		Station Base Period vs. Percentage of Station Long-Term Average Measured Annual Precipitation	New figure	
6-134		Station Base Period vs. Percentage of Station Long-Term Average Measured Annual Precipitation - Precipitation Stations with 100+ Years of Available Data	New figure	
6-135		Station Base Period vs. Percentage of Long-Term Average Annual Streamflow	New figure	
6-136		Cumulative Departure from Mean Annual Precipitation for the san Bernardino County Hospital Station and Criteria for Base Period Selection	New figure	
6-137	6.2-1	Model Grid of the San Bernardino Basin Area Groundwater Model	DRAFT EIR – Appendix B	
6-138		Model Conceptualization	New figure	
6-139		USGS Model Layers	New figure	
6-140	6.2-2	Transmissivity of Model Layers	DRAFT EIR – Appendix B	
6-141	6.2-3	Storativity of Model Layers	DRAFT EIR – Appendix B	
6-142	6.2-4	Vertical Leakance Values Between Model Layer 1 and	DRAFT EIR – Appendix B	

Exhibit No.	Original Figure Number	Title	Original Location	Modification
		Model Layer 2		
6-143	6.2-5	Hydraulic Characteristics of Groundwater Barriers	DRAFT EIR – Appendix B	
6-144	6.2-6	Location of Stream Segments	DRAFT EIR – Appendix B	
6-145	6.2-7	Total Annual Streamflow Inflow for the SBBA	DRAFT EIR – Appendix B	
6-146	6.2-8	Streambed Conductance Values for Stream Segments	DRAFT EIR – Appendix B	
6-147	6.2-9	Recharge from Local Runoff Generated by Precipitation for the SBBA	DRAFT EIR – Appendix B	
6-148	6.2-10	Average Annual Precipitation for the SBBA	DRAFT EIR – Appendix B	
6-149	6.2-11	Locations of Recharge from Mountain Front Runoff	DRAFT EIR – Appendix B	
6-150	6.2-12	Annual recharge from Mountain Front Runoff for the SBBA	DRAFT EIR – Appendix B	
6-151	6.2-13	Locations of Artificial Recharge of Imported Water	DRAFT EIR – Appendix B	
6-152	6.2-14	Annual Artificial Recharge of Imported Water for the SBBA	DRAFT EIR – Appendix B	
6-153	6.2-15	Locations of Groundwater Pumping Wells	DRAFT EIR – Appendix B	
6-154	6.2-16	Annual Groundwater Pumping for the SBBA	DRAFT EIR – Appendix B	
6-155	6.2-17	Annual Return Flow from Groundwater Pumping of the SBBA	DRAFT EIR – Appendix B	
6-156	6.2-18	Locations of Underflow Recharge and Discharge	DRAFT EIR – Appendix B	
6-157	6.2-19	Annual Underflow Recharge of the SBBA	DRAFT EIR – Appendix B	
6-158	6.2-20	Annual Underflow Discharge of the SBBA	DRAFT EIR – Appendix B	
6-159	6.2-21	Selected Hydrographs Flow Model Calibration	DRAFT EIR – Appendix B	
6-160	6.2-22	Comparison of Measured and Model-Generated Groundwater Levels – Model Calibration (1945-1998)	DRAFT EIR – Appendix B	
6-161	6.2-23	Comparison of Measured and Model-Generated SBBA Sreamflow Outflow Model Calibration	DRAFT EIR – Appendix B	
6-162	6.2-24	Comparison of measured and model generated groundwater levels model verification	DRAFT EIR – Appendix B	
6-163	6.3-1	Bottom Elevation of Model Layer 1	DRAFT EIR – Appendix B	
6-164	6.3-2	Bottom Elevation of Model Layer 2	DRAFT EIR – Appendix B	
6-165	6.3-3	Thickness of Model Layer 1	DRAFT EIR – Appendix B	
6-166	6.3-4	Thickness of Model Layer 2	DRAFT EIR – Appendix B	
6-167	6.4-1	Initial PCE Concentrations for Model Calibration	DRAFT EIR – Appendix B	
6-168	6.4-2	Initial TCE Concentrations for Model Calibration	DRAFT EIR – Appendix B	
6-169	6.4-3	Mass Loading for PCE Model Calibration	DRAFT EIR – Appendix B	
