SANTA ANA RIVER WASTE LOAD ALLOCATION MODEL UPDATE

SUMMARY REPORT

Part 1 of 3: Text

PREPARED FOR:

Santa Ana Watershed Project Authority

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***GEOSCIENCE* Support Services, Inc. Ground Water Resources Development**

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ACRONYMS, ABBREVIATIONS, and INITIALISMS

Abbrev.	Description
2004 WLAM	Waste Load Allocation Model Developed by WEI in 2002-2003 and included in the 2004 Basin Management Plan.
2008 WLAM	Waste Load Allocation Model Developed by WEI in 2008-2009. Note: Scenario 8 was completed in 2015.
2017 WLAM HSPF	Waste Load Allocation Model Developed by GEOSCIENCE as part of the current WLAM update (2018).
BMP	best management practice
BPA	Basin Plan Amendment
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
CIWQS	California Integrated Water Quality System
CONS	HSPF section of Module RCHRES that simulates the behavior of conservative constituents (i.e., do not decay with time or leave RCHRES by any mechanism other than advection)
DBSA	Daniel B. Stephens & Associates, Inc.
DP	discharge point
EMWD	Eastern Municipal Water District
ET	evapotranspiration
EVMWD	Elsinore Valley Municipal Water District
EVWD	East Valley Water District

ACRONYMS, ABBREVIATIONS, and INITIALISMS (continued)

Abbrev.	Description
ft	feet
GEOSCIENCE	GEOSCIENCE Support Services, Inc.
GMZ	groundwater management zone
HCP	Habitat Conservation Plan
hr	hour
HSPF	Hydrological Simulation Program – Fortran
IEUA	Inland Empire Utilities Agency
IMPLND	HSPF module that simulates water quantity and quality processes which occur on an impervious land segment.
in.	inches
IQUAL	HSPF module that simulates water quality constituents (e.g., TDS/TIN) in the outflows from impervious land segments
LID	low-impact development
MWD	Metropolitan Water District
MWDOC	Metropolitan Water District of Orange County
MGD	million gallons per day
mg/L	milligrams per liter
MS4	municipal separate storm sewer system
NCDC	National Climatic Data Center
NCEI	National Centers for Environmental Information

ACRONYMS, ABBREVIATIONS, and INITIALISMS (continued)

Abbrev.	Description
NEXRAD	Next Generation Weather Radar
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSE	Nash-Sutcliffe Efficiency
NWIS	National Water Information System
OCPW	Orange County Public Works
OCWD	Orange County Water District
OPMODEL	Daily reservoir operations model developed to estimate the quantity of available unappropriated SAR water for the Valley/Western water rights applications.
PERLND	HSPF module that simulates water quantity and quality processes which occur on a pervious land segment.
POTW	publicly owned treatment work
PQUAL	HSPF module that simulates water quality constituents (e.g., TDS/TIN) in the outflows from pervious land segments
QA/QC	quality assurance/quality control
QUALIF	HSPF subroutine of PQUAL that simulates water quality constituents associated with interflow
QUALOF	HSPF subroutine of PQUAL that simulates water quality constituents associated with overland flow
R^2	coefficient of determination (representing the goodness-of-fit)

ACRONYMS, ABBREVIATIONS, and INITIALISMS (continued)

Abbrev.	Description
RCFCWCD	Riverside County Flood Control and Water Conservation District
RCHRES	HSPF module that simulates the processes which occur in a single reach of open or closed channel
Regional Board	California Regional Water Quality Control Board, Santa Ana Region
RFM	Recharge Facilities Model (operated by OCWD)
RIX	Rapid Infiltration and Extraction
RMSE	root mean square error
RP	regional plant
RQUAL	HSPF section of Module RCHRES that simulates the behavior of constituents involved in biochemical transformations (e.g., TIN)
RWQCP	regional water quality control plant
SAR	Santa Ana River
SARMP	Santa Ana River Mainstem Project
SAWPA	Santa Ana Watershed Project Authority
SBBA	San Bernardino Basin Area. Includes Bunker Hill and Lytle Groundwater Basins
SBC	San Bernardino County
SBCFCD	San Bernardino County Flood Control District
SBVMWD	San Bernardino Valley Municipal Water District (also known as Valley District)
SCAG	Southern California Association of Governments
SNMP	Salt and Nutrient Management Plan

ACRONYMS, ABBREVIATIONS, and INITIALISMS (continued)

Abbrev.	Description
SNRC	Sterling Natural Resources Center
SSURGO	Soil Survey Geographic
Task Force	Basin Monitoring Program Task Force
TDS	total dissolved solids
TIN	total inorganic nitrogen
TM	technical memorandum
U.C.	University of California
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
Valley District	San Bernardino Valley Municipal Water District
WEI	Wildermuth Environmental, Inc.
WLAM	Waste Load Allocation Model
WMWD	Western Municipal Water District
WRCRWA	Western Riverside County Regional Wastewater Authority Plant
WRF	water recycling facility or water reclamation facility
WRP	water reclamation plant
WWRF	wastewater reclamation facility
WWTP	wastewater treatment plant

ACRONYMS, ABBREVIATIONS, and INITIALISMS (continued)

Abbrev.	Description
WY	Water Year (representing the period from October of one year to September of the next. For example, WY 2016 represents the period from October 2015 through September 2016).
YVWD	Yucaipa Valley Water District

SANTA ANA RIVER WASTE LOAD ALLOCATION MODEL UPDATE

SUMMARY REPORT

1.0 INTRODUCTION

1.1 Purpose and Scope

The tributaries of the Santa Ana River (SAR) begin in the San Bernardino, San Gabriel, San Jacinto, and Santa Ana Mountains. The tributaries merge with the SAR, which flows to the Pacific Ocean. The SAR Watershed includes portions of San Bernardino County, Riverside County, Orange County, and a small portion of Los Angeles County. SAR stream reaches and associated groundwater management zones (GMZs) are shown on Figure 1.

The Santa Ana Watershed Project Authority (SAWPA) and Basin Monitoring Program Task Force (Task Force) retained GEOSCIENCE Support Services, Inc. (GEOSCIENCE) to update the Waste Load Allocation Model (WLAM) by developing and calibrating a watershed model using the Hydrological Simulation Program - Fortran (HSPF) computer code. During the course of developing this watershed model, referred to as the 2017 WLAM HSPF, the previous WLAM boundary was also expanded to include additional reaches of the SAR within Orange County (see Figure 2 for the 2017 WLAM HSPF boundary). The 2017 WLAM HSPF was then used to estimate the projected total dissolved solids (TDS) and total inorganic nitrogen (TIN) concentrations of the SAR recharge water and discharge at Prado Dam. This effort satisfies monitoring and analysis requirements in the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan).

The scope of work for this WLAM update included:

- Task 1 — Update the Data Used in the WLAM
- Task 2 — Update and Recalibrate the WLAM
- Task 3 — Evaluate Waste Load Allocation Scenarios for Major Stream Segments
- Task 4 — Develop WLAM for Managed Recharge in Percolation Basins (cancelled)
- Task 5 — Estimate Off-Channel Recharge from Natural Precipitation
- Task 6 — Run the WLAM in Retrospective Mode, using Historical Discharge Data, to Estimate the Quantity and Quality of Recharge that Actually Occurred

- Task 7 — Compile the WLAM into a Run-Time Software Simulation Package
- Task 8 — Draft Task Reports, Draft and Final Report
- Task 9 — Monthly Project Meetings
- Task 10 — Pilot Evaluation of the Doppler Data Compared to Precipitation Gauge Data

During the project, Tasks 1 through 3, 5, and 6 were summarized in individual technical memorandums (TMs; GEOSCIENCE 2018a-c and 2019a-b). Each draft TM was submitted to the Task Force for comment and review. A summary of comments submitted on the draft TMs, along with GEOSCIENCE responses, is presented in Appendix A. This summary report satisfies Task 8 and incorporates the material from the previous five TMs and Task Force comments. **NOTE: the final Summary Report was originally submitted on 12-Nov-19. This version of the report, dated 19-Jun-20 includes some additional changes, which are detailed in Appendix T.**

1.2 Project Location

The SAR watershed is located in southern California and is approximately 2,840 square miles in size (see Figure 1). The tributaries of the SAR begin in the San Bernardino, San Gabriel, San Jacinto, and Santa Ana Mountains. These tributaries merge with the SAR, which flows to the Pacific Ocean. The watershed includes portions of San Bernardino County, Riverside County, Orange County, and a small portion of Los Angeles County.

1.3 Model Background

The TIN/TDS Task Force, consisting of representatives from water, wastewater, and groundwater agencies in the SAR Watershed, was established in 1995 to evaluate the impact of TDS/TIN on water resources. To do so, Wildermuth Environmental, Inc. (WEI) was contracted to perform a multi-phase TIN/TDS Study. Phase 1A of the study defined watershed hydrology and developed water quality objectives. Phase 1B evaluated analytical methodologies to investigate watershed hydrology. Phase 2A of the study was geared at developing a nitrogen loss rate for surface water recharge, developing a new monitoring plan, updating groundwater management zones and groundwater quality objectives, and estimating TIN/TDS concentrations in groundwater. Phase 2B included the development of a surface water WLAM and the Santa Ana Watershed Data Collection and Management Program.

Regional Basin Plans are required by the California Water Code (Section 13240) to protect the beneficial use of surface and groundwater resources within the basin, establish water quality objectives, and implement management plans to meet those objectives. The SAR Watershed Basin Plans include waste load allocations for discharges to the SAR. As part of the 2004 Basin Plan, WEI performed the waste load allocation analysis for both TIN and TDS using the surface water WLAM developed as part of the TIN/TDS Study Phase 2B (WEI, 2002 and 2003). Known as the 2004 WLAM, it was officially adopted into the Basin Plan by the California Regional Water Quality Control Board, Santa Ana Region (Regional Board) through Resolution No. R8-2004-0001. As of the date of this TM, the 2004 WLAM is the only WLAM to have gone through a formal review process and be approved by the Regional Board.

The 2004 WLAM was based on work conducted in Chino Basin for the Chino Basin Watermaster, and used in-house computer codes developed by WEI. These codes (RUNOFF and ROUTER) estimate surface runoff and route it through the watershed. TIN/TDS concentrations are also tracked by the computer codes using a water quality component. The 2004 WLAM was calibrated to observed streamflow and water quality data (TIN and TDS) for the period from Water Year (WY)[1] 1995 through 1999. The calibrated model was then used to evaluate 50-year scenarios using future (2010) publicly owned treatment work (POTW) discharge assumptions and hydrology from WY 1950 through 1999.

Shortly after the completion of the 2004 WLAM, the Basin Monitoring Program Task Force was established. As an extension of the TIN/TDS Task Force, the Basin Monitoring Program Task Force (hereafter referred to as "Task Force") facilitates the implementation of Basin Plan Amendments and oversees the collection and evaluation of water quality data to ensure compliance with surface water and groundwater quality objectives. In 2008, the Task Force contracted with WEI to update the 2004 WLAM in order to account for changing plans and conditions in the watershed (e.g., land use). The 2008 WLAM was calibrated to observed streamflow and water quality data (TIN and TDS) for WY 1995 through 2006. Six 50-year scenarios (WY 1950 through 1999) were modeled with the calibrated 2008 WLAM for various future (2010 and 2020) discharge and Seven Oaks Dam operating assumptions. Following issuance of the 2008 WLAM model report (WEI, 2009), WEI was tasked with running an additional model scenario (Scenario 7) with the 2008 WLAM. When the Seven Oaks Dam operating assumptions were reevaluated, WEI ran another scenario (Scenario 8) with updated assumptions and hydrology from WY 1950 through 2012. The results of this scenario were presented in an addendum report to the 2008 WLAM (WEI, 2015a). While the 2008 WLAM was submitted to the Regional Board for review, it was never formally approved.

In order to further update the WLAM, GEOSCIENCE constructed and calibrated the 2017 WLAM HSPF from October 1, 2006 through September 30, 2016 (WY 2007 through 2016) using the Hydrologic Simulation Program – Fortran (HSPF) computer code. The 2017 WLAM HSPF was expanded from the existing 2008 WLAM model area to include additional reaches of the SAR within Orange County (see Figure 2). This process began with updating the data used in in the WLAM, which was summarized in

[1] A WY represents the period from October of one year to September of the next. For example, WY 2016 represents the period from October 2015 through September 2016.

draft TM-1 (GEOSCIENCE, 2018a) and is presented in Section 2.0 of this summary report. The development of the HSPF model and calibration process are discussed in Sections 3.0 and 4.0, as well as TM-2 (GEOSCIENCE, 2018b). This updated model was then used to run predictive scenario runs to evaluate water quality in major stream segments for maximum, most likely, and minimum expected discharges under 2020 and 2040 conditions. Scenario assumptions are outlined in Section 5.0 of this report while the predictive scenario results are presented in Section 6.0 and TM-3 (GEOSCIENCE, 2018c). Following calibration and predictive scenario runs, the model was used to estimate the amount of off-channel recharge that occurred during the model calibration period (refer to Section 7.0 and TM-5; GEOSCIENCE, 2019a) and was run in retrospective mode to estimate the quantity and quality of recharge that occurred during the calibration period (refer to Section 8.0 and TM-6; GEOSCIENCE, 2019b).

2.0 DATA COLLECTION

The first step of updating the WLAM was to collect available data for the time period following the last WLAM calibration (i.e., the period from WY 2007 through 2016). The primary data sources for the data collection and update include:

- San Bernardino County Flood Control District (SBCFCD),
- Riverside County Flood Control and Water Conservation District (RCFCWCD),
- Orange County Public Works (OCPW),
- Chino Basin Watermaster
- SAWPA database,
- California Irrigation Management Information System (CIMIS),
- California Integrated Water Quality System (CIWQS) database,
- Soil Survey Geographic (SSURGO) Database
- Southern California Association of Governments (SCAG), and
- Multiple local agencies.

Data collection is summarized in the following sections. It should be noted that the discussion below only covers the data collected for the 2017 WLAM HSPF model calibration period (WY 2007 through 2016) – not prior data used in the 2008 WLAM.

2.1 Land Use

Land use is an important data source for the HSPF model because different land uses produce different amounts of infiltration and/or surface runoff depending on the amount of permeable area associated with a given land use. Land use maps for 2012 and General Plan conditions were acquired from SCAG (2015a and 2015b) and completely cover the entire 2017 WLAM HSPF area, including the area tributary to Reach 2 of the SAR (see Figures 3 and 4, respectively). The 2012 land use was used for the calibration period (WY 2007 through 2016). 2012 and General Plan land use was used for future model simulations to represent 2020 and 2040 conditions, respectively. New development and re-development that incorporated Low Impact Development Best Management Practices (LID BMPs), as required by the 2010 Municipal Separate Storm Sewer System (MS4) Permit, were also acquired for a limited number of parcels within Riverside County.

2.2 Soil Types

Soil type also affects the amount of infiltration and runoff generated within the model area. Some soils (e.g., sands and gravels) are associated with high infiltration rates, while others (e.g., clays) have high runoff potential. Information on both type and distribution of soil types within in the 2017 WLAM HSPF area were obtained from the SSURGO Database (Soil Survey Staff et al., 2011). The distribution of soil types in the 2017 WLAM HSPF area is shown on Figure 5.

2.3 Precipitation Data

Daily data from over 81 precipitation stations located within the 2017 WLAM HSPF model boundary were collected and compiled. Precipitation data were received primarily from SBCFCD, RCFCWCD, OCPW, and the National Climatic Data Center (NCDC). Many of the precipitation stations showed large data gap periods or were no longer active – in some cases having ceased data collection many years ago. Rather than interpolate the precipitation data for missing periods, only 19 of the evaluated stations were ultimately chosen for model calibration based on the completeness of their record (greater than 95% complete). Two of these precipitation stations (Santa and Villapark in Orange County) are new to the 2017 WLAM HSPF version to provide coverage for the area tributary to Reach 2 of the SAR, and were not used in previous versions. The precipitation stations used for the 2017 WLAM HSPF are shown on Figure 6 and summarized in the table below. Precipitation data are provided in Appendix B.

Table 2-1. Daily Precipitation Data Summary

Station ID	Precipitation Station Name	Source of Data	Period of Record	Data Gaps
13	Beaumont	RCFCWCD	10/1/2006 - 9/30/2016	-
35	Chase & Taylor	RCFCWCD	10/1/2006 - 9/30/2016	-
67	Elsinore	RCFCWCD	10/1/2006 - 9/30/2016)	-
102	Lake Mathews	RCFCWCD	10/1/2006 - 9/30/2016	-
178	Riverside North	RCFCWCD	10/1/2006 - 9/30/2016	-
179	Riverside South	RCFCWCD	10/1/2006 - 9/30/2016	-
250	Woodcrest	RCFCWCD	10/1/2006 - 9/30/2016	-

Station ID	Precipitation Station Name	Source of Data	Period of Record	Data Gaps
265	Indian Hills	RCFCWCD	10/1/2006 - 9/30/2016	-
3273	Loma Linda (V.G.C.)	SBCFCD	10/1/2006 - 9/30/2016	5/1/2007 - 5/31/2007, 5/1/2015 - 5/31/2015, 1/1/2016 - 1/31/2016, 9/1/2016 - 9/30/2016
1021AUTO	Mira Loma Space Center	SBCFCD	10/1/2006 - 9/30/2016	10/2/2008 - 11/20/2008, 9/9/2010, 4/6/2016, 5/5/2016 - 7/7/2016, 9/26/2016
2005B	Declez	SBCFCD	10/1/2006 - 9/30/2016	3/24/2008 - 3/26/2008, 4/4/2010 - 4/6/2010, 8/1/2010 - 8/3/2010, 6/4/2011 - 6/7/2011, 6/25/2011 - 6/27/2011, 1/18/2013 - 1/19/2013, 2/15/2013 - 2/25/2013, 2/27/2013 - 3/2/2013, 6/16/2013 - 6/21/2013, 10/2/2013 - 10/3/2013, 3/8/2015 - 3/9/2015, 6/19/2015, 6/20/2015, 11/24/2015 - 11/26/2015, 2/3/2016 - 2/6/2016
2015AUTO	Del Rosa Ranger Station	SBCFCD	10/1/2006 - 9/30/2016	10/16/2007 - 11/29/2007, 9/8/2010, 7/23/2012 - 9/17/2012, 7/9/2013, 3/19/2014, 10/4/2014 - 10/14/2014, 2/18/2015 - 4/14/2015, 7/8/2015, 2/2/2016 - 6/27/2016, 7/14/2016
2017AUTO	Fontana 5N (Getchell)	SBCFCD	10/1/2006 - 9/30/2016	4/5/2016, 5/5/2016 - 7/5/2016, 8/1/2016, 9/22/2016
2146AUTO	S. B. County Hospital	SBCFCD	10/1/2006 - 9/30/2016	3/22/2016, 6/1/2016 - 6/27/2016, 7/27/2016
2159AUTO	Lytle Creek at Foothill Blvd	SBCFCD	10/1/2006 - 9/30/2016	1/14/2010, 8/11/2010, 4/24/2016 - 4/26/2016, 5/12/2016, 6/30/2016 - 7/2/2016, 7/7/2016, 7/10/2016 - 7/11/2016, 7/14/2016, 7/16/2016 - 7/17/2016, 7/19/2016, 7/22/2016, 7/25/2016, 7/28/2016, 7/31/2016 - 8/3/2016, 8/8/2016, 8/10/2016 - 8/11/2016, 8/14/2016, 8/17/2016, 8/19/2016, 8/23/2016 - 8/24/2016, 8/31/2016 - 9/2/2016, 9/10/2016
3014AUTO	Oak Glen	SBCFCD	10/1/2006 - 9/30/2016	8/14/2009 - 10/9/2009, 6/7/2016, 6/14/2016, 6/29/2016
3162AUTO	Santa Ana P.H. #3	SBCFCD	10/1/2006 - 9/30/2016	4/15/2016
SANTANA	Santana	OCPW	10/1/2006 - 9/30/2016	-
VILLAPARK	Villapark	OCPW	10/1/2006 - 9/30/2016	-

In order to distribute the observed daily precipitation from the 19 precipitation stations throughout the model domain, precipitation adjustment factors were developed based on long-term average annual precipitation. Therefore, gridded historical average annual precipitation from 1981 through 2010 was also collected from the PRISM Climate Group (2017). This time period covers a variety of hydrologic conditions (i.e., wet, dry, and average). The method used for applying precipitation data to the 2017 WLAM HSPF is discussed in Section 3.2.4.

2.4 Evaporation Data

Hourly reference evapotranspiration values were collected for CIMIS stations at Pomona (Pomona #78) and the University of California, Riverside (U.C. Riverside #44). The data collected from these evaporation stations are summarized in the following table while the station locations are shown on Figure 7. Reference evapotranspiration data are provided in Appendix B.

Table 2-2. Hourly Reference Evapotranspiration Data Summary

Evaporation Station Name	Source of Data	Period of Record	Data Gaps*
Pomona #78	CIMIS	10/1/2006 - 9/30/2016	5/16/2008, 8/14/2008 - 8/15/2008, 8/22/2008 - 8/23/2008, 11/14/2008 - 11/15/2008, 12/5/2009, 4/23/2010, 5/4/2012, 6/27/2014, 3/31/2016, 4/10/2016, 4/12/2016 - 4/13/2016, 4/26/2016, 4/28/2016, 4/30/2016, 5/5/2016 - 5/6/2016, 5/8/2016
U.C. Riverside #44	CIMIS	10/1/2006 - 9/30/2016	12/23/2006 - 12/31/2006, 1/1/2007 - 2/25/2007, 4/12/2008, 8/31/2009 - 9/1/2009, 9/8/2009 - 9/9/2009, 9/12/2009, 9/14/2009, 9/20/2009, 9/23/2009 - 9/24/2009, 9/30/2009, 10/2/2009 - 10/3/2009, 10/7/2009 - 10/9/2009, 10/17/2009, 10/20/2009, 10/26/2009, 10/29/2009, 11/7/2009, 11/10/2009, 2/18/2010, 6/15/2011, 1/2/2012 - 1/3/2012, 1/20/2012, 4/21/2012 - 4/23/2012, 4/25/2012, 5/29/2012, 3/17/2013 - 3/18/2013, 5/10/2013, 5/30/2013, 6/5/2013 - 6/6/2013, 11/16/2013

*Dates listed indicate some amount of hourly coverage is missing for that day.

2.5 Streamflow Data

Flow data for WY 2007 through 2016 were collected and consolidated from USGS gaging stations and United States Army Corps of Engineers (USACE) operations data at Prado Dam, along with discharges from POTWs and all other flow data sources present in the existing SAR database. In addition to the streamflow gages used for the 2008 WLAM, the model update includes the addition of three new gaging stations in the expanded model area. These gages include Santiago Creek at Santa Ana, Carbon Creek below Carbon Canyon Dam, and Santa Ana River at Santa Ana. Streamflow gage data are summarized in the table below, while the gage locations are shown on Figure 8. Streamflow data are also provided in Appendix B.

Table 2-3. Daily and Monthly Streamflow Data Summary

Station ID	Streamflow Gaging Station Name	Source of Data	Period of Record	Data Gaps	Data Accuracy*
11051501	Santa Ana River and Canals near Mentone	USGS	10/1/2006 - 9/30/2016	-	Poor-Good: 2009-2016 Good: 2007-2008
11054001	Mill Creek and Canals near Yucaipa	USGS	No Data Available	10/1/2006 - 9/30/2012	-
11055501	Plunge Creek and Canals near East Highlands	USGS	10/1/2006 - 9/30/2012	10/1/2012 - 9/30/2016	Poor: 2009 Poor-Fair: 2008, 2010-2017
11055801	City Creek and City Creek Water Company's Canal near Highland	USGS	10/1/2006 - 9/30/2016	-	Poor-Fair: 2011-2017 Fair: 2010 Good: 2007-2009
11057500	San Timoteo Creek near Loma Linda	USGS	10/1/2006 - 9/30/2016	-	Poor: 2007-2008, 2010-2013 Fair: 2009, 2014-2016
11058500	East Twin Creek near Arrowhead Springs	USGS	10/1/2006 - 9/30/2016	-	Poor: 2010-2013 Poor-Fair: 2014-2017 Poor-Good: 2007 Fair: 2008-2009
11059300	Santa Ana River at E St.	USGS	10/1/2006 - 9/30/2016	-	Poor: 2007-2016
11060400	Warm Creek near San Bernardino	USGS	10/1/2006 - 9/30/2016	-	Poor-Fair: 2007, 2013 Poor-Good: 2008, 2010-2011, 2014-2016 Good: 2009, 2012
11062001	Lytle Creek, Southern California Edison Co.'s Lytle Creek Conduit, and Fontana Water Co.'s Infiltration Line Diversion near Fontana	USGS	10/1/2006 - 9/30/2016	-	Poor: 2007, 2009-2013 Poor-Fair: 2008 Poor-Good: 2014-2017
11063510	Cajon Creek below Lone Pine Creek near Keenbrook	USGS	10/1/2006 - 9/30/2016	-	Poor-Fair: 2008-2017 Fair: 2007
11063680	Devil Canyon Creek near San Bernardino	USGS	10/1/2006 - 9/30/2016	-	Poor-Good: 2009-2012 Good: 2007-2008, 2013-2017
11066460	Santa Ana River at MWD Crossing	USGS	10/1/2006 - 9/30/2016	-	Poor: 2011-2016 Poor-Fair: 2008-2010 Fair-Good: 2007
11067000	Day Creek near Etiwanda	USGS	No Data Available	10/1/2006 - 9/30/2016	-
11072100	Temescal Creek at Main St.	USGS	10/1/2006 - 9/30/2016	-	Poor-Fair: 2007-2016

Station ID	Streamflow Gaging Station Name	Source of Data	Period of Record	Data Gaps	Data Accuracy*
11073360	Chino Creek at Schaefer Ave.	USGS	10/1/2006 - 9/30/2016	-	Poor-Fair: 2007-2008 Fair: 2009-2010 Fair-Good: 2014-2016 Good: 2011-2013
11073470	Cucamonga Creek near Upland	USGS	No Data Available	10/1/2006 - 9/30/2016	-
11073495	Cucamonga Creek near Mira Loma	USGS	10/1/2006 - 9/30/2016	-	Poor: 2008-2009 Poor-Fair: 2010-2016 Fair: 2007
11074000	Santa Ana River below Prado Dam	USGS	10/1/2006 - 9/30/2016	-	Poor-Fair: 2007-2008 Poor-Good: 2009 Fair: 2011-2013 Good: 2010, 2014-2016
11075720	Carbon Creek below Carbon Canyon Dam	USGS	10/1/2006 - 9/30/2016	-	Poor-Fair: 2007-2017
11077500	Santiago Creek at Santa Ana	USGS	10/1/2006 - 9/30/2016	7/1/2010	Poor: 2010-2017 Fair: 2007-2009
11078000	Santa Ana River at Santa Ana	USGS	10/1/2006 - 9/30/2016	-	Poor: 2009, 2011-2016 Fair: 2007-2008, 2010
-	Santa Ana River Inflow to Prado	USACE	10/1/2006 - 9/30/2016	-	-

*From USGS Water-Year Summaries for each station:

"Poor" indicates that daily discharges have less than "Fair" accuracy.

"Fair" indicates that about 95% of the daily discharges are within 15% of the true value.

"Good" indicates that about 95% of the daily discharges are within 10% of the true value.

2.5.1 Discharges

Wastewater discharge from POTWs represents a significant source of streamflow in the 2017 WLAM HSPF area. Discharge volumes of recycled water were obtained from the SAWPA database, wastewater facilities, and the CIWQS database. Additional discharges from the Arlington Desalter, San Bernardino Geothermal Plant, and Orange County Water District's (OCWD's) turnout OC-59 also contribute to streamflow in the model area. The data collected for these discharge facilities are summarized in the following table while the discharge locations are shown on Figure 9. Discharge data are provided in Appendix B and hydrographs are provided in Appendix C.

Table 2-4. Daily Discharge Data Summary

Discharge Facility Name	Source of Data	Period of Record	Data Gaps
Arlington Desalter	WMWD	10/2006 - 9/2016 (Monthly)	-
Beaumont Wastewater Treatment Plant (WWTP)	SAWPA database (10/1/2006 - 12/31/2011), CIWQS (1/1/2012 - 9/30/2016)	10/1/2006 - 9/30/2016	-
Carbon Canyon Water Reclamation Facility (WRF)	SAWPA database (10/1/2006 - 12/31/2011), CIWQS (1/1/2012 - 9/30/2016)	10/1/2006 - 9/30/2016	5/1/2016 - 5/31/2016
City of Corona (Corona) Wastewater Treatment Plant No. 1 (WWTP-1)	City of Corona	10/1/2006 - 9/30/2016	-
City of Corona (Corona) Wastewater Treatment Plant No. 3 (WWTP-3)	City of Corona	10/1/2006 - 9/30/2016	-
Colton Wastewater Treatment Plant (WWTP)	SAR Watermaster	10/1/2006 - 9/30/2016 (No Discharge)	-
Eastern Municipal Water District's (EMWD's) Region-Wide Water Recycling System	EMWD (10/1/2006 - 2/28/2013) (Discharge ends after 2/28/2013)	10/1/2006 - 2/28/2013	-
Elsinore Valley Municipal Water District (EVMWD) Regional Wastewater Reclamation Facility (WWRF)	EVMWD	10/1/2006 - 9/30/2016	-
Inland Empire Utility Agency (IEUA) Regional Plant No. 1 (RP-1)	SAWPA database (10/1/2006 - 12/31/2011), CIWQS (1/1/2012 - 9/30/2016)	10/1/2006 - 9/30/2016	12/25/2013 - 12/30/2013, 2/1/2016 - 2/7/2016, 5/1/2016 - 5/31/2016
Inland Empire Utility Agency (IEUA) Regional Plant No. 2 (RP-2)	SAR Watermaster	10/1/2006 - 9/30/2016 (No Discharge)	-
Inland Empire Utility Agency (IEUA) Regional Plant No. 4 (RP-4)	SAWPA database (10/1/2006 - 12/31/2011), CIWQS (1/1/2012 - 9/30/2016)	10/1/2006 - 9/30/2016	12/1/2009 - 12/31/2009, 5/1/2016 - 5/31/2016
Inland Empire Utility Agency (IEUA) Regional Plant No. 5 (RP-5)	SAWPA database (10/1/2006 - 12/31/2011), CIWQS (1/1/2012 - 9/30/2016)	10/1/2006 - 9/30/2016	8/1/2014 - 8/31/2014, 5/1/2016 - 5/31/2016, 7/1/2016 - 8/31/2016

Discharge Facility Name	Source of Data	Period of Record	Data Gaps
Orange County Water District (OCWD) Turnout OC-59	MWDOC billing records	10/2006 - 9/2016 (Monthly)	-
Rialto Wastewater Treatment Plant (WWTP)	SAWPA database (10/1/2006 - 1/31/2011, 1/1/2012 - 12/31/2012), SAR Watermaster (2/1/2011 - 12/31/2011), CIWQS (1/1/2013 - 9/30/2016)	10/1/2006 - 9/30/2016	-
Riverside Regional Water Quality Control Plant (RWQCP)	SAWPA database (10/1/2006 - 12/31/2011), CIWQS (1/1/2012 - 9/30/2016)	10/1/2006 - 9/30/2016	12/27/2009
San Bernardino/Colton Rapid Infiltration and Extraction (RIX) Facility	SAWPA database (10/1/2006 - 12/31/2006, 1/1/2008 - 12/31/2012), SAR Watermaster (1/1/2007 - 12/31/2007), CIWQS (1/1/2013 - 9/30/2016)	10/1/2006 - 9/30/2016	-
San Bernardino Geothermal Plant (SB Geo)	City of San Bernardino	10/2006 - 9/2016 (Monthly)	-
San Bernardino Water Reclamation Plant (WRP)	City of San Bernardino / SAR Watermaster	10/1/2006 - 9/30/2016	-
Temescal Valley Water Reclamation Plant (WRP)	SAWPA database (10/1/2006 - 12/31/2012), SAR Watermaster (1/1/2013 - 9/30/2016)	10/1/2006 - 9/30/2016	4/1/2010
Western Riverside County Regional Wastewater Authority Plant (WRCRWA)	SAWPA database (10/1/2006 - 12/31/2011), CIWQS (1/1/2012 - 9/30/2016)	10/1/2006 - 9/30/2016	1/1/2010 - 1/2/2010
Yucaipa Valley Water District (YVWD) Henry N. Wochholz Regional Water Recycling Facility (WRF)	SAWPA database (10/1/2006 - 12/31/2011), CIWQS (1/1/2012 - 9/30/2016)	10/1/2006 - 9/30/2016	4/1/2015 - 4/30/2015, 8/1/2015 - 8/31/2015, 1/21/2016, 1/26/2016, 3/21/2016, 3/26/2016

Projected discharge volumes for 2020 and 2040 were also collected from POTWs for use in the predictive model scenarios. The data request form is provided in Appendix D. While this form included fields for projected recycled water recharge in support of Task 4 (Develop WLAM for Managed Recharge in Percolation Basins), the Task Force later decided to forgo this aspect of the project.

