Modeling Analysis for Development of TMDLs for Metals in the Los Angeles River and Tributaries

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Los Angeles Regional Water Quality Control Board
United States Environmental Protection Agency – Region 9

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1: INTRODUCTION

The State of California is required to develop Total Maximum Daily Loads (TMDLs) for waters not meeting water quality standards, in accordance with Section 303(d) of the Clean Water Act and the U. S. Environmental Protection Agency (EPA) Water Quality Planning and Management Regulations (40 CFR Part 130). Several segments of the Los Angeles (LA) River and its tributaries were included on the State Water Resources Control Board's 303(d) list of impaired waters in California for a variety of pollutants. A Consent Decree established a schedule of development for TMDLs in the LA Region and grouped the 700 waterbody-pollutant combinations into 92 analytical units for TMDL development. The TMDLs developed for LA River and its tributaries represent Analytical Unit 11 of the Consent Decree, which consists of segments impaired by metals, specifically copper, lead, zinc, cadmium, nickel, aluminum, selenium. TMDLs established to address these impairments are presented in LARWQCB (2004).

This report is a supporting technical document for the TMDLs and describes the development of a system of models used to assess metals impairments within the LA River and its tributaries under low-flow conditions. Specifically, these models were developed to assess instream concentrations and sources of copper, lead, and zinc. Additionally, this document outlines the assumptions used in the model development and application for the LA River. The work presented herein was performed in cooperation with EPA Region 9, the Southern California Coastal Water Research Project (SCCWRP), the Los Angeles Regional Water Quality Control Board (LARWQCB), the City of Los Angeles, the Los Angeles County Department of Public Works (LACDPW), and the Los Angeles and San Gabriel Rivers Watershed Council.

1.1 Study Area Description

The 55-mile LA River flows from the Santa Monica Mountains at the western end of the San Fernando Valley to the Pacific Ocean. The headwaters of the LA River are located in the Santa Monica Mountains at the confluence of Arroyo Calabasas and Bell Creek. Arroyo Calabasas drains Woodland Hills Calabasas, and Hidden Hills in the Santa Monica Mountains. Bell Creek drains the Simi Hills, and receives discharges from Chatsworth Creek. From the confluence of Arroyo Calabasas and Bell Creek, the LA River flows east through the southern portion of the San Fernando Valley, a heavily developed residential and commercial area. Major tributaries to the river in the San Fernando Valley are the Pacoima Wash, Tujunga Wash (both drain portions of the Angeles National Forest in the San Gabriel Mountains), Burbank Western Channel, and Verdugo Wash (both drain the Verdugo Mountains). The LA River turns in an area known as the Glendale Narrows and flows south for approximately 25 miles through industrial and commercial areas and is bordered by railyards, freeways, and major commercial and government buildings. Below the Glendale Narrows, three major tributaries feed the LA River—Arroyo Seco Wash, Rio Hondo, and Compton Creek. The river discharges to the Pacific Ocean at Queensway Bay, a portion of San Pedro Bay in Long Beach. Figure 1-1 shows the LA River watershed in relation to neighboring counties and the State of California.

Due to major flood events at the beginning of the century, most of LA River was lined with concrete by the 1950s. In the San Fernando Valley, there is a section of the river with a soft bottom at the Sepulveda Flood Control Basin, a 2,150-acre open space upstream of the Sepulveda Dam that is designed to collect flood waters during major storms. In the area around the Glendale Narrows, the water table was too high to allow laying of concrete; the river in this area has a rocky, unlined bottom with concrete-lined or rip-rap sides. This stretch of the river is fed by natural springs and supports stands of willows, sycamores, and cottonwoods. South of the Glendale Narrows, the river is contained in a concrete-lined channel down to Willow Street in Long Beach.