6-170	6.4-4	Mass Loading for TCE Model Calibration	DRAFT EIR – Appendix B	
6-171	B 50	Measured and Model Generated Plume Boundaries for PCE Model, Layer 1	FINAL EIR – Errata	
6-172	B 51	Measured and Model Generated Plume Boundaries for PCE Model, Layer 2	FINAL EIR – Errata	
6-173	B 52	Measured and Model Generated Plume Boundaries for TCE Model, Layer 1	FINAL EIR – Errata	
6-174	B 53	Measured and Model Generated Plume Boundaries for TCE Model, Layer 2	FINAL EIR – Errata	
6-175	B 54	Measured vs. Model Generated PCE Concentrations at Selected Locations	FINAL EIR – Errata	
6-176	B 55	Measured vs. Model Generated TCE Concentrations at Selected Locations	FINAL EIR – Errata	

Exhibit No.	Original Figure Number	Title	Original Location	Modification
6-177	B 56	Histogram of PCE Calibrated Residuals	DRAFT EIR – Appendix B (Addendum)	
6-178	B57	Histogram of TCE Residuals for Model Calibration – 1986 to 2000	DRAFT EIR – Appendix B (Addendum)	
6-179	6.4-5	Initial PCE Concentrations for Model Scenarios	DRAFT EIR – Appendix B	
6-180	6.4-6	Initial Concentrations for Model Scenarios	DRAFT EIR – Appendix B	
6-181	6.4-7	Equal Concentration Zones for TDS	DRAFT EIR – Appendix B	
6-182	6.4-8	Equal Concentration Zones for Nitrate	DRAFT EIR – Appendix B	
6-183	6.4-9	Initial TDS Concentrations for Model Scenarios	DRAFT EIR – Appendix B	
6-184	6.4-10	Initial Nitrate Concentrations for Model Scenarios	DRAFT EIR – Appendix B	
6-185	6.4-11	Initial Perchlorate Concentrations for Model Scenarios	DRAFT EIR – Appendix B	
6-186	B 88	Idealized Lithologic Log for Well Raub #8	DRAFT EIR – Appendix B (Addendum)	
6-187	B 89	Drawdown Loading Function at Well Raub #8 in Model Layer 1	DRAFT EIR – Appendix B (Addendum)	X
6-188	B 90	Drawdown Loading Function at Well Raub #8 in Model Layer 2	DRAFT EIR – Appendix B (Addendum)	X
6-189	B 91	Model Predicted Subsidence at Raub #8	DRAFT EIR – Appendix B (Addendum)	X
6-190	B 11	Groundwater Elevations and Areas of Depth to Water Less than 50 ft from Land Surface – Layer 1, No Project Condition	DRAFT EIR – Appendix B (Addendum)	
6-191	B12	Groundwater Elevations – Layer 2, No Project Condition	DRAFT EIR – Appendix B (Addendum)	
6-192		Hydrologic Budget for the No Project Condition (2001 – 2039)	New figure	
6-193	6.2-25	Area of Depth to Water Less than 50 ft from Land Surface of SBBA for Model Scenarios – 2001 to 2039	DRAFT EIR – Appendix B	X
6-194	6.2-26	Area of Depth to water less than 50 ft from Land Surface within the Pressure Zone for Model Scenarios – 2001 to 2039	DRAFT EIR – Appendix B	X
6-195	B 17	Groundwater Elevations and Areas of Depth to Water Less than 50 ft from Land Surface – Layer 1, Scenario A	DRAFT EIR – Appendix B (Addendum)	
6-196	B 18	Groundwater Elevations – Layer 2, Scenario A	DRAFT EIR – Appendix B (Addendum)	
6-197	B 25	Differences in Groundwater Level Between No Project and Scenario A, Layer 1	DRAFT EIR – Appendix B (Addendum)	
6-198	B 26	Differences in Groundwater Level Between No Project and Scenario A, Layer 2	DRAFT EIR – Appendix B (Addendum)	
6-199 through 6-223	B 29a – y	Hydrographs at selected well points and spreading grounds	DRAFT EIR – Appendix B (Addendum)	
6-224		Hydrologic Budget for Scenario A (2001 – 2039)	New figure	