2.5.2 Seven Oaks Dam Outflow

Streamflow from Seven Oaks Dam outflow (i.e., Santa Ana Canyon) to the SAR is also one of the external sources of streamflow for the 2017 WLAM HSPF. These discharges were accounted for in the gaged streamflow at the downstream Santa Ana River near Mentone, CA gage. Conversations with San Bernardino Valley Municipal Water District (Valley District) have indicated that for now, the existing control manual (covering discharges) is the underlying assumption for future conditions.

2.5.3 Stormwater Management Facilities and Channel Type

Stormwater management facility maps were acquired for the entire SAR watershed. These maps depict the most recent channel configuration and stormwater recharge basin locations available from SBCFCD, RCFCWCD, and OCPW. Storm channels and recharge basin locations are shown on Figure 10. Diversions from streamflow for off-channel recharge were accounted for in the 2017 WLAM HSPF by removing the stormwater recharge volumes obtained from the Chino Basin Watermaster from the streamflow in the channel. GEOSCIENCE also contacted SBCFCD in an attempt to obtain spreading data for recharge to off-channel percolation basins in the San Bernardino Basin Area (SBBA), but no data were available. Stormwater recharge data collected for the 2017 WLAM HSPF calibration period are summarized in the following table and provided in Appendix B.

Table 2-5. Monthly Stormwater (Off-Channel) Recharge Data Summary

Recharge Basin Name	Source of Data	Period of Record	Data Gaps
15th Street	Chino Basin Watermaster	10/2006 - 9/2016	July 2008 - June 2010
7th Street	Chino Basin Watermaster	10/2006 - 9/2016	-
8th Street	Chino Basin Watermaster	10/2006 - 9/2016	-
Banana	Chino Basin Watermaster	10/2006 - 9/2016	-
Brooks	Chino Basin Watermaster	10/2006 - 9/2016	-
College Heights	Chino Basin Watermaster	10/2006 - 9/2016	-
Conservation Ponds	Chino Basin Watermaster	10/2006 - 9/2016	July 2008 - June 2011
Declez	Chino Basin Watermaster	10/2006 - 9/2016	-
Ely 1, 2 & 3	Chino Basin Watermaster	10/2006 - 9/2016	-
Etiwanda Debris Basin	Chino Basin Watermaster	10/2006 - 9/2016	-

Recharge Basin Name	Source of Data	Period of Record	Data Gaps
Grove	Chino Basin Watermaster	10/2006 - 9/2016	-
Hickory	Chino Basin Watermaster	10/2006 - 9/2016	-
Jurupa	Chino Basin Watermaster	10/2006 - 9/2016	July 2008 - June 2013
Lower Day	Chino Basin Watermaster	10/2006 - 9/2016	-
Montclair 1, 2, 3, 4	Chino Basin Watermaster	10/2006 - 9/2016	-
Riverside	Chino Basin Watermaster	10/2006 - 9/2016	July 2008 - June 2010
RP3 Cell 1, 2, 3 and 4	Chino Basin Watermaster	10/2006 - 9/2016	-
San Sevaine 1, 2, 3, 4 and 5	Chino Basin Watermaster	10/2006 - 9/2016	-
Turner 1& 2	Chino Basin Watermaster	10/2006 - 9/2016	-
Turner 3 & 4	Chino Basin Watermaster	10/2006 - 9/2016	-
Upland	Chino Basin Watermaster	10/2006 - 9/2016	-
Victoria	Chino Basin Watermaster	10/2006 - 9/2016	-
Wineville	Chino Basin Watermaster	10/2006 - 9/2016	July 2008 - June 2010

In addition, as part of the 2012 Basin Plan amendment for bacteria standards, the Counties were required to submit information on channel characteristics to the Regional Board. These stream channel characteristics (e.g., lined or unlined) were used to determine the degree to which streamflow is able to infiltrate in stream reaches within the model area. Stream channel type is also shown on Figure 10.

2.6 TDS and TIN Data

Periodic TDS and TIN[2] water quality data for discharges were obtained from the SAWPA database, POTWs, the CIWQS database, MWDOC billing records, the City of San Bernardino, and WMWD. POTW discharge chemographs are provided as Appendix E. Water quality data for streamflow were also obtained for three USGS gaging stations: Santa Ana River at MWD Crossing, Santa Ana River below Prado Dam, and Santa Ana River at Imperial Highway near Anaheim.

2 TIN measurements were augmented by including measurements of Ammonia + Nitrate + Nitrite.

Table 2-6. TDS Water Quality Data Summary

Location	Source of Data	Period of Record	Data Gaps*	Number of TDS Observations
Discharge Points				
Arlington Desalter	WMWD	6/2007 - 9/2016	10/2006 - 5/2007, 7/2007, 4/2009 - 11/2009, 2/2011, 4/2011, 9/2012, 2/2013 - 4/2013	97
Beaumont Wastewater Treatment Plant (WWTP)	SAWPA database (10/2006 - 12/2012) CIWQS (2/2014 - 2/2015)	10/2006 - 2/2015	11/2009, 1/2013 - 1/2014, 3/2014 - 1/2015, 3/2015 - 9/2016	76
Carbon Canyon Water Reclamation Facility (WRF)	SAWPA database (10/2006 - 12/2012) CIWQS (1/2012 - 9/2016)	10/2006 - 9/2016	12/2007, 4/2011, 8/2013 - 9/2013	427
City of Corona (Corona) Wastewater Treatment Plant No. 1 (WWTP-1)	City of Corona	10/2006 - 9/2016	-	120
City of Corona (Corona) Wastewater Treatment Plant No. 3 (WWTP-3)	City of Corona	10/2006 - 9/2016	4/2007	119
Colton Wastewater Treatment Plant (WWTP)	-	No Discharge	10/2006 - 9/2016	0
Eastern Municipal Water District's (EMWD's) Region-Wide Water Recycling System	SAWPA database (10/2006 - 2/2012) CIWQS (2/2012 - 2/2013) (Discharge ends after 2/2013)	10/2006 - 2/2013	5/2007 - 11/2007, 5/2008, 7/2008 - 11/2008, 4/2009 - 12/2009, 4/2010 - 12/2010, 5/2011 - 10/2011, 1/2012, 3/2012 - 12/2012, 3/2013 - 9/2016	52
Elsinore Valley Municipal Water District (EVMWD) Regional Wastewater Reclamation Facility (WWRF)	SAWPA database (6/2007 - 12/2012) CIWQS (3/2013 - 9/2016)	6/2007 - 9/2016	10/2006 - 5/2007, 7/2007 - 12/2010, 1/2013 - 2/2013	151
Inland Empire Utility Agency (IEUA) Regional Plant No. 1 (RP-1)	SAWPA database (10/2006 - 12/2012) CIWQS (1/2012 - 9/2016)	10/2006 - 9/2016	12/2007, 4/2011	399
Inland Empire Utility Agency (IEUA) Regional Plant No. 2 (RP-2)	-	No Discharge	10/2006 - 9/2016	0
Inland Empire Utility Agency (IEUA) Regional Plant No. 4 (RP-4)	SAWPA database (10/2006 - 12/2012) CIWQS (1/2012 - 9/2016)	10/2006 - 9/2016	12/2007, 4/2011	432

Location	Source of Data	Period of Record	Data Gaps*	Number of TDS Observations
Inland Empire Utility Agency (IEUA) Regional Plant No. 5 (RP-5)	SAWPA database (10/2006 - 12/2012) CIWQS (1/2012 - 6/2016)	10/2006 - 6/2016	12/2007, 9/2010, 3/2011 - 4/2011, 7/2011 - 9/2011, 8/2014 - 10/2014, 7/2015 - 8/2015, 7/2016 - 9/2016	345
Orange County Water District (OCWD) Turnout OC-59	MWDOC billing records	10/2006 - 6/2016	-	9
Rialto Wastewater Treatment Plant (WWTP)	SAWPA database (10/2006 - 6/2012) CIWQS (2/2012 - 9/2016)	10/2006 - 9/2016	1/2010 - 6/2010, 8/2010 - 10/2010, 8/2012	180
Riverside Regional Water Quality Control Plant (RWQCP)	SAWPA database (10/2006 - 12/2012) CIWQS (1/2012 - 9/2016)	10/2006 - 9/2016	12/2007	338
San Bernardino Geothermal Plant (SB Geo)	City of San Bernardino	10/2006 - 9/2016	11/2007	119
San Bernardino Water Reclamation Plant (WRP)	City of San Bernardino	10/2006 - 9/2016	-	521
San Bernardino/Colton Rapid Infiltration and Extraction (RIX) Facility	SAWPA database (10/2006 - 12/2011) CIWQS (1/2012 - 9/2016)	10/2006 - 9/2016	-	181
Temescal Valley Water Reclamation Plant (WRP)	SAWPA database (10/2006 - 12/2012) CIWQS (2/2015 - 3/2015)	10/2006 - 3/2015	11/2009 - 12/2009, 6/2010, 1/2013 - 1/2015, 4/2015 - 9/2016	130
Western Riverside County Regional Wastewater Authority Plant (WRCRWA)	SAWPA database (10/2006 - 12/2012) CIWQS (1/2012 - 9/2016)	10/2006 - 9/2016	12/2007, 5/2015	218
Yucaipa Valley Water District (YVWD) Henry N. Wochholz Regional Water Recycling Facility (WRF)	SAWPA database (12/2006 - 12/2012) CIWQS (1/2012 - 9/2016)	12/2006 - 9/2016	10/2006 - 11/2006, 4/2015, 9/2015	132
Streamflow Gages				
Santa Ana River at MWD Crossing	USGS	10/2006 - 9/2016	2/2011, 11/2011	229
Santa Ana River below Prado Dam	USGS	10/2006 - 9/2016	-	3,300
Santa Ana River at Imperial Hwy near Anaheim	OCWD	10/2006 - 9/2016	12/2007	162

*No TDS measurement available during month(s) listed

Table 2-7. TIN Water Quality Data Summary

Location	Source of Data	Period of Record	Data Gaps*	Number of TIN Observations
Discharge Points				
Arlington Desalter	WMWD	6/2007 - 9/2016	10/2006 - 5/2007, 4/2009 - 11/2009, 2/2011, 4/2011, 9/2012	101
Beaumont Wastewater Treatment Plant (WWTP)	SAWPA database (10/2006 - 12/2012) CIWQS (1/2013 - 9/2016)	10/2006 - 9/2016	5/2014	120
Carbon Canyon Water Reclamation Facility (WRF)	SAWPA database (4/2011 - 12/2012) CIWQS (1/2012 - 9/2016)	4/2011 - 9/2016	10/2006 - 3/2011, 6/2011, 8/2013 - 9/2013	1,227
City of Corona (Corona) Wastewater Treatment Plant No. 1 (WWTP-1)	City of Corona	10/2006 - 9/2016	-	163
City of Corona (Corona) Wastewater Treatment Plant No. 3 (WWTP-3)	City of Corona	10/2006 - 9/2016	4/2007, 7/2013	186
Colton Wastewater Treatment Plant (WWTP)	-	No Discharge	10/2006 - 9/2016	0
Eastern Municipal Water District's (EMWD's) Region-Wide Water Recycling System	SAWPA database (10/2006 - 2/2012) CIWQS (1/2013 - 2/2013) (Discharge ends after 2/2013)	10/2006 - 2/2013	5/2007 - 11/2007, 5/2008, 7/2008 - 11/2008, 4/2009 - 12/2009, 4/2010 - 12/2010, 5/2011 - 11/2011, 1/2012, 3/2012 - 12/2012	30
Elsinore Valley Municipal Water District (EVMWD) Regional Wastewater Reclamation Facility (WWRF)	SAWPA database (10/2006 - 2/2012) CIWQS (3/2013 - 9/2016)	10/2006 – 9/2016	2/2012, 1/2013 - 2/2013, 1/2014, 3/2014	118
Inland Empire Utility Agency (IEUA) Regional Plant No. 1 (RP-1)	SAWPA database (4/2011 - 12/2012) CIWQS (1/2012 - 9/2016)	4/2011 - 9/2016	10/2006 - 3/2011, 5/2011 - 6/2011	268
Inland Empire Utility Agency (IEUA) Regional Plant No. 2 (RP-2)	-	No Discharge	10/2006 - 9/2016	0
Inland Empire Utility Agency (IEUA) Regional Plant No. 4 (RP-4)	SAWPA database (4/2011 - 12/2012) CIWQS (1/2012 - 9/2016)	4/2011 - 9/2016	10/2006 - 3/2011, 5/2011 - 6/2011, 9/2011	1,301

Location	Source of Data	Period of Record	Data Gaps*	Number of TIN Observations
Inland Empire Utility Agency (IEUA) Regional Plant No. 5 (RP-5)	SAWPA database (4/2011 - 12/2012) CIWQS (1/2012 - 6/2016)	4/2011 - 6/2016	10/2006 - 3/2011, 5/2011 - 9/2011, 8/2014 - 10/2014, 7/2015 - 8/2015, 7/2016 - 9/2016	912
Orange County Water District (OCWD) Turnout OC-59	MWDOC billing records (10/2006 - 6/2016) OCWD lab (7/2011 - 8/2016)	10/2006 - 8/2016	-	14
Rialto Wastewater Treatment Plant (WWTP)	SAWPA database (10/2006 - 6/2012) CIWQS (7/2012 - 9/2016)	10/2006 - 9/2016	1/2010 - 6/2010, 9/2010, 8/2012	195
Riverside Regional Water Quality Control Plant (RWQCP)	SAWPA database (10/2006 - 6/2009) CIWQS (1/2012 - 9/2016)	10/2006 - 9/2016	12/2007, 7/2009 - 12/2011	1,743
San Bernardino Geothermal Plant (SB Geo)	City of San Bernardino ONLY NITRATE AVAILABLE	10/2006 - 9/2016	11/2007, 1/2015 - 7/2016	100
San Bernardino Water Reclamation Plant (WRP)	City of San Bernardino	10/2006 - 9/2016	10/2009 - 11/2009	510
San Bernardino/Colton Rapid Infiltration and Extraction (RIX) Facility	SAWPA database (10/2006 - 12/2011) CIWQS (1/2012 - 9/2016)	10/2006 - 9/2016	-	523
Temescal Valley Water Reclamation Plant (WRP)	SAWPA database (10/2006 - 12/2012) CIWQS (2/2015 - 3/2015)	10/2006 - 3/2015	11/2009 - 12/2009, 6/2010, 12/2010, 1/2013 - 1/2015, 4/2015 - 9/2016	127
Western Riverside County Regional Wastewater Authority Plant (WRCRWA)	SAWPA database (10/2006 - 6/2009) CIWQS (1/2012 - 9/2016)	10/2006 - 9/2016	7/2009 - 12/2011, 12/2014	133
Yucaipa Valley Water District (YVWD) Henry N. Wochholz Regional Water Recycling Facility (WRF)	SAWPA database (1/2008 - 11/2012) CIWQS (1/2013 - 9/2016)	1/2008 - 9/2016	10/2006 - 12/2007, 9/2012, 4/2015, 8/2015	124
Streamflow Gages				

Location	Source of Data	Period of Record	Data Gaps*	Number of TIN Observations
Santa Ana River at MWD Crossing	USGS	10/2006 - 9/2016	12/2007, 5/2008, 9/2008, 11/2008 - 12/2008, 1/2010 - 2/2010, 4/2010 - 7/2010, 9/2010 - 7/2011, 9/2011 - 7/2012, 9/2012 - 5/2013, 7/2013, 10/2013 - 7/2014, 9/2014 - 7/2015, 9/2015 - 7/2016, 9/2016	78
Santa Ana River below Prado Dam	USGS / OCWD	10/2006 - 9/2016	-	335
Santa Ana River at Imperial Hwy near Anaheim	OCWD	10/2006 - 9/2016	12/2007	165

*No TIN measurement available during month(s) listed

2.7 Quality Assurance / Quality Control

A systematic Quality Assurance/Quality Control (QA/QC) review was performed on data collected for the 2017 WLAM HSPF model calibration period to identify potential errors and outliers in the flow and water quality data. In general, the QA/QC process involved plotting data, identifying extreme outliers, and comparing questionable data with those from surrounding or nearby stations/measurements. In addition, for periods of overlapping data availability, data was compared and cross-checked between multiple sources (e.g., SAWPA database, CIWQS, and SAR Watermaster Reports). The consolidated database was also reviewed to identify and eliminate duplicate data. It was assumed that data from previous versions of the WLAM had already undergone a QA/QC process. Therefore, these prior data (which were used for model simulations) were not reevaluated.

Data excluded from further modeling analysis include the following:

- Three extremely high, single TDS measurements for POTW discharge (approximately double the concentration of surrounding measurements), and
- Negative values for reference evapotranspiration.

The outlier TDS measurements have been flagged in the data provided in Appendix B. Since it is not possible to have negative values for evapotranspiration, these values were removed and assumed to be missing data.

3.0 WASTE LOAD ALLOCATION MODEL UPDATE

3.1 2017 WLAM HSPF Development

The 2017 WLAM HSPF area was divided into 568 sub-watersheds, including 526 sub-watersheds for the 2008 WLAM area and 42 sub-watersheds for the expanded model area (see Figure 11). Delineation of each sub-watershed was based on topography, drainage pattern, type of stream channel, and location of streamflow gaging stations.

Each sub-watershed consists of a stream segment and either pervious, impervious, or a combination of both land surfaces. Sub-watersheds, or elements, are areas that are assumed to have similar hydrogeologic characteristics. They were created for the 2017 WLAM HSPF with the United States Environmental Protection Agency (USEPA) BASINS 4.1 program. The program segments the watershed into sub-watersheds and stream reaches using a delineation tool and a United States Geological Survey (USGS) 10-meter-by-10-meter digital elevation model (DEM), as well as user-specified outlet locations. The location of these outlets was based on the change in channel type (e.g., lined, unlined, etc.) and geography.

3.1.1 Model Code

The 2017 WLAM HSPF uses the Hydrologic Simulation Program – Fortran (HSPF) computer code. This is different from the model computer code that was used for the 2004 and 2008 WLAMs. Benefits for migrating to the HSPF model code include:

- HSPF is a comprehensive and physically based watershed model that can simulate all water cycle and water quality components with a time step of less than one day. The simulated components include rain, vegetation interception, evaporation of rain, evapotranspiration from plants, infiltration of applied water into the upper soil zone, percolation to groundwater, interflow of water through the upper soil layer to a stream channel, stream channel losses to groundwater, and stream channel gains from groundwater (Bicknell et al., 2001). Figure 12 is a schematic diagram showing the water cycle component simulated by the HSPF.

- HSPF is supported and maintained by federal agencies. HSPF is jointly supported and maintained by both the USEPA and the USGS – a rare occurrence where two federal agencies agree on support of a single modeling system. HSPF has enjoyed widespread usage and acceptance since its initial release in 1980, as demonstrated through hundreds of applications across the United

States and abroad. This widespread usage and support has helped ensure the continued availability and maintenance of the code for more than two decades.

- HSPF has an established standard and guideline for model calibration (USEPA, 2000). The calibration process involves adjusting model parameters so that the model-simulated flow and water quality match observed data. The USEPA and its consultant, AQUA TERRA Consultants, have established model calibration performance criteria. In addition, typical and reasonable ranges of the model parameters are provided by the USEPA as a guideline for model calibration.

- HSPF is a windows-based interface with powerful pre- and post- processors. WinHSPF provides a windows-based interface for data input into the HSPF. WinHSPF also assists the user to view, understand, and modify the model representation of a watershed. In addition, the pre-processor included in the BASINS interfaces through GIS, allowing spatial data to be brought together easier. All HSPF software is free and includes comprehensive user's manuals[3].

3.1.1.1 HSPF Modules

The HSPF model code consists of a hierarchy of modules to simulate a range of hydrologic and water quality processes. The three main application modules that simulate water quality and quantity processes are: PERLND (representing pervious land segments), IMPLND (representing impervious land segments), and RCHRES (representing stream channels) (Bicknell et al., 2001). HSPF accounts for the mechanisms of transport and storage for these land types according to specified watershed characteristics, such as topography, land use, soil type, and channel properties. Based on available hydrological data (e.g., precipitation and evaporation), HSPF then simulates runoff and infiltration through each linked module to simulate watershed response. For example, precipitation falling on land surface is first intercepted by vegetation. As demonstrated on Figure 12, this water then becomes infiltration, runoff, or is lost to evapotranspiration (ET) depending on the characteristics of each segment. Water that directly infiltrates on pervious land segments becomes lower zone storage, active groundwater storage, or deep percolation (representing groundwater recharge). Direct runoff is temporarily put in surface detention storage, from where it either becomes interflow or storage in the upper zone (representing ditches, swales, or other depressions in the land surface). This water then enters the stream system as runoff, is lost to ET, or infiltrates into the subsurface. Water routed into stream reaches can be lost to ET, become streambed percolation, or exit the model area through surface outflow.

[3] The HSPF User's Manual (Bicknell et al., 2001) is available from the USEPA's National Service Center for Environmental Publications at: https://www.epa.gov/nscep.

Various submodules in HSPF were used to simulate TDS and TIN. The PQUAL module simulates the accumulation of TDS/TIN on the pervious land surface and its removal by a constant unit rate and by overland flow (subroutine QUALOF), as well as the occurrence of TDS/TIN in interflow (subroutine QUALIF). For impervious land, the HSPF module IQUAL was used, which simulates TDS/TIN in the outflows from an impervious land segment. Since TDS is considered conservative in nature (i.e., does not interact with other water quality parameters or decay with time), the CONS section of HSPF module RCHRES was used. The subroutines utilized by this section simulate the normal longitudinal advection of TDS. TIN, which is a non-conservative constituent (i.e., chemically reactive), was simulated using the RQUAL section of HSPF module RCHRES. The subroutines in this section simulate the reduction of nitrate by anaerobic bacteria (i.e., denitrification). Schematic diagrams of HSPF TDS and TIN simulation are provided as Figures 13 and 14, respectively. Comprehensive information and technical descriptions of each HSPF module can be found in the HSPF User's Manual (Bicknell et al., 2001)

3.2 Data Needs for the 2017 WLAM HSPF

Watershed hydrologic modeling requires a variety of data to characterize the water balance and hydrologic processes that occur in a watershed. These data include:

- Land surface elevations,
- Soil types,
- Land use,
- Precipitation,
- Evaporation,
- Streamflow,
- Stream Channel Characteristics, and
- TDS and TIN concentrations.

Data for the construction and calibration of the 2017 WLAM HSPF were collected for the period from WY 2007 through 2016 (see Section 2.0). Application of these data in the 2017 WLAM HSPF is discussed in the following sections.

3.2.1 Land Surface Elevations

Land surface elevations were obtained by using a USGS 10-meter-by-10-meter DEM in ESRI ArcMap 10. The DEMs are used to evaluate surface water runoff patterns, and in turn to delineate the watershed and sub-watershed boundaries.

3.2.2 Soil Types

Soil type and distribution affects infiltration, surface runoff, interflow, groundwater storage, and deep groundwater losses. Information on both type and distribution of soil types in the study area is available from an ESRI shapefile of Soil Survey Geographic (SSURGO) Database hydrologic soil group information (Soil Survey Staff et al., 2011) (see Figure 5). There are four basic types of soils under this classification system (Group A through D), which are based on soil texture and properties. SSURGO describes each type as the following:

- Group A soils have a high infiltration rate (low runoff potential) when thoroughly wet. They consist mainly of deep, well drained to excessively drained sands or gravelly sands and have a high rate of water transmission. Examples include sand, loamy sand, or sandy loam types of soils.
- Group B soils have a moderate infiltration rate when thoroughly wet. They consist mainly of moderately deep or deep, moderately drained soils that have moderately fine texture to moderately coarse texture and have a moderate rate of water transmission. This includes the silt loam and loam soils.
- Group C soils have a slow infiltration rate when thoroughly wet. They consist mainly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. They have a slow rate of water transmission. The predominant soil in this group is a sandy clay loam.
- Group D soils have a very slow infiltration rate (high runoff potential) when thoroughly wet. They consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. Therefore, they have a very slow rate of water transmission. This includes clay loam, silty clay loam, sandy clay, silty clay or clay type soils. Bedrock is also included in this group due to its very low infiltration rate.

A relative infiltration rate is associated with each soil group, ranging from soils with a high infiltration rate characteristic of coarser sediments (Group A) to a very low infiltration rate characteristic of finer grained materials (Group D). Each sub-watershed is given an average infiltration index based on the percentage of the various soil types within its borders. The infiltration rate was assigned initially based on the calculated infiltration index and adjusted during model calibration. Table 1 shows the initial and model-calibrated infiltration rates for each sub-watershed.

3.2.3 Land Use

Land use and development affect how water enters or leaves a system by altering infiltration, surface runoff, runoff location, degree of evapotranspiration, and where water is applied in the form of irrigation. Since the 2017 WLAM HSPF period covers WY 2007 through 2016, 2012 land use information from Southern California Association of Governments (SCAG) was used to locate and designate areas as being pervious or impervious within the model boundary during the simulation period (see Figure 3). Six main land use categories were used for the purpose of identifying perviousness:

- Agriculture/Golf Course/Parks,
- Commercial/Industrial/Public Facility[4],
- Open Space/Dry Agriculture/Water Body,
- Residential Low Density,
- Residential Medium Density, and
- Residential High Density.

The 2012 acreages of each land use category are shown in Table 2.

The land use category determines to what degree areas are pervious or impervious. Even urban areas are assumed to have a percentage of perviousness associated with them (i.e., landscaping). The assumed pervious percentages in the 2017 WLAM HSPF were taken from an Aqua Terra modeling study conducted in Ventura County (Aqua Terra, 2005). These pervious percentages also fall within the ranges suggested by the Riverside County Flood Control and Water Conservation District (RCFCWCD) and San Bernardino County (SBC) Hydrology Manuals (RCFCWCD, 1978; Williamson and Schmid, 1986). Table 3-1 below summarizes the pervious percentages for different land use categories. The recommended percentages from the RCFCWCD and SBC Hydrology Manuals, as well as those used in the 2004 and 2008 versions of the WLAM, are included for comparison.

[4] Agricultural processing was assigned as "industrial" for the purpose of assigning a pervious percentage.

Table 3-1. Assumed Pervious Percentages for Land Use

Land Use Category	% Pervious				
	RCFCWCD	SBC	2004 WLAM	2008 WLAM	2017 WLAM HSPF
Agriculture/Golf Courses/Parks	90-100	75-100	95-98	98-100, 20[1]	**100**
Open Space/Dry Agriculture/Water	90-100	100	98-100	98	**100**
Commercial/Industrial/Public Facilities	0-20	0-20	0-100	10	**20**
Residential Low Density	75-90	75-95	60	70	**90**
Residential Medium Density	55-70	50-80	40	50	**50**
Residential High Density	10-55	10-65	20	25	**40**

[1] 20% pervious area used for parks and schools

3.2.4 Precipitation

Precipitation data are available from a multitude of precipitation gaging stations within the 2017 WLAM HSPF model boundary. As discussed in Section 2.3, daily precipitation was collected from over 81 stations. However, due to data gap periods at many of the stations, only 19 of the evaluated stations were ultimately chosen based on the completeness of their record. The locations of these stations are shown on Figure 6. While this resulted in fewer precipitation stations than those used in previous versions of the WLAM (43 precipitation stations were used in the 2004 and 2008 WLAMs), it provided a more complete data set that required fewer assumptions for days with missing data. For the few days for which data were missing in the 2017 WLAM HSPF precipitation data set, daily precipitation was estimated based on the correlation (ratio) of average annual precipitation at the station in question to average annual precipitation at the San Bernardino County Hospital gage (2146AUTO). The San Bernardino County Hospital gage was selected for its complete data set. The ratio correlating precipitation at the gage with missing data and the San Bernardino County Hospital gage and was then used to calculate the missing day(s) of precipitation based on the reading at the San Bernardino County Hospital gage.

In order to distribute the observed daily precipitation from the 19 precipitation stations throughout the model domain, precipitation adjustment factors were developed based on long-term average annual precipitation. Gridded historical average annual precipitation from 1981 through 2010 was used from the PRISM Climate Group (2017), which covers a variety of hydrologic conditions (i.e., wet, dry, and average). These long-term average contours also account for increased precipitation at higher elevations and allows for the application of higher precipitation in mountainous sub-watersheds instead of relying on direct values from precipitation stations in valley areas. The process of calculating the precipitation adjustment factors for each sub-watershed involved the following steps:

- An average annual precipitation value was calculated for each sub-watershed based on isohyetal contours of gridded PRISM historical average annual precipitation (1981-2010) in the 2017 WLAM HSPF area (see Figure 15).
- The average annual precipitation value from the isohyetal contours was noted for each precipitation station.
- The average annual precipitation values within each sub-watershed were compared to the average precipitation at each precipitation station. The station with an average annual precipitation value closest to that at individual sub-watersheds in the vicinity was used to assign daily values (typically coinciding with Theissen polygon boundaries).
- A precipitation adjustment factor was then calculated by dividing the average annual precipitation value for each sub-watershed by the average precipitation value of the station that was designated as being the closest match in terms of long-term average precipitation (from PRISM isohyetal contours).
- Historical daily precipitation values for each station were then multiplied by the precipitation adjustment factor to determine daily precipitation within each sub-watershed.

Precipitation adjustment factors and designated precipitation stations are shown on Figure 15. As an example, the average PRISM precipitation for Sub-Watershed A-71, located just southwest of the Indian Hills precipitation station (#265), is 9.86 inches. The average PRISM precipitation at the Indian Hills station is 10.44 inches. This results in a precipitation adjustment factor of 94% (9.86 inches / 10.44 inches = 0.94). Therefore, daily precipitation for Sub-Watershed A-71 represents 94% of the daily precipitation recorded at the Indian Hills gage (on 3/8/16, 0.42 inches of precipitation were recorded at Indian Hills gage and 0.39 inches were applied to Sub-Watershed A-71).

3.2.5 Evapotranspiration

Evapotranspiration (ET) represents a significant outflow term and is included in the 2017 WLAM HSPF using the following methodology:

- Monthly average reference ET (ETo) was collected for California Irrigation Management Information System (CIMIS) ETo Zones 6, 9, and 14 (refer to Figure 7 for zone locations).

- Hourly ET rates were collected from CIMIS stations at the University of California, Riverside (UC Riverside #44; data available from 6/2/1985) and Pomona (Pomona #78; data available from 3/14/1989), located in CIMIS Zones 6 and 9, respectively. The locations of these evaporation stations are also shown on Figure 7. Assumed values for missing hourly data were calculated based on average daily ET at that station or interpolated from recordings on either side of the missing data.
- Adjustment factors were developed for ETo Zones 6 and 9 based on average annual ET rates and data from the CIMIS ET stations. The adjustment factor is equal to the ETo Zone average annual ET divided by the CIMIS station average annual ET.
- The adjustment factors were then used to apply hourly ET rates from the CIMIS station in a given zone to each sub-watershed within that same zone (ET for a given sub-watershed = corresponding ETo Zone CIMIS station hourly ET x adjustment factor). Hourly ET rates were also developed for sub-watersheds within CIMIS ETo Zone 14 based on the monthly average reference ET for that zone. For CIMIS Zone 14, daily evapotranspiration values were assumed to be constant within each month.