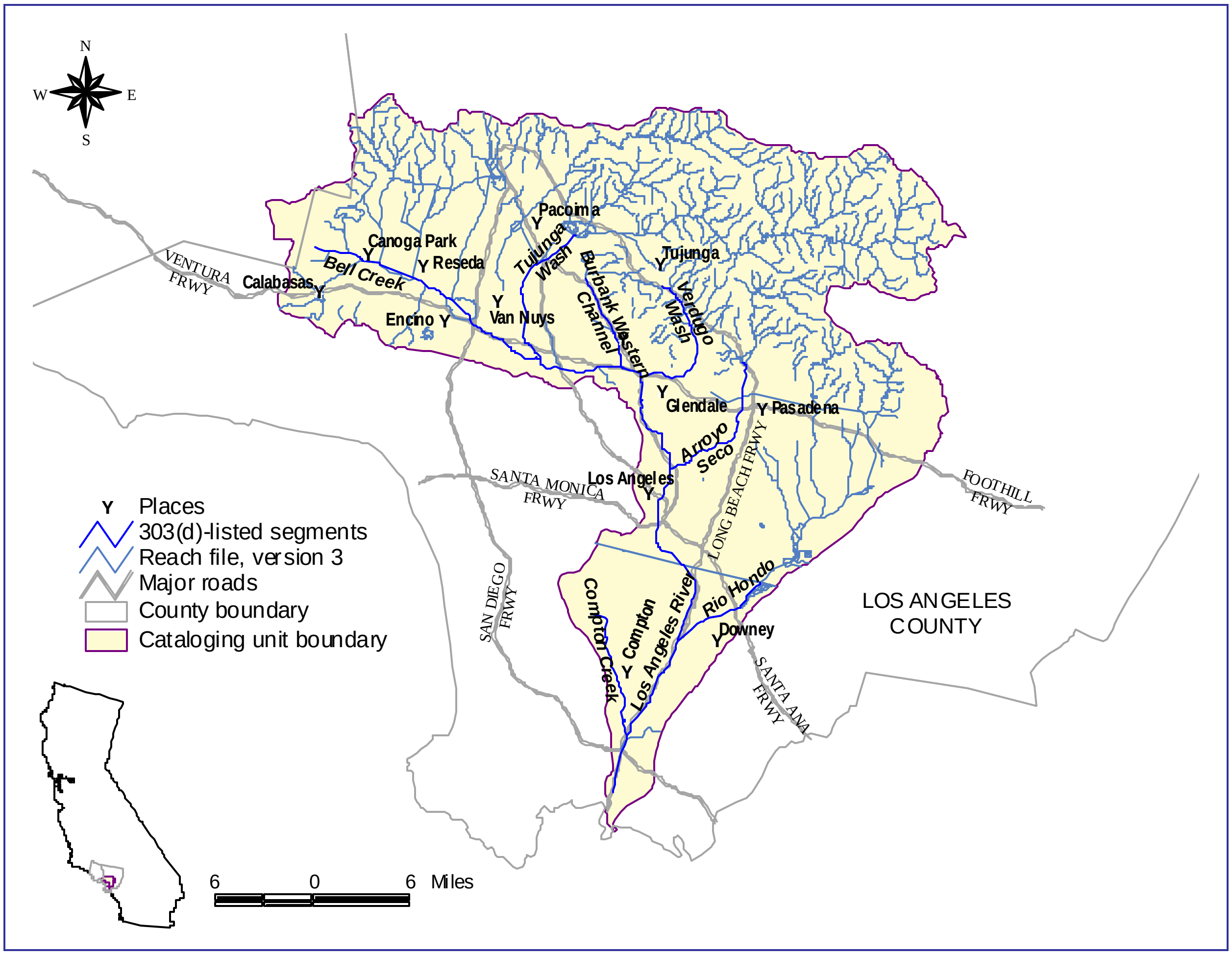


Figure 1-1. Los Angeles River Basin

The Rio Hondo, through the Whittier Narrows Reservoir, hydraulically connects the river to the San Gabriel River Watershed. Flows from the San Gabriel River and Rio Hondo merge at this reservoir during larger flood events, and flows from the San Gabriel River watershed may impact the LA River. Most of the water in the Rio Hondo is used for groundwater recharge during dry weather.

The LA River watershed is one of the largest in the region, covering 819 square miles (mi^2). It is also one of the most diverse in terms of land use patterns. Figure 1-2 and Table 1-1 present the landuse distribution throughout the LA River watershed, based on 1994 data from the Los Angeles County Department of Public Works (LACDPW). Seven general landuse categories were used for the purposes of characterizing the watershed. Approximately 364 mi^2 of the watershed are covered by forest and open space mostly concentrated at the headwaters in the Santa Monica, Santa Susana, and San Gabriel Mountains. The remainder of the watershed is highly developed. Landuse patterns within the LA River Watershed closely follow the topographic features. The mountainous regions are primarily open forested land while the low-lying areas are a mixture of high-density residential, industrial and commercial uses.