6-225	B 36	Comparisons of Groundwater Budgets for SBBA Between No Project Condition and Scenario A – 2001 to 2039	DRAFT EIR – Appendix B (Addendum)	
6-226 through 6-234	B 44a – i	Particle Tracks from Spreading Grounds, No Project Condition vs. Scenario A	DRAFT EIR – Appendix B (Addendum)	

Exhibit No.	Original Figure Number	Title	Original Location	Modification
6-235 through 6-243	B 45a – i	Particle Tracks from Plume Fronts, No Project Condition vs. Scenario A	DRAFT EIR – Appendix B (Addendum)	
6-244	B 46	Particle Tracks from Spreading Grounds and Plume Fronts, Year 2039, No Project Condition vs. Scenario A	DRAFT EIR – Appendix B (Addendum)	
6-245	B 62	PCE Plume Boundary Layer 1 No Project Condition vs. Scenario A	DRAFT EIR – Appendix B (Addendum)	
6-246	B 63	PCE Plume Boundary Layer 2 No Project Condition vs. Scenario A	DRAFT EIR – Appendix B (Addendum)	
6-247		Screenshot of PCE Plume Animation (Scenario A, 2001 – 2039)	New figure	
6-248	111	PCE Plume Area (2001 – 2039)	New figure	
6-249	B 70	TCE Plume Boundary Layer 1 No Project Condition vs. Scenario A	DRAFT EIR – Appendix B (Addendum)	
6-250	B 71	TCE Plume Boundary Layer 2 No Project Condition vs. Scenario A	DRAFT EIR – Appendix B (Addendum)	
6-251		Screenshot of TCE Plume Animation (Scenario A, 2001 – 2039)	New figure	
6-252		TCE Plume Area (2001 – 2039)	New figure	
6-253 through 6-286	B 74a – ah	TDS at selected well points and spreading grounds	DRAFT EIR – Appendix B (Addendum)	
6-287	3.2-16	Location of Index Wells and Spreading Grounds in Relation to Proposed SARWQCB Management Zone Boundaries	DRAFT EIR – Main Report	
6-288	3.2-17	TDS Concentrations at IW14, Leroy Street Well	DRAFT EIR – Main Report	
6-289	3.2-18	TDS Concentrations at IW17, Well 32	DRAFT EIR – Main Report	
6-290	3.2-19	TDS Concentrations at IW11, Raub 1 Well	DRAFT EIR – Main Report	
6-291	3.2-20	TDS Concentrations at IW12, Lower Kelly Well	DRAFT EIR – Main Report	
6-292 through 6-325	B 75a – ah	Nitrate at Selected Well Points and Spreading Grounds	DRAFT EIR – Appendix B (Addendum)	
6-326	B 80	Perchlorate Plume Boundary Layer 1 No Project Condition vs. Scenario A	DRAFT EIR – Appendix B (Addendum)	
6-327	B 81	Perchlorate Plume Boundary Layer 2 No Project Condition vs. Scenario A	DRAFT EIR – Appendix B (Addendum)	
6-328		Perchlorate Plume Areas (2001 – 2039)	New figure	
6-329	B 32	Depth to Groundwater Less than 50 ft from Land Surface for No Project Condition and Scenario A, Years 2016 and 2022	DRAFT EIR – Appendix B (Addendum)	
6-330		Screenshot of Liquefaction Potential Animation (Scenario A, 2001 – 2039)	New figure	
6-331	B 86	Groundwater Mounds Resulting from Artificial Recharge at Cactus, Garden Air Creek and Wilson Spreading Grounds, Scenario A	DRAFT EIR – Appendix B (Addendum)	
6-332	3-1	Forward Particle Tracking of Perchlorate Plume – Changes between Project Scenario A and No Project Condition	Final EIR	

Exhibit No.	Original Figure Number	Title	Original Location	Modification
6-333	B 15	Groundwater Elevations and Areas of Depth to Water Less than 50 ft from Land Surface – Layer 1, Scenario D	DRAFT EIR – Appendix B (Addendum)	
6-334	B 16	Groundwater Elevations – Layer 2, Scenario D	DRAFT EIR – Appendix B (Addendum)	
6-335	B 23	Differences in Groundwater Levels Between No Project and Scenario D, Layer 1	DRAFT EIR – Appendix B (Addendum)	