3.2.6 Streamflow

3.2.6.1 External Inflow

External inflow into the model area is represented by streamflow from tributaries flowing into the 2017 WLAM HSPF area. The amount of streamflow was quantified based on daily historical gaged data. Figure 8 shows the location of these gaging stations, located in Cucamonga, Lytle, Cajon, Devil Canyon, East Twin, City, Plunge, Mill, Carbon, and Santiago Creeks.

Streamflow from Seven Oaks Dam outflow (i.e., Santa Ana Canyon) to the SAR is also one of the external sources of streamflow for the 2017 WLAM HSPF. These discharges were accounted for in the gaged streamflow at the downstream Santa Ana River near Mentone, CA gage.

3.2.6.2 Discharges

Wastewater discharge from POTWs represents a significant source of streamflow in the 2017 WLAM HSPF area. Wastewater facilities within the model area that discharge into the SAR and its tributaries include:

- Beaumont Wastewater Treatment Plant (WWTP),
- Carbon Canyon WRF,
- Colton WWTP,
- Corona WWTP,
- Eastern Municipal Water District (EMWD) Regional Water Reclamation Facilities (WRFs),
- Elsinore Valley Municipal Water District (EVMWD) Regional Wastewater Reclamation Facility (WWRF),
- IEUA Regional Plants (RPs),
- Rialto WWTP,
- Riverside Regional Water Quality Control Plant (RWQCP),
- San Bernardino/Colton Rapid Infiltration and Extraction (RIX) Facility (including direct discharges during extreme wet weather conditions),
- San Bernardino Water Reclamation Plant (WRP),
- Temescal Valley WRF (formerly Lee Lake Water District WWTP),
- Western Riverside County Regional Wastewater Authority Plant (WRCRWA), and
- YVWD Henry N. Wochholz Water Recycling Facility (WRF).

Additional discharges incorporated in the 2017 WLAM HSPF include:

- San Bernardino Geothermal Plant,
- Arlington Desalter, and
- OCWD's turnout OC-59.

Historically, Valley District has also operated a dewatering discharge of approximately 6.3 cfs. While this discharge was included in the 2008 WLAM, no dewatering discharges were made by Valley District during the 2017 WLAM HSPF calibration period. The same is true of Lake Elsinore stormwater discharges. Discharge locations are shown on Figure 9 and average monthly discharges are provided in Table 3.

3.2.6.3 Surface Water Diversions for Off-Channel Recharge

A two-step model run was used to apply streamflow diversion data in the Chino Basin area. Model diversion points were established in the 2017 WLAM HSPF downstream of recharge basins for each main tributary to the SAR. Recharge basin and diversion point locations are shown on Figure 10. Daily streamflow at each diversion point was then calculated from an initial HSPF model run before applying streamflow diversions. This flow was used to develop a daily factor within each given month. Monthly streamflow diversion data provided by Chino Basin Watermaster was then distributed proportionally into daily diversions based on the amount of flow calculated by the initial model run. Undiverted daily streamflow was calculated by subtracting the daily streamflow diversion from the model-simulated daily streamflow of the first model run at each diversion point. Undiverted streamflow was then routed back into the second HSPF model run as inflow at the diversion points. TDS and TIN concentrations of this flow were assumed to be the same as those calculated at the diversion points during the initial HSPF model run.

In the SBBA, Valley District diversions from the SAR for recharge at the SAR Spreading Grounds were simulated according to recorded flow at the Parshall Flume. This flow includes diversions from the SAR at Cuttle Weir as well as overflow from the SCE System. This overflow is assumed to be the average from the Safe Yield Period (WY 1935 through WY 1962; Western/San Bernardino Watermaster, 1972). Other recharge facilities overlying the Bunker Hill-B GMZ are operated by SBCFCD. The 2017 WLAM HSPF does not account for diversions to these basins since no spreading data were able to be obtained. This is something that should be considered in future updates to the WLAM.

Spreading activities in Orange County are accounted for in the 2017 WLAM HSPF by using the OCWD Recharge Facilities Model (RFM), as discussed in Section 3.2.6.5.

3.2.6.4 Prado Wetlands

The Prado Wetlands, operated by OCWD, receives approximately fifty percent (50%) of SAR discharge (up to 100 cfs). This water is diverted into a series of wetland ponds for the removal of nitrate and other pollutants and flows out of the ponds into Chino Creek. In order to account for additional ET losses that occur for river flows diverted through these ponds, a separate, discrete impoundment was created for the 2017 WLAM HSPF using a spreadsheet model.

The OCWD Prado Wetlands spreadsheet model was developed based on the pond schematic and descriptions provided by OCWD. Inflow into the wetlands through the SAR diversion channel represents 50% of model-calculated flow in the SAR at the diversion point, up to 100 cfs. Flow is then routed through the wetland ponds by the spreadsheet model through a series of weirs and channels according to the flow diagram provided as Figure 16. The spreadsheet model tracks pond storage and flow depending on the elevation of each pond zone and outflow weir. Model-calculated flow from the spreadsheet model is added into the 2017 WLAM HSPF at the discharge location in Chino Creek.

Limited percolation is thought to occur in the wetland ponds due to the presence of fine-grained sediments[5]. Therefore, percolation in the Prado Wetlands spreadsheet model was assumed to be zero.

[5] Greg Woodside (Executive Director of Planning and Natural Resources, OCWD), personal communication.

Los Angeles County pan evaporation rates from Puddingstone Reservoir were used to calculate ET in the wetlands for freshwater marsh and open water habitat, according to the method outlined in the "Evaporation Analysis of the Prado Basin, Santa Ana River, California" by Merkel & Associates, Inc. (2007). The spreadsheet model was run for the period from WY 1995 through 2016 to avoid artificial, transient effects from initial filling of the model prior to the 2017 WLAM HSPF model calibration period (WY 2007 through 2016).

3.2.6.5 OCWD Operations at and below Prado Dam

Within the expanded 2017 WLAM HSPF model area in Orange County, the OCWD Recharge Facilities Model (RFM) was used to account for operations at Prado Dam and OCWD diversions from the SAR to recharge spreading facilities in the cities of Anaheim and Orange. The RFM was created by CH2M Hill using GoldSim software (CH2M Hill, 2009). GoldSim is a software developed by GoldSim Technology Group for simulating complex systems in engineering, business, and science through a series of user-defined equations and data input into a visual spreadsheet. GoldSim is capable of performing dynamic, probabilistic simulations and predicting system responses to changing conditions. The OCWD RFM incorporates OCWD operational practices and was calibrated to available diversion, storage, and percolation data from July 2002 through June 2008. CH2M Hill provides a full overview of the model in their 2009 OCWD RFM technical memorandum.

The 2017 WLAM HSPF and the RFM were used in a two-way coupling fashion. The RFM is used only as an accounting tool to track diversions from the SAR and does not estimate runoff from all of the adjacent land areas. Therefore, the 2017 WLAM HSPF was run to calculate local run-off in the watershed areas upstream of and surrounding the stretch of the SAR for which the RFM operates (Reach 2 of the SAR, shown in green on Figure 17). This model-calculated runoff, along with Prado Dam calculated inflow, was used as RFM input. The RFM was then run to calculate diversions to OCWD recharge spreading facilities and discharge at the RFM outlet (see Figure 17). The 2017 WLAM HSPF was then run to calculate run-off in the watershed area below the RFM (area shown in gray on Figure 17) and streamflow at the SAR at Santa Ana gage, using the RFM-calculated discharge as inflow.

3.2.7 Stream Channel Characteristics

As part of the 2012 Basin Plan amendment for bacteria standards, the Counties were required to submit information on channel characteristics to the Regional Board. These stream channel characteristics (e.g., lined or unlined) were used to determine the degree to which streamflow is able to infiltrate in stream reaches within the model area. Figure 10 shows stream channel types. The type of stream channel for each stream reach segment was analyzed to determine the hydraulic behavior through the use of an

FTABLE (hydraulic table). FTABLEs determine the infiltration volume of stream reaches by using the HSPF best management practice (BMP) Toolkit created by the USEPA, which takes into account the lining type, slope, Manning's Roughness Coefficient (used for flow calculations), and the length of the stream reach. Each sub-watershed was assigned model parameter values based on the available data in the area. Where stream segments are unlined, the assigned streambed percolation rate was adjusted during model calibration.

3.2.8 Rising Water

Rising water discharges to the SAR at Riverside Narrows and in the vicinity of Prado Basin (refer to Figure 18 for locations). A recent study by WEI (2017) has also identified rising water in Temescal Creek upstream of the Main Street gage. In natural systems, the amount of rising water fluctuates depending on groundwater elevations relative to stream stage. Since groundwater elevation was not modeled by the 2017 WLAM HSPF, discharge from the groundwater system to the surface water system in the form of rising groundwater was not automatically modeled in response to water levels. Assumptions for rising water in the 2017 WLAM HSPF were therefore developed to account for this known process.

During initial development of the 2017 WLAM HSPF, accounting for rising water was done in a post-processing step. However, after further technical review and discussions by the Task Force, it was ultimately decided to use the approach used by previous versions of the WLAM. With this approach, rising water was treated as an additional flow source by assigning an assumed flow rate and concentration in the surface water model at the location of rising water. In the 2004 WLAM, a constant rising water volume (varied seasonally) with assumed TDS/TIN concentrations was applied at the Riverside Narrows (WEI, 2002) and at both Prado Basin and the Riverside Narrows in the 2008 WLAM (WEI, 2009). Neither the 2004 WLAM nor the 2008 WLAM included rising water in Temescal Creek. Differences in calibration results using the two approaches (post-processing approach versus rising water as a flow source) and sensitivity analysis of rising water assumptions are summarized in Section 4.6.

The 2017 WLAM HSPF applied an assumed rising water flow with associated TDS/TIN concentrations in Temescal Creek upstream of the Main Street gaging station (in Reach 2 at the boundary of the Upper Temescal Valley GMZ), in the SAR Reach 3 upstream of MWD Crossing (Riverside Narrows), and in the vicinity of Prado Basin (below River Rd.). The amount of rising water in Temescal Creek was initially based on estimates provided in the Salt and Nutrient Management Plan (SNMP) for the Upper Temescal Valley (WEI, 2017). These values were then calibrated during additional model calibration (see Appendix T). Rising water in Riverside Narrows and Prado was based on model-calculated rising water from the WRIME groundwater flow model of the Riverside-Arlington Groundwater Basin (WRIME, 2010; currently being updated by GEOSCIENCE as part of the Integrated SAR Model), and model-calculated rising water from the Chino Basin groundwater flow model developed by GEOSCIENCE in 2014, respectively[6]. These model-simulated estimates, which were on the order of previous estimates of rising water, were used to preserve some of the natural, real-world fluctuation of rising water in response to hydrology and corresponding groundwater levels. Annual rising water volumes in Temescal Creek, Riverside Narrows, and Prado Vicinity is shown on Figures 19, 20, and 21, respectively. Monthly rising water assumptions for the calibration period are summarized in Table 4. TDS and TIN concentrations of rising water are discussed in Section 3.2.9.3.

Upstream of the Riverside Narrows, no streambed percolation was assumed to occur in Reach 3 of the SAR (see Figure 22). In this reach within Riverside A GMZ, which represents the location of rising water, the hydraulic gradient of the groundwater was assumed to be such that gaining stream conditions were present and streamflow was therefore unable to percolate. This assumption is consistent with the approach used for the 2008 WLAM and is supported by limited USGS streamflow measurements at SAR gages downstream of the confluence of RIX outflow, and at Riverside Dr., Market St., and Mission Blvd. Dry-weather flow at these gages is shown on Figure 22 for measurements taken in July of 2015 and 2016 and August of 2015 and 2016. As shown, streamflow in the SAR decreases between the RIX outfall and Riverside Rd. for all four measurement events. This indicates losing stream conditions where surface flow is percolating into the underlying groundwater systems. Losing stream conditions are also generally present between Riverside Rd. and Market St., although measurements in July of 2015 indicate very little, if any, percolation between these two gages. After Market St. and before Mission Blvd., gaining stream conditions (indicative of rising groundwater) are seen in August of 2015. The loss of flow to streambed percolation in this reach during the other measurement events is also reduced. This indicates that the area around Mission Blvd. (coinciding with the division between Reach 4 and Reach 3) represents an area of transition from losing stream to gaining stream conditions. These observations help support the assumption that Reach 3 is typically gaining upgradient of MWD Crossing.

3.2.9 TDS and TIN

In order to estimate average daily and monthly TDS/TIN concentrations in major stream segments, the 2017 WLAM HSPF was calibrated to observed TDS and TIN data in the SAR at MWD Crossing, below Prado Dam, and at Imperial Highway near Anaheim (see Figure 8 for station locations). The TDS/TIN concentrations at these locations are a product of multiple contributing sources, including runoff, discharges to streamflow, and rising groundwater. Each source has an associated concentration. TDS/TIN

[6] While the 2017 WLAM HSPF was being developed and calibrated, an integrated groundwater/surface water model of the Upper SAR (known as the Integrated SAR Model) was concurrently being developed by GEOSCIENCE. However, calibrated model-calculated rising water estimates from the Integrated SAR Model were not available to be used for the 2017 WLAM HSPF calibration. Therefore, previous estimates from the WRIME model and 2014 GEOSCIENCE Chino Basin model were used.

concentrations were collected for each discharging agency and the three water quality streamflow gages used for calibration (see Section 2.6). TIN measurements were augmented by including measurements of Ammonia + Nitrate + Nitrite[7]. TDS data were provided in mg/L.

3.2.9.1 TDS and TIN in Runoff and Percolation from Precipitation

Concentrations of recharge from precipitation are significantly altered by evaporation and transport processes. As such, TDS and TIN in runoff is modeled by HSPF through dry deposition, which includes contributions from rainfall, agricultural irrigation, and urban irrigation. The average amount of dry deposition (mass per area per time) suggested by the USEPA was used as an initial concentration in the 2017 WLAM HSPF. This rate was then adjusted during model calibration within the limits established in USEPA BASINS Technical Note 6 (2000) to produce TDS and TIN concentrations in runoff that follow the relationships developed by WEI in the 2004 WLAM (WEI, 2002). During the model calibration period (WY 2017 through 2016), the TDS and TIN concentrations in runoff ranged from 67 to 232 mg/L and 0.5 to 2.0 mg/L, respectively.

3.2.9.2 TDS and TIN in Discharges

TDS and TIN measurements for discharges to the SAR and its tributaries are typically taken periodically; they do not represent daily data. If monthly data were provided (i.e., one measurement per month), the concentration of the daily discharge was assumed to be constant for the whole month. In months were several data points were available, daily discharge was assumed to have a concentration equal to the average measured concentration for each month. However, some discharge locations provided decent coverage (i.e., approximately 15 or more measurements per month). When this density of data was available (e.g., IEUA RP-1), daily concentrations were assumed to be constant between readings.

3.2.9.3 TDS and TIN in Rising Groundwater

In the 2017 WLAM HSPF, rising water occurs in the Riverside Narrows, Prado Basin (Prado Vicinity), and in Temescal Creek upgradient of Main Street. An assumed rising water flow with associated TDS/TIN concentrations were applied at these locations. The concentration of rising water in Temescal Creek was based on the values reported in the Upper Temescal Valley SNMP (WEI, 2017). TDS and TIN concentrations of rising water at the Riverside Narrows and Prado vicinity were initially assigned the same values used in the 2004 and 2008 WLAM, and then adjusted during model calibration. Average

[7] Nitrite is not critical for the computation of TIN since the contribution is typically very small.

concentrations of rising water are summarized in the following table while monthly rising water concentrations are summarized in Table 4.

Table 3-2. Average TDS and TIN Concentrations of Rising Water

Area	2004 WLAM		2008 WLAM		2017 WLAM HSPF	
	TDS	TIN	TDS	TIN	TDS	TIN
	[mg/L]					
Riverside Narrows	900	11	900	11	794	11
Prado Vicinity	1,100	11	1,100	11	1,046	5
Temescal Creek	-	-	-	-	775	6

3.2.9.4 TDS and TIN in Prado Wetlands Outflow

As mentioned in Section 3.2.6.4, the Prado Wetlands are used to treat some of the SAR discharge for nitrate and other pollutants. Communications from OCWD staff (OCWD Comment #7 on TM-2, see Appendix A) have revealed that nitrate removal in the wetlands varies seasonally (higher in summer, lower in winter). OCWD recommended an outflow nitrate concentration of 1 mg/L be applied from May through October and a concentration of 4 mg/L be applied from November through April. Outflow from the wetlands has slightly increased TDS concentrations due to the removal of flow through the additional ET calculated by the spreadsheet model (TDS remains in solution while part of the flow is removed through ET).

3.2.9.5 Nitrogen Reaction Rate Coefficients

The nitrogen reaction rate coefficient simulates the loss of nitrogen in surface flow due to the reduction of nitrate by facultative anaerobic bacteria (i.e., denitrification). These reaction rate coefficients are incorporated in the surface water model and are therefore considered in model-calculated surface water quality. Nitrogen loss coefficients, on the other hand, are considered during post-processing to account for additional nitrogen loss as surface water percolates into the ground and is consumed by vegetation. Nitrogen loss coefficients are discussed in Section 5.4.3. The initial reaction rate coefficients for nitrogen in surface discharge were 0.1 day^{-1} upstream of Riverside Narrows, 0.25 day^{-1} from Riverside Narrows to Prado Dam, and 0.1 day^{-1} downstream of Prado Dam. During model calibration, these coefficients were found to provide satisfactory results between model-calculated and observed TIN concentrations in surface water.

3.3 WLAM Differences

The 2017 WLAM HSPF represents a departure from the previous modeling used for the 2004 and 2008 WLAMs. Some of the key differences are summarized in the following table.

Table 3-3. Key Similarities and Differences between WLAM Versions

Item	2004 WLAM	2008 WLAM	2017 WLAM HSPF
Computer Code	RUNOFF & ROUTER • WEI proprietary software • Water left unaccounted for after individual modules are combined (infiltration included in the initial abstraction was not accounted for in the soil moisture calculation) • Field data not always honored • Limited capability: relies on Arc GIS to prepare model input and is executed through DOS	RUNOFF & ROUTER • WEI proprietary software • Water left unaccounted for after individual modules are combined (infiltration included in the initial abstraction was not accounted for in the soil moisture calculation) • Field data not always honored • Limited capability: relies on Arc GIS to prepare model input and is executed through DOS	HSPF **(NEW)** • Supported and maintained by Federal agencies (USEPA and USGS) • Publicly available • Comprehensive and physically based – accounts for all water cycle components • Established standards and guidelines • Windows-based interface with powerful pre- and post-processors
Sub-Watersheds (or Hydrologic Simulation Areas)	Not Provided Includes SAR Watershed area from Seven Oaks Dam to Prado Dam	220 Includes SAR Watershed area from Seven Oaks Dam to Prado Dam	568 Includes SAR Watershed area from Seven Oaks Dam to Prado Dam and downstream of Prado Dam to the SAR at Santa Ana gage in Orange County **(NEW)**
Soil Data	• Soil Conservation Service (SCS) surveys in: - Pasadena (1917), - Riverside (1971), and - San Bernardino County (1977). • San Bernardino County Hydrology Manual (Williamson and Schmid, 1986)	• Soil Conservation Service (SCS) surveys in: - Pasadena (1917), - Riverside (1971), and - San Bernardino County (1977). • San Bernardino County Hydrology Manual (Williamson and Schmid, 1986)	• SSURGO Database (Soil Survey Staff et al., 2011) **(NEW)**
Land Use	1993 (SCAG)	2005 (SCAG)	2012 (SCAG) **(NEW)**
Precipitation Stations	Collected all available precipitation data in model area. Interpolated missing data at each station and applied daily data to hydrologic simulation areas based on Thiessen polygons. 43 precipitation stations used: • Mira Loma Space Center (1021AUTO) • Ontario Fire Station (1026)	Collected all available precipitation data in model area. Interpolated missing data at each station and applied daily data to hydrologic simulation areas based on Thiessen polygons. (Note: more than half of the stations were without data for the calibration period) 43 precipitation stations used:	Collected all available precipitation data in model area. Used only precipitation stations with good records (over 95% complete). Used adjustment factors based on PRISM 30-year average precipitation to apply daily data to sub-watersheds. 19 precipitation stations used: • Mira Loma Space Center (1021AUTO)

Item	2004 WLAM	2008 WLAM	2017 WLAM HSPF
	• San Bern. City – Devil (2071) • Lytle Cr at Foothill Blvd (2159AUTO) • San Bern. City – Newmark (2166) • San Bern. City – Lytle Cr (2198) • Oak Glen (3014AUTO) • Loma Linda (V.G.C) (3273) • Chino – Imbach (1079) • San Antonio Heights CDF (1085) • Yucaipa CDF (3129) • Claremont Pomona College (1034) • Chino Substation – Edison (1067) • Alta Loma Forney (1175) • Declez (2005B) • Reche Canyon – Manton (2009A) • Del Rosa Ranger Stn (2015AUTO) • Fontana 5N (Getchell) (2017AUTO) • Lytle Cr Ranger Stn (2037AUTO) • San Bern. Co. Hospital (2146AUTO) • Fontana Union Water Co (2194) • San Bern. City – Hanford (2286AUTO) • Santa Ana PH #3 (3162AUTO) • Upland – Chapel (1019AUTO) • Mentone – Blue Goose (3058) • Beaumont (13) • Chase & Taylor (35) • Elsinore (67) • Temescal Cyn Ws (75) • Riverside East (177) • Riverside North (178) • Riverside South (179) • Wildomar (246) • Arlington (7) • Calimesa (31) • Cherry Valley (36) • Corona North (44) • La Sierra (100) • Lake Mathews (102) • Santiago Peak (202) • Woodcrest (250) • Gavilan Springs (71) • Indian Hills (265)	• Mira Loma Space Center (1021AUTO) • Ontario Fire Station (1026) • San Bern. City – Devil (2071) • Lytle Cr at Foothill Blvd (2159AUTO) • San Bern. City – Newmark (2166) • San Bern. City – Lytle Cr (2198) • Oak Glen (3014AUTO) • Loma Linda (V.G.C) (3273) • Chino – Imbach (1079) • San Antonio Heights CDF (1085) • Yucaipa CDF (3129) • Claremont Pomona College (1034) • Chino Substation – Edison (1067) • Alta Loma Forney (1175) • Declez (2005B) • Reche Canyon – Manton (2009A) • Del Rosa Ranger Stn (2015AUTO) • Fontana 5N (Getchell) (2017AUTO) • Lytle Cr Ranger Stn (2037AUTO) • San Bern. Co. Hospital (2146AUTO) • Fontana Union Water Co (2194) • San Bern. City – Hanford (2286AUTO) • Santa Ana PH #3 (3162AUTO) • Upland – Chapel (1019AUTO) • Mentone – Blue Goose (3058) • Beaumont (13) • Chase & Taylor (35) • Elsinore (67) • Temescal Cyn Ws (75) • Riverside East (177) • Riverside North (178) • Riverside South (179) • Wildomar (246) • Arlington (7) • Calimesa (31) • Cherry Valley (36) • Corona North (44) • La Sierra (100) • Lake Mathews (102) • Santiago Peak (202) • Woodcrest (250) • Gavilan Springs (71) • Indian Hills (265)	• Lytle Cr at Foothill Blvd (2159AUTO) • Oak Glen (3014AUTO) • Loma Linda (V.G.C) (3273) • Declez (2005B) • Del Rosa Ranger Stn (2015AUTO) • Fontana 5N (Getchell) (2017AUTO) • San Bern. Co. Hospital (2146AUTO) • Santa Ana PH #3 (3162AUTO) • Beaumont (13) • Chase & Taylor (35) • Elsinore (67) • Riverside North (178) • Riverside South (179) • Lake Mathews (102) • Woodcrest (250) • Indian Hills (265) • Santana (OC SANTANA) **(NEW)** • Villapark (OC VILLAPARK) **(NEW)**

Item	2004 WLAM	2008 WLAM	2017 WLAM HSPF
Evapotranspiration Stations	• LA County Evaporation Station at Puddingstone Reservoir	• CIMIS Station Pomona #78 (included in model files but not mentioned in report) • CIMIS Station UC Riverside #44 (included in model files but not mentioned in report) • LA County Evaporation Station at Puddingstone Reservoir	• CIMIS Station Pomona #78 • CIMIS Station UC Riverside #44 • LA County Evaporation Station at Puddingstone Reservoir
Streamflow Gaging Stations	Boundary Inflow (12): • SAR nr Mentone (11051500) • SAR nr Mentone + Canals (11051501) • Mill Ck nr Yucaipa (11054000) • Plunge Ck nr E Highlands (11055500) • Plunge Ck nr E Highlands + Canals (11055500) • City Ck nr Highland (11055800) • E Twin Ck nr Arrowhead Springs (11058500) • Lytle Ck nr Fontana (11062000) • Cajon Ck below Lone Pine Ck nr Keenbrook (11063510) • Devil Cyn Ck nr San Bernardino (11063680) • Day Ck nr Etiwanda (11067000) • Cucamonga Ck nr Upland (11073470) Flow Calibration (7): • San Timoteo Ck nr Loma Linda (11057500) • SAR at E St (11059300) • SAR at MWD Crossing (11066460) • Temescal Ck at Main St (11072100) • Chino Ck at Schaefer Ave (11073360) • Cucamonga Ck nr Mira Loma (11073495) • SAR Inflow to Prado Dam (USACE calculation)	Boundary Inflow (12): • SAR nr Mentone (11051500) • SAR nr Mentone + Canals (11051501) • Mill Ck nr Yucaipa (11054000) • Plunge Ck nr E Highlands (11055500) • Plunge Ck nr E Highlands + Canals (11055500) • City Ck nr Highland (11055800) • E Twin Ck nr Arrowhead Springs (11058500) • Lytle Ck nr Fontana (11062000) • Cajon Ck below Lone Pine Ck nr Keenbrook (11063510) • Devil Cyn Ck nr San Bernardino (11063680) • Day Ck nr Etiwanda (11067000) • Cucamonga Ck nr Upland (11073470) Flow Calibration (7): • San Timoteo Ck nr Loma Linda (11057500) • SAR at E St (11059300) • SAR at MWD Crossing (11066460) • Temescal Ck at Main St (11072100) • Chino Ck at Schaefer Ave (11073360) • Cucamonga Ck nr Mira Loma (11073495) • SAR Inflow to Prado Dam (USACE calculation)	Boundary Inflow (12): • SAR nr Mentone + Canals (11051501) • Mill Ck + Canals nr Yucaipa (11054001) • Plunge Ck + Canals nr E Highlands (11055501) • City Ck & City Ck Water Co's Canal nr Highland (11055801) • E Twin Ck nr Arrowhead Springs (11058500) • Lytle Cr, SCE Co's Lytle Ck Conduit, and Fontana Water Co's Infiltration Line Diversion nr Fontana (11062001) • Cajon Ck below Lone Pine Ck nr Keenbrook (11063510) • Devil Cyn Ck nr San Bernardino (11063680) • Day Ck nr Etiwanda (11067000) • Cucamonga Ck nr Upland (11073470) • Carbon Ck below Carbon Cyn Dam (11075720) **(NEW)** • Santiago Ck at Santa Ana (11077500) **(NEW)** Flow Calibration (9): • San Timoteo Ck nr Loma Linda (11057500) • Warm Ck nr San Bernardino (11060400) • SAR at E St (11059300) • SAR at MWD Crossing (11066460) • Temescal Ck at Main St (11072100) • Chino Ck at Schaefer Ave (11073360) • Cucamonga Ck nr Mira Loma (11073495) • SAR Inflow to Prado Dam (USACE calculation)

Item	2004 WLAM	2008 WLAM	2017 WLAM HSPF
			• SAR at Santa Ana (11078000) **(NEW)**
TIN/TDS from Streamflow Gaging Stations	• SAR at MWD Crossing (11066460) • SAR below Prado Dam (11074000)	• SAR at MWD Crossing (11066460) • SAR below Prado Dam (11074000)	• SAR at MWD Crossing (11066460) • SAR below Prado Dam (11074000) • SAR at Imperial Hwy nr Anaheim (11075600) **(NEW)**
POTW and Other Discharges	Recycled Water Discharges: • Beaumont WWTP • Colton WWTP • Corona WWTP • EMWD Temescal Discharge • EVMWD • IEUA Carbon Canyon WRF • IEUA RP1 001 • IEUA RP1 002 • IEUA RP2 • LLWD WWTP • Rialto WWTP • Riverside Discharge • RIX • San Bernardino WWTP • WRCRWA • YVWD WWTP Other Discharges: • Arlington Desalter • OC-59 • SBVMWD Exchange (dewatering) • Lake Elsinore Stormwater Discharge	Recycled Water Discharges: • Beaumont WWTP • Colton WWTP • Corona WWTP #1 • EMWD Temescal Discharge • EVMWD Regional WWRP • IEUA Carbon Canyon WRP • IEUA RP1 001 • IEUA RP1 002 Cucamonga and RP4 • IEUA RP2 • LLWD WWTP • Rialto WWTP • Riverside RWQCP • RIX Facility • San Bernardino WWTP • WRCRWA • YVWD H.N. Wochholz WTP Other Discharges: • Arlington Desalter • OC-59 • SBVMWD Exchange (dewatering) • Lake Elsinore Stormwater Discharge	Recycled Water Discharges: • Beaumont WWTP • Colton WWTP • Corona WWTP #1 and #3 **(NEW)** • EMWD Regional WRFs • EVMWD Regional WWRF • IEUA Carbon Canyon WRF • IEUA RP1 001 Prado • IEUA RP1 002 Cucamonga and RP4 • IEUA RP2 • IEUA RP5 **(NEW)** • Temescal Valley WRF (formerly LLWD WWTP) • Rialto WWTP • Riverside RWQCP • RIX Facility • San Bernardino WRP • WRCRWA • YVWD H.N. Wochholz WRF Other Discharges: • Arlington Desalter • OC-59 • San Bernardino Geothermal Plant **(NEW)** Note: Valley District dewatering, and Lake Elsinore stormwater discharges were not included since none occurred during the calibration period.
Rising Water (Flow)	Assumed flow at: • Riverside Narrows • Prado Vicinity	Assumed flow at: • Riverside Narrows • Prado Vicinity	Assumed flow at: • Riverside Narrows • Prado Vicinity • Temescal Creek upstream of Main St. **(NEW)**
Rising Water (TDS/TIN)	Assumed TDS concentration at: • Riverside Narrows = 900 mg/L • Prado Vicinity = 1,100 mg/L	Assumed TDS concentration at: • Riverside Narrows = 900 mg/L • Prado Vicinity = 1,100 mg/L	Assumed TDS concentration at: • Riverside Narrows = 794 mg/L • Prado Vicinity = 1,046 mg/L

Item	2004 WLAM	2008 WLAM	2017 WLAM HSPF
	Assumed TIN concentration at: • Riverside Narrows = 11 mg/L • Prado Vicinity = 11 mg/L	Assumed TIN concentration at: • Riverside Narrows = 11 mg/L • Prado Vicinity = 11 mg/L	• Temescal Creek = 775 mg/L **(NEW)** Assumed TIN concentration at: • Riverside Narrows = 11 mg/L • Prado Vicinity = 5 mg/L • Temescal Creek = 6 mg/L **(NEW)**
Nitrogen Reaction Rate Coefficients	0.1 upstream of Riverside Narrows, 0.25 downstream of Riverside Narrows	0.1 upstream of Riverside Narrows, 0.25 downstream of Riverside Narrows	0.1 upstream of Riverside Narrows, 0.25 from Riverside Narrows to Prado Dam, 0.1 downstream of Prado Dam **(NEW)**
Calibration Period	WY 1995-1999	WY 1995-2006	WY 2007-2016 **(NEW)**
Calibration Methodology	Flow*: • Adjusted Curve Number • Adjusted channel percolation rates • Adjusted rising water estimates TDS/TIN: • Adjusted concentrations for runoff • Adjusted assumed concentrations of rising water • Adjusted nitrogen reaction rate coefficients *Note: original model files were not available. Therefore, this summary relies on information provided in the 2004 WLAM report (WEI, 2002 and 2003).	Flow: • Adjusted Curve Number • Adjusted channel percolation rates • Adjusted rising water estimates • Adjusted precipitation TDS/TIN: • Adjusted concentrations for runoff • Adjusted assumed concentrations of rising water • Adjusted nitrogen reaction rate coefficients	Flow: • Adjusted HSPF model parameters within limits defined in USEPA BASINS Technical Note 6 (e.g., soil storage, ET parameters, channel geometry and infiltration, etc. For details, refer to Section 4.1) TDS/TIN: • Adjusted dry deposition for runoff concentrations • Adjusted assumed concentrations/mass of rising water • Adjusted nitrogen reaction rate coefficients
Methods used to Account for Flow at Select Locations	Not Applicable (model files unavailable)	• Added flow at San Timoteo Creek near Loma Linda and Chino Creek at Schaefer Avenue • Applied discharge from Corona WWTP #1 above Temescal Creek at Main Street gage instead of below Refer to Section 4.3 for details	• Model-simulated
Calibration Criteria	Monthly Flow: • R^2 • Percent Error TDS/TIN: None (not enough data)	Monthly Flow: • R^2 • Root mean square error (RMSE)* • RMSE Percent of Average Flow • Nash-Sutcliffe Efficiency (NSE) TDS/TIN: None (not enough data)	Monthly and **Daily** Flow: • R^2 • Average Residual **(NEW)** • Average Residual Percentage of Observed **(NEW)** • RMSE • RMSE as Percentage of Range of Observed

Item	2004 WLAM	2008 WLAM	2017 WLAM HSPF
		*Note: RMSE formula was applied incorrectly (using measured data instead of squared residuals) – leading to an underestimation of the residuals.	TDS/TIN **(NEW)**: • Average Residual • Average Residual Percentage of Observed • Standard Deviation • RMSE

3.3.1 Initial Comparison of 2008 WLAM and HSPF

One of the initial steps taken for the WLAM update was to compare streamflow results from the 2017 WLAM HSPF to the 2008 WLAM for the period from WY 1995 through 2006. To do so, model input data from the 2008 WLAM (including 2005 land use) was applied to the 2017 WLAM HSPF after its initial construction. Model-calculated streamflow was then compared at several key gaging stations.