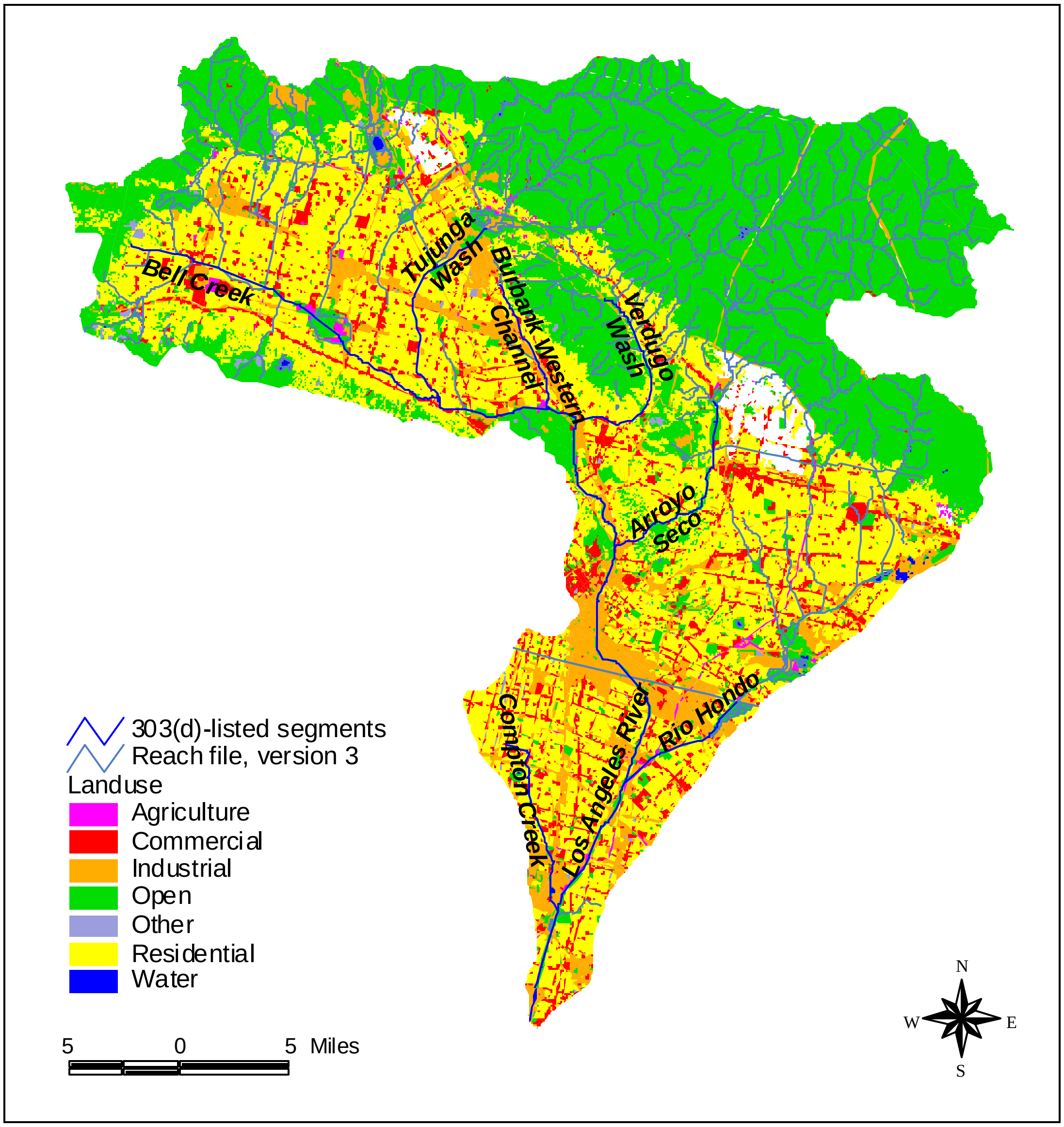


Figure 1-2. Landuse Distribution in the LA River Watershed

Table 1-1. Landuse Areas in the LA River Watershed

Landuse	Area (acres)	Area (mi^2)	Percentage of Total
Open	232,832	363.80	43.60%
Residential	189,645	296.32	35.51%
Industrial	55,377	86.53	10.37%
Commercial	39,878	62.31	7.47%
Agricultural	3,817	5.96	0.71%
Other	1,654	2.58	0.31%
Water	1,069	1.67	0.20%
Total Area	524,272	819.18	100.00%

The LA River has two distinct flow conditions as a result of the prevailing rainfall patters in the region. Typically the high-flow (or wet weather) conditions occur between October and March, while the low-flow (or dry weather) conditions occur from April through September. The wet weather periods are marked by events where flows in the river and tributaries rise and fall rapidly, reaching flow levels on the order of thousands of cubic feet per second (cfs). Flows during the wet weather periods are generated by storm runoff in the watershed. Stormwater runoff in the sewered urban areas of the watershed is carried to the river through a system of approximately 5,000 miles of stormdrains. During times of higher flow, stormwater runoff delivers nutrients from nonpoint sources in the watershed. The stormwater also increases the volume of water in the river, creating a larger capacity for assimilating pollutant loads.

In between rainfall events and during low-flow periods, the flows are significantly lower and less variable. The predominant contribution to instream flow comes from the primary point source discharges to the system. The predominant contribution of metals varies from point and non-point sources depending on the conditions. Discharges from the three major point sources (water reclamation plants) can comprise up to 80 to 100 percent of the flow in the LA River and 40 to 80 percent of the metals load.

1.2 Purpose and Outline of Report

This report presents the supporting modeling efforts used to assess water quality impairments in the LA River resulting from sources of metals, specifically copper, lead and zinc. This report presents the model development and application process for the LA River and includes the following sections:

- Section 2 discusses the selection process used in developing the analytical approach and provides descriptions of the selected models and their applicability to the LA River modeling evaluation.
- Section 3 discusses the model application to the LA River, including model calibration, validation and comparison.
- Appendices are included with supporting information and data.

2: TECHNICAL MODELING APPROACH

When selecting an appropriate technical approach for a water quality study, it is important to identify and understand the defining characteristics of the waterbody system, the goals and planned uses of the modeling system, and any unique aspects of the waterbody or impairment that will guide the approach. A technical committee comprised of representatives from various agencies coordinated the selection of an appropriate modeling approach for addressing the metals impairments in the LA River and tributaries, as well as supporting monitoring. This committee included representatives from EPA Region 9, LARWQCB, SCCWRP, the City of Los Angeles, LACDPW, and the Los Angeles and San Gabriel Rivers Watershed Council.

The following sections present the information that led to the selection of the technical approach and descriptions of the chosen models and their applicability to the evaluation of the LA River.

2.1 Guiding Assumptions

The LA River is a complex and unique system with many concrete-lined channels and distinct hydrologic behavior and responses, some of the major characteristics that define the evaluation of metals effects in the river were identified prior to model selection. The following "guiding assumptions" represent factors that shaped the model selection and development for the LA River TMDLs for copper, lead and zinc.