6-336	B 24	Differences in Groundwater Levels Between No Project and Scenario D, Layer 2	DRAFT EIR – Appendix B (Addendum)	
6-337		Hydrologic Budget for Scenario D (2001 – 2039)	New figure	
6-338	B 35	Comparisons of Groundwater Budgets for SBBA Between No Project Condition and Scenario D – 2001 to 2039	DRAFT EIR – Appendix B (Addendum)	
6-339 through 6-347	B 41a – i	Particle Tracks from Spreading Grounds, No Project Condition vs. Scenario D	DRAFT EIR – Appendix B (Addendum)	
6-348 through 6-356	B 42 a –i	Particle Tracks from Plume Fronts, No Project Condition vs. Scenario D	DRAFT EIR – Appendix B (Addendum)	
6-357	B 43	Particle Tracks from Spreading Grounds and Plume Fronts, Year 2039, No Project Condition vs. Scenario D	DRAFT EIR – Appendix B (Addendum)	
6-358	B 60	PCE Plume Boundary – Layer 1, No Project Condition vs. Scenario D	DRAFT EIR – Appendix B (Addendum)	
6-359	B 61	PCE Plume Boundary – Layer 2, No Project Condition vs. Scenario D	DRAFT EIR – Appendix B (Addendum)	
6-360	B 68	TCE Plume Boundary – Layer 1, No Project Condition vs. Scenario D	DRAFT EIR – Appendix B (Addendum)	
6-361	B 69	TCE Plume Boundary – Layer 2, No Project Condition vs. Scenario D	DRAFT EIR – Appendix B (Addendum)	
6-362	B 78	Perchlorate Plume Boundary Layer 1 No Project Condition vs. Scenario D	DRAFT EIR – Appendix B (Addendum)	
6-363	B 79	Perchlorate Plume Boundary Layer 2 No Project Condition vs. Scenario D	DRAFT EIR – Appendix B (Addendum)	
6-364	B 31	Depth to Groundwater Less Than 50 ft From Land Surface For No Project Condition and Scenario D, Years 2016 and 2022	DRAFT EIR – Appendix B (Addendum)	
6-365	B 85	Groundwater Mounds Resulting from Artificial Recharge at Cactus, Garden Air Creek and Wilson Spreading Grounds, Scenario D	DRAFT EIR – Appendix B (Addendum)	
6-366		Groundwater Elevations and Areas of Depth to Water Less than 50 ft from Land Surface – Layer 1, Most Likely Scenario	New figure	
6-367		Groundwater Elevations – Layer 2, Most Likely Scenario	New figure	
6-368		Differences in Groundwater Levels Between No Project and Most Likely Scenario, Layer 1	New figure	
6-369		Differences in Groundwater Levels Between No Project and Most Likely Scenario, Layer 2	New figure	
6-370		Hydrologic Budget for Most Likely Scenario (2001 – 2039)	New figure	

Exhibit No.	Original Figure Number	Title	Original Location	Modification
6-371		Comparisons of Groundwater Budgets for SBBA Between No Project Condition and Scenario D – 2001 to 2039	New figure	
6-372		Depth to Groundwater Less Than 50 ft From Land Surface For No Project Condition and Scenario D, Years 2016 and 2022	New figure	
6-373 through 6-388		Tables detailed in “List of Tables”	See “List of Tables”	
6-389		PowerPoint Presentation by Dennis E. Williams Santa Ana River Water Rights Hearing	New	

XVI. List of Tables

Exhibit No.	Table No. in Ex. 6-1	Original Table Number	Table Title	Location in Testimony	Original Location	Modified
6-1	1		Comparison between Original USGS Model and USGS Model Update Used to Develop Optimum Management Scenarios for EIR	In text	New table	
6-1	2		Summary of Groundwater Recharge and Discharge Terms	In text	New table	
6-1	3		Upper Santa Ana River – Number of Days with Flow, Statistics for Water Year 1966-67 to Water Year 1999-00	In text	New table	
6-1	4		Upper Santa Ana River - Monthly Average Flow Rate, Statistics for Water Year 1966-67 to Water Year 1999-00	In text	New table	