The performance of the model calibration in regards to streamflow was also evaluated quantitatively using the goodness of fit (i.e., R^2 value) between measured and model-simulated streamflow. Figures 23 through 26 show scatterplots of measured and model-simulated daily streamflow for selected gaging stations from the 2008 WLAM and 2017 WLAM HSPF for Water Years 1995 through 2006 under 2005 land use conditions. Scatterplots of measured and model-simulated monthly streamflow are shown on Figures 27 through 30. For a perfect calibration, all points (observed along the x-axis and model-simulated along the y-axis) would fall on the diagonal line with a R^2 value of 1. Greater deviation of points from the diagonal line correspond with lower the R^2 values and poorer model calibration performance.

The following table summarizes calibration performance criteria from Donigian (2002), which were used to assess the results.

Table 3-4. Streamflow Calibration Performance Criteria

Type of Flow Data	R^2 (Goodness-of-Fit)	Calibration Performance
Daily Flow	$R^2 < 0.60$	Poor
Daily Flow	$0.60 < R^2 < 0.70$	Fair
Daily Flow	$0.70 < R^2 < 0.80$	Good
Daily Flow	$R^2 > 0.80$	Very Good
Monthly Flow	$R^2 < 0.65$	Poor
Monthly Flow	$0.65 < R^2 < 0.75$	Fair
Monthly Flow	$0.75 < R^2 < 0.85$	Good
Monthly Flow	$R^2 > 0.85$	Very Good

The results of the initial comparison between the 2008 WLAM and 2017 WLAM HSPF are summarized in the following tables.

Table 3-5. 2008 WLAM and 2017 WLAM HSPF Initial Comparison: Daily Simulated Streamflow Performance (Water Year 1995-2006 and 2005 Land Use)

Gaging Station	2008 WLAM		2017 WLAM HSPF	
	R^2	Calibration Performance	R^2	Calibration Performance
San Timoteo Ck near Loma Linda	0.72	Good	0.97	Very Good
Warm Ck near San Bernardino	0.62	Fair	0.71	Good
Santa Ana River at E Street	0.72	Good	0.74	Good
Santa Ana River at MWD Crossing	0.68	Fair	0.73	Good

Table 3-6. 2008 WLAM and 2017 WLAM HSPF Initial Comparison: Monthly Simulated Streamflow Performance (Water Year 1995-2006 and 2005 Land Use)

Gaging Station	2008 WLAM		2017 WLAM HSPF	
	R^2	Calibration Performance	R^2	Calibration Performance
San Timoteo Ck near Loma Linda	0.84	Good	0.99	Very Good
Warm Ck near San Bernardino	0.70	Fair	0.79	Good
Santa Ana River at E Street	0.93	Very Good	0.89	Very Good
Santa Ana River at MWD Crossing	0.91	Very Good	0.86	Very Good

As seen in Tables 3-5 and 3-6 above, the 2017 WLAM HSPF performs similarly to or slightly better than the 2008 WLAM.

The updated data compiled for the 2017 WLAM HSPF (WY 2007 through 2016) were then used as model input, along with 2012 land use, for the 2008 WLAM. Both models were rerun with this input data for comparison. Figures 31 through 34 show scatterplots of measured and model-simulated daily streamflow for each gaging station from the 2008 WLAM and 2017 WLAM HSPF for WY 2007 through 2016 under 2012 land use conditions. Scatterplots of measured and model-simulated monthly streamflow are shown on Figures 35 through 38. The results are summarized in the following tables.

Table 3-7. 2008 WLAM and 2017 WLAM HSPF Initial Comparison: Daily Simulated Streamflow Performance (Water Year 2007-2016 and 2012 Land Use)

Gaging Station	2008 WLAM		2017 WLAM HSPF	
	R^2	Calibration Performance	R^2	Calibration Performance
San Timoteo Ck near Loma Linda	0.73	Good	0.94	Very Good
Warm Ck near San Bernardino	0.50	Poor	0.70	Good
Santa Ana River at E Street	0.90	Very Good	0.95	Very Good
Santa Ana River at MWD Crossing	0.93	Very Good	0.88	Very Good

Table 3-8. 2008 WLAM and 2017 WLAM HSPF Initial Comparison: Monthly Simulated Streamflow Performance (Water Year 2007-2016 and 2012 Land Use)

Gaging Station	2008 WLAM		2017 WLAM HSPF	
	R^2	Calibration Performance	R^2	Calibration Performance
San Timoteo Ck near Loma Linda	0.62	Poor	0.98	Very Good
Warm Ck near San Bernardino	0.80	Good	0.91	Very Good
Santa Ana River at E Street	0.88	Very Good	0.98	Very Good
Santa Ana River at MWD Crossing	0.96	Very Good	0.97	Very Good

As shown, the 2017 WLAM HSPF performs as good as or slightly better than the 2008 WLAM. This initial comparison confirmed that the HSPF code is adequate to use for the purposes of the WLAM.

4.0 2017 WLAM HSPF CALIBRATION

4.1 Calibration Process

Model calibration is a trial-and-error process which consists of iteratively adjusting model parameters, within acceptable ranges, until the model provides a reasonable match between the model-simulated and measured data. Proper calibration is important in order to reduce uncertainty in the model results (Engel et al., 2007). The accuracy of data simulated by the calibrated model is evaluated using the techniques recommended by the one of authors for HSPF (Donigian, 2002).

After the 2017 WLAM HSPF was constructed, it was calibrated against measured streamflow and TDS/TIN data for the period from October 1, 2006 through September 30, 2016 (WYs 2007 through 2016). This calibration period represents an appropriate time period for calibration to 2012 land use.

Streamflow data from nine gaging stations (see Figure 8 for locations) were used during the calibration process. The period of record, including data gaps, are presented in Section 2.5. The streamflow gages used for flow calibration include:

- San Timoteo Creek near Loma Linda — USGS Gage 11057500 — [34.061402, -117.267542]
- Warm Creek near San Bernardino — USGS Gage 11060400 — [34.078346, -117.300321]
- Santa Ana River at E Street — USGS Gage 11059300 — [34.065013, -117.300321]
- Santa Ana River at MWD Crossing — USGS Gage 11066460 — [33.968626, -117.448381]
- Temescal Creek at Main Street — USGS Gage 11072100 — [33.889182, -117.562827]
- Chino Creek at Schaefer Avenue — USGS Gage 11073360 — [34.003901, -117.727001]
- Cucamonga Creek near Mira Loma — USGS Gage 11073495 — [33.982791, -117.599497]
- Santa Ana River into Prado Dam — Calculated by the USACE — [33.890293, -117.640885]
- Santa Ana River at Santa Ana — USGS Gage 11078000 — [33.751128, -117.908391]

As indicated above, model calibration in the Prado Vicinity was conducted using the USACE-calculated inflow to Prado Dam. While there is a USGS gage with measured flow data below the gage, this flow is controlled by releases from Prado Dam. The calculated inflow, which is based on stage measurements and storage relationships, allows for a better comparison between model-simulated streamflow and natural flow in the SAR before it becomes storage behind the dam. A cumulative frequency distribution graph of daily flow to Prado Dam is provided on Figure 39 to illustrate the range of flow conditions.

TDS/TIN data from three gaging stations were also used during the calibration process. These stations were chosen based on data availability and include:

- Santa Ana River at MWD Crossing USGS Gage 11066460 [33.968626, -117.448381]
- Santa Ana River below Prado USGS Gage 11074000 [33.883349, -117.64533]
- Santa Ana River at Imperial Highway near Anaheim USGS Gage 11075600 [33.856404, -117.790611]

Model calibration was performed in accordance with guidelines provided by the USEPA (2000). The major parameters adjusted during calibration of the 2017 WLAM HSPF included the following:

- Lower zone nominal soil moisture storage,
- Upper zone nominal soil moisture storage,
- Interception storage,
- Interflow inflow parameter,
- Infiltration rate,
- Base groundwater recession,
- Fraction of groundwater inflow to deep recharge,
- Fraction of remaining ET from baseflow,
- ET by riparian vegetation,
- Lower zone ET parameter,
- Dry deposition,
- Function tables (FTABLE) which include physical information (shape, depth, width, slope, length, Manning Factor, and materials), and infiltration rates for reaches of each sub-watershed, and
- Nitrogen loss coefficient.

These parameters were altered either on the stream reach level (including sub-watersheds contributing to flow within that reach) or globally, within the limits outlined in USEPA BASINS Technical Note 6 (2000).

4.2 Calibration Criteria

As mentioned above, the 2017 WLAM HSPF was calibrated against measured streamflow at nine gaging stations and measured TDS/TIN at three gaging stations for the period from October 1, 2006 through September 30, 2016 (WY 2007 through 2016). The qualitative calibration results are shown as:

- Hydrographs of measured and model-simulated daily streamflow;
- Hydrographs of measured and model-simulated monthly streamflow;
- Scatterplots of measured versus model-simulated daily streamflow;
- Scatterplots of measured versus model-simulated monthly streamflow; and

- Chemographs of measured versus model-simulated TDS/TIN concentrations.

In addition to the qualitative calibration results listed above, the following quantitative measures of calibration performance were used:

- **R^2** (flow). Indicates the "goodness of fit" between measured and model-simulated streamflow values. Examined in accordance with the performance criteria suggested by Donigian (2002). For a perfect calibration, all points (observed along the x-axis and model-simulated along the y-axis) would fall on the diagonal line (regression line) with a R^2 value of 1. A greater deviation of points from the diagonal line corresponds with lower R^2 values and poorer model calibration performance. Due to the scarcity of water quality data, R^2 values for TDS/TIN calibration were not calculated.

- **Average Residual** (flow and concentration). Equal to the average of the observed values minus the model-simulated values. Represents a measure of how far model-simulated values are from the regression line. One of the goals of model calibration is to minimize residuals between model-calculated and observed values. In general, lower residuals (i.e., closer to zero) indicate a calibration that is more representative of observed data. Positive residuals indicate model underestimation, negative residuals indicate model overestimation.

- **Average Residual Percentage of Average Observed** (flow and concentration).

- **Root Mean Square Error (RMSE)** (flow and concentration). Equal to the standard deviation of the residuals. Represents a measure of how spread out the residuals are. In general, a lower RMSE (i.e., closer to zero) indicates a calibration that is more representative of observed data.

- **RMSE as percentage of the range of observed** (flow).

- **Standard Deviation** (concentration). Represents a measure of how spread out the residuals are from the observed average.

At the request of the Task Force, an effort has been made to compare the 2017 WLAM HSPF calibration results with previous waste load allocation modeling. 2017 WLAM HSPF calibration results are therefore presented below along with 2008 WLAM calibration results[8] in the following sections, as a general comparison and indication of previous acceptable levels of calibration. However, these models do not have the same calibration period (WY 2007-2016 vs. WY 1995-2006) so should not be compared directly.

4.3 Streamflow Calibration Results

Hydrographs showing model-simulated and measured daily and monthly streamflow for the nine gaging stations from October 1, 2006 through September 30, 2016 were plotted to evaluate model calibration performance (Figures 40 through 48 for daily and Figure 49 through 57 for monthly). Model calibration results for the period from October 1, 1994 through September 30, 2006 from the 2008 WLAM were also shown in the hydrographs for comparison purposes and to ensure that model calibration performance is consistent with previous work. As shown, there are similar temporal dynamics in both model-simulated and measured daily and monthly streamflow at the nine gaging stations for both the 2008 WLAM and the 2017 WLAM HSPF.

As with the initial comparison made at the onset of the WLAM update (Section 3.3.1), the performance of the model calibration in regard to streamflow was also evaluated quantitatively using the goodness of fit (i.e., R^2 value) between measured and model-simulated streamflow. Figures 58 through 66 show scatterplots of measured and model-simulated daily streamflow for each gaging station from the 2008 WLAM (Water Years 1995 through 2006) and 2017 WLAM HSPF (Water Years 2007 through 2016). Scatterplots of measured and model-simulated monthly streamflow are shown on Figure 67 through 75.

Calibration performance criteria from Donigian (2002), which were used to assess calibration results, are presented in Table 3-4. It should be noted that daily flow calibration performance is allowed a lower range of R^2 values than monthly flow. This is due to sources of uncertainty related to daily data, including lag time between precipitation events and increased flow at stream gages, daily variations in discharge, and stream gage accuracy (refer to Table 2-3 and Section 9.0 for more information). However, given that the primary use of the 2017 WLAM HSPF is to protect groundwater quality in the SAR Groundwater Basin, calibration to a monthly time step is more than adequate to implement Basin Plan objectives[9].

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8 Notes regarding the 2008 WLAM calibration results shown in this report:

2008 WLAM daily flow statistics were not provided in the model report (WEI, 2009). The values shown here were calculated using the 2008 WLAM model output files.

RMSE values shown in this report also vary from those reported in the 2008 WLAM report due to a difference in units and an error found in the original calculation of RMSE (measured data was used instead of squared residuals). This resulted in an underestimation of the residuals.

9 Groundwater objectives are calculated as a 20-year average and recharge compliance is computed using a 10-year average.

The results of the 2008 WLAM and 2017 WLAM HSPF model calibrations are summarized in the following tables.

Table 4-1. WLAM Calibration Results – Daily Simulated Streamflow Performance

Gaging Station	2008 WLAM WY 1995-2006	2017 WLAM HSPF WY 2007-2016
San Timoteo Ck near Loma Linda		
R^2	0.72	0.68
Calibration Performance	Good	Fair
Average Residual, cfs	-2.2	-1.4
Average of Observed, cfs	5.4	8.2
Average Residual Percentage of Average Observed, %	-40%	-17%
RMSE	44.1	25.7
RMSE as Percentage of Range of Observed, %	4%	3%
Warm Ck near San Bernardino		
R^2	0.62	0.73
Calibration Performance	Fair	Good
Average Residual, cfs	4.9	-1.3
Average of Observed, cfs	6.4	3.5
Average Residual Percentage of Average Observed, %	77%	-37%
RMSE	14.9	9.8
RMSE as Percentage of Range of Observed, %	4%	2%
Santa Ana River at E Street		
R^2	0.72	0.95
Calibration Performance	Good	Very Good
Average Residual, cfs	12.8	-6.4
Average of Observed, cfs	69.3	26.2
Average Residual Percentage of Average Observed, %	19%	-24%
RMSE	194.2	96.1
RMSE as Percentage of Range of Observed, %	2%	1%

Gaging Station	2008 WLAM WY 1995-2006	2017 WLAM HSPF WY 2007-2016
Santa Ana River at MWD Crossing		
R^2	0.68	0.91
Calibration Performance	Fair	Very Good
Average Residual, cfs	33.1	-1.5
Average of Observed, cfs	182.5	97.2
Average Residual Percentage of Average Observed, %	18%	-2%
RMSE	382.9	145.1
RMSE as Percentage of Range of Observed, %	2%	1%
Temescal Ck at Main Street		
R^2	0.42	0.79
Calibration Performance	Poor	Good
Average Residual, cfs	-1.2	-0.6
Average of Observed, cfs	33.7	17.2
Average Residual Percentage of Average Observed, %	-4%	-3%
RMSE	155.7	59.9
RMSE as Percentage of Range of Observed, %	7%	2%
Chino Ck at Schaefer Avenue		
R^2	0.69	0.81
Calibration Performance	Fair	Very Good
Average Residual, cfs	1.8	-2.4
Average of Observed, cfs	24.4	9.0
Average Residual Percentage of Average Observed, %	7%	-26%
RMSE	40.7	32.5
RMSE as Percentage of Range of Observed, %	3%	4%

Gaging Station	2008 WLAM WY 1995-2006	2017 WLAM HSPF WY 2007-2016
Cucamonga Ck near Mira Loma		
R^2	0.48	0.88
Calibration Performance	Poor	Very Good
Average Residual, cfs	9.4	-0.2
Average of Observed, cfs	64.5	37.3
Average Residual Percentage of Average Observed, %	15%	-1%
RMSE	113.2	36.2
RMSE as Percentage of Range of Observed, %	2%	1%
Santa Ana River into Prado Dam		
R^2	0.66	0.93
Calibration Performance	Fair	Very Good
Average Residual, cfs	11.4	-1.7
Average of Observed, cfs	396.3	223.0
Average Residual Percentage of Average Observed, %	3%	-1%
RMSE	681.9	190.8
RMSE as Percentage of Range of Observed, %	3%	1%
Santa Ana River at Santa Ana		
R^2	NA	0.57
Calibration Performance	NA	Poor
Average Residual, cfs	NA	-1.2
Average of Observed, cfs	NA	49.7
Average Residual Percentage of Average Observed, %	NA	-2%
RMSE	NA	296.3
RMSE as Percentage of Range of Observed, %	NA	3%

Note: Residual = Observed – Model-Simulated (positive numbers indicate model underestimation, negative numbers indicate model overestimation)

Table 4-2. WLAM Calibration Results – Monthly Simulated Streamflow Performance

Gaging Station	2008 WLAM WY 1995-2006	2017 WLAM HSPF WY 2007-2016
San Timoteo Ck near Loma Linda		
R^2	0.84	0.68
Calibration Performance	Good	Fair
Average Residual, cfs	-2.2	-1.4
Average of Observed, cfs	5.5	8.2
Average Residual Percentage of Average Observed, %	-41%	-17%
RMSE	9.2	12.4
RMSE as Percentage of Range of Observed, %	7%	16%
Warm Ck near San Bernardino		
R^2	0.70	0.91
Calibration Performance	Fair	Very Good
Average Residual, cfs	4.9	-1.3
Average of Observed, cfs	6.4	3.5
Average Residual Percentage of Average Observed, %	77%	-37%
RMSE	8.0	3.4
RMSE as Percentage of Range of Observed, %	15%	7%
Santa Ana River at E Street		
R^2	0.93	0.97
Calibration Performance	Very Good	Very Good
Average Residual, cfs	12.8	-6.3
Average of Observed, cfs	69.8	26.3
Average Residual Percentage of Average Observed, %	18%	-24%
RMSE	45.0	40.8
RMSE as Percentage of Range of Observed, %	4%	5%

Gaging Station	2008 WLAM WY 1995-2006	2017 WLAM HSPF WY 2007-2016
Santa Ana River at MWD Crossing		
R^2	0.91	0.97
Calibration Performance	Very Good	Very Good
Average Residual, cfs	32.9	-1.6
Average of Observed, cfs	183.3	97.2
Average Residual Percentage of Average Observed, %	18%	-2%
RMSE	110.1	33.3
RMSE as Percentage of Range of Observed, %	5%	2%
Temescal Ck at Main Street		
R^2	0.77	0.87
Calibration Performance	Good	Very Good
Average Residual, cfs	-1.3	-0.5
Average of Observed, cfs	34.1	17.3
Average Residual Percentage of Average Observed, %	-4%	-3%
RMSE	32.4	17.4
RMSE as Percentage of Range of Observed, %	8%	8%
Chino Ck at Schaefer Avenue		
R^2	0.84	0.83
Calibration Performance	Good	Good
Average Residual, cfs	1.8	-2.4
Average of Observed, cfs	24.5	9.0
Average Residual Percentage of Average Observed, %	7%	-26%
RMSE	14.9	11.4
RMSE as Percentage of Range of Observed, %	7%	12%

Gaging Station	2008 WLAM WY 1995-2006	2017 WLAM HSPF WY 2007-2016
Cucamonga Ck near Mira Loma		
R^2	0.76	0.94
Calibration Performance	Good	Very Good
Average Residual, cfs	9.6	-0.3
Average of Observed, cfs	64.9	37.4
Average Residual Percentage of Average Observed, %	15%	-1%
RMSE	28.6	11.2
RMSE as Percentage of Range of Observed, %	7%	3%
Santa Ana River into Prado Dam		
R^2	0.93	0.98
Calibration Performance	Very Good	Very Good
Average Residual, cfs	11.5	-1.7
Average of Observed, cfs	399.0	223.6
Average Residual Percentage of Average Observed, %	3%	-1%
RMSE	123.5	52.3
RMSE as Percentage of Range of Observed, %	4%	2%
Santa Ana River at Santa Ana		
R^2	NA	0.80
Calibration Performance	NA	Good
Average Residual, cfs	NA	-1.3
Average of Observed, cfs	NA	49.7
Average Residual Percentage of Average Observed, %	NA	-3%
RMSE	NA	105.9
RMSE as Percentage of Range of Observed, %	NA	7%

Note: Residual = Observed – Model-Simulated (positive numbers indicate model underestimation, negative numbers indicate model overestimation)

As seen in Tables 4-1 and 4-2 above, model calibration for the 2017 WLAM HSPF shows good to very good performance at the majority of the streamflow gages from WY 2006 through WY 2016. In addition, the 2017 WLAM HSPF performs equal to or better than the 2008 WLAM for all gages, except for daily and monthly streamflow at the San Timoteo Creek near Loma Linda gaging station and monthly streamflow at the Chino Creek at Schaefer Avenue gaging station.

The observed streamflow at San Timoteo Creek near Loma Linda proved difficult to calibrate the 2017 WLAM HSPF to, resulting in a “fair” model performance for both daily and monthly simulated streamflow (Figures 40 and 49). It is believed that much of the discrepancy seen in the calibration data at this location is due to channel conditions upstream that are not taken into account by the model. In particular, basin modifications such as the San Timoteo Sediment Basins alter flow and affect timing in San Timoteo Creek. These details were not able to be captured by the 2017 WLAM HSPF. The 2008 WLAM was able to produce better calibration results at the San Timoteo Creek near Loma Linda gage. According to the model files for the 2008 WLAM, additional flow was added at this location. No explanation for this assumption is provided in the modeling report.

Observed streamflow at the Chino Creek at Schaefer Avenue gaging station indicates that there is a consistent, low baseflow at this location which is likely caused by urban runoff (Figures 45 and 54). In addition, the decommissioning of IEUA’s RP-2 in 2002, which discharged into Chino Creek, likely altered subsequent streambed percolation rates. This loss of perennial flows may also contribute to some calibration discrepancies at this location. While the 2017 WLAM HSPF does not reproduce the observed baseflow, the 2008 WLAM does (Figure 54). The 2008 WLAM establishes a minimum flow of 2.1 cfs at this location in Chino Creek. The 2017 WLAM HSPF does not make this assumption and no explanation is provided in the 2008 WLAM report regarding it. However, it should be noted that while the baseflow from urban runoff is fairly constant throughout the 2008 WLAM calibration period (WY 1995 through 2006), the baseflow drops off during the 2017 WLAM HSPF model period – likely due to water conservation measures.

Both the 2008 WLAM and 2017 WLAM HSPF show good calibration performance at the Temescal Creek at Main Street gaging station (Figure 53). In the 2017 WLAM HSPF, this good calibration is facilitated by the addition of rising water upstream of the gaging station (refer to Figure 18). However, this rising water was unknown at the time the 2008 WLAM was constructed and calibrated. An examination of the model input files shows that discharge from the Corona WWTP #1 was misplaced in the 2008 WLAM; instead of discharging below the gaging station, the discharge was added upstream and was therefore represented in the model-simulated flow at the Main Street gage. This extra flow allowed the 2008 WLAM to produce good monthly calibration results at the Temescal Creek at Main Street gage without taking into account the additional rising water that is thought to occur upstream.

Daily streamflow calibration performance in the 2017 WLAM HSPF is “poor” at the SAR at Santa Ana gaging station (Figure 48). Model-simulated streamflow at this location is largely dependent on the results of the OCWD RFM, which simulates Prado Dam operations and OCWD diversions. However, actual releases from Prado may be different since the USACE does not always follow their own operating rules. This is especially true for wet years (e.g., WY 2011). These deviations are not accounted for in the modeling, which can lead to discrepancies between model-calculated and observed streamflow at the SAR at Santa Ana gaging station. This is especially true for daily model-simulated streamflow. As seen in Table 4-2 and on Figure 57, the 2017 WLAM HSPF produces good calibration results for monthly model-simulated streamflow at this same location. Model calibration results at this stream gage also improve significantly when high flow values during very wet periods (representing times when USACE may have deviated from normal Prado Dam operations) are removed (see Figures 66 and 75).

4.3.1 Streamflow Outlier Analysis

At the request of the Task Force, an outlier analysis was conducted on the 2017 WLAM HSPF model-simulated streamflow. The purpose of this analysis was to determine the effect that extreme deviations (outliers) in model-simulated streamflow have on calibration performance. Points were designated outliers if model-calculated and observed streamflow differed by more than two orders of magnitude. These points were excluded from scatterplots of measured and model-simulated daily streamflow for each gaging station, except for SAR at MWD Crossing and SAR into Prado Dam gages where no outliers were found. Outliers were also not found for monthly model-simulated streamflow at the Temescal Creek at Main Street, Chino Creek at Schaefer Avenue, and Cucamonga Creek near Mira Loma. Tables 4-3 and 4-4 below show a comparison of daily and monthly simulated streamflow performance, respectively, with outliers included (as presented above) and removed.

Table 4-3. Outlier Analysis – Daily Simulated Streamflow Performance

Gaging Station	R^2		Average Residual, cfs	
	2017 WLAM HSPF WY 2007-2016	Outliers Removed	2017 WLAM HSPF WY 2007-2016	Outliers Removed
San Timoteo Ck near Loma Linda	0.68	0.68	-1.36	-1.34
Warm Ck near San Bernardino	0.73	0.74	-1.32	-1.19
Santa Ana River at E Street	0.95	0.95	-6.36	-6.40
Santa Ana River at MWD Crossing	0.91	NA	-1.52	NA
Temescal Ck at Main Street	0.79	0.79	-0.56	-0.66
Chino Ck at Schaefer Avenue	0.81	0.81	-2.37	-2.48
Cucamonga Ck near Mira Loma	0.89	0.89	-0.22	-0.34
Santa Ana River into Prado Dam	0.93	NA	-1.74	NA
Santa Ana River at Santa Ana	0.57	0.58	-1.17	-1.76

Table 4-4. Outlier Analysis – Monthly Simulated Streamflow Performance

Gaging Station	R^2		Average Residual, cfs	
	2017 WLAM HSPF WY 2007-2016	Outliers Removed	2017 WLAM HSPF WY 2007-2016	Outliers Removed
San Timoteo Ck near Loma Linda	0.68	NA	-1.38	NA
Warm Ck near San Bernardino	0.91	0.91	-1.31	-1.31
Santa Ana River at E Street	0.97	0.97	-6.32	-6.23
Santa Ana River at MWD Crossing	0.97	NA	-1.58	NA
Temescal Ck at Main Street	0.87	NA	-0.50	NA
Chino Ck at Schaefer Avenue	0.86	NA	-2.37	NA
Cucamonga Ck near Mira Loma	0.97	NA	-0.28	NA
Santa Ana River into Prado Dam	0.98	NA	-1.66	NA
Santa Ana River at Santa Ana	0.80	0.80	-1.25	-1.37

As shown, R^2 values remain the same or improve slightly by removing outlier points. The average residual value slightly increased or decreased depending on the distribution of the outlier points.

4.4 TDS and TIN Calibration

Chemographs showing daily model-simulated and measured TDS and TIN for the three gaging stations from October 1, 2006 through September 30, 2016 (WY 2007 through 2016) are provided as Figures 76 through 78 for TDS and Figures 79 through 81 for TIN. Monthly average TDS and TIN concentrations are provided as Figures 82 through 84 and Figures 85 through 87, respectively. For comparison purposes, model calibration results for the period from October 1, 1994 through September 30, 2006 (WY 1995 through 2006) from the 2008 WLAM were also shown in the applicable chemographs. However, these results are not shown on the chemographs for the SAR at Imperial Highway near Anaheim, as this station was not used for 2008 WLAM calibration. The chemographs exhibit similar temporal dynamics between model-simulated and measured TDS concentrations at the gaging stations for both the 2008 WLAM and the 2017 WLAM HSPF.

The following tables summarize TDS and TIN residuals for the 2008 WLAM and 2017 WLAM HSPF. It should be noted that the 2008 WLAM did not attempt to optimize model-calculated water quality by maximizing R^2 or minimizing the RMSE due to an insufficient amount of data.

Table 4-5. WLAM Calibration Results – Daily Simulated TDS and TIN Performance

Gaging Station	TDS		TIN	
	2008 WLAM WY 1995-2006	2017 WLAM HSPF WY 2007-2016	2008 WLAM WY 1995-2006	2017 WLAM HSPF WY 2007-2016
Santa Ana River at MWD Crossing				
Average Residual, mg/L	16.4	0.5	-0.45	-0.14
Average of Observed, mg/L	591	587	6.14	8.45
Average Residual Percentage of Average Observed, %	2.8%	0.1%	-7.4%	-1.7%
Standard Deviation, mg/L	75.5	73.0	2.38	1.24
RMSE	77.3	72.8	2.42	1.24
Santa Ana River below Prado Dam				
Average Residual, mg/L	20.7	-5.5	-0.07	-0.57
Average of Observed, mg/L	535	615	5.13	3.92
Average Residual Percentage of Average Observed, %	3.9%	-0.9%	-1.4%	-14.5%
Standard Deviation, mg/L	74.7	104.1	1.61	1.39
RMSE	77.4	104.2	1.61	1.50
Santa Ana River at Imperial Highway near Anaheim				
Average Residual, mg/L	NA	0.2	NA	0.00
Average of Observed, mg/L	NA	640	NA	3.09
Average Residual Percentage of Average Observed, %	NA	0.0%	NA	0.0%
Standard Deviation, mg/L	NA	68.1	NA	1.05
RMSE	NA	67.9	NA	1.05

Note: Residual = Observed – Model-Simulated (positive numbers indicate model underestimation, negative numbers indicate model overestimation)

Table 4-6. WLAM Calibration Results – Monthly Simulated TDS and TIN Performance

Gaging Station	TDS		TIN	
	2008 WLAM WY 1995-2006	2017 WLAM HSPF WY 2007-2016	2008 WLAM WY 1995-2006	2017 WLAM HSPF WY 2007-2016
Santa Ana River at MWD Crossing				
Average Residual, mg/L	-15.6	0.6	-0.47	-0.16
Average of Observed, mg/L	548	587	6.31	8.42
Average Residual Percentage of Average Observed, %	-2.8%	0.1%	-7.4%	-1.9%
Standard Deviation, mg/L	71.6	53.1	2.54	0.93
RMSE	73.0	52.9	2.56	0.93
Santa Ana River below Prado Dam				
Average Residual, mg/L	21.3	-5.5	-0.23	-0.54
Average of Observed, mg/L	536	613	5.21	3.96
Average Residual Percentage of Average Observed, %	4.0%	-0.9%	-4.4%	-13.6%
Standard Deviation, mg/L	48.6	49.0	1.49	1.14
RMSE	52.9	49.1	1.51	1.26
Santa Ana River at Imperial Highway near Anaheim				
Average Residual, mg/L	NA	0.8	NA	-0.04
Average of Observed, mg/L	NA	637	NA	3.19
Average Residual Percentage of Average Observed, %	NA	0.1%	NA	-1.2%
Standard Deviation, mg/L	NA	68.2	NA	1.13
RMSE	NA	68.0	NA	1.13

Note: Residual = Observed – Model-Simulated (positive numbers indicate model underestimation, negative numbers indicate model overestimation)

As seen in Tables 4-5 and 4-6 above, model calibration for the 2017 WLAM HSPF produces low TDS/TIN residuals from WY 2006 through 2016. In addition, residuals from the 2017 WLAM HSPF are lower than the 2008 WLAM for all gages, except for TIN at the SAR below Prado Dam. However, the 2017 WLAM HSPF produces a standard deviation and RMSE for TIN that is less than those produced by the 2008 WLAM at this location.