- The approach for TMDLs should evaluate the entire watershed, rather than take a reach-by-reach approach. Since many of the listed segments affect the conditions of downstream listed segments, it is important to be able to evaluate the relationship between the segments.

- The LA River should be simulated as a waterbody with all the potential riverine features, including hydrologic/hydraulic transport, drainage, and chemical and biological activity.

- The modeling approach for the LA River should be consistent in design with other models developed for the LA River (i.e., nutrients and bacteria). In addition, to provide consistency throughout the region, it is anticipated that the LA River approach will also be used to develop other TMDLs in the region (e.g., San Gabriel River TMDLs).

- The LA River experiences two distinct flow conditions associated with wet and dry weather. Although this modeling study focuses on low-flow conditions, future applications may also evaluate high-flow conditions. The model should be able to simulate the range of conditions occurring under low flows and under high flow conditions.

- The LA River modeling approach may be expanded in the future for TMDLs in downstream San Pedro Bay. Therefore, the chosen model should be capable of simulating estuaries or should allow for linkage or incorporation of another appropriate model or approach for addressing tidal systems.

2.2 Model Selection

Based on review of the guiding principles and the waterbody and metals related impairments, a list of selection criteria were identified the LA River application. The selection criteria define the specific model characteristics required to address the parameters set forth in the guiding assumptions and local conditions. As shown in Table 2-1, the selected model or series of models should be capable of simulating the hydrology and the water quality of the river system and should be capable of addressing the influential characteristics or aspects of the waterbody system. The model capabilities should be relevant to water quality issues of concern and the watershed and waterbody characteristics (e.g., nonpoint and point source inputs, low flows, etc.). The hydrodynamic model should also be easily linked with a water quality model.

The modeling criteria and types of models were evaluated against available models and recent applications of models for TMDL development. Model selection also considered access to models, model distribution and support, and acceptance by EPA in similar TMDL applications. Based on the review a suite of models requiring minimal modifications were selected for the LA River application.

The 1-dimensional version of the hydrodynamic model Environmental Fluid Dynamics Code (EFDC) linked with the Water Quality Analysis Simulation Program (WASP) water quality model were selected for the LA River application. These models, both in the public domain and with a track record of TMDL applications, met most of the identified model selection criteria. The WASP model was modified slightly to meet the criteria for simulation of multiple individual point sources. The following sections describe in more detail the models chosen for application in the LA River system, including why the models are the most appropriate for the analysis. Supplemental monitoring needs for application of the selected models were identified as well.

Table 2-1. Criteria for Model Selection for the LA River Model Application

Model Type	Characteristics/Capabilities
Hydrodynamic	• Simulation of hydrology in tributaries and mainstem • Low flow or constant flow conditions • Variable flow (future applications) • Physical channel features (dams, weirs) • Incorporate point source inputs at specific locations • Ability to link to water quality model
Water Quality	• Simulate Metals as either conservative substance or with a 1st order decay • Nutrient cycle • Eutrophication processes • Algal growth • Benthic algae • Low flow or constant flow conditions • Variable flow (future applications) • Incorporate point source inputs at specific locations • Capability to simulate fecal coliforms (future applications) • Ability to link to watershed loading models (future applications)

2.2.1 Hydrodynamic Model — EFDC

EFDC is a general purpose modeling package for simulating 1-D, 2-D, and 3-D flow and transport in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and near shore to shelf-scale coastal regions. The EFDC model was originally developed at the Virginia Institute of Marine Science for estuarine and coastal applications, has been extensively tested and documented, and is considered public domain software.

In EFDC, a 1-dimensional variable cross-section sub-model solves the 1-D continuity, momentum, and transport equations within a variable cross-section framework. The 1-D sub-model uses the efficient numerical solution routines within the more general 2-D/3-D EFDC hydrodynamic model as well as the transport and meteorological forcing functions. Specific details on the model equations, solution techniques and assumptions can be found in Hamrick (1996).

The 1-D version of EFDC was used to simulate hydrodynamics in LA River and its tributaries. The 1-D version of EFDC was appropriate for use in the LA River analysis (as opposed to the 2-D or 3-D) because the evaluation focused on longitudinal changes in water quality conditions and data were not available to support use of the 2-D or 3-D versions of the model. The nature of the 1-D EFDC model as an extension of the more general 2-D/3-D model also provides the potential for direct linkage to future applications in the receiving waters at the confluence of the LA River with San Pedro Bay.

The use of variable cross-sections in EFDC makes it possible to use data available for the LA River channels to better define the channel and provide finer distinctions among channel segments, including areas of unlined channel and concrete channels. Because of the variable cross-section features, EFDC has the ability to account for the spreading grounds and the low-flow channels in the LA River system. The ability to incorporate the spreading grounds in the system is important for the application of the model to future TMDLs considering wet weather conditions.

2.2.2 Water Quality Model — WASP5

EPA's Water Quality Analysis Simulation Program (WASP5) is an enhancement of the original WASP model (Di Toro et al., 1983; Connolly and Winfield, 1984; Ambrose, R.B. et al., 1988), which is a dynamic compartment model program for assessing aquatic systems, including both the water column and the underlying benthos. The time-varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange are represented in the basic program. Water quality processes are represented in special kinetic subroutines that are either chosen from a library or written by the user. WASP is structured to permit easy substitution of kinetic subroutines into the overall package to form problem-specific models. WASP5 permits the modeler to structure one, two, and three-dimensional models, allows the specification of time-variable exchange coefficients, advective flows, waste loads and water quality boundary conditions, and permits tailored structuring of the kinetic processes, all within the larger modeling framework without having to write or rewrite large sections of computer code.