6-1	5		Upper Santa Ana River – Total Monthly Flow Quantity, Statistics for Water Year 1966-67 to Water Year 1999-00	In text	New table	
6-1	6		Upper Santa Ana River – Total Annual Flow Quantity, Statistics for Water Year 1966-67 to Water Year 1999-00	In text	New table	
6-1	7		Upper Santa Ana River – Number of Days without Flow, Statistics for Water Year 1966-67 to Water Year 1999-00	In text	New table	
6-1	8	3.2-5	Groundwater Quality Objectives for the SBBA	In text	DRAFT EIR – Main Report	Was Proposed, now Current
6-1	9	3.2-6	Prevalence of Contaminants in SBBA Wells	In text	DRAFT EIR – Main Report	
6-1	10	3.2-7	Constituents in Groundwater Contamination Plumes in the SBBA	In text	DRAFT EIR – Main Report	X
6-1	11	3.2-9	Groundwater Quality Objectives for the Rialto-Colton Basin	In text	DRAFT EIR – Main Report	Was Proposed, now Current
6-1	12	3.2-10	Prevalence of Contaminants in Rialto-Colton Basin Wells	In text	DRAFT EIR – Main Report	
6-1	13	3.2-12	Groundwater Quality Objectives for the Yucaipa Basin	In text	DRAFT EIR – Main Report	Was Proposed, now Current
6-1	14	3.2-13	Prevalence of Contaminants in Yucaipa Basin Wells	In text	DRAFT EIR – Main Report	
6-1	15	3.2-14	Groundwater Quality Objectives for the San Timoteo Basin	In text	DRAFT EIR – Main Report	Was Proposed, now Current

Exhibit No.	Table No. in Ex. 6-1	Original Table Number	Table Title	Location in Testimony	Original Location	Modified
6-1	16	3.2-15	Prevalence of Contaminants in San Timoteo Basin Wells	In text	DRAFT EIR – Main Report	
6-1	17	6.2-1	Recharge and Discharge Terms and Associated MODFLOW Package Used	In text	DRAFT EIR – Appendix B	
6-1	18	6.4-1	Summary of Solute Transport Model Parameters	In text	DRAFT EIR – Appendix B	
6-1	19	6.4-2	Assumptions for TDS and Nitrate Concentrations	In text	DRAFT EIR – Appendix B	X
6-1	20	6.4-3	TDS and Nitrate Concentrations for Santa Ana River and SWP Water (mg/L)	In text	DRAFT EIR – Appendix B	
6-1	21	3.0-1	Parameters Used in Model Simulations	In text	DRAFT EIR – Main Report	
6-373		3.0-2	Project Simulations and Project Scenarios	Stand alone table	DRAFT EIR – Main Report	
6-374		3.0-3	Estimates of Unappropriated Santa Ana River Water Available for Capture by Muni/Western for Base Period WY 1961-62 through WY 1999-2000 (Project Diversion Capacity of 1,500 cfs)	Stand alone table	DRAFT EIR – Main Report	
6-375		3.0-4	Estimates of Unappropriated Santa Ana River Water Available for Capture by Muni/Western for Base Period WY 1961-62 through WY 1999-2000 (Project Diversion Capacity of 500 cfs)	Stand alone table	DRAFT EIR – Main Report	
6-1	22	6.2-3	Assumptions for Model Scenarios	In text	DRAFT EIR – Appendix B	X
6-1	23		Summary of Allocation of Santa Ana River Water	In text	New table	
6-376		B 1	Annual Releases to Santa Ana River from the Seven Oaks Reservoir for Model Scenarios – 2001 to 2039	Stand alone table	DRAFT EIR – Appendix B (Addendum)	
6-377		B 2	Annual Artificial Recharge for No Project Condition – 2001 to 2039	Stand alone table	DRAFT EIR – Appendix B (Addendum)	
6-378		B 3	Annual Artificial Recharge for Scenario A – 2001 to 2039	Stand alone table	DRAFT EIR – Appendix B (Addendum)	
6-379		B 4	Annual Artificial Recharge for Scenario B – 2001 to 2039	Stand alone table	DRAFT EIR – Appendix B (Addendum)	