4.4.1 Water Budgets and Mass Balance

Annual flow and TDS/TIN mass balances for each GMZ and associated SAR Reach are provided in Tables 5 through 18. These mass balance tables are presented for model calibration purposes and only reflect the surface water system. Terms included in the mass balance tables include:

- **Upstream Inflow:** model-calculated surface flow in the SAR running into the stream reach overlying a given GMZ from directly upgradient. This term does not include inflow from tributary stream segments.

- **Surface Runoff from Precipitation and Tributary Inflow:** model-calculated flow entering the SAR from surrounding watershed area and tributaries to the main stream segment. Includes POTW and other discharges to tributary streams. The tributary areas for which flow is included are based on the delineation of sub-watersheds built into the 2017 WLAM HSPF (Figure 11).

- **POTW Discharge:** effluent from POTWs. Each facility is accounted for separately and values are based on reported discharges (model input).

- **Rising Water:** flow entering the SAR from the underlying groundwater system. This flow represents model input values based on previous investigations (refer to Sections 3.2.8 and 3.2.9.3).

- **Streambed Percolation:** model-calculated flow leaving the SAR surface water system to the groundwater system. The mass balance values for this term do not include nitrogen loss experienced as surface water percolates into the ground and is consumed by vegetation (i.e., nitrogen loss coefficient). Therefore, these values should not be compared to the streambed recharge concentrations calculated for the predictive scenarios (Section 6.0) and retrospective model run (Section 8.0).

- **Evapotranspiration:** model-calculated flow lost to ET processes.

- **Denitrification:** model-calculated loss of nitrogen in surface streamflow due to the reduction of nitrate by facultative anaerobic bacteria (note: this is not the same as the nitrogen loss experienced during percolation into the subsurface).

- **Downstream Outflow:** model-calculated surface flow in the SAR leaving a given GMZ and entering the GMZ immediately downstream (or leaving the model area in the case of Orange County GMZ).

- **OCWD Prado Wetland Diversion:** model-calculated flow diverted out of the SAR in Prado Basin and routed through the Prado Wetlands spreadsheet model (applies to Prado Basin Management Zone only; Tables 15 and 16). This flow, less ET, is later returned as flow to Chino Creek within the Prado Basin Management Zone (included in the tributary inflow term).

The amount of model-calculated streambed percolation and the associated TDS/TIN concentrations for each SAR reach within the 2017 WLAM HSPF area are summarized in the following table.

Table 4-7. Average Annual Streambed Percolation and TDS/TIN Mass (Water Years 2007 through 2016)

Management Zone	Streambed Percolation [acre-ft/yr]	TDS Mass [tons/yr]	TIN Mass [tons/yr]
Bunker Hill-B (SAR Reach 5)	12,652	3,383	37
Colton (SAR Reach 4)	1,374	436	3
Riverside-A (SAR Reach 4)	47,249	26,549	411
Riverside-A (SAR Reach 3)	0	0	0
Chino-South (SAR Reach 3)	38,507	20,779	262
Prado Basin (SAR Reach 3)	17,263	13,490	141
Orange County (SAR Reach 2)	79,565	42,861	400

In addition, the average mass balances (by source) for each major stream segment are summarized below, based on the flow-weighted annualized average (see Table 19 for annual streambed percolation).

Table 4-8. Mass Balance (by Source) for Reach 5 of the Santa Ana River overlying the Bunker Hill-B GMZ (Water Years 2007 through 2016)

Source	Flow [acre-ft/yr (% of total)]	TDS [tons/yr (% of total)]	TIN [tons/yr (% of total)]
SAR Upstream Inflow	7,950 (22%)	1,760 (21%)	10 (9%)
Surface Runoff and Tributary Inflow	27,900 (77%)	6,450 (76%)	90 (82%)
San Bernardino WRP	460 (1%)	320 (4%)	10 (9%)
TOTAL	**36,310 (100%)**	**8,530 (100%)**	**110 (100%)**

Table 4-9. Mass Balance (by Source) for Reach 4 of the Santa Ana River overlying the Colton GMZ (Water Years 2007 through 2016)

Source	Flow [acre-ft/yr (% of total)]	TDS [tons/yr (% of total)]	TIN [tons/yr (% of total)]
SAR Upstream Inflow	23,620 (75%)	5,150 (80%)	70 (88%)
Surface Runoff and Tributary Inflow	7,880 (25%)	1,320 (20%)	10 (12%)
TOTAL	**31,500 (100%)**	**6,470 (100%)**	**80 (100%)**

Table 4-10. Mass Balance (by Source) for Reach 4 of the Santa Ana River overlying the Riverside-A GMZ (Water Years 2007 through 2016)

Source	Flow [acre-ft/yr (% of total)]	TDS [tons/yr (% of total)]	TIN [tons/yr (% of total)]
SAR Upstream Inflow	29,740 (36%)	6,030 (17%)	80 (14%)
Surface Runoff and Tributary Inflow	7,540 (9%)	1,050 (3%)	10 (2%)
Colton WWTP	0 (0%)	0 (0%)	0 (0%)
Rialto WWTP	6,800 (8%)	3,710 (10%)	80 (14%)
RIX Facility	37,760 (46%)	25,280 (70%)	390 (70%)
TOTAL	**81,840 (100%)**	**36,070 (100%)**	**560 (100%)**

Table 4-11. Mass Balance (by Source) for Reach 3 of the Santa Ana River overlying the Riverside-A GMZ (Water Years 2007 through 2016)

Source	Flow [acre-ft/yr (% of total)]	TDS [tons/yr (% of total)]	TIN [tons/yr (% of total)]
SAR Upstream Inflow	34,390 (50%)	9,500 (26%)	140 (27%)
Surface Runoff and Tributary Inflow	10,500 (15%)	2,180 (6%)	20 (4%)
Rising Water	23,460 (34%)	25,360 (68%)	350 (69%)
TOTAL	**68,350 (100%)**	**37,040 (100%)**	**510 (100%)**

Table 4-12. Mass Balance (by Source) for Reach 3 of the Santa Ana River overlying the Chino South GMZ (Water Years 2007 through 2016)

Source	Flow [acre-ft/yr (% of total)]	TDS [tons/yr (% of total)]	TIN [tons/yr (% of total)]
SAR Upstream Inflow	68,260 (55%)	37,040 (55%)	500 (58%)
Surface Runoff and Tributary Inflow	23,300 (19%)	2,950 (4%)	20 (2%)
Riverside RWQCP	32,840 (26%)	27,640 (41%)	340 (40%)
TOTAL	**124,400 (100%)**	**67,630 (100%)**	**860 (100%)**

Table 4-13. Mass Balance (by Source) for Reach 3 of the Santa Ana River overlying the Prado Basin GMZ (Water Years 2007 through 2016)

Source	Flow [acre-ft/yr (% of total)]	TDS [tons/yr (% of total)]	TIN [tons/yr (% of total)]
SAR Upstream Inflow	85,320 (41%)	46,840 (39%)	580 (52%)
Surface Runoff and Tributary Inflow	94,730 (46%)	42,450 (35%)	380 (34%)
WRCRWA	6,480 (3%)	4,700 (4%)	20 (2%)
Corona WWTP-1	3,350 (2%)	3,250 (3%)	30 (2%)
Rising Water	15,850 (8%)	22,940 (19%)	110 (10%)
TOTAL	**205,730 (100%)**	**120,180 (100%)**	**1,120 (100%)**

Table 4-14. Mass Balance (by Source) for Reach 2 of the Santa Ana River overlying the Orange County GMZ (Water Years 2007 through 2016)

Source	Flow [acre-ft/yr (% of total)]	TDS [tons/yr (% of total)]	TIN [tons/yr (% of total)]
SAR Upstream Inflow	162,850 (86%)	89,780 (95%)	730 (95%)
Surface Runoff and Tributary Inflow	25,750 (14%)	4,620 (5%)	40 (5%)
TOTAL	**188,600 (100%)**	**94,400 (100%)**	**770 (100%)**

4.5 Rising Water Sensitivity Analysis

4.5.1 Rising Water Calibration Approaches

As mentioned in Section 3.2.8, two different approaches were tried for simulating rising water in the 2017 WLAM HSPF. During the initial calibration run, streambed percolation was adjusted (reduced) upgradient of MWD Crossing and Prado Dam so the model closely simulated the observed flow at these locations. Rising water volumes, which were based on model-simulated rising water from the WRIME groundwater flow model of the Riverside-Arlington Groundwater Basin (WRIME, 2010) and Chino Basin groundwater flow model developed by GEOSCIENCE in 2014, were then added to the HSPF-calculated groundwater recharge upstream of the location of rising water during a post-processing step. Mass was also added upstream of MWD Crossing or in Prado Basin in the 2017 WLAM HSPF to reflect the assumed concentration of rising water (see Section 3.2.9.3). This method was initially chosen for the 2017 WLAM HSPF so the model could respond to changing hydrologic conditions (e.g., different rising water assumptions for scenario runs to reflect anticipated changes in groundwater levels) without requiring additional calibration.

Following additional technical review and discussions with the Task Force, it was ultimately decided to maintain the rising water approach used by previous versions of the WLAM – with which an assumed rising water flow and associated TDS/TIN concentrations were added directly to the 2017 WLAM HSPF at all three locations of rising water (Temescal Creek upstream of the Main Street gaging station, in the SAR upstream of MWD Crossing (Riverside Narrows), and in the vicinity of Prado Basin). The amount of rising water in Temescal Creek was calibrated from initial estimates based on the SNMP for the Upper Temescal Valley (WEI, 2017), while model-calculated rising water from the WRIME groundwater flow model and GEOSCIENCE Chino Basin groundwater flow model was used for the Riverside Narrows and Prado vicinity, respectively. Results of these two model calibration runs are presented below for comparison.

Table 4-15. Rising Water Approach Comparison – Daily Simulated Streamflow Performance

Gaging Station	2017 WLAM HSPF (WY 2007-2016)	
	Initial Rising Water Approach (Added during Post-Processing)	Revised Calibration Approach (Rising Water as a Source of Inflow)*
Santa Ana River at MWD Crossing		
R^2	0.91	0.91
Calibration Performance	Very Good	Very Good
Average Residual, cfs	-12.0	-1.5
Average of Observed, cfs	97.2	97.2
Average Residual Percentage of Average Observed, %	-12%	-2%
RMSE	147.0	145.1
RMSE as Percentage of Range of Observed, %	1%	1%
Santa Ana River into Prado Dam		
R^2	0.92	0.92
Calibration Performance	Very Good	Very Good
Average Residual, cfs	-1.3	0.0
Average of Observed, cfs	223.0	223.0
Average Residual Percentage of Average Observed, %	-1%	0%
RMSE	199.7	194.7
RMSE as Percentage of Range of Observed, %	1%	1%

*Note: revised calibration shown here is from the November issue of the final report and does not include the updated changes made to Upper Temescal Valley GMZ (see Appendix T). The results shown here provide a better comparison between the different rising water approaches since no other changes were made between the model runs.

Table 4-16. Rising Water Approach Comparison – Monthly Simulated Streamflow Performance

Gaging Station	2017 WLAM HSPF (WY 2007-2016)	
	Initial Rising Water Approach (Added during Post-Processing)	Revised Calibration Approach (Rising Water as a Source of Inflow)
Santa Ana River at MWD Crossing		
R^2	0.97	0.97
Calibration Performance	Very Good	Very Good
Average Residual, cfs	-12.1	-1.6
Average of Observed, cfs	97.2	97.2
Average Residual Percentage of Average Observed, %	-12%	-2%
RMSE	37.4	33.3
RMSE as Percentage of Range of Observed, %	2%	2%
Santa Ana River into Prado Dam		
R^2	0.97	0.97
Calibration Performance	Very Good	Very Good
Average Residual, cfs	-1.3	0.1
Average of Observed, cfs	223.6	223.6
Average Residual Percentage of Observed, %	-1%	0%
RMSE	54.2	50.7
RMSE as Percentage of Range of Observed, %	2%	2%

*Note: revised calibration shown here is from the November issue of the final report and does not include the updated changes made to Upper Temescal Valley GMZ (see Appendix T). The results shown here provide a better comparison between the different rising water approaches since no other changes were made between the model runs.

Table 4-17. Rising Water Approach Comparison – Daily Simulated TDS and TIN Performance

Gaging Station	2017 WLAM HSPF (WY 2007-2016)			
	TDS		TIN	
	Initial Rising Water Approach	Revised Calibration Approach*	Initial Rising Water Approach	Revised Calibration Approach*
Santa Ana River at MWD Crossing				
Average Residual, mg/L	0.6	0.5	-0.14	-0.14
Average of Observed, mg/L	587	587	8.45	8.45
Average Residual Percentage of Average Observed, %	0.1%	0.1%	-1.7%	-1.7%
Standard Deviation, mg/L	74.6	73.0	1.24	1.24
RMSE	74.5	72.8	1.24	1.24
Santa Ana River below Prado Dam				
Average Residual, mg/L	-6.8	-6.0	-0.61	-0.53
Average of Observed, mg/L	615	615	3.92	3.92
Average Residual Percentage of Average Observed, %	-1.1%	-1.0%	-15.4%	-13.6%
Standard Deviation, mg/L	103.2	104.1	1.24	1.35
RMSE	103.4	104.3	1.38	1.45

*Note: revised calibration shown here is from the November issue of the final report and does not include the updated changes made to Upper Temescal Valley GMZ (see Appendix T). The results shown here provide a better comparison between the different rising water approaches since no other changes were made between the model runs.

Table 4-18. Rising Water Approach Comparison – Monthly Simulated TDS and TIN Performance

Gaging Station	2017 WLAM HSPF (WY 2007-2016)			
	TDS		TIN	
	Initial Rising Water Approach	Revised Calibration Approach*	Initial Rising Water Approach	Revised Calibration Approach*
Santa Ana River at MWD Crossing				
Average Residual, mg/L	1.0	0.6	-0.16	-0.16
Average of Observed, mg/L	587	587	8.42	8.42
Average Residual Percentage of Average Observed, %	0.2%	0.1%	-1.9%	-1.9%
Standard Deviation, mg/L	55.0	53.1	0.93	0.93
RMSE	54.8	52.9	0.93	0.93
Santa Ana River below Prado Dam				
Average Residual, mg/L	-7.1	-6.1	-0.56	-0.50
Average of Observed, mg/L	613	613	3.96	3.96
Average Residual Percentage of Average Observed, %	-1.2%	-1.0%	-14.1%	-12.7%
Standard Deviation, mg/L	48.7	48.9	0.99	1.09
RMSE	49.0	49.1	1.14	1.20

*Note: revised calibration shown here is from the November issue of the final report and does not include the updated changes made to Upper Temescal Valley GMZ (see Appendix T). The results shown here provide a better comparison between the different rising water approaches since no other changes were made between the model runs.

As shown in the tables above, the revised calibration approach – in which rising water was treated as a source of flow accounted for directly by the HSPF model – improved calibration slightly over the approach of post-processing rising water. In particular, the revised calibration approach improved the average streamflow residual by an order of magnitude. This confirmed the choice to use the approach of treating rising water as a model input for the 2017 WLAM HSPF final calibration. This final calibration run was then used to conduct predictive scenarios.

4.5.2 Rising Water Sensitivity Analysis

In the real world, the amount of rising water is largely dependent on underlying groundwater levels, which vary through time depending on hydrology and basin management. Since HSPF and other watershed models are limited in the fact that they are not able to simulate the interaction between groundwater and surface water, rising water – which affects the amount of model-calculated streambed percolation – represents a source of uncertainty. Given the potential for assumptions of rising water to impact policy interpretations, the Task Force suggested conducting a sensitivity run to determine the effect of changes in rising water on model-calculated streambed recharge. To do so, the assumed volume of rising water was reduced by 50% and the 2017 WLAM HSPF was recalibrated by adjusting the streambed conductance. The calibration results for the sensitivity run are presented below with the final calibration statistics for comparison.

Table 4-19. Rising Water Sensitivity Run – Daily Simulated Streamflow Performance

Gaging Station	2017 WLAM HSPF (WY 2007-2016)	
	Final Calibration Run (Rising Water as a Source of Inflow)	Sensitivity Run (Calibrated with 50% Less Rising Water)
Santa Ana River at MWD Crossing		
R^2	0.91	0.91
Calibration Performance	Very Good	Very Good
Average Residual, cfs	-1.5	-1.3
Average of Observed, cfs	97.2	97.2
Average Residual Percentage of Average Observed, %	-2%	-1%
RMSE	145.1	145.1
RMSE as Percentage of Range of Observed, %	1%	1%

Table 4-20 Rising Water Sensitivity Run – Monthly Simulated Streamflow Performance

Gaging Station	2017 WLAM HSPF (WY 2007-2016)	
	Final Calibration Run (Rising Water as a Source of Inflow)	Sensitivity Run (Calibrated with 50% Less Rising Water)
Santa Ana River at MWD Crossing		
R^2	0.97	0.97
Calibration Performance	Very Good	Very Good
Average Residual, cfs	-1.6	-1.3
Average of Observed, cfs	97.2	97.2
Average Residual Percentage of Average Observed, %	-2%	-1%
RMSE	33.3	33.0
RMSE as Percentage of Range of Observed, %	2%	2%

Table 4-21. Rising Water Sensitivity Run – Daily Simulated TDS and TIN Performance

Gaging Station	2017 WLAM HSPF (WY 2007-2016)			
	TDS		TIN	
	Final Calibration Run	Sensitivity Run	Final Calibration Run	Sensitivity Run
Santa Ana River at MWD Crossing				
Average Residual, mg/L	0.5	0.4	-0.14	-0.02
Average of Observed, mg/L	587	587	8.45	8.45
Average Residual Percentage of Average Observed, %	0.1%	0.1%	-1.7%	-0.2%
Standard Deviation, mg/L	73.0	82.2	1.24	1.23
RMSE	72.8	82.1	1.24	1.22

Table 4-22. Rising Water Sensitivity Run – Monthly Simulated TDS and TIN Performance

Gaging Station	2017 WLAM HSPF (WY 2007-2016)			
	TDS		TIN	
	Final Calibration Run	Sensitivity Run	Final Calibration Run	Sensitivity Run
Santa Ana River at MWD Crossing				
Average Residual, mg/L	0.6	0.7	-0.16	-0.02
Average of Observed, mg/L	587	587	8.42	8.42
Average Residual Percentage of Average Observed, %	0.1%	0.1%	-1.9%	-0.3%
Standard Deviation, mg/L	53.1	59.2	0.93	0.90
RMSE	52.9	58.9	0.93	0.89

The sensitivity model calibration resulted in residual statistics that were very similar to those achieved by the final 2017 WLAM HSPF model calibration. The model-calculated recharge from this sensitivity run (specifically in SAR Reach 4 and 3 overlying Riverside-A GMZ) was then compared to that calculated by the final calibration run.

Table 4-23 Rising Water Sensitivity Analysis – Average Annual Flow

River Reach	Flow [acre-ft/yr]	
	Final Calibration Run (Rising Water as a Source of Inflow)	Sensitivity Run (Calibrated with 50% Less Rising Water)
Santa Ana River Reach 4 Overlying Riverside-A GMZ		
Upstream Inflow	29,740	29,730
Surface Runoff from Precipitation	7,540	7,540
Rialto WWTP	6,800	6,800
RIX Facility	37,760	37,760
ET	160	160
Streambed Percolation	*47,250*	*35,690*
Outflow to Reach 3	34,390	45,940
Santa Ana River Reach 3 Overlying Riverside-A GMZ		
Inflow from Reach 4	34,390	45,940
Surface Runoff from Precipitation	10,500	10,500
ET	80	80
Rising Water	*23,460*	*11,730*
Downstream Outflow	68,260	68,090

As shown in Table 4-23 above, model-calculated streambed percolation decreases by 76% with a decrease in assumed rising water of 50%.

4.6 Precipitation Sensitivity Analysis

As part of Task 10, a pilot evaluation was conducted assess possible impacts from using Doppler precipitation data instead of the precipitation gage data currently used in the 2017 WLAM HSPF. Next Generation Weather Radar System (NEXRAD) data are available from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI). This gridded precipitation data provides higher resolution between precipitation gages, and is likely to cause localized changes in precipitation. A sensitivity analysis was therefore conducted at the SAR at E Street gaging station to determine the model's sensitivity to precipitation assumptions, particularly in regard to localized changes in precipitation. The tributary area to the E Street gaging station includes 165 sub-watersheds, totaling 375 square miles within the 2017 WLAM HSPF area, as well as SAR inflow below Seven Oaks Dam with a tributary area of 210 square miles. Two sensitivity runs were performed by adding an additional 10% and 20% of precipitation to an average sized sub-watershed (SE-42), tributary to the SAR at E Street gaging station.

A 10% increase in precipitation resulted in no change to the average streamflow residuals and only a slight increase in the RMSE (a 0.4 cfs increase to the daily RMSE and a 0.1 cfs increase to the monthly RMSE). A 20% increase in precipitation also resulted in no change of the daily average streamflow residuals, although a 0.1 cfs increase was observed in the monthly average residual. In addition, the 20% increase led to slight changes in the daily RMSE (0.8 cfs) and monthly RMSE (0.3 cfs). These sensitivity runs indicate that the model is not very sensitive to localized changes in precipitation at the E Street gage. It is unlikely that the use of NEXRAD precipitation data over the current precipitation gage data will have any significant impact on model results. However, the tributary area contributing to the gage at E Street is quite large. In smaller watershed areas and/or in more urbanized areas where there is more runoff, localized changes in precipitation may have more effect on model-calculated streamflow in certain locations. This is something that may want to be considered for the next WLAM update.

5.0 PREDICTIVE SCENARIO ASSUMPTIONS

Six predictive scenario runs (Scenario A through Scenario F) were made using the calibrated 2017 WLAM HSPF by varying the amount of recycled water discharge to surface water. The major assumptions are summarized in the table below.

Table 5-1. Major Assumptions for Predictive Scenarios

Model Scenario	Hydrologic Period	Model Conditions	Land Use	Recycled Water Discharge to Surface Water			TDS and TIN	
				Maximum Expected Discharge	Most Likely Discharge	Minimum Expected Discharge	Permit TDS	Permit TIN
A	WY 1950 - 2016	WY 2020	2012	X			X	X
B					X		X	X
C						X	X	X
D		WY 2040	General Plan (2040)	X			X	X
E					X		X	X
F						X	X	X

5.1 Hydrologic Period

The 2008 WLAM constructed and calibrated by WEI (2009) ran predictive scenarios for the 50-year hydrologic period from October 1949 through September 1999. The 2008 WLAM was also calibrated for the period from October 1994 through September 2006. During the construction and calibration of the 2017 WLAM HSPF, the hydrologic data was updated through September 2016 and the model was calibrated for the period from October 2007 through September 2016. The predictive scenarios for the 2017 WLAM HSPF make use of all of the available hydrologic data. Therefore, the 67-year period from October 1949 (WY 1950) through September 2016 (WY 2016) was used as the hydrologic base period for the 2017 WLAM HSPF scenarios. This base period was selected because it represents wet, dry and average hydrological conditions – therefore providing a range of hydrologic conditions under which to evaluate discharge effects. The same range of precipitation patterns seen over the hydrologic base period was assumed to represent future (2020 and 2040) conditions.

The hydrologic data used for the base period include precipitation, evaporation, and external sources of streamflow into the 2017 WLAM HSPF model area. The appropriate land use and discharge assumptions were also applied to the 2017 WLAM HSPF for each model run. When running predictive scenarios, it is assumed that the range of meteorological conditions expected to occur should fall within the same range of conditions that have been observed over the previous six decades. This is not meant to imply that the actual pattern of rainfall over the next 67 years will look exactly like the last 67 years.

5.2 Land Use

Scenarios A through C represent the range of flows (wastewater and runoff) that may occur under 2020 land use and population conditions. While SAWPA has 2016 aerial mapping available (broken down by basic land use categories; as discussed at the April 16, 2018 Task Force Meeting), the land uses associated with this data set (and therefore pervious/impervious percentages) are not the same as those used to calibrate the 2017 WLAM HSPF. After discussing land use options with SAWPA, it was determined that the 2016 mapping would not be compatible with the calibrated model. In addition, the 2017 WLAM HSPF is already calibrated against SCAG 2012 land use through 2016 and shows satisfactory agreement between measured and observed streamflow. Therefore, the 2012 land use was also used to represent 2020 land use conditions.

Scenarios D through F represent the range of wastewater and runoff flows that may occur using appropriate land use and population assumptions for the year 2040. General plan (2040) land use conditions were used to represent these future land use conditions.

5.3 Streamflow

5.3.1 Discharges to Surface Water

5.3.1.1 De Minimis Discharge

De minimis discharge is defined by the Regional Board as discharges to surface waters that pose an insignificant threat to water quality, including dewatering discharges. While individual discharges may not have much of an impact on surface water quality, collectively and cumulatively they might. No de minimis discharges were included in the 2017 WLAM HSPF scenario assumptions due to a lack of assimilative capacity for TDS.

5.3.1.2 Recycled Water Discharge

Appendix D shows the data request form that was sent to the individual POTWs to establish current and projected (2020 and 2040) discharge volumes to surface water and associated concentrations for use in the predictive model scenarios. While this form also included fields for projected recycled water recharge in support of Task 4 (Develop WLAM for Managed Recharge in Percolation Basins), the Task Force later decided to forgo this aspect of the project. The recycled water discharge point locations are shown on Figure 88.

The completed data request forms are provided in Appendix F[10]. Recycled water discharge to surface water was obtained for the following facilities:

- Beaumont Wastewater Treatment Plant (WWTP)
- Yucaipa Valley Water District (YVWD) H.N. Wochholz Water Recycling Facility (WRF)
- East Valley Water District (EVWD) Sterling Natural Resource Center (SNRC)
- Rialto WWTP
- Rapid Infiltration and Extraction (RIX) facility
- Riverside Regional Water Quality Control Plant (RWQCP)
- Inland Empire Utility Agency (IEUA) Regional Plants (RPs) and Carbon Canyon Water Recycling Facility (CCWRF)
- Western Riverside County Regional Wastewater Authority Plant (WRCRWA)
- Corona WWTPs
- Temescal Valley Water Reclamation Facility (WRF)
- Elsinore Valley Municipal Water District (EVMWD) Regional Wastewater Reclamation Facility (WWRF)
- Eastern Municipal Water District (EMWD) Regional WRFs

Attached Table 20 shows the predictive model scenario flow assumptions. It should be noted that the expected discharges under 2020 and 2040 conditions were based on the values provided by the individual POTWs – with a few notable exceptions, as described in the following sections. Additional comments or specific assumptions for individual POTWs are provided below.

5.3.1.2.1 Riverside RWQCP

Based on comments received from City of Riverside, a portion of the 2040 most likely discharge (labeled "average expected discharge on the data request forms) and minimum expected discharge for 2020 and 2040 will be piped to select upstream tributary locations to provide Santa Ana Sucker habitat as part of a regional project with Valley District and the Upper SAR Habitat Conservation Plan (HCP). This project is not yet permitted, but was included in these scenario runs to provide an indication of the project effects. Discharge quantities and locations are described below and shown on Figure 88.

- Plant Discharge (2040 Most Likely Discharge): 18.1 MGD

[10] Revised forms were provided, where available. Some discharge assumptions used for the predictive model scenarios were changed verbally or through email. These changes are indicated on the forms and documented in the change log provided in Appendix F.

- Plant Discharge (2020 and 2040 Minimum Expected Discharge): 14.6 MGD
- Anza Drain (33.966, -117.415): 0.6 MGD
- Old Farm Rd. (33.970, -117.412): 1.3 MGD
- Tequesquite (33.976, -117.397): 0.6 MGD
- Evans Drain (33.997, -117.382): 1.9 MGD

The most likely discharge under 2020 conditions (25 MGD) and maximum expected discharge under 2020 and 2040 conditions (33.8 and 46 MGD, respectively) was simulated entirely as plant discharge.

5.3.1.2.2 IEUA RPs and CCWRF

IEUA owns and operates three RPs (RP-1, RP-4, and RP-5) and the CCWRF. IEUA discharges effluent from these facilities at four discharge points, including Discharge Point (DP) 001 at Prado Park Lake, DP-002 at Cucamonga Creek, DP-003 at Chino Creek, and DP-004 at Chino Creek.

Current maximum, average, and minimum discharges were available for each DP. Since maximum expected discharge was not available for future conditions, plant capacity was assumed for maximum discharge under 2020 and 2040 conditions. Total (combined) minimum expected discharges were provided for 2020 and 2040. This total minimum discharge was distributed to the individual DPs using current (FY16/17) average and minimum flow relationships. Monthly discharge values for each DP, which exhibit a seasonal fluctuation, were provided by IEUA/WEI for most likely (average expected) discharge conditions (Scenarios B and E). This seasonal fluctuation was added to the most likely discharge to more accurately reflect discharge conditions since these discharge points can significantly affect the Baseflow Average (i.e., August and September without influence of storm events) TDS/TIN streamflow concentrations in Prado.

5.3.1.2.3 Corona WWTPs

Historically, City of Corona's WWTP No. 3 has discharged to Temescal Creek. However, this WWTP is expected to be decommissioned in 2020. The flow that used to go to this plant will be split between WRCRWA and Corona WWTP No. 2 (which discharges to recharge basins). This redistribution of flow has been accounted for in the estimated flows for WWTP No. 1, and WWTP No. 3 is not simulated in the predictive scenarios.

5.3.1.2.4 EVMWD Regional WWRF

EVMWD Regional WWRF discharges tertiary treated and disinfected wastewater to Temescal Creek (DP001) and Lake Elsinore (DP002). EVMWD is committed to discharge most of their recycled water to Lake Elsinore; only a small portion (approximately 0.5 MGD) is committed to Temescal Creek. Historically, EVMWD has discharged more recycled water to Temescal Creek than the estimated discharge of 0.5 MGD only during extreme wet conditions in which Lake Elsinore is completely full. The current Lake Elsinore agreement precludes EVMWD from discharging water into the lake when it reaches 1,247 ft, which is 8 ft below the spill elevation of 1,255 ft. Rather than develop assumptions for lake spill and wet-weather discharges, the Task Force decided to bookend EVMWD discharge assumptions such that the minimum discharge to Temescal Creek was defined as 0.5 MGD for 2020 and 2040 conditions, and maximum discharge to Temescal Creek was defined as 8.0 MGD and 12.0 MGD for 2020 and 2040 conditions, respectively. These maximum discharge assumptions cover the existing permit conditions, which allows EVMWD to discharge up to 8 MGD to Lake Elsinore AND/OR to Temescal Creek, and provides a “worst case” scenario. The most likely (average expected) discharge was assumed to be 0.5 MGD to Temescal Creek since that is how EVMWD plans to continue operating.

5.3.1.2.5 EMWD Regional WRFs

Maximum and average expected discharge for all years (current, 2020, and 2040) were provided by EMWD as 52.5 MGD for 6 months and 52.5 MGD for 1 month, respectively. Per the recommendations of EMWD, the 1-month discharge of 52.5 MGD was applied to February of every year, while the 6-month discharge of 52.5 MGD was applied to the months of November through April during the wettest half of the years (34 years of the 67-year simulation period). It is important to note that these discharge assumptions are extremely conservative, since actual EMWD discharges are currently and are expected to continue to be much less. A minimum expected discharge value of 0 MGD was assumed for all scenarios, since the goal of EMWD is to utilize all of their recycled water.