WASP was chosen for use in the modeling analysis of LA River because it can simulate all of the parameters of concern and it is easily linked with EFDC output. WASP also allowed for the simulation of metals as either a conservation substance (meaning no loss of mass) or with a 1st order decay coefficient. For the LA River application, metals were modeled as a conservative substance. This is an appropriate assumption for this system since the travel times are very fast, thereby not allowing the metals to either decay or go through speciation.

2.2.3 Modifications to WASP

To accurately address the unique conditions in the LA River and its listed tributaries, the original WASP5 computer code was modified to allow input of more than one load into a single segment. The original WASP code limits the user to input only one load into any one segment. To input more than one load into a segment, these loads would be added together and the single combined load would have been used as input into the model. For most modeling applications this is sufficient. However, for the LA River and its listed tributaries, WASP was modified to input the loads separately, providing an efficient way to clearly identify and track each load input into the model.

2.3 Supplemental Monitoring

This modeling study focuses on the critical low-flow period for metals loading to the LA River system when point sources provide the majority of the instream flow. During low-flow conditions, the three major WWRPs comprise 60 to 80 percent of the river's flow and approximately 40 to 80 percent of the metals loading. In addition to the major WWRPs, other dry-weather sources that deliver flow and metals to the LA River system include stormdrain discharges (e.g., dry weather runoff from residential and commercial water use) and tributaries.

To evaluate the loading and transport of metals in the LA River system it is necessary to characterize and account for each of the sources in the model. However, data were not available to appropriately characterize all of the sources. Previously collected data focused on larger segments of the mainstem and on the major point sources. Flow and water quality data were readily available for the point sources and were used for model input for the WWRPs. However, available data did not provide the information necessary to define the smaller inputs to the system. To better characterize the sources influencing flow and water quality in the LA River system, SCCWRP conducted intensive monitoring in the watershed in September 2000 and July 2001 during periods representative of typical low-flow conditions. The first monitoring event was conducted on September 10 and 11, 2000, and the second was conducted on July 29 and 30, 2001. The datasets collected represent snapshots of the flow distribution and water quality conditions throughout the LA River system.

Data collected by SCCWRP included measurements of flow and water quality at the following locations:

- LA County Department of Public Works (LACDPW) monitoring stations
- Mainstem and tributary headwaters
- Confluence of tributaries and the mainstem LA River (2001 only)
- Dry-weather stormwater inputs on the mainstem LA River (33 locations in 2000; 69 locations in 2001)
- Dry-weather stormwater inputs on the 303(d)-listed tributaries (15 locations in 2000; no locations in 2001)

Data were collected by SCCWRP for use as model input as well as for comparison to model results during calibration and validation. Flow and water quality measurements collected at tributary stations (headwater or confluence stations) during the intensive monitoring efforts were used as model input to represent the tributary discharges into the LA River mainstem. Flow and water quality data were also collected for identified dry-weather stormwater flows during the September 2000 and July 2001 monitoring and used as model input to represent the dry-weather discharges from stormdrains.

In addition to data used as input to the model, SCCWRP collected data to provide instream flow and water quality measurements to compare with model results during model calibration, validation and comparison. During the summer of 2000, SCCWRP performed three dye studies in the LA River mainstem to collect data to use in calibrating the hydrodynamic model for velocity. Flow and water quality measurements collected at LACDPW mainstem stations during September 2000 were used for model calibration while data collected during the July 2001 monitoring efforts were used for model validation. For all of the stations, triplicate composite samples were collected at each location to provide a measure of the system variability for water quality calibration. The following parameters were collected and simulated in the WASP water quality model:

- Total Copper
- Total Lead
- Total Zinc

The use of the data for model calibration, validation and comparison is discussed in the following sections.

3: MODEL DEVELOPMENT FOR THE LOS ANGELES RIVER

The selected models were applied to the LA River system according to a standard modeling strategy. The following steps were executed in the development of the model.

- Model configuration and identification of application conditions, including model linkages, simulation period, model boundaries and all model inputs.
- Sensitivity analysis.
- Hydrodynamic calibration and validation.
- Water quality comparison.

These sequential steps were designed to build the modeling system and provide testing and evaluation of model performance at each step. The initial configuration stage defines the essential structure of the modeling network. This is where the river is divided into "segments," or units for analysis, and the locations of all the various inputs are defined. During this step the various input data are compiled and the time periods for analysis are defined. Next the hydrodynamic portion of the analysis is performed. The hydrodynamic application is first "calibrated," by using the best available information and adjusting parameters within reasonable range to achieve the best fit with the observed data. Next, the hydrodynamic application is "validated" by testing the input file (without adjustment) with another time period. Once the hydrodynamic validation is complete, the calibration/validation process is performed for the water quality simulation. A supplemental sensitivity analysis can also be used to explore or evaluate the response of the model to changes in selected parameters. The sensitivity analysis can be used to test and evaluate options in the setup or configuration of the model. This sequence of application and testing is used to build a modeling system that is representative of local conditions and able to evaluate the various management scenarios.