6-380		B 5	Annual Artificial Recharge for Scenario C – 2001 to 2039	Stand alone table	DRAFT EIR – Appendix B (Addendum)	
6-381		B 6	Annual Artificial Recharge for Scenario D – 2001 to 2039	Stand alone table	DRAFT EIR – Appendix B (Addendum)	
6-1	24	6.2-5	Summary of Average Annual Artificial Recharge, 2001-2039	In text	DRAFT EIR – Appendix B	X
6-1	25	6.2-6	Average Annual Groundwater Pumping, 2001 to 2039	In text	DRAFT EIR – Appendix B	X
6-382		6.2-7	Annual Groundwater Pumping for Model Scenarios – 2001 to 2039	Stand alone table	DRAFT EIR – Appendix B (Addendum)	

Exhibit No.	Table No. in Ex. 6-1	Original Table Number	Table Title	Location in Testimony	Original Location	Modified
6-383		B 7	Groundwater Budgets for No Project Condition – 2001 to 2039	Stand alone table	DRAFT EIR – Appendix B (Addendum)	
6-1	26	6.2-9	Average Annual Groundwater Budgets, 2001-2039	In text	DRAFT EIR – Appendix B	X
6-1	27	6.6-1	Total Subsidence and Average Subsidence Rate at the Location of Raub Well #8, 2001-2039	In text	DRAFT EIR – Appendix B	
6-384		B 8	Groundwater Budgets for Scenario A – 2001 to 2039	Stand alone table	DRAFT EIR – Appendix B (Addendum)	
6-1	28	6.3-1	Seepage Velocity Determined by MODPATH Model under Different Model Scenarios	In text	DRAFT EIR – Appendix B	
6-1	29	6.4-4	Average of the Difference in TDS Concentration for the SBBA from No Project Condition - 2039	In text	DRAFT EIR – Appendix B	X
6-1	30	3.2.17	Average TDS Levels at the End of Model Simulation (Year 2039)	In text	DRAFT EIR – Main Report	X
6-1	31	3.2-18	Frequency of Impact Determinations for TDS	In text	DRAFT EIR – Main Report	X
6-1	32	6.4-5	Average of the Difference in Nitrate (as NO_3) Concentration for the SBBA from No Project Condition – 2039	In text	DRAFT EIR – Appendix B	X
6-1	33	3.2.17	Average Nitrate Levels at the End of Model Simulation (Year 2039)	In text	DRAFT EIR – Main Report	X
6-1	34	3.2-19	Frequency of Impact Determinations for Nitrate	In text	DRAFT EIR – Main Report	X
6-1	35	6.6-1	Total Subsidence and Average Subsidence Rate at the Location of Raub Well #8, 2001-2039	In text	DRAFT EIR – Appendix B	
6-385		B 12	Annual Artificial Recharge at Cactus, Garden Air Creek and Wilson Spreading Grounds for Model Scenarios (Years 2001 to 2039)	Stand alone table	DRAFT EIR – Appendix B (Addendum)	
6-1	36	6.5-1	Parameters Used in Hantush Equation - Cactus Spreading Grounds	In text	DRAFT EIR – Appendix B	
6-1	37	6.5-2	Parameters Used in Hantush Equation - Wilson Spreading Grounds	In text	DRAFT EIR – Appendix B	
6-1	38	6.5-3	Parameters Used in Hantush Equation - Garden Air Creek Spreading Grounds	In text	DRAFT EIR – Appendix B	
6-386		B 11	Groundwater Budgets for Scenario D – 2001 to 2039	Stand alone table	DRAFT EIR – Appendix B (Addendum)	
6-387			Groundwater Budgets for Most Likely Scenario – 2001 to 2039	Stand alone table	New table	
6-388			Summary of Spreading for Model Prediction Runs	Stand alone table	New table	
6-1	39		Maximum Scenario A Spreading vs.Recorded Peak (Hydrologic Year 1980) Scenario A Spreading	In text	New table	

Exhibit No.	Table No. in Ex. 6-1	Original Table Number	Table Title	Location in Testimony	Original Location	Modified
6-1	40	3.2-3	Groundwater Recharge Facilities	In text	DRAFT EIR – Main Report	X
6-1	41		Summary of Findings	In text	New table	