5.3.1.3 Other Discharges to Surface Water

While the calibration period accounts for flows from OCWD’s turnout OC-59, this discharge was not included in the predictive model scenario runs at the recommendation of the Task Force. However, assumptions were developed for discharges from the Arlington Desalter and San Bernardino Geothermal Plant. While the Arlington Desalter is not currently discharging, predictive scenario discharge assumptions were developed through conversations with Western based on future operational goals. These assumptions are summarized in Table 20. San Bernardino Geothermal Plant discharge was assumed to be the average of the last five years (WY 2012-2016). During this period, flows from Geothermal Plant discharge locations averaged approximately 1.0 MGD.

Outflow from Seven Oaks Dam to the SAR was included in the 2017 WLAM HSPF calibration as part of the external inflow to the model area. Conversations with Valley District have indicated that, for now, operations at Seven Oaks Dam (including discharges to the SAR) will follow the existing control manual. Therefore, the underlying assumption for future conditions is that historical discharges will be representative of future discharges for similar hydrology. Annual projected volumes of diverted and undiverted stormwater from Seven Oaks Dam (assuming a diversion capacity of 500 cfs[11]) are shown in Table 21 for the predictive period, representing hydrology from WY 1950 through 2016. However, it should be noted that the USACE does not always follow formal operating rules and there is no way to predict these deviations in 2017 WLAM HSPF future model scenarios. The same is true of operations at Prado Dam.

While Valley District historically discharged water to the SAR as part of their dewatering program, no assumptions were included in the predictive scenarios for future dewatering discharge. Per conversations with Valley District staff, surface water discharges from dewatering activities are not foreseen in the future, especially since the new dewatering program no longer requires discharges.

5.3.2 Surface Water Diversions for Off-Channel Recharge

Streamflow diversions for off-channel recharge were accounted for in the 2017 WLAM HSPF predictive scenarios by removing stormwater recharge volumes from streamflow in the channel using the same two-step process described for model calibration (Section 3.2.6.3). Daily projected streamflow diversions for each basin were provided by IEUA/WEI for the predictive model period (covering hydrology from WY 1950 through 2016). Annual streamflow diversions for off-channel recharge in Chino Basin are summarized in Table 22. Off-channel recharge is not accounted for in the 2017 WLAM HSPF beyond the surface water diversion aspect.

In the SBBA, diversions at Cuttle Weir for recharge in the SAR Spreading Grounds are dependent on SAR Flows at Mentone. Assuming a diversion capacity of 500 cfs, the OPMODEL[12] was used to calculate diversions for the Spreading Grounds and undiverted flow (which becomes streamflow inflow to the SAR) for the period from October 1, 1961 through December 31, 2001. An extra 300 cfs diversion capacity was

11 Diversion modification for the SAR Spreading Grounds was completed in November of 2018, increasing the diversion capacity from 200 cfs to 500 cfs.

12 The OPMODEL is a daily reservoir operations model developed to estimate the quantity of available unappropriated SAR water for the Valley/Western water rights applications (SBVMWD and WMWD, 2007).

also applied to current diversion and undiverted flow measurements from January 1, 2002 through December 31, 2016 to represent a change from a diversion capacity of 200 cfs to 500 cfs (i.e., correct historical diversions to account for increased capacity under projected conditions). Since pre-dam hydrology for SAR Flows at Mentone is not valid for the predictive scenarios, spreading and undivered flow were estimated using OPMODEL-calculated flow from the year with the closest annual precipitation for the period prior to WY 1961. Annual projected volumes of diverted stormwater for recharge at the SAR Spreading Grounds are shown in Table 21. As with model calibration, the 2017 WLAM HSPF predictive scenarios make no assumptions for diversions to other recharge basins in the Bunker Hill-B GMZ operated by SBCFCD.

Recharge operations in Orange County were accounted for in predictive scenario runs using the RFM (see Section 5.3.4).

5.3.3 Prado Wetlands

The OCWD Prado Wetlands spreadsheet model developed for the calibration of the 2017 WLAM HSPF (refer to Section 3.2.6.4) was also used for the predictive scenario runs. The same flow diversion, wetland parameters, and nitrate removal schematic as the calibration model were assumed for the scenario runs. Historical precipitation and evapotranspiration were used to calculate additional losses from evapotranspiration.

5.3.4 OCWD Operations at and below Prado Dam

As with the 2017 WLAM HSPF calibration, the OCWD RFM was used in the predictive scenarios as an accounting tool to track diversions from the SAR. Since the RFM does not estimate runoff from all of the adjacent land areas modeled in the 2017 WLAM HSPF, the RFM was used to track diversions from the SAR but runoff estimates from the RFM were not used. Instead, the 2017 WLAM HSPF was used to calculate local run-off in the watershed areas upstream of and surrounding the stretch of the SAR for which the RFM operates for the period from WY 1950 through 2016. This model-calculated runoff, along with Prado Dam calculated inflow, was used as RFM input. The RFM was then run for the period from WY 1950 through 2016.

5.3.5 Rising Water

In the 2017 WLAM HSPF predictive scenarios, rising water in Temescal Creek upstream of the Main Street gaging station, in the SAR Reach 3 upstream of MWD Crossing (Riverside Narrows), and in the vicinity of Prado Basin (below River Rd.) was handled using the same approach used for model calibration (see

Section 3.2.8). Rising water volumes at Riverside Narrows and the Prado vicinity were assumed to be the average monthly rising water from the calibration period. Rising water volumes in Temescal Creek were calibrated from initial values based on estimates presented in the Upper Temescal Valley SNMP (WEI, 2017). Monthly rising water assumptions for the predictive scenarios are presented in attached Table 23.

5.4 TDS and TIN

In order to evaluate water quality for major stream segments using the 2017 WLAM HSPF predictive scenarios, the TDS/TIN concentrations associated with the contributing sources (including runoff, discharges to streamflow, and rising groundwater) were needed. TDS and TIN concentrations for runoff were assumed to be the same as those used for model calibration. TDS and TIN data for the predictive model scenarios were also obtained from the POTWs listed in Section 5.3.1.2. The data request form (Appendix D) contained fields for the following TDS and TIN information:

- Effluent Limit in Current Discharge Permit
- Recent 12-mos. Volume Weighted Average
- Est. 12 mos. Volume Weighted Average in 2040

Table 20 shows the predictive model scenario flow assumptions. In general, the TDS and TIN effluent limits for current discharge permits provided by the individual POTWs were assumed for all predictive model scenarios. These represent very conservative assumptions since actual discharge is typically lower than the permitted levels, and often much lower. Additional comments or specific assumptions for individual discharge locations are provided below.

5.4.1 Discharges to Surface Water

5.4.1.1 Recycled Water Discharge

5.4.1.1.1 Beaumont WWTP

As shown in Table 20, the City of Beaumont has dual TDS and TIN effluent limits. Discharge requirements for the initial 1.8 MGD of flow have higher allowable TDS and TIN concentrations (400 mg/L and 6 mg/L, respectively). Any flows following the initial 1.8 MGD are subject to stricter water quality requirements (300 mg/L for TDS and 3.6 mg/L for TIN).

5.4.1.1.2 EVWD SNRC

The effluent limits for the SNRC will likely be based on the water quality objectives established for the Bunker Hill-B GMZ, unless the Regional Board agrees to grant an allocation of assimilative capacity following a maximum benefit demonstration. Since this information is not yet available, the estimated 12-month volume-weighted average in 2040 was applied for all model scenarios throughout the model period. Modeled concentrations for TDS and TIN were 500 mg/L and 6 mg/L, respectively.

5.4.1.1.3 IEUA RPs and CCWRF

IEUA's NPDES permit allows them to calculate compliance with effluent limits for TDS and TIN based on the system-wide, volume-weighted average off all four RPs, including CCWRF. For the purposes of the 2017 WLAM HSPF model scenarios, the combined effluent limits were assumed at each discharge location.

5.4.1.1.4 Corona WWTPs

TDS concentrations for discharge from WWTP No. 1 were modeled seasonally in both the 2008 WLAM and 2017 WLAM HSPF. The purpose of this seasonal fluctuation was to simulate typical variability in TDS concentration in the Plant 1 effluent to more accurately evaluate compliance with the Baseflow Average Reach 3 TDS objective. Summer discharge was simulated with a TDS concentration of 725 mg/L while winter discharge was simulated with a TDS concentration of 665 mg/L, such that the average TDS concentration of Corona effluent will be equal to the permitted limit of 700 mg/L, as shown in the following table.

Table 5-2. Corona Discharge TDS Concentration Assumptions for Scenario Runs

Month	Corona WWTP No. 1 Effluent TDS Concentration [mg/L]
January	665
February	665
March	665
April	665
May	725
June	725
July	725
August	725
September	725
October	725
November	725
December	665
Average	**700**

5.4.1.1.5 Temescal Valley WRF

EVMWD and EMWD completed a SNMP which was approved by the Regional Board (WEI, 2017). A Basin Plan Amendment (BPA) will be developed to formally adopt the water quality objectives for the newly defined Upper Temescal Valley GMZ. The Regional Board anticipates completing the BPA sometime in 2020.

While Temescal Valley has a current TIN limit of 13.3 mg/L, Best Available Treatment (BAT) is generally considered to be 10 mg/L. At the request of the Regional Board, the TIN concentration for Temescal Valley WRF was assumed to be 10 mg/L for all scenario runs. This lower TIN limit could potentially help with waste load allocation compliance for downstream permittees and meet the proposed Nitrate-N objective of 7.9 mg/L for the Upper Temescal Valley GMZ (assuming 25% nitrogen loss).

5.4.1.1.6 EVMWD Regional WWRF

Similar to discharges from Temescal Valley, the TIN concentration for EVMWD Regional WWRF discharge was assumed to be 10 mg/L for all scenario runs, despite the current TIN effluent limit of 13 mg/L.

5.4.1.1.7 Other Discharges to Surface Water

For the predictive scenarios, concentrations of discharge from the San Bernardino Geothermal Plant and Arlington Desalter were assumed to be the average of the last five years (WY 2012-2016). During this period, flows from Geothermal Plant discharge locations had an average TDS concentration of 264 mg/L and TIN concentration of 0.7 mg/L. Average TDS and TIN concentrations for Arlington Desalter were 260 mg/L and 4.4 mg/L, respectively.

5.4.2 Rising Water

The TDS/TIN concentrations associated with rising water at the Riverside Narrows, Prado Basin (Prado Vicinity), Warm Creek, and in Temescal Creek upgradient of Main Street were incorporated into the predictive scenarios using the same approach used for model calibration (see Section 3.2.9.3). Rising water concentrations at Riverside Narrows and the Prado vicinity were assumed to be the average monthly concentrations from the calibration period. Concentrations of rising water in Temescal Creek were based on estimates presented in the Upper Temescal Valley SNMP (WEI, 2017). Monthly rising water assumptions for the predictive scenarios are presented in attached Table 23.

5.4.3 Nitrogen Loss Coefficients

In addition to the denitrification process that occurs in surface water, further nitrogen loss occurs as surface water percolates into the subsurface. This loss is represented by applying a nitrogen loss coefficient to model-calculated streambed percolation in order to assess the quality of water recharging underlying groundwater basins. A range of nitrogen loss coefficients were identified in the Basin Plan. Based on the recommendation of the Task Force, a region-wide nitrogen loss of 25% was applied to all discharges that affect groundwater in the model area, with the exception of the lower portions of Reach 3 of the SAR that overlie the Chino South GMZ. The Regional Board has approved a higher nitrogen loss coefficient for the lower portion of Reach 3 overlying the Chino South GMZ based on site-specific scientific studies prepared and submitted by the City of Riverside.

6.0 PREDICTIVE SCENARIO RESULTS

The 2017 WLAM HSPF generates daily estimates of discharge and TDS/TIN concentrations of surface water and water recharging the GMZs along San Timoteo Creek, Temescal Creek, and the SAR over the entire predictive scenario simulation period. These daily estimates were used to compute monthly or annual volume-weighted average concentrations. Flow-weighted average TDS and TIN concentrations were evaluated over various time periods, including 1-year, 5-year, 10-year, 20-year, and 67-year. Each of these time periods is useful for evaluating possible compliance, depending on the planning objective. The 1-year averaging period is representative of the period of compliance for permits, while the 5-year averaging period typically covers the duration of the permit. The 10-year averaging period is useful for identifying possible future compliance issues because it represents a period of time that is typically long enough to cover one meteorological cycle (i.e., contains both wet and dry periods). This time period in particular is a useful indicator of how different discharge assumptions will affect the various GMZs. The rolling 10-year average is intended to identify periods of prolonged drought and to provide a surrogate indication of what might be expected to occur in response to projected climate change in the region. The 20-year averaging period represents the amount of time over which ambient groundwater concentrations are generally computed. Finally, the 67-year averaging period covers the entire predictive scenario duration and is useful for long-term planning.

The maximum 1-year, 5-year, 10-year, and 20-year flow-weighted averages from the model scenario runs are summarized in attached Tables 24 and 25 for TDS and TIN, respectively. To be consistent with the methodology used in previous WLAM reporting (WEI, 2015a), annual model-calculated values from the end of the simulation period were "rolled over" to allow long-term averages to be calculated for each year of the model simulation. This was considered appropriate since the simulated hydrology is intended to represent a range of possible hydrological conditions – not a specific sequence.

Included in Tables 24 and 25 are water quality objectives, current groundwater ambient quality, and the magnitude of assimilative capacity, if any, for each GMZ and surface water body affected by POTW discharge. Bold black values represent concentrations above the ambient but below the objective, and identify conditions where a potential use of assimilative capacity may occur. Bold red values represent concentrations above basin objectives. The results of Scenarios A through F are also fully documented by management zone and for surface water flow in Appendices G through Q. These appendices include time history charts, frequency distribution plots, and tables summarizing annual results for the predictive simulations.

6.1 Groundwater Recharge

It is important to note that the model-calculated water quality results for surface water becoming groundwater recharge through streambed percolation were generally only calculated for permeable reaches of the SAR and its main tributaries that coincide with reaches where wastewater discharges flow. At the request of the Task Force, stream reaches upgradient of the farthest upstream discharge points in Beaumont and Bunker Hill-B Basin were included in the computation of compliance metrics. This represents a change in methodology from previous WLAM calculations. The 2017 WLAM HSPF still does not include streambed recharge that occurs in the numerous tributary creeks that receive no discharges of treated wastewater from POTWs, except as necessary to calculate tributary flow. As such, it is likely to underestimate the streambed recharge from runoff associated with natural precipitation, which also tends to be relatively low in TDS/TIN. This is a conservative approach that provides a small margin of safely for the WLAM. In addition, the 2017 WLAM HSPF only accounts for off-channel recharges to the extent necessary to adjust streamflow in the SAR and its tributaries for any surface water diversions.

The predictive scenario results, along with a description of the area over which each recharge and quality were computed, are summarized in the following sections for each GMZ. References to “current” ambient groundwater quality are based on the volume-weighted average of well samples collected in the 20-year period from 1999 through 2018, representing the most recent ambient water quality update report (Tables 3-1 and 3-2 in WSC, 2020). At the time of this report publication, these ambient concentrations are pending Regional Board approval. Ambient water quality estimates are revised triennially; the next update will be published in 2023. It should be noted that the ambient water quality is computed based on water quality from selected wells throughout the GMZ – not just those areas under direct influence from the stream segments reported here.

6.1.1 Beaumont Groundwater Management Zone (Noble Creek and San Timoteo Creek Reach 4)

The 2004 Basin Plan amendment established both “antidegradation” and “maximum benefit” nitrogen and TDS objectives for Beaumont GMZ. TDS and TIN maximum benefit objectives for the Beaumont GMZ are 330 mg/L and 5.0 mg/L, respectively. Alternative TDS and TIN antidegradation objectives of 230 mg/L and 1.5 mg/L, respectively, may apply should the Regional Board find that maximum benefit is not demonstrated (see Table 6-1 below). Current ambient groundwater quality is 280 mg/L for TDS and 2.7 mg/L for TIN, creating an assimilative capacity of 50 mg/L for TDS and 2.3 mg/L for TIN based on maximum benefit objectives. POTW discharge in the Beaumont GMZ comes from Beaumont WWTP No. 1. Annual recharge from streambed percolation and water quality was calculated for Noble Creek above and below Beaumont DP 008, the unnamed tributary to Marshall Creek below Beaumont DP 007, Cooper's Creek below Beaumont WWTP No. 1, and Reach 4 of San Timoteo Creek overlying the

Beaumont GMZ (Figure G-1). Recharge occurring in this reach is influenced by direct precipitation, surface runoff (including inflow from tributaries), and Beaumont WWTP No. 1.

Table 6-1. Predictive Scenario Results – Beaumont GMZ (Noble Creek and San Timoteo Creek Reach 4)

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE					
					2020 Conditions			2040 Conditions		
					Scen A (Max)	Scen B (Avg)*	Scen C (Min)	Scen D (Max)	Scen E (Avg)*	Scen F (Min)
	[mg/L]	[mg/L]	[mg/L]		[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
TDS	330[1]/230[2]	280[3]	50[4]	1-year	255	257	259	228	228	228
				5-year	226	227	228	208	208	208
				10-year	218	220	221	204	204	204
				20-year	217	218	219	203	203	203
				67-year	208	209	210	200	200	200
TIN	5.0[1]/1.5[2]	2.7[3]	2.3[4]	1-year	2.29	2.32	2.36	1.86	1.87	1.88
				5-year	1.88	1.90	1.92	1.60	1.61	1.61
				10-year	1.77	1.79	1.81	1.54	1.54	1.54
				20-year	1.74	1.75	1.77	1.52	1.52	1.53
				67-year	1.60	1.61	1.62	1.46	1.46	1.46
Average Annual Streambed Recharge [acre-ft/yr]					1,870	1,869	1,868	2,327	2,327	2,326

[1] "Maximum benefit" objectives apply unless the Regional Board determines that lowering of water quality is not of maximum benefit to the people of the state

[2] "Antidegradation" objectives apply when the Regional Board determines that the lowering of water quality is not of maximum benefit to the people of the state

[3] 2018 estimate of ambient water quality (WSC, 2020)

[4] Based on maximum benefit objectives

*Represents most likely discharge conditions.

As shown in Tables 24 and 25 and in the graphs provided in Appendix G, the TDS and TIN concentrations under Scenario A through Scenario F conditions do not exceed the TDS or TIN maximum benefit objectives for Beaumont GMZ. The maximum 10-year volume-weighted TDS average ranges from 204 mg/L under Scenarios D, E, and F conditions to 221 mg/L under Scenario C conditions, while the 10-year volume weighted TIN average ranges from 1.5 mg/L under Scenarios D, E, and F conditions to

1.8 mg/L under Scenario C conditions. The differences between water quality concentrations under the different scenario assumptions indicate that reduced discharge actually leads to greater concentrations of TDS and TIN in recharge water. This is largely due to the dual limit for discharge from the City of Beaumont. Since any discharge over 1.8 MGD is subject to stricter water quality requirements, TDS and TIN concentrations are lower at higher discharge rates.

6.1.2 San Timoteo Groundwater Management Zone (San Timoteo Creek Reaches 2, 3, & 4)

As with the Beaumont GMZ, the 2004 Basin Plan amendment established both antidegradation and maximum benefit nitrogen and TDS objectives for San Timoteo GMZ. TDS and TIN maximum benefit objectives for the San Timoteo GMZ are 400 mg/L and 5.0 mg/L, respectively. Alternative TDS and TIN antidegradation objectives of 300 mg/L and 2.7 mg/L, respectively, may apply should the Regional Board find that maximum benefit is not demonstrated (see Table 6-2 below). Current ambient groundwater quality is 420 mg/L for TDS and 1.5 mg/L for TIN, assuming maximum benefit objectives, creating an assimilative capacity of 3.5 mg/L for TIN, but none for TDS. POTW discharges that may affect groundwater quality in the San Timoteo GMZ includes those from YVWD H.N. Wochholz WRF, located within the GMZ, and upgradient Beaumont WWTP No. 1. Annual recharge from streambed percolation and water quality was calculated for Cooper's Creek and San Timoteo Creek Reaches 2, 3, and 4 overlying the San Timoteo GMZ (Figure H-1).

Table 6-2. Predictive Scenario Results – San Timoteo GMZ (Cooper's Creek and San Timoteo Creek Reaches 2, 3, & 4)

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE					
					2020 Conditions			2040 Conditions		
					Scen A (Max)	Scen B (Avg)*	Scen C (Min)	Scen D (Max)	Scen E (Avg)*	Scen F (Min)
	[mg/L]	[mg/L]	[mg/L]		[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
TDS	400[1]/300[2]	420[3]	None	1-year	372	369	369	349	346	329
				5-year	356	353	353	307	304	288
				10-year	338	335	334	281	278	266
				20-year	338	335	332	280	277	266
				67-year	290	286	281	237	235	223
TIN	5.0[1]/2.7[2]	1.5[3]	3.5[4]	1-year	***4.27***	***4.15***	***4.02***	***3.80***	***3.71***	***3.26***
				5-year	***4.07***	***3.95***	***3.81***	***3.27***	***3.18***	***2.84***
				10-year	***3.85***	***3.73***	***3.58***	***2.98***	***2.92***	***2.61***
				20-year	***3.84***	***3.70***	***3.53***	***2.98***	***2.91***	***2.59***
				67-year	***3.22***	***3.08***	***2.92***	***2.46***	***2.40***	***2.11***
Average Annual Streambed Recharge [acre-ft/yr]					6,473	6,386	6,337	7,945	7,872	7,716

Note: Bold black values represent concentrations above ambient groundwater quality, but below the maximum benefit objective

1 "Maximum benefit" objectives apply unless the Regional Board determines that lowering of water quality is not of maximum benefit to the people of the state

2 "Antidegradation" objectives apply when the Regional Board determines that the lowering of water quality is not of maximum benefit to the people of the state

3 2018 estimate of ambient water quality (WSC, 2020)

4 Based on maximum benefit objectives

*Represents most likely discharge conditions.

As shown in Tables 24 and 25 and in the graphs provided in Appendix H, the TDS concentrations under Scenario A through Scenario F conditions do not exceed the maximum benefit objectives. The maximum 10-year volume-weighted TDS average ranges from 266 mg/L under Scenario F conditions to 338 mg/L under Scenario A conditions. On the other hand, water recharged in the San Timoteo GMZ from Coopers Creek and San Timoteo Creek Reaches 2, 3, and 4 causes TIN concentrations to rise above ambient groundwater concentrations, but below maximum benefit objectives. The maximum 10-year volume weighted TIN average ranges from 2.6 mg/L under Scenario F conditions to 3.9 mg/L under Scenario A conditions. The increased TIN concentrations in water recharging San Timoteo GMZ is an “authorized degradation,” provided it continues to comply with the 5.0 mg/L objective in the Basin Plan.

It is important to note that the 2017 WLAM HSPF does not currently take into account the effect of upgradient landfills, like the Riverside County Badlands Landfill. This is something that may be useful to investigate in subsequent WLAM updates. In addition, YVWD is currently investigating the removal of its effluent from San Timoteo Creek (i.e., zero discharge), and plans to reassess this possibility during the next WLAM update.

6.1.3 Bunker Hill-B Groundwater Management Zone (San Timoteo Creek Reach 1 and SAR Reach 5)

TDS and TIN objectives for the Bunker Hill-B GMZ are 330 mg/L and 7.3 mg/L, respectively (see Table 6-3 below). Current ambient groundwater quality is 280 mg/L for TDS and 5.8 mg/L for TIN, creating an assimilative capacity of 50 mg/L for TDS and 1.5 mg/L for TIN. Annual recharge from streambed percolation and water quality was calculated for San Timoteo Creek Reach 1 overlying the Bunker Hill-B GMZ and SAR Reach 5 from the northernmost boundary of Bunker Hill-B to the San Jacinto Fault (coincident with the western boundary of the GMZ; Figure I-1). Since there are no POTW outfalls in San Timoteo Creek Reach 1, the water quality of recharge from the San Timoteo Creek in this GMZ is largely affected by upstream Reaches 2 and 3 (i.e., discharges from YVWD’s Henry N. Wochholz WRF and the Beaumont WWTP). Other discharges that may affect groundwater quality in the Bunker Hill-B GMZ include those from the proposed EVWD SNRC. However, the modeling indicates that discharge from the SNRC does not typically reach the SAR except during periods of high precipitation. Additional SNRC modeling for permitting, which includes contribution from upgradient groundwater underflow and evaluates groundwater impacts, was conducted as part of the Environmental Impact Report (ESA, 2016) and Title 22 Engineering Report (RMC/Woodard & Curran, 2017).

Table 6-3. Predictive Scenario Results – Bunker Hill-B GMZ (San Timoteo Creek Reach 1 and SAR Reach 5)

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE					
					2020 Conditions			2040 Conditions		
					Scen A (Max)	Scen B (Avg)*	Scen C (Min)	Scen D (Max)	Scen E (Avg)*	Scen F (Min)
	[mg/L]	[mg/L]	[mg/L]		[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
TDS	330	280[1]	50	1-year	***329***	***295***	239	***311***	***302***	267
				5-year	***300***	261	226	277	266	230
				10-year	***287***	250	221	265	254	226
				20-year	277	245	216	257	247	220
				67-year	252	226	198	239	229	206
TIN	7.3	5.8[1]	1.5	1-year	3.63	3.26	2.84	3.35	3.23	2.82
				5-year	3.24	2.69	2.37	2.87	2.68	2.29
				10-year	3.14	2.62	2.27	2.78	2.60	2.21
				20-year	2.93	2.51	2.20	2.65	2.52	2.14
				67-year	2.68	2.29	1.93	2.46	2.33	1.96
Average Annual Streambed Recharge [acre-ft/yr]					17,391	15,174	13,110	19,970	19,141	17,105

Note: Bold black values represent concentrations above ambient groundwater quality, but below the objective. Bold red values represent concentrations above the basin objective.

[1] 2018 estimate of ambient water quality (WSC, 2020)

*Represents most likely discharge conditions.

As shown in Tables 24 and 25 and in the graphs provided in Appendix I, the TIN concentrations under Scenario A through Scenario F conditions do not exceed the TIN objectives for Bunker Hill-B GMZ. The maximum 10-year volume-weighted TIN average ranges from 2.2 mg/L under Scenario F conditions to 3.1 mg/L under Scenario A conditions. Some of the maximum 1-year volume-weighted average TDS concentrations exceed ambient concentrations under Scenarios A, B, D, and E conditions (i.e., maximum and most likely expected discharge). In addition, the 5-year and 10-year volume-weighted average TDS concentrations of Scenario A exceed ambient concentrations. The maximum 10-year volume-weighted TDS average ranges from 221 mg/L under Scenario C conditions to 287 mg/L under Scenario A conditions.

A review of the water budgets in this area indicated that Bunker Hill-B recharge from San Timoteo Creek has higher model-calculated TDS concentrations than that from the SAR for most years except under very wet conditions. Therefore, the SAR tends to dilute the TDS concentrations in flow from San Timoteo Creek. For example, during the year producing the highest 1-year volume-weighted maximum TDS concentration (329 mg/L in WY 1961 under Scenario A conditions), the volume-weighted average TDS concentration of streambed recharge from San Timoteo Creek overlying Bunker Hill-B is approximately 378 mg/L. This is a product of discharge from Beaumont WWTP (discharge with an average TDS concentration of 347 mg/L under Scenario A conditions) and YVWD's Henry N. Wochholz WRF (discharge with a concentration of 400 mg/L).

6.1.4 Colton Groundwater Management Zone (SAR Reach 4)

TDS and TIN objectives for the Colton GMZ are 410 mg/L and 2.7 mg/L, respectively. Current ambient groundwater quality is 490 mg/L for TDS and 3.3 mg/L for TIN, meaning that no assimilative capacity exists for either constituent (see Table 6-4 below). Annual recharge from streambed percolation and water quality was calculated for the SAR Reach 4 overlying the Colton GMZ (Figure J-1). Since there are no POTW discharges in the Colton GMZ, this area is primarily affected by upgradient discharges.

Table 6-4. Predictive Scenario Results – Colton GMZ (SAR Reach 4)

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE					
					2020 Conditions			2040 Conditions		
					Scen A (Max)	Scen B (Avg)*	Scen C (Min)	Scen D (Max)	Scen E (Avg)*	Scen F (Min)
	[mg/L]	[mg/L]	[mg/L]		[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
TDS	410	490[1]	none	1-year	399	307	260	346	356	293
				5-year	340	250	221	307	300	237
				10-year	317	246	217	290	281	233
				20-year	305	237	211	282	275	225
				67-year	279	211	188	264	253	199
TIN	2.7	3.3[1]	none	1-year	***3.97***	2.36	2.31	***3.53***	***3.43***	2.24
				5-year	***3.33***	1.99	1.82	***3.02***	***2.76***	1.85
				10-year	***3.12***	1.95	1.66	***2.87***	2.64	1.81
				20-year	***3.01***	1.84	1.58	***2.81***	2.58	1.72
				67-year	2.69	1.68	1.39	2.56	2.35	1.55
Average Annual Streambed Recharge [acre-ft/yr]					2,709	2,147	2,003	3,224	2,960	2,409

Note: Bold red values represent concentrations above the basin objective.

[1] 2018 estimate of ambient water quality (WSC, 2020)

*Represents most likely discharge conditions.

As shown in Tables 24 and 25 and in the graphs provided in Appendix J, the TDS concentrations under Scenario A through Scenario F conditions do not exceed the TDS objectives for Colton GMZ. The maximum 10-year volume-weighted TDS average ranges from 217 mg/L under Scenario C conditions to 317 mg/L under Scenario A conditions. However, TIN concentrations exceed TIN objectives under Scenario A, Scenario D, and Scenario E conditions. The 10-year volume weighted TIN average ranges from 1.7 mg/L under Scenario C conditions to 3.1 mg/L under Scenario A conditions.

6.1.5 Riverside-A Groundwater Management Zone (SAR Reach 4)

TDS and TIN objectives for the Riverside-A GMZ are 560 mg/L and 6.2 mg/L, respectively (see Table 6-5 below). Current ambient groundwater quality is 430 mg/L for TDS and 5.7 mg/L for TIN, creating an assimilative capacity of 130 mg/L for TDS and 0.5 mg/L for TIN. As described in Section 3.2.8, no streambed percolation in SAR Reach 3 overlying Riverside-A GMZ was assumed to occur due to the presence of rising water. Therefore, the annual model-calculated recharge from streambed percolation reflects only that which occurs in SAR Reach 4 (since volume-weighted recharge concentrations for areas of zero recharge would be zero) (Figure K-1). Primary discharges that affect surface water quality in the Riverside-A GMZ include those from RIX and the Rialto WWTP.

The predictive scenarios also assume additional discharge locations from the Riverside RWQCP, which are located within the Riverside-A GMZ. However, among the four relocated discharge points, Tequesquite, Old Farm Rd., and Anza Drain are located on tributaries to SAR Reach 3, where no percolation is assumed to occur. The Evans Drain discharge point sits below Market St. and within one mile of Mission Blvd. This area represents a transition zone between losing stream conditions and rising groundwater conditions. Given the assumption that very little to no streambed percolation will occur in this location depending on groundwater level elevations, relocating discharge from the Riverside RWQCP in Chino South GMZ to Riverside-A GMZ is not anticipated to have a significant effect on recharging water quality in Riverside-A GMZ.