The above steps describe the typical model development for a hydrodynamic and water quality model. For the LA River system, a water quality calibration and validation were not performed. Instead, the water quality model results were simply compared to the observed data. This was done as not enough data were collected to perform a complete metals speciation model. Therefore, each metal constituent was modeled as a conservative substance, limiting the ability to vary model parameters through a calibration/validation exercise. Modeling metals as conservative substances is a valid assumption as the travel times in the LA River system are fast (under 2 days), and each metal would have limited time to experience speciation. The following sections describe each of the key steps in the model development process.

3.1 Model Configuration and Application Conditions

The following subsections describe the model set-up for the LA River system, including model linkages, simulation period, model boundaries, and model input parameters.

3.1.1 Model Linkages

The 1-D EFDC model was utilized to simulate the flow and transport within the LA River under dry weather conditions. Metals were simulated as a conservative substance (zero order decay) using the WASP5 model system. The EFDC model was externally linked to the WASP model through a hydrodynamic forcing file that contains the flows, volumes, and exchange coefficients between adjacent cells. The EFDC model takes the user-defined flow inputs (e.g., point source discharges, dry-weather stormdrain discharges, etc.) and develops in-stream flows and transport that are passed to the WASP5 model through a hydrodynamic linkage file. The WASP water quality model then runs on a similar time step with the same grid network layout. Figure 3-1 presents a schematic of the instream model network used throughout this study, with the reaches shown corresponding to the listed segments within the LA River watershed.

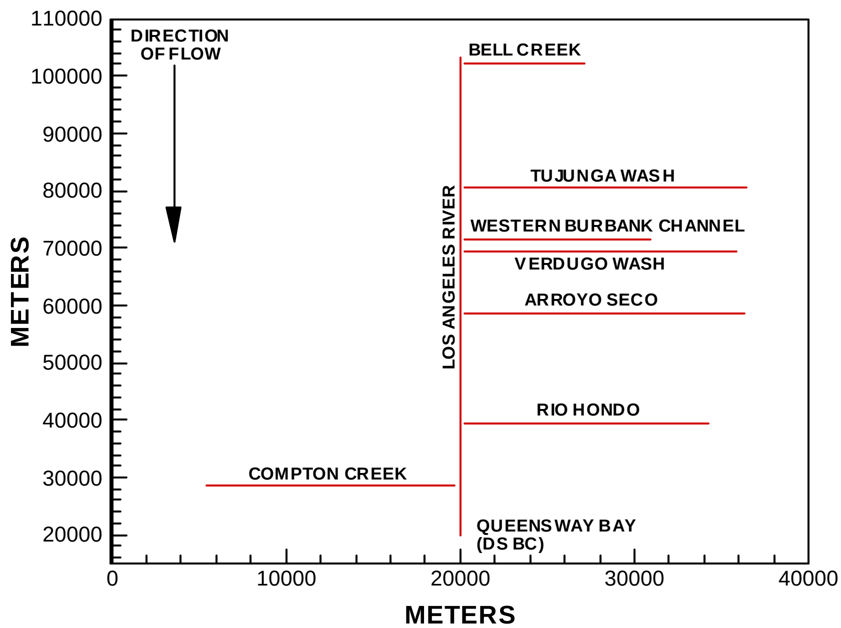


Figure 3-1. Schematic Representation of EFDC 1-D Model Grid

3.1.2 Simulation Period

Selection of the model simulation periods was based on the low-flow period (April to September). Because data were limited to characterize tributary and dry-weather inflows under low-flow conditions, SCCWRP conducted two intensive monitoring efforts throughout the watershed to better understand these “unmeasured” inflows.

Simulation periods for hydrodynamic model calibration and validation, and the water quality model comparison, correspond to the dates of the two monitoring efforts. Hydrodynamic model calibration was performed for September 10 and 11, 2000, and model validation was performed for July 29 and 30, 2001. Water quality comparisons were performed during each time period.

3.1.3 Downstream Boundary

The downstream boundary used for the hydrodynamic simulations was the tidal signal from the Long Beach Inner Harbor Tide Station. The tidal signal in the LA River does not impact the areas of concern for this study, but the boundary was set with the intention of providing future links to hydrodynamic and water quality models in the harbor area.

3.1.4 Model Setup and Inputs

The following describes data that were used in the model setup and the inputs used in the 1997, 2000 and 2001 simulations for low-flow conditions. These include the following hydrodynamic (EFDC) and water quality (WASP5) inputs:

- Geometry
- Topography
- Meterological data
- Source data

Geometry

All of the waterways modeled were concrete lined except for a small segment of the LA River near Glendale where a high groundwater table prevents the placement of concrete and the area of the Sepulveda Basin. The major waterways in the LA River watershed were planned and constructed in the early part of the twentieth century. Over time, modifications have been made to the LA River watershed conduit system such as adding low-flow channel sections, repairing deteriorated portions, and other various as-needed work. As a result of the size of the watershed conduit system and time period for the majority of the construction, there was not a readily discernible location for complete and current geometric information on the major waterways.