Table 6-5. Predictive Scenario Results – Riverside-A GMZ (SAR Reach 4[1])

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE					
					2020 Conditions			2040 Conditions		
					Scen A (Max)	Scen B (Avg)*	Scen C (Min)	Scen D (Max)	Scen E (Avg)*	Scen F (Min)
	[mg/L]	[mg/L]	[mg/L]		[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
TDS	560	430[2]	130	1-year	***511***	***488***	***486***	***492***	***478***	***472***
				5-year	***487***	***454***	***450***	***467***	***447***	***433***
				10-year	***477***	***441***	***437***	***457***	***434***	418
				20-year	***472***	***435***	***431***	***452***	428	411
				67-year	***443***	400	395	425	398	377
TIN	6.2	5.7[2]	0.5	1-year	***6.95***	***6.68***	***6.64***	***6.80***	***6.59***	***6.39***
				5-year	***6.60***	***6.16***	***6.10***	***6.42***	***6.09***	***5.79***
				10-year	***6.45***	***5.97***	***5.91***	***6.27***	***5.91***	5.58
				20-year	***6.35***	***5.83***	***5.77***	***6.16***	***5.78***	5.43
				67-year	***5.87***	5.25	5.17	***5.71***	5.26	4.86
Average Annual Streambed Recharge [acre-ft/yr]					51,690	37,522	35,841	55,882	45,632	37,579

Note: Bold black values represent concentrations above ambient groundwater quality, but below the objective. Bold red values represent concentrations above the basin objective.

[1] Due to rising water conditions, no streambed recharge occurs in SAR Reach 3 overlying Riverside-A GMZ.

[2] 2018 estimate of ambient water quality (WSC, 2020)

*Represents most likely discharge conditions.

As shown in Tables 24 and 25 and in the graphs provided in Appendix K, the TDS concentrations under Scenario A through Scenario F conditions do not exceed the TDS objectives for Riverside-A GMZ. However, the maximum 1-year and 5-year volume-weighted average TDS concentrations are above ambient under all of the scenario conditions. 10-year and 20-year volume-weighted average TDS concentrations in excess of the ambient also occur under 2020 conditions (Scenarios A through C) and maximum expected 2040 conditions (Scenario D). TDS concentrations in excess of the ambient dare also seen for the 10-year volume-weighted average under most likely 2040 discharge conditions (Scenario E). The maximum 10-year volume-weighted TDS average ranges from 418 mg/L under Scenario F conditions to 477 mg/L under Scenario A conditions. All of the maximum 1-year volume-weighted average TIN concentrations exceed TIN objectives, along with the maximum 5-year concentrations under maximum expected discharge conditions (Scenarios A and D). The maximum 10-year volume-weighted TIN average ranges from 5.6 mg/L under Scenario F conditions to 6.5 mg/L under Scenario A conditions.

6.1.6 Chino-South Groundwater Management Zone (SAR Reach 3)

TDS and TIN objectives for the Chino-South GMZ are 680 mg/L and 5.0 mg/L, respectively (see Table 6-6 below). Current ambient groundwater quality is 920 mg/L for TDS and 27.6 mg/L for TIN, meaning that no assimilative capacity exists for either constituent. Annual recharge from streambed percolation and water quality was calculated for the portion of the SAR Reach 3 overlying the Chino-South GMZ (Figure L-1). POTW discharge that affects Chino-South GMZ comes from upstream discharges, and discharges from the Riverside RWQCP.

Table 6-6. Predictive Scenario Results – Chino-South GMZ (SAR Reach 3)

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE					
					2020 Conditions			2040 Conditions		
					Scen A (Max)	Scen B (Avg)*	Scen C (Min)	Scen D (Max)	Scen E (Avg)*	Scen F (Min)
	[mg/L]	[mg/L]	[mg/L]		[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
TDS	680	920[1]	none	1-year	629	644	646	599	618	624
				5-year	497	506	509	461	461	464
				10-year	458	466	468	417	419	422
				20-year	457	465	466	415	418	420
				67-year	380	381	380	353	344	344
TIN	5.0[2]	27.6[1]	none	1-year	4.47	4.45	4.42	4.35	4.27	4.25
				5-year	3.48	3.47	3.45	3.29	3.12	3.11
				10-year	3.20	3.18	3.16	2.96	2.84	2.82
				20-year	3.20	3.17	3.15	2.95	2.83	2.81
				67-year	2.64	2.58	2.55	2.49	2.32	2.29
Average Annual Streambed Recharge [acre-ft/yr]					49,785	47,672	47,022	58,387	53,897	52,898

[1] 2018 estimate of ambient water quality (WSC, 2020)

[2] On August 4, 2017, the California Regional Water Quality Control Board, Santa Ana Region, adopted Resolution No. R8-2017-0036 revising the water quality objective for nitrate as nitrogen from 4.2 mg/L to 5.0 mg/L in the Chino South Groundwater Management Zone. The State Water Resource Control Board approved the amendment under Resolution No. 2018-0004 on February 6, 2018. The new objective became effective when the Office of Administrative Law approved the Basin Plan amendment on July 2, 2018.

*Represents most likely discharge conditions.

As shown in Tables 24 and 25 and in the graphs provided in Appendix L, the TDS and TIN concentrations under Scenario A through Scenario F conditions do not exceed the TDS or TIN objectives for Chino-South GMZ. The maximum 10-year volume-weighted TDS average ranges from 417 mg/L under Scenario D conditions to 468 mg/L under Scenario C conditions. The 10-year volume weighted TIN average ranges from 2.8 mg/L under Scenario F conditions to 3.2 mg/L under Scenario A conditions. As evident by the 2018 ambient groundwater concentrations and model-calculated recharge from the predictive scenario runs, streambed recharge actually helps to improve water quality in Chino-South GMZ since recharging water is so much lower in TDS and TIN than the receiving groundwater and Basin Plan objectives.

6.1.7 Upper Temescal Valley Groundwater Management Zone (Temescal Creek Reaches 2, 3, 4, 5 & 6)

The proposed TDS and TIN objectives for the Upper Temescal Valley GMZ[13] are 820 mg/L and 7.9 mg/L, respectively (see Table 6-7 below). However, as mentioned in Section 5.4.1.1.5, these proposed limits have yet to be approved. The Basin Plan Amendment to adopt the SNMP for the Upper Temescal Valley GMZ is expected to be approved in 2020. Nevertheless, the 2017 WLAM HSPF was used to evaluate the impact and the compliance of streamflow and groundwater recharge with the proposed TDS and TIN objectives. Current ambient groundwater quality, according to the 2017 SNMP, is 750 mg/L for TDS and 4.7 mg/L for TIN. Therefore, with the current proposed objectives, there is an assimilative capacity of 70 mg/L for TDS and 3.2 mg/L for TIN. Annual recharge from streambed percolation and water quality was calculated for Temescal Creek Reaches 2, 3, 4, 5, and the upper portion of 6 overlying the Upper Temescal Valley GMZ (Figure M-1). POTW discharges that affect groundwater quality in Upper Temescal Valley GMZ include Temescal Valley WRF, EVMWD Regional WWRF, and EMWD Regional WRFs.

[13] Proposed Upper Temescal Valley GMZ includes Bedford GMZ, Lee Lake GMZ, and Warm Springs Valley GMZ – for which numeric objectives were not established in the existing Basin Plan.

Table 6-7. Predictive Scenario Results – Upper Temescal Valley GMZ (Temescal Creek Reaches 2, 3, 4, 5 & 6)

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE					
					2020 Conditions			2040 Conditions		
					Scen A (Max)	Scen B (Avg)*	Scen C (Min)	Scen D (Max)	Scen E (Avg)*	Scen F (Min)
	[mg/L]	[mg/L]	[mg/L]		[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
TDS	820[1]	750[2]	70	1-year	676	584	544	662	560	509
				5-year	662	537	469	645	502	445
				10-year	658	519	442	638	481	419
				20-year	654	514	430	631	472	405
				67-year	634	448	367	605	413	352
TIN	7.9[1]	4.7[2]	3.2	1-year	***7.20***	***6.38***	***5.47***	***7.05***	***6.09***	***5.38***
				5-year	***7.14***	***5.77***	***4.71***	***6.93***	***5.31***	4.46
				10-year	***7.08***	***5.57***	4.41	***6.82***	***5.05***	4.16
				20-year	***7.02***	***5.49***	4.32	***6.73***	***4.95***	4.03
				67-year	***6.76***	4.58	3.46	***6.39***	4.13	3.29
Average Annual Streambed Recharge [acre-ft/yr]					12,950	5,297	4,194	13,518	6,423	5,571

Note: Bold black values represent concentrations above ambient groundwater quality, but below the objective.

[1] Proposed objective from June 2018 CEQA Scoping Meeting

[2] Based on Salt and Nutrient Management Plan for the Upper Temescal Valley, Table 6-B (WEI, 2017)

*Represents most likely discharge conditions.

As shown in Tables 24 and 25 and in the graphs provided in Appendix M, the TDS and TIN concentrations under Scenario A through Scenario F conditions do not exceed the proposed TDS or TIN objectives for Upper Temescal Valley GMZ. However, TIN concentrations rise above ambient groundwater concentrations, but below proposed objectives, under maximum and most likely discharge conditions (Scenarios A, B, D, and E) as well as the 1-year and 5-year maximum TIN concentrations under Scenario C conditions and the 1-year maximum TIN concentration under Scenario F conditions.. The maximum 10-year volume-weighted TDS average ranges from 419 mg/L under Scenario F conditions to 658 mg/L under Scenario A conditions. The 10-year volume weighted TIN average ranges from 4.2 mg/L under Scenario F conditions to 7.1 mg/L under Scenario A conditions.

Boldface TIN values in Table 6-7 (indicating concentrations above ambient but below water quality objectives) are likely driven by extremely conservative (i.e., high flow) discharge assumptions for EVMWD and EMWD. Assumed flow for the predictive scenario runs is compared to average historical discharges from the plants over the last 10 years in the following table.

Table 6-8. Elsinore Valley Municipal Water District and Eastern Municipal Water District - Comparison of Actual Discharge to Assumed Discharge for Predictive Scenarios

Historical Discharge	Average Discharge [MGD]	
	EVMWD Regional WWRF	EMWD Regional WRFs
2007	4.3	11.5
2008	0.7	9.6
2009	0.5	5.9
2010	0.8	4.4
2011	4.0	5.1
2012	0.7	1.1
2013	0.6	2.4
2014	0.6	0.0
2015	0.6	0.0
2016	0.6	0.0

Predictive Scenario Assumptions	Discharge [MGD]	
	EVMWD Regional WWRF	EMWD Regional WRFs
Scen A (2020 Max)	8.0	0 / 52.5[1]
Scen B (2020 Avg*)	0.5	0 / 52.5[2]
Scen C (2020 Min)	0.5	0
Scen D (2020 Max)	12.0	0 / 52.5[1]
Scen E (2020 Avg*)	0.5	0 / 52.5[2]
Scen F (2020 Min)	0.5	0

[1] Discharge of 52.5 MGD was only applied in February for all years and from November through April (6 months) during the wettest half of the years (34 years of the 67-year simulation period).

[2] Discharge of 52.5 MGD was only applied in February (1 month).

*Represents most likely discharge conditions.

6.1.8 Orange County Groundwater Management Zone (SAR Reach 2)

TDS and TIN objectives for the Orange County GMZ are 580 mg/L and 3.4 mg/L, respectively (see Table 6-9 below). Current ambient groundwater quality is 600 mg/L for TDS and 3.0 mg/L for TIN, creating an assimilative capacity of 0.4 mg/L for TIN, but none for TDS. POTW discharges affecting the Orange County GMZ come from upgradient sources.

Annual recharge from streambed percolation and water quality was calculated for SAR Reach 2 overlying the Orange County GMZ (Figure N-1) in two model runs. OCWD's RFM was used to calculate streambed percolation between Imperial Dam and Five Coves Dam, as well as SAR downstream of the Five Coves Inflatable Dam. Recharge in spreading basins from the RFM was not accounted for in the volume-weighted recharge (this recharge is tabulated separately; see Section 6.4). The 2017 HSPF WLAM was used to calculate streambed percolation for the SAR Reach 2 stretch from the outflow of the RFM to the SAR at Santa Ana streamflow gage. No streambed percolation is assumed to occur between Prado Dam and the SAR at Imperial Highway gage. Water quality in streambed percolation reflects that calculated at the Imperial Highway gage, since the model was calibrated to observed data at this location.

Table 6-9. Predictive Scenario Results – Orange County GMZ (SAR Reach 2)

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE					
					2020 Conditions			2040 Conditions		
					Scen A (Max)	Scen B (Avg)*	Scen C (Min)	Scen D (Max)	Scen E (Avg)*	Scen F (Min)
	[mg/L]	[mg/L]	[mg/L]		[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
TDS	580	600[1]	none	1-year	***603***	***681***	***734***	***589***	***684***	***728***
				5-year	568	***649***	***690***	547	***645***	***677***
				10-year	529	***609***	***629***	510	***593***	***607***
				20-year	525	***604***	***623***	504	***591***	***603***
				67-year	471	520	523	458	502	506
TIN	3.4	3.0[1]	0.4	1-year	***3.60***	***3.10***	2.66	***3.58***	***3.25***	2.68
				5-year	***3.41***	2.97	2.49	***3.34***	***3.06***	2.52
				10-year	***3.20***	2.81	2.32	***3.13***	2.84	2.30
				20-year	***3.19***	2.78	2.29	***3.11***	2.83	2.27
				67-year	2.88	2.44	2.02	2.85	2.44	1.99
Average Annual Streambed Recharge [acre-ft/yr]					103,317	79,148	65,085	120,404	85,301	69,587

Note: Bold black values represent concentrations above ambient groundwater quality, but below the objective. Bold red values represent concentrations above the basin objective.

[1] 2018 estimate of ambient water quality (WSC, 2020)

*Represents most likely discharge conditions.

As shown in Tables 24 and 25 and in the graphs provided in Appendix N, all of the maximum 1-year volume-weighted average TDS concentrations exceed TDS objectives, along with some of the maximum 5-year, 10-year and 20-year concentrations. The maximum 10-year volume-weighted TDS average ranges from 510 mg/L under Scenario D to 629 mg/L under Scenario C conditions. Maximum 1-year volume-weighted TIN concentrations exceed TIN objectives under Scenario A and D conditions while the maximum 5-year volume-weighted TIN concentration exceeds TIN objectives under Scenario A conditions. In addition, the maximum volume-weighted TIN concentrations rise above the ambient but below the objective in Scenarios A (10-year and 20-year), B (1-year), D (5-year, 10-year, and 20-year) and E (1-year and 5-year). The 10-year volume weighted TIN average ranges from 2.3 mg/L under Scenario F conditions to 3.2 mg/L under Scenario A conditions.

6.2 Wetlands

6.2.1 Prado Basin Management Zone (SAR Reach 3)

Prado Basin is treated as surface water management zone since no significant percolation occurs in this area. Annual recharge from streambed percolation and water quality presented here was calculated only for SAR Reach 3 above River Rd, where percolation is thought to occur (Figure O-1). Any percolation is considered temporary, as it is assumed to become streamflow again through rising groundwater farther downstream. While the objectives of the streams that flow into the Prado Basin Management Zone continue to apply to those streams within the management zone, Prado Basin Management Zone does not have its own separate water quality objectives. However, since very little percolation occurs within Prado Basin, the objectives are somewhat irrelevant in this area. Instead, the Basin Plan recommends using the baseflow objective for Reach 3 and the 5-year moving average for Reach 2 to assess potential impacts to groundwater quality in Orange County GMZ. These objectives are discussed in Section 6.3 and are therefore not compared to model-calculated recharge in Prado Basin Management Zone upstream of River Rd. POTW discharge that affects surface water quality above River Rd. comes from discharges to the SAR upstream of Prado (including RIX, Rialto, and the City of Riverside). Discharges to Temescal Creek, Carbon Canyon WRF, WRCRWA, Corona WWTP-1, and IEUA RP-1 001, RP-1 002, RP-2, RP-4, and RP-5 enter Prado Basin Management Zone below River Rd. and are accounted for in the SAR below Prado water quality calculations (see Section 6.3.1).

Table 6-10. Predictive Scenario Results – Prado Basin Management Zone (SAR Reach 3 above River Rd.)

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE					
					2020 Conditions			2040 Conditions		
					Scen A (Max)	Scen B (Avg)*	Scen C (Min)	Scen D (Max)	Scen E (Avg)*	Scen F (Min)
	[mg/L]	[mg/L]	[mg/L]		[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
TDS	na[1]	na[2]	na	1-year	652	662	666	636	650	654
				5-year	637	646	649	622	635	638
				10-year	630	638	640	616	627	629
				20-year	621	629	630	607	617	619
				67-year	589	603	602	587	592	592
TIN	na[1]	na[2]	na	1-year	6.46	6.34	6.26	6.53	6.29	6.21
				5-year	6.30	6.18	6.09	6.38	6.13	6.05
				10-year	6.24	6.10	6.00	6.31	6.05	5.97
				20-year	6.16	6.02	5.92	6.24	5.97	5.88
				67-year	5.90	5.73	5.60	6.00	5.68	5.58
Average Annual Streambed Recharge[3] [acre-ft/yr]					14,713	14,700	14,692	14,729	14,706	14,698

[1] Prado Basin Management Zone does not have its own set of water quality objectives, although the objectives of the streams that flow into the Prado Basin Management Zone (presented in the Prado Basin Surface Water Management Zone Section of the 2016 Water Quality Control Plan (Basin Plan) for the Santa Ana River Basin, pg. 4-29) continue to apply. For the purposes of this investigation, no objectives were evaluated for Prado Basin Management Zone.

Note: SAR Reach 3 TDS/TIN objectives are identified in the Basin Plan as "baseflow" objectives. According to the 1983 Basin Plan, compliance with these objectives should be assessed without the influence of stormflow events. Model-calculated maximum volume-weighted concentrations in Table 6-10 do not represent baseflow conditions. Baseflow Average concentrations for Reach 3, without the influence of storm events, are presented in Section 6.3.1 for surface water flow at the Santa Ana River Below Prado Dam.

[2] No Prado Basin ambient TDS or Nitrate as Nitrogen was computed after 1997

[3] Streambed recharge in Prado Basin Management Zone only occurs above River Rd. This recharge is assumed to be temporary and become rising water farther downstream.

*Represents most likely discharge conditions.

Prado Basin Management Zone TDS and TIN concentrations above River Rd. under Scenario A through Scenario F conditions are shown in Tables 24 and 25 and in the graphs provided in Appendix O. The maximum 10-year volume-weighted TDS average ranges from 616 mg/L under Scenario D conditions to 640 mg/L under Scenario C conditions. The 10-year volume weighted TIN average ranges from 6.0 mg/L under Scenario F conditions to 6.3 mg/L under Scenario D conditions. These TIN values are nearly double that seen recharging Orange County GMZ (Table 6-9, Section 6.1.8). Some of the difference between values shown in Tables 6-9 and 6-10 includes the additional nitrate loss in Orange County and when water is routed through the Prado Wetlands, as well as additional stormwater flowing into Reach 2 from tributary channels and the surrounding watershed.

6.3 Surface Water Flow

The TDS and TIN concentrations of surface water were also evaluated in two locations: at the SAR below Prado Dam and SAR at Santa Ana. Traditionally, the quality of streamflow below Prado Dam has been used as an indication of the quality of recharge in the Orange County GMZ. Annual water quality measurements are reported in the Annual Report of the Santa Ana River Water Quality (SAWPA, 2017). Predicted water quality results from the scenario runs for surface water below Prado Dam and at Santa Ana are presented in attached Tables 24 and 25, while charts and summary tables are provided in Appendices P and Q. The results are also summarized in the following sections.

It is important to note that TDS and TIN concentrations reported for surface water are difficult to compare directly with model-calculated water quality for water recharging underlying groundwater basins because of the difference in averaging periods used. In addition, the model-calculated concentrations of surface flow do not include the additional nitrogen loss that occurs when surface water percolates to underlying groundwater systems. Due to the volume-weighted nature of the calculations, high volumes of stormwater (with lower TDS and TIN) also have a greater effect on the overall average of streamflow water quality. On the other hand, groundwater recharging through the streambed sees less influence of storm events since recharge is limited by streambed percolation. Stormflows can flow out of the system fairly quickly during large storm events and much of this water is not able to percolate.

6.3.1 Santa Ana River below Prado Dam

Surface water flow and quality in the SAR below Prado Dam (Figure P-1) was compared to Reach 3 (Baseflow Average) and Reach 2 (5-year moving average of the 1-year volume-weighted average) surface water objectives. The Baseflow Average objectives for Reach 3 are 700 mg/L for TDS and 10.0 mg/L for TIN (see Table 6-11 below). The Basin Plan describes the baseflow period as flow and water quality conditions which prevail when contribution from stormwater runoff and rising groundwater is at its annual minimum – principally during August and September. Previous WLAM efforts have reported “August-Only” conditions, reflecting water quality and flow only in August of each year. This is an unofficial colloquialism that has typically been used to quickly convey a more complex concept. As such, the Task Force has requested that the Baseflow Average reported for the 2017 WLAM HSPF represent conditions from August and September. Since baseflow volume-weighted average of TDS and TIN is used to determine whether the water quality objectives for base flow in Reach 3 are being met, days affected by precipitation were excluded from this calculation to avoid results biased by the high-quality stormwater[14]. For Reach 2, the 5-year moving average objective for TDS is 650 mg/L. There is currently no TIN objective for Reach 2. The Regional Board also does not currently recognize the existence of assimilative capacity for TDS or TIN in surface water.

14 Over the 67-year predictive run period, stormwater-influenced flow in August and September at Below Prado Dam was observed in 53 years, totaling 591 days. These measurements were excluded from the calculation of Baseflow Average concentrations.

Since precipitation events appear at the precipitation stations in the 2017 WLAM HSPF model area to varying degrees (depending on storm intensity and coverage), an approach using a set precipitation threshold to identify stormflow events was not used. Instead, a visual approach was used. Storm events (days with recorded precipitation in August and September) for each of the 19 precipitation stations used in the model were identified. Model-calculated flow and TDS/TIN concentrations at Prado for these days (including several days after to allow for delayed stormflow effects) were then evaluated. If the model-calculated flow showed a significant increase and/or model-calculated TDS/TIN concentrations showed a significant decrease, these days were removed from the calculation of the Baseflow Average.

Table 6-11. Predictive Scenario Results – Santa Ana River below Prado Dam

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED STREAM CONCENTRATION					
					2020 Conditions			2040 Conditions		
					Scen A (Max)	Scen B (Avg)*	Scen C (Min)	Scen D (Max)	Scen E (Avg)*	Scen F (Min)
	[mg/L]	[mg/L]	[mg/L]		[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
TDS	700	na	na[1]	Baseflow Average[2] (Reach 3)	621	***733***	***774***	618	***730***	***761***
	650[3]	na	na[1]	5-year moving average of the 1-year volume-weighted average (Reach 2)	525	485	445	521	464	416
TIN	10.0	na	na[1]	Baseflow Average[2] (Reach 3)	7.05	5.95	5.34	6.99	6.25	5.28
	na	na	na[1]	5-year moving average of the 1-year volume-weighted average (Reach 2)	5.90	4.28	3.17	5.89	4.25	3.03
Average Annual Discharge [acre-ft/yr]					293,497	174,906	141,776	365,287	204,971	167, 381

Note: Bold red values represent concentrations above the basin objective.

[1] The Regional Board currently does not recognize the existence of assimilative capacity for TDS or TIN in surface water

[2] Represents baseflow conditions in August and September; storm-influenced data have been excluded

[3] 5-year moving average

*Represents most likely discharge conditions.

TDS and TIN concentrations in surface water flow at SAR below Prado Dam under Scenario A through Scenario F conditions are shown in Tables 24 and 25 and in the graphs provided in Appendix P. As shown, the maximum Baseflow Average TDS concentration for volume-weighted discharge exceeds the Reach 3 objective under Scenarios B, C, E, and F conditions, despite the majority of POTW discharges being below the 700 mg/L objective. Baseflow Average exceedances are likely caused by rising water. The influence of these higher TDS contributions are even more significant in August and September since there is no dilution from higher quality, low TDS stormwater. The 5-year moving average of the 1-year volume-weighted average TDS meets Reach 2 objectives. Baseflow Average maximum TIN concentrations also meet the Reach 3 water quality objective under all scenario conditions.

6.3.2 Santa Ana River at Santa Ana

Surface water flow and quality was also evaluated in the SAR at Santa Ana (Figure Q-1). Flow at this location is essentially streamflow and stormwater runoff that OCWD was unable to capture, divert, and recharge. For the SAR Reach 2, the 5-year moving average objective for TDS is 650 mg/L. There are currently no TIN objectives for Reach 2. The Regional Board does not currently recognize the existence of assimilative capacity for TDS or TIN in surface water.

Table 6-12. Predictive Scenario Results – Santa Ana River at Santa Ana

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED STREAM CONCENTRATION					
					2020 Conditions			2040 Conditions		
					Scen A (Max)	Scen B (Avg)*	Scen C (Min)	Scen D (Max)	Scen E (Avg)*	Scen F (Min)
	[mg/L]	[mg/L]	[mg/L]		[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]	[mg/L]
TDS	650[1]	na	na[2]	5-year moving average of the 1-year volume-weighted average (Reach 2)	331	197	146	395	161	135
TIN	na	na	na[2]	5-year moving average of the 1-year volume-weighted average (Reach 2)	2.80	1.29	0.94	3.33	1.33	1.14
Average Annual Discharge [acre-ft/yr]					96,586	50,296	46,586	143,011	62,413	53,233

[1] 5-year moving average
[2] The Regional Board currently does not recognize the existence of assimilative capacity for TDS or TIN in surface water
*Represents most likely discharge conditions.

TDS and TIN concentrations in surface water flow at SAR at Santa Ana under Scenario A through Scenario F conditions are shown in Tables 24 and 25 and in the graphs provided in Appendix Q. As shown, the 5-year moving average of the 1-year volume-weighted average TDS and TIN concentrations at Santa Ana do not exceed surface water TDS objectives in Reach 2 of the SAR.

6.4 Surface Water Diversion and Off-Channel Recharge

While the 2017 WLAM HSPF accounts for known stormwater and surface water diversions, recharge of this stormwater in off-channel spreading basins is not included in the calculation of the volume-weighted average TDS and TIN concentrations in recharge to each GMZ. Recharged stormwater is typically higher quality water that is low in TDS and TIN. Surface water diversion volumes and model-calculated concentrations for surface water recharge activities in the SBBA, Chino Basin, and Orange County are summarized in attached Tables 26, 27, and 28, respectively.

7.0 ESTIMATING OFF-CHANNEL RECHARGE FROM NATURAL PRECIPITATION

One of the objectives of developing the 2017 WLAM HSPF is to estimate off-channel recharge from natural precipitation (Task 5.0). Recharge from natural precipitation represents an HSPF model-calculated value that is affected by various factors including land cover, soil type, topography, and antecedent soil moisture. Off-channel recharge from precipitation is calculated by the 2017 WLAM HSPF, and previous WLAMs, during the process of calculating runoff from tributary areas[15]. This is just the first time that the Task Force has requested this information be presented. It is provided here to offer an indication of another source of high quality recharge not considered in the recharge estimates presented in Sections 6.0 (predictive model runs) and 8.0 (retrospective model run).

In HSPF, the hydrologic process of natural rainfall percolating into the underlying groundwater basin begins with precipitation supplying moisture to land segments and becoming available for runoff, interception (and ultimately evapotranspiration), and direct infiltration. As shown on Figure 12, percolation of off-channel recharge can occur through the direct infiltration of precipitation (precipitation → infiltration → deep percolation) or during the runoff process (runoff → upper zone storage/flow → percolation → deep percolation). Any overflow from interception storage becomes inflow to the surface detention storage. Surface detention storage is added to the existing storage and also becomes available for infiltration and runoff. Precipitation that infiltrates may become upper or lower zone storage (subject to evapotranspiration), active groundwater storage (also subject to evapotranspiration), or deep percolation. This deep percolation term calculated from pervious land segments represents the off-channel recharge from natural precipitation. Any percolation that occurs from runoff and interflow outflow making it to the stream reach is included in the model-calculated recharge values presented in Sections 6.0 and 8.0.

The model-calculated off-channel recharge from natural precipitation (deep percolation) and the associated TDS/TIN concentrations for each GMZ within the 2017 WLAM HSPF area are summarized in the following table and detailed in attached Table 29. Annual volumes of percolation from precipitation area also provided by GMZ in Appendix R. Please note that the model-calculated off-channel recharge from natural precipitation and associated TDS/TIN concentrations were only calculated for the geographic area within the 2017 WLAM HSPF model area shown on Figure 2. Therefore, the recharge shown for Orange County GMZ only represents a portion of the actual GMZ area. Concentrations of deep percolation of precipitation reflect water quality changes from transport and infiltration through the subsurface, including dry deposition (refer to Section 3.2.9.1).

[15] Off-channel recharge from precipitation is presented here for the calibration period (WY 2007-2016). Since this term is calculated by the HSPF model at the same time runoff and recharge from streambed percolation is calculated, the modeling assumptions are consistent with those used for model calibration (refer to Section 3.0).

Table 7-1. Average Annual Deep Percolation of Precipitation and Associated TDS/TIN Concentrations (Water Years 2007 through 2016)

GMZ	Deep Percolation [acre-ft/yr]	TDS Concentration [mg/L]	TIN Concentration [mg/L]
Bunker Hill-A[1]	4,741	221	2
Bunker Hill-B	8,795	223	2
Riverside-A	1,058	223	2
Chino-North[1]	5,705	224	2
Chino-South	582	222	2
Orange County[2]	4,814	219	2

[1]While not included in any of the 2017 WLAM HSPF calculations presented in Section 6.0, these GMZs represent areas within the model area with a significant amount of deep percolation from precipitation.

[2]Only calculated for the geographic area within the 2017 WLAM HSPF model area (see Figure 2), not the entire Orange County GMZ.

8.0 2017 WLAM HSPF RETROSPECTIVE RUN

The calibrated 2017 WLAM HSPF was also run using historical daily precipitation data and historical discharge data to estimate the volume and quality of water recharged to the Beaumont, San Timoteo, Bunker Hill-B, Colton, Riverside-A, Chino South, Upper Temescal Valley, Prado Basin, and Orange County Management Zones for the period from WY 2005 through 2016[16]. This run is referred to as the retrospective model run and is an indication of recharge that occurred based on reported precipitation, discharges, diversions, and model calibration to observed streamflow and water quality. Model input data for the retrospective model run are the same as those used for 2017 WLAM HSPF model calibration for the period from WY 2007 through 2016 (refer to Section 2.0) and were taken from the 2008 WLAM for the period from WY 2005 through 2006. Average POTW discharges during this time are summarized in Table 30. With the exception of WY 2005 through 2006, this run is very similar to the calibration step reported earlier in Section 4.0, but summarizes the data in a form similar to that reported for the predictive scenarios (Section 6.0).

For comparison purposes, graphs showing daily observed versus model-calculated TDS concentrations for the SAR below Prado Dam for the retrospective model run period (WY 2005 through 2016) are provided in Appendix S as Figures S-1 through S-12. As shown in the plots, the 2017 WLAM HSPF tends to overestimate TDS in spring. This is likely due to a deviation between the Prado Dam operating rules built into the 2017 WLAM HSPF and actual releases following the accumulation of stormflows behind the dam. The resolution of the model at this location may be able to be improved in future modeling efforts by refining operating rules based on repeatable, observed reservoir releases. It is unknown what is causing the periodic high spikes in TDS, but they may be due to temporary discharges not accounted for in the model or changes in rising water.

The results of this retrospective model run are summarized in the following sections for each GMZ. These results are also shown in comparison to the model-calculated projections from the 2020 scenario runs (Scenarios A through C; refer to Section 6.0) in Appendix S under the same hydrologic conditions. The 2020 scenario runs were made using the same land use conditions for which the 2017 WLAM HSPF was calibrated (2012 land use), thereby making these predictive scenarios more comparable than the 2040 scenarios. Stream reaches for which groundwater recharge in each GMZ was calculated for are consistent with those from the predictive scenarios (refer to Appendices G through Q).

[16] This period includes the wet winters of 2005 and 2011, but not the wet winter of 2016-2017.

8.1 Groundwater Recharge

8.1.1 Beaumont Groundwater Management Zone (Noble Creek and San Timoteo Creek Reach 4)

Table 8-1. Retrospective Model Run Results – Beaumont GMZ (Noble Creek and San Timoteo Creek Reach 4)

Constituent	Objective [mg/L]	Ambient [mg/L]	Assimilative Capacity [mg/L]	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE [mg/L]
TDS	330[1]/230[2]	280[3]	50[4]	1-year	276
				5-year	239
				10-year	221
				12-year	215
TIN	5.0[1]/1.5[2]	2.7[3]	2.3[4]	1-year	2.42
				5-year	1.70
				10-year	1.48
				12-year	1.44

[1] "Maximum benefit" objectives apply unless the Regional Board determines that lowering of water quality is not of maximum benefit to the people of the state

[2] "Antidegradation" objectives apply when the Regional Board determines that lowering of water quality is not of maximum benefit to the people of the state

[3] 2018 estimate of ambient water quality (WSC, 2020)

[4] Based on maximum benefit objectives

As shown in Tables 31 and 32 and in Appendix S (Figures S-13 and S-14 and Table S-15), the TDS and TIN concentrations under the retrospective run did not exceed the TDS or TIN maximum benefit objectives for Beaumont GMZ. The maximum 10-year volume-weighted TDS and TIN average was 221 mg/L and 1.5 mg/L, respectively. Over the 12-year retrospective simulation period (WY 2005 through 2016), Beaumont WWTP No. 1 had an average discharge of 2.5 MGD, which is lower than the projected discharge used for all predictive scenario runs (project discharge under Scenarios A through F ranged from 3.2 MGD to 6.3 MGD).

Higher 1-year volume-weighted TDS concentration in WY 2016 streambed recharge for the retrospective run, as compared to the majority of the predictive model scenario runs, is due to higher TDS concentrations observed from Beaumont WWTP discharge (average of 414 mg/L) than that modeled under Scenario A through F conditions (400 mg/L for initial 1.8 MGD of flow and 300 MGD for any additional flow; refer to Table 20). The 1-year volume-weighted TIN concentration is generally lower under historical conditions than scenario projections in most years given the lower discharge rate and lower TIN concentration of discharge (historical average TIN concentration of 4.16 mg/L versus a TIN concentration of 6 mg/L for the initial 1.8 MGD of flow followed by 3.6 mg/L for any additional flow under scenario conditions; refer to Table 20). During WY 2016, exceptionally high TIN values were observed in Beaumont WWTP discharge (from CIWQS – California Integrated Water Quality System), as shown in the following table. This resulted in a correspondingly higher TIN concentration for streambed recharge (see Figure S-14).

Table 8-2. Observed TIN Concentrations for Beaumont WWTP Discharge (WY 2016)

Sample Date	TIN, mg/L
10/5/2015	9.3
11/2/2015	13
12/7/2015	14
1/4/2016	12
2/2/2016	16
3/7/2016	8.7
4/4/2016	7.6
5/2/2016	11
6/6/2016	1.4
7/11/2016	1.4
8/2/2016	7.2
9/6/2016	4.2

Source of data: CIWQS

8.1.2 San Timoteo Groundwater Management Zone (San Timoteo Creek Reaches 2, 3, & 4)

Table 8-3. Retrospective Model Run Results – San Timoteo GMZ (Cooper's Creek and San Timoteo Creek Reaches 2, 3, & 4)

Constituent	Objective [mg/L]	Ambient [mg/L]	Assimilative Capacity [mg/L]	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE [mg/L]
TDS	400[1]/300[2]	420[3]	None	1-year	***446***
				5-year	***401***
				10-year	371
				12-year	352
TIN	5.0[1]/2.7[2]	1.5	3.5[4]	1-year	***6.09***
				5-year	***4.09***
				10-year	***3.45***
				12-year	***3.13***

Note: Bold black values represent concentrations above ambient groundwater quality, but below the maximum benefit objective. Bold red values represent concentrations above the basin objective.

[1] "Maximum benefit" objectives apply unless the Regional Board determines that lowering of water quality is not of maximum benefit to the people of the state

[2] "Antidegradation" objectives apply when the Regional Board determines that the lowering of water quality is not of maximum benefit to the people of the state

[3] 2018 estimate of ambient water quality (WSC, 2020)

[4] Based on maximum benefit objectives

As shown in Tables 31 and 32 and in Appendix S (Figures S-16 and S-17 and Table S-18), the maximum 10-year volume-weighted average TDS and TIN concentration under the Retrospective Mode did not exceed the TDS or TIN maximum benefit objectives for the San Timoteo GMZ. However, the maximum 1-year and 5-year volume-weighted average TDS concentrations and 1-year volume-weighted average TIN concentrations exceeded basin objectives. As with the predictive scenario runs, the 10-year running average is typically used to assess whether the approved waste load allocation is likely to assure compliance with the related water quality objectives. 5-year and 10-year volume-weighted average TIN concentrations also exceeded ambient concentrations. This represents "authorized degradation" in accordance with the maximum benefit demonstration previously authorized by the Regional Board. The maximum 10-year volume-weighted TDS and TIN average was 371 mg/L and 3.5 mg/L, respectively.

YVWD H.N. Wochholz WRF had an average discharge of 3.6 MGD during the 12-year retrospective run period from WY 2005 through 2016, which is similar to Scenario B most likely discharge of 3.8 MGD. The higher 1-year volume-weighted TDS concentrations in streambed recharge seen in the retrospective run is due to the higher TDS concentrations observed in Beaumont WWTP discharge (see Figure S-13 and Section 8.1.1). Volume-weighted annual TIN concentration in streambed recharge is largely affected by TIN concentrations from YVWD discharge. Exceptionally high TIN was observed in YVWD discharge during WY 2005, 2006, and 2008 (from 2008 WLAM and SAWPA database), as shown in the following table. In other years when observed TIN concentrations for YVWD discharge are lower than permit TIN concentrations used for the predictive scenarios, model-calculated TIN concentrations in streambed recharge for the retrospective run are lower than those projected under similar discharge conditions (Scenario B). The higher TIN concentration in streambed recharge for the retrospective run during WY 2016 is due to the higher observed TIN concentrations in discharge from the upgradient Beaumont WWTP No. 1 (see Figure S-14 and refer to Section 8.1.1).

Table 8-4. Observed TIN Concentrations for YVWD H.N. Wochholz WRP Discharge (WY 2005, 2006, and 2008)

Sample Date / Model Input Period	TIN, mg/L
Oct-04	9.6
Nov-04	6.9
Dec-04	11.8
Jan-05	14.65
Feb-05	14.08
Mar-05	13.26
Apr-05	9.65
May-05	11.35
Jun-05	12.44
Jul-05	8.45
Aug-05	9.36
Sep-05	10.33
Oct-05	8.63
Nov-05	8.63
Dec-05	8.63
Jan-06	16.85
Feb-06	16.25
Mar-06	18.88
Apr-06	15.93
May-06	17.56
Jun-06	16.38

Sample Date / Model Input Period	TIN, mg/L
Jul-06	15.73
Aug-06	16.98
Sep-06	19.35
1/3/2008	14.4
1/17/2008	16.3
1/30/2008	23.4
2/14/2008	23.8
2/28/2008	25.2
3/5/2008	26.7
3/13/2008	29
3/27/2008	26.3
4/3/2008	24.8
4/24/2008	27.2
5/8/2008	16
5/21/2008	19.7
6/5/2008	23
6/18/2008	13.5
7/2/2008	25.2
7/17/2008	26.1
7/31/2008	27
8/14/2008	8.4
8/28/2008	8.9
9/11/2008	3.5
9/25/2008	11.1

Source of monthly data prior to WY 2007: 2008 WLAM input (WEI, 2009)
Source of data after WY 2006: SAWPA database

It is important to note that while the data accurately represent historical water quality at YVWD, it is not representative of current TIN effluent concentrations. The treatment plant was upgraded and the discharge now complies with the more restrictive permit limit of 6.7 mg/L for TIN.

8.1.3 Bunker Hill-B Groundwater Management Zone (San Timoteo Creek Reach 1 and SAR Reach 5)

Table 8-5. Retrospective Model Run Results – Bunker Hill-B GMZ (San Timoteo Creek Reach 1 and SAR Reach 5)

Constituent	Objective [mg/L]	Ambient [mg/L]	Assimilative Capacity [mg/L]	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE [mg/L]
TDS	330	280[1]	50	1-year	262
				5-year	241
				10-year	224
				12-year	215
TIN	7.3	5.8[1]	1.5	1-year	2.41
				5-year	2.04
				10-year	1.91
				12-year	1.84

Note: Bold black values represent concentrations above ambient groundwater quality, but below the objective.
[1] 2018 estimate of ambient water quality (WSC, 2020)

As shown in Tables 31 and 32 and in Appendix S (Figures S-19 and S-20 and Table S-21), the TDS and TIN concentrations from the retrospective run did not exceed the TDS or TIN objectives for Bunker Hill-B GMZ. However, the maximum 1-year volume-weighted average TDS concentration exceeded the ambient concentration, but was below basin objectives. The maximum 10-year volume-weighted TDS and TIN average was 224 mg/L and 1.9 mg/L, respectively. Exceptionally high observed TIN concentrations in discharge from YVWD's H.N. Wochholz WRF (WY 2005, 2006, and 2008; see Section 8.1.2) and the Beaumont WWTP (WY 2016; see Section 8.1.1) are largely affecting streambed recharge in Bunker Hill-B GMZ. It is also important to note that the predictive scenarios include discharge assumptions for SNRC while the retrospective model run does not.

8.1.4 Colton Groundwater Management Zone (SAR Reach 4)

Table 8-6. Retrospective Model Run Results – Colton GMZ (SAR Reach 4)

Constituent	Objective [mg/L]	Ambient [mg/L]	Assimilative Capacity [mg/L]	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE [mg/L]
TDS	410	490[1]	none	1-year	265
				5-year	227
				10-year	224
				12-year	219
TIN	2.7	3.3[1]	none	1-year	1.92
				5-year	1.72
				10-year	1.62
				12-year	1.55

[1] 2018 estimate of ambient water quality (WSC, 2020)

As shown in Tables 31 and 32 and in Appendix S (Figures S-22 and S-23 and Table S-24), the TDS and TIN concentrations from the retrospective run did not exceed the TDS or TIN objectives for Colton GMZ. The maximum 10-year volume-weighted TDS and TIN average was 224 mg/L and 1.6 mg/L, respectively.

8.1.5 Riverside-A Groundwater Management Zone (SAR Reach 4)

Table 8-7. Retrospective Model Run Results – Riverside-A GMZ (SAR Reach 4[1])

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE
	[mg/L]	[mg/L]	[mg/L]		[mg/L]
TDS	560	430[2]	130	1-year	***465***
				5-year	426
				10-year	413
				12-year	398
TIN	6.2	5.7[2]	0.5	1-year	***5.92***
				5-year	5.12
				10-year	4.81
				12-year	4.51

Note: Bold black values represent concentrations above ambient groundwater quality, but below the objective.

[1] Due to rising water conditions, no streambed recharge occurs in SAR Reach 3 overlying Riverside-A GMZ.

[2] 2018 estimate of ambient water quality (WSC, 2020)

As shown in Tables 31 and 32 and in Appendix S (Figures S-25 and S-26 and Table S-27), the TDS and TIN concentrations for the Retrospective Mode did not exceed the TDS or TIN objectives for Riverside-A GMZ. However, the maximum 1-year volume-weighted average TDS and TIN concentrations exceeded ambient concentrations. The maximum 10-year volume-weighted TDS and TIN average was 413 mg/L and 4.8 mg/L, respectively.

8.1.6 Chino-South Groundwater Management Zone (SAR Reach 3)

Table 8-8. Retrospective Model Run Results – Chino-South GMZ (SAR Reach 3)

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE
	[mg/L]	[mg/L]	[mg/L]		[mg/L]
TDS	680	920[1]	none	1-year	598
				5-year	484
				10-year	408
				12-year	360
TIN	5.0[2]	27.6[1]	none	1-year	4.25
				5-year	2.80
				10-year	2.56
				12-year	2.31

[1] 2018 estimate of ambient water quality (WSC, 2020)

[2] On August 4, 2017, the California Regional Water Quality Control Board, Santa Ana Region, adopted Resolution No. R8-2017-0036 revising the water quality objective for nitrate as nitrogen from 4.2 mg/L to 5.0 mg/L in the Chino South Groundwater Management Zone. The State Water Resource Control Board approved the amendment under Resolution No. 2018-0004 on February 6, 2018. The new objective became effective when the Office of Administrative Law approved the Basin Plan amendment on July 2, 2018

As shown in Tables 31 and 32 and in Appendix S (Figures S-28 and S-29 and Table S-30), the TDS and TIN concentrations from the retrospective run did not exceed the TDS or TIN objectives for Chino-South GMZ. The maximum 10-year volume-weighted TDS and TIN average was 408 mg/L and 2.6 mg/L, respectively.

8.1.7 Upper Temescal Valley Groundwater Management Zone (Temescal Creek Reaches 2, 3, 4, 5 & 6)

Table 8-9. Retrospective Model Run Results – Upper Temescal Valley GMZ (Temescal Creek Reaches 2, 3, 4, 5 & 6)

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE
	[mg/L]	[mg/L]	[mg/L]		[mg/L]
TDS	820[1]	750[2]	70	1-year	648
				5-year	592
				10-year	542
				12-year	525
TIN	7.9[1]	4.7[2]	3.2	1-year	***5.60***
				5-year	4.24
				10-year	3.66
				12-year	3.40

[1] Proposed objective from June 2018 CEQA Scoping Meeting
[2] Based on SNMP for the Upper Temescal Valley (WEI, 2017)

As shown in Tables 31 and 32 and in Appendix S (Figures S-31 and S-32 and Table S-33), the TDS and TIN concentrations from the retrospective run did not exceed the TDS or TIN objectives for Upper Temescal Valley GMZ, though the maximum 1-year volume weighted TIN concentration exceeded ambient water quality. The maximum 10-year volume-weighted TDS and TIN average was 542 mg/L and 3.7 mg/L, respectively. Historical discharge from Temescal Valley WRF was generally lower than expected in Scenarios A through F with lower discharge TDS and TIN concentration – resulting in lower TDS and TIN concentrations in streambed recharge.

As discussed in Section 6.1.7, actual discharges from EMWD and EVMWD to Temescal Creek are extremely rare and typically persist for only a short period of time. This differs significantly from the assumptions used to model the maximum expected discharges (Scenario A) and explains much of the difference between the 1-year, 5-year, and 10-year values shown in Tables 31 and 32. In addition the drop-off in TDS and TIN concentrations seen in the retrospective model run (Figures S-31 and S-32) are in response to the reduction of discharge from EMWD Regional WRFs, which stopped discharging in 2014 (refer to Table 6-8).

8.1.8 Orange County Groundwater Management Zone (SAR Reach 2)

Table 8-10. Retrospective Model Run Results – Orange County GMZ (SAR Reach 2)

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE
	[mg/L]	[mg/L]	[mg/L]		[mg/L]
TDS	580	600[1]	none	1-year	***662***
				5-year	***632***
				10-year	575
				12-year	540
TIN	3.4	3.0[1]	0.4	1-year	***3.05***
				5-year	2.40
				10-year	2.22
				12-year	2.08

[1] 2018 estimate of ambient water quality (WSC,2020)
Note: Bold red values represent concentrations above the basin objective.

As shown in Tables 31 and 32 and in Appendix S (Figures S-34 and S-35 and Table S-36), the TIN concentrations from the retrospective run did not exceed objectives for Orange County GMZ but both the 1-year and 5-year maximum volume-weighted TDS concentrations exceeded objectives. The maximum 10-year volume-weighted TDS and TIN average was 575 mg/L and 2.2 mg/L, respectively. POTW discharges affecting the Orange County GMZ come largely from upgradient sources. High TDS concentration in recharge mostly come from streambed percolation between Imperial Dam and Five Coves Dam, as well as downstream of the Five Coves Inflatable Dam, as calculated by the RFM. Water quality in streambed percolation reflects that calculated at the Imperial Highway gage, since the model was calibrated to observed data at this location. It is also important to note that OC-59 water is included in the retrospective model run, since these discharges happened historically, but are not accounted for in the predictive scenarios.

8.2 Wetlands

8.2.1 Prado Basin Management Zone (SAR Reach 3)

Table 8-11. Retrospective Model Run Results – Prado Basin Management Zone (SAR Reach 3 above River Rd.)

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED RECHARGE
	[mg/L]	[mg/L]	[mg/L]		[mg/L]
TDS	na[1]	na[2]	none	1-year	600
				5-year	584
				10-year	575
				12-year	558
TIN	na[1]	na[2]	none	1-year	5.72
				5-year	5.10
				10-year	4.68
				12-year	4.54

[1] Prado Basin Management Zone does not have its own set of water quality objectives, although the objectives of the streams that flow into the Prado Basin Management Zone (presented in the Prado Basin Surface Water Management Zone Section of the 2016 Water Quality Control Plan (Basin Plan) for the Santa Ana River Basin, pg. 4-29) continue to apply. For the purposes of this investigation, no objectives were evaluated for Prado Basin Management Zone.
Note: SAR Reach 3 TDS/TIN objectives are identified in the Basin Plan as "baseflow" objectives. According to the 1983 Basin Plan, compliance with these objectives should be assessed without the influence of stormflow events. Model-calculated maximum volume-weighted concentrations in Table 8-11 do not represent baseflow conditions. Baseflow Average concentrations for Reach 3, without the influence of storm events, are presented in Section 8.3.1 for surface water flow at the Santa Ana River Below Prado Dam.

[2] No Prado Basin ambient TDS or Nitrate as Nitrogen was computed after 1997.

TDS and TIN concentrations from the retrospective model run are shown in Tables 31 and 32 and in Appendix S (Figures S-37 and S-38 and Table S-39) for Prado Basin Management Zone. The maximum 10-year volume-weighted TDS and TIN average was 575 mg/L and 4.7 mg/L, respectively. Overall, historical discharge from POTWs contributing to Prado Basin Management Zone is generally between the maximum expected discharge and most likely discharge, but with lower TDS and TIN concentration compared to expected scenarios.

8.3 Surface Water Flow

8.3.1 Santa Ana River below Prado Dam

Table 8-12. Retrospective Model Run Results – Santa Ana River below Prado Dam

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED STREAM CONCENTRATION
	[mg/L]	[mg/L]	[mg/L]		[mg/L]
TDS	700	na	na[1]	Baseflow Average[2] (Reach 3)	686
	650[3]	na	na[1]	5-year moving average of the 1-year volume-weighted average (Reach 2)	467
TIN	10.0	na	na[1]	Baseflow Average[2] (Reach 3)	5.32
	na	na	na[1]	5-year moving average of the 1-year volume-weighted average (Reach 2)	4.00

[1] The Regional Board currently does not recognize the existence of assimilative capacity for TDS or TIN in surface water

[2] Represents baseflow conditions during August and September; storm-influenced data have been excluded

[3] 5-year moving average

As shown in Tables 31 and 32 and in Appendix S (Figures S-40, S-41, S-45 and S-46, and Tables S-44 and S-49), the TDS and TIN concentrations from the retrospective run did not exceed the TDS or TIN objectives for SAR Reach 3 or Reach 2. However, there were multiple years between 2005 and 2016 when the SAR at Below Prado Dam historical observed TDS concentrations exceeded 700 mg/L. The 2017 WLAM HSPF was calibrated to all available data from WY 2007 through 2016 – not just August and September. The results of this calibration are provided in Section 4.0. Calibration residuals and the retrospective model run indicate that the model tends to underestimate TDS concentrations at Prado Dam in August and September. This is an aspect of the surface water model that should continue to be improved in future work.

As mentioned previously, the retrospective model run includes discharges from OC-59. These discharges are responsible for the decrease in TDS and TIN concentrations in 2006 and 2011 shown on Figures S-40 and S-41. At the request of the Task Force, a simplified comparison was made between the 2020 predictive scenarios and the retrospective model run without the influence of OC-59 water. For the purposes of the comparison, it was assumed that none of the OC-59 water was lost to streambed percolation, surface water diversion, or ET prior to reaching SAR below Prado Dam. The reported OC-59 flow and concentration (mass) was then removed from flow at SAR below Prado Dam to provide a general indication of conditions without OC-59 discharge. These results are presented on Figures S-42, S-43, S-47 and S-48, as well as on Tables S-44 and S-49. However, the assumption that none of the OC-59 water was lost before reaching below Prado Dam is likely inaccurate and leads to the underestimation of flow water quality at this location. In order to determine the actual difference between historical discharge conditions with and without OC-59 water is to run two separate model scenarios with and without the discharge. This was beyond the scope of the current study.

8.3.2 Santa Ana River at Santa Ana

Table 8-13. Retrospective Model Run Results – Santa Ana River at Santa Ana

Constituent	Objective	Ambient	Assimilative Capacity	Averaging Period	MAXIMUM VALUE FOR THE VOLUME-WEIGHTED STREAM CONCENTRATION
	[mg/L]	[mg/L]	[mg/L]		[mg/L]
TDS	650[1]	na	na[2]	5-year moving average of the 1-year volume-weighted average (Reach 2)	339
TIN	na	na	na[2]	5-year moving average of the 1-year volume-weighted average (Reach 2)	1.67

[1] 5-year moving average

[2] The Regional Board currently does not recognize the existence of assimilative capacity for TDS or TIN in surface water

As shown in Tables 31 and 32 and in Appendix S (Figures S-50 and S-51 and Table S-52), the 5-year moving average of the 1-year volume-weighted average TDS and TIN concentrations at Santa Ana did not exceed surface water objectives in Reach 2 of the SAR.

9.0 SOURCES OF UNCERTAINTY AND ERROR

The 2017 WLAM HSPF is a useful tool for evaluating streamflow and TDS/TIN concentrations in surface water. However, it is a simplified approximation of a complex hydrogeologic system and has been designed with certain built-in assumptions. HSPF watershed modeling has very extensive data requirements (Skahill, 2004). A reliable watershed model depends upon accurate and abundant sources of measured data and a satisfactory calibration period. Often, in absence of complete or accurate records, model input represents estimated and/or averaged values. Future use of an extended data set and calibration period should continue to improve the accuracy and reliability of the model.

Sources of uncertainty and areas of significant model limitation were found to be:

- Uncertainty in data from streamflow gages typically increases with decreased flow. At low flow rates, the water in the channel may not reach the gage due to gage detection limits (e.g., 0.1 cfs – 1.0 cfs) or flow by-passing the gage. Therefore, some of the variability between model-calculated and observed streamflow at low flow rates may be attributed to gage sensitivity and precision of gage detection limits. However, errors at this end of the range of flow have very little effect on actual recharges due to the minor amount of flow they represent.

- USGS gaged data is used to calibrate model-calculated streamflow. However, stream gage accuracy, as defined in the USGS Water-Year Summaries for each gaging station (refer to Table 2-3), varies each year. In many of the years, stream gage accuracy has been classified as "poor" – indicating that less than 95% of the daily discharge values are within 15% of the true value.

- Model-calculated flow downstream of Prado Dam is largely dependent on the results from the OCWD RFM, which simulates Prado Dam operations and OCWD diversions. However, actual releases from Prado may be different since the USACE does not always follow their own operating rules. This is especially true for wet years (e.g., Water Year 2011). There is no way for the surface water model to account for such deviations because they represent departures from the Standard Operating Procedures and, by definition, follow no predictable rule-based procedure. These deviations can lead to discrepancies between model-calculated and observed streamflow at the SAR at Santa Ana gaging station.

- Flow from the SAR is diverted to the Prado Wetlands using a sand dike. During high flow events associated with stormwater runoff conditions, this dike has been known to wash out and may not be rebuilt for several weeks. This is a detail that the 2017 WLAM HSPF is not able to take into account and it is assumed that this diversion structure remains in-place throughout all simulation conditions. However, this assumption does not alter the amount flow estimated to flow through

Prado Dam and has only a slight effect on water quality. This assumption may lead to a slight overestimation of TDS since, without the dike, there is less evaporative loss in the Prado Wetlands. TIN may also be underestimated because, without the dike diverting flows, the nitrogen loss that normally occurs in the wetlands will not happen. In addition, while washouts typically occur in the winter during high flow events, the dike is generally repaired before the baseflow reporting period (i.e., August and September), which poses the biggest challenge for regulatory compliance.

- Dry weather urban runoff from return flow and landscape irrigation is not explicitly accounted for in the 2017 WLAM HSPF. While there is a long-term declining trend in urban runoff due to water conservation efforts, the unaccounted for flow from this runoff may explain some of the discrepancy between model-calculated and observed values, particularly in dry weather, low flow conditions.

- Channel conditions are not constant. For example, significant channel improvements have been made to San Timoteo Creek during the model calibration period. These improvements have included lined channel sections, sediment control basins, earthen low-flow channels, and landscaping treatments (FEMA, 2007). Changes in streambeds can alter flow, detection limits of streamflow, and timing.

- IEUA's RP-2, which discharged into Chino Creek, was decommissioned in 2002. The loss of perennial flows likely altered subsequent streambed percolation rates in Chino Creek, which may contribute to some calibration discrepancies at this location.

- There are unavoidable discrepancies associated with delays between rainfall events and the arrival of runoff at a streamflow gage. In natural ephemeral stream systems, increased flow from a rainfall event may not appear at a downstream gage that same day. For this reason, model-calculated monthly streamflow typically shows better calibration performance than daily streamflow.

- Daily discharge and diversion values are not always available (e.g., Temescal Valley WRP discharge, OC-59 discharge, surface water diversions for off-channel recharge). Daily discharge and diversions at locations for which only monthly data are available was therefore assumed to be constant throughout the month. This modeling assumption may also contribute to some of the discrepancy between model-calculated and observed daily streamflow.

- In the real world, the amount of rising water is largely dependent on underlying groundwater levels, which vary through time based on hydrology and basin management. Since HSPF and other watershed models are limited in the fact that they are not able to simulate the interaction between groundwater and surface water, rising water – which affects the amount of model-calculated streambed percolation – represents a source of uncertainty. The modeling of rising water in future WLAM updates can be facilitated by using an integrated surface and groundwater model, which will be able to simulate changes in rising water caused by groundwater level fluctuations. Additional studies to verify or refine estimates of rising water can also help reduce uncertainty.

- The 2017 WLAM HSPF does not account for streamflow diversions by SBCFCD in the SBBA since no spreading data were available. This is something that should be considered in future updates to the WLAM.

- Nitrogen loss coefficients to account for additional nitrogen loss as surface water percolates into the ground are currently based on the coefficients outlined in the 2004 Basin Plan. The nitrogen loss coefficient used by the 2017 WLAM HSPF was 25% throughout the model area, except for Reach 3 of the SAR overlying the Chino South GMZ (nitrogen loss here is assumed to be 50% due to the wetlands in this area). Nitrogen loss may also be higher in the Riverside-A GMZ, which has significant riparian vegetation areas. A reassessment of the coefficient in this area through a nitrogen loss study may improve the accuracy of model-calculated TIN concentrations along this reach of the SAR, which currently oscillate around the basin objective.

  However, it is worth noting that the 25% nitrogen loss assumption was deliberately designed to be conservative and is not intended to be an accurate estimate of the site-specific nitrogen losses that occur in the various streambeds. Consequently, using this conservative assumption also creates something of a safety factor for the estimated TIN concentrations associated with streambed recharge.

10.0 SUMMARY

The 2017 WLAM HSPF for the SAR watershed was constructed and calibrated to provide an updated tool for predicting future conditions. The 2017 WLAM HSPF uses the HSPF computer code and includes an expanded area over the 2008 WLAM model boundary to incorporate additional reaches of the SAR within Orange County. HSPF is a publicly available, federally-supported software system capable of simulating all water cycle and water quality components with small time steps (i.e., less than one day).

The 2017 WLAM HSPF was constructed using recent data and calibrated from October 1, 2006 through September 30, 2016 (WY 2007 through 2016). Streamflow data from nine gaging stations and TDS/TIN measurements from three gaging stations were used for model calibration. The calibration results show:

- Similar temporal dynamics in model-simulated and measured daily and monthly streamflow and TDS/TIN concentrations.
- Good to very good performance at the majority of the streamflow gages from WY 2006 through WY 2016.
- The calibration performance of the 2017 WLAM HSPF is equal to or better than that of the 2008 WLAM at nearly all gages.
- TDS/TIN residuals from the 2017 WLAM HSPF calibration are lower than the 2008 WLAM residuals for nearly all gages.
- The results indicate a satisfactory model calibration.

The calibrated 2017 WLAM HSPF was used to run predictive scenarios to evaluate water quality in major stream segments for maximum, most likely (average), and minimum expected discharges under 2020 and 2040 conditions. The scenario runs covered the 67-year hydrologic period from October 1949 (WY 1950) through September 2016 (WY 2016). Flow-weighted average TDS and TIN concentrations were evaluated over various time periods, including 1-year, 5-year, 10-year, 20-year, and 67-year. Each of these time periods is useful for evaluating possible compliance, depending on the planning objective. The 10-year averaging period is particularly useful for identifying possible future compliance issues because it represents a period of time that is typically long enough to cover one meteorological cycle (i.e., contains both wet and dry periods).

In general, the predictive model scenarios show:

- TDS and TIN concentrations under Scenario A through Scenario F conditions do not exceed the TDS or TIN objectives or ambient groundwater quality for the Beaumont GMZ (maximum benefit), Chino-South GMZ, and Prado Basin Management Zone above River Rd.
- In the San Timoteo GMZ, TDS concentrations under Scenario A through Scenario F conditions do not exceed maximum benefit objectives. However, water recharged in the San Timoteo GMZ from Cooper's Creek and San Timoteo Creek Reaches 2, 3, and 4 causes TIN concentrations to rise above ambient groundwater concentrations, but below basin objectives.
- TIN concentrations under Scenario A through Scenario F conditions do not exceed the TIN objectives or ambient for Bunker Hill-B GMZ. However, the maximum 1-year volume-weighted average TDS concentration under Scenarios A and D (maximum expected discharge for 2020 and 2040), and Scenarios B and E (most-likely discharge for 2020 and 2040) exceeds ambient TDS concentrations. The 5-year and 10-year volume-weighted averages under Scenario A conditions also exceed the ambient TDS concentration.
- The TDS concentrations under Scenario A through Scenario F conditions do not exceed the TDS objectives for Colton GMZ. However, TIN concentrations exceed TIN objectives under Scenario A, Scenario D, and Scenario E conditions.
- In the Riverside-A GMZ, TDS concentrations under Scenario A through Scenario F conditions do not exceed the TDS objectives, though most rise above current ambient. However, all of the maximum 1-year volume-weighted average TIN concentrations exceed TIN objectives, along with the maximum 5-year and 10-year concentrations under maximum expected discharge conditions (Scenarios A and D) and 20-year concentration under Scenario A conditions.
- TDS and TIN concentrations under Scenario A through Scenario F conditions do not exceed the proposed TDS or TIN objectives for Upper Temescal Valley GMZ. However, TIN concentrations rise above ambient groundwater concentrations, but below proposed objectives, under maximum and most likely discharge conditions (Scenarios A, B, D and E) as well as the 1-year maximum concentration under Scenarios C and F conditions and 5-year concentration under Scenario C conditions.
- All of the maximum volume-weighted average TDS concentrations in Orange County exceed TDS objectives, with the exception of the maximum 5-year, 10-year and 20-year concentrations under maximum expected discharge conditions (Scenarios A and D). Maximum 1-year volume-weighted TIN concentrations exceed TIN objectives under Scenario A (1-year and 5-year) and D (1-year) conditions and rise above the ambient but below the objective in Scenarios A (10-year and 20-year), B (1-year), D (5-year, 10-year, and 20-year), and E (1-year and 5-year).

- In the SAR below Prado Dam, the maximum Baseflow TDS concentration for volume-weighted discharge exceeds the Reach 3 objective under Scenarios B, C, E, and F conditions. Baseflow Average maximum TIN concentrations meet the Reach 3 water quality objective under all scenario conditions.
- The 5-year moving average of the 1-year volume-weighted average TDS and TIN concentrations at Santa Ana do not exceed surface water objectives in Reach 2 of the SAR.

The calibrated 2017 WLAM HSPF was also used to estimate off-channel recharge from natural precipitation and estimate the volume and quality of water recharged to the Beaumont, San Timoteo, Bunker Hill-B, Colton, Riverside-A, Chino South, Upper Temescal Valley, Prado Basin, and Orange County GMZs for the period from WY 2005 through 2016. The 2017 WLAM HSPF is a useful tool for evaluating streamflow and TDS/TIN concentrations in surface water. However, it is a simplified approximation of a complex hydrogeologic system and has been designed with certain built-in assumptions. Modeling results should be considered in light of these assumptions.

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