However, detailed geometry data were needed to physically define the LA River system in the models to appropriately simulate flow and transport under low-flow conditions. The model of the LA River and tributaries was established with a variable cross-section grid and a total of 302 grid cells averaging 600 meters in length. For these cross-sections geometric input files were established for the model with the following user-defined information:

- Invert elevation
- A range of depths measured above the invert, covering the full depth of the cross-section
- Cross-sectional area associated with each depth above the invert
- Wetted perimeter associated with each depth above the invert
- Top width associated with each depth above the invert

The geometric input files represent the full cross-section of the river, including the low-flow channel. The EFDC model is then capable of simulating the full range of flow conditions that do not overtop the existing channel.

Invert elevation and cross sectional geometry for the waterways in this study were determined from review of approximately 1,500 construction plans and as-built drawings, approximately 80 typical section sheets from the LACDA USACE O&M Manual, approximately 20 FEMA flood study HEC-2 decks, photographs, and limited field reconnaissance.

Figures 3-2a through 3-2d show photographs of various sections along the mainstem LA River and provide examples of cross-sectional variation throughout the system. As the photos show, the channel geometry changes significantly throughout the system. In certain locations a significant low-flow channel exists and the side banks are sloped (Figure 3-2a). In other locations the banks are vertical with a deep low-flow channel (Figure 3-2b). For the model segmentation the cross-sections remained constant until alternate sections were defined within the as-built drawings or other sources.

Appendix A presents detailed descriptions of the channel geometry and extent of cross-sections used in the model. Within the mainstem LA River and listed tributaries, grids were established to correspond to areas of changing cross-section, slope or channel characteristics. Appendix B provides the detailed geometric data for each model segment for the mainstem LA River and the tributaries, including channel slope, grid length, grid location (river mile), and invert elevation.

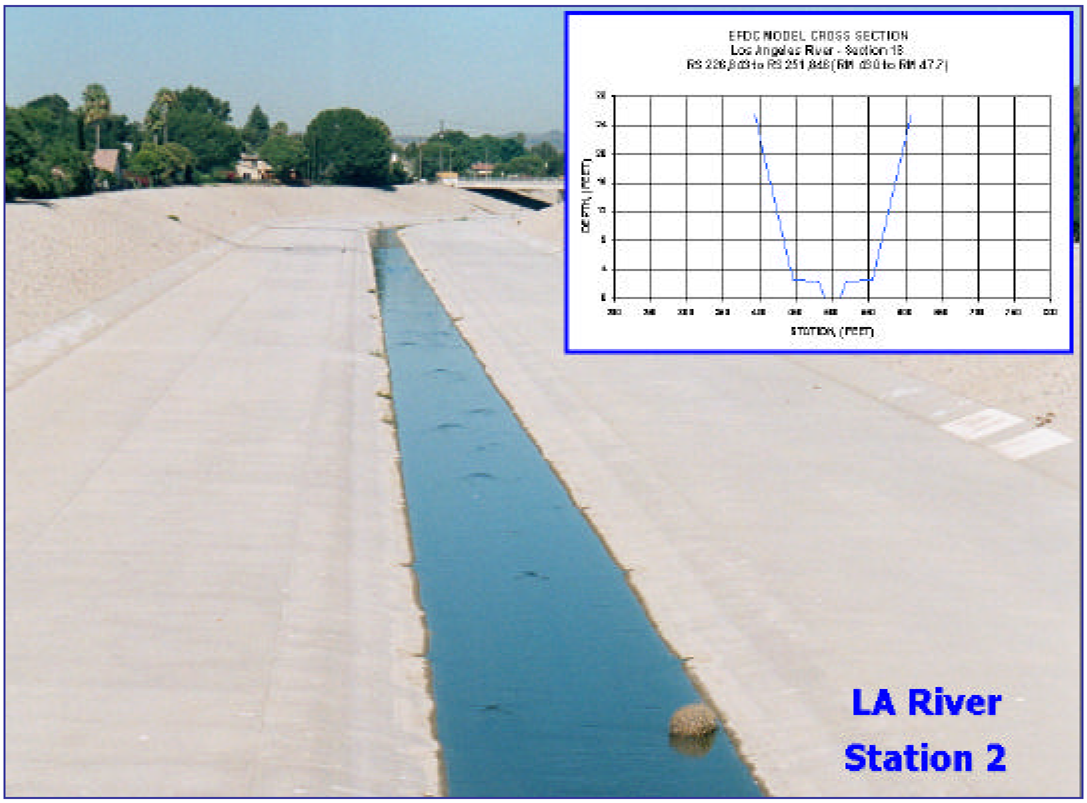


Figure 3-2a. Channel Cross-Section at LA River Station 2

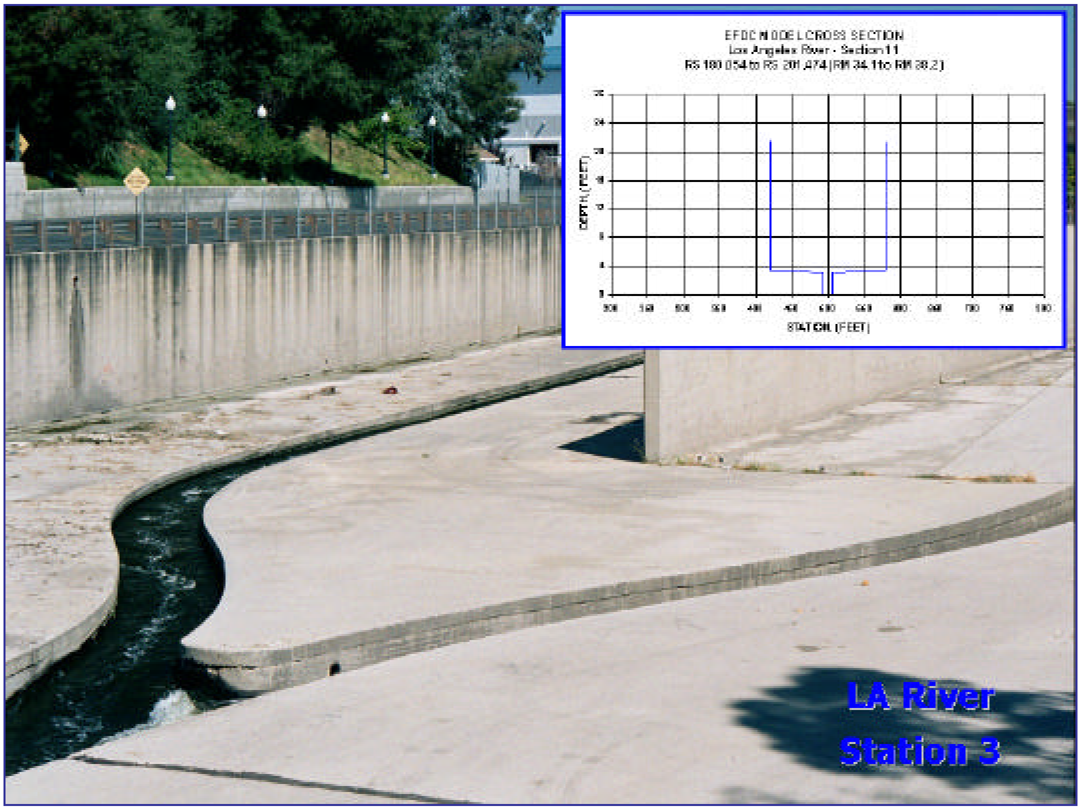


Figure 3-2b. Channel Cross-Section at LA River Station 3

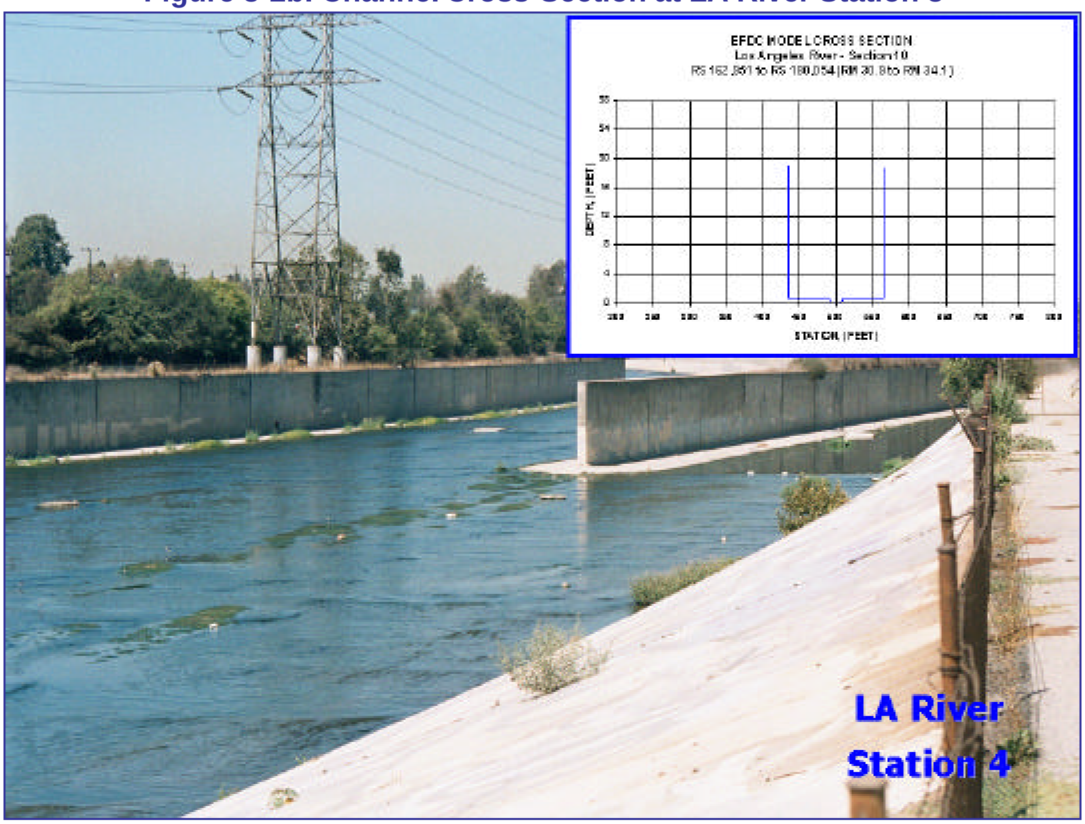


Figure 3-2c. Channel Cross-Section at LA River Station 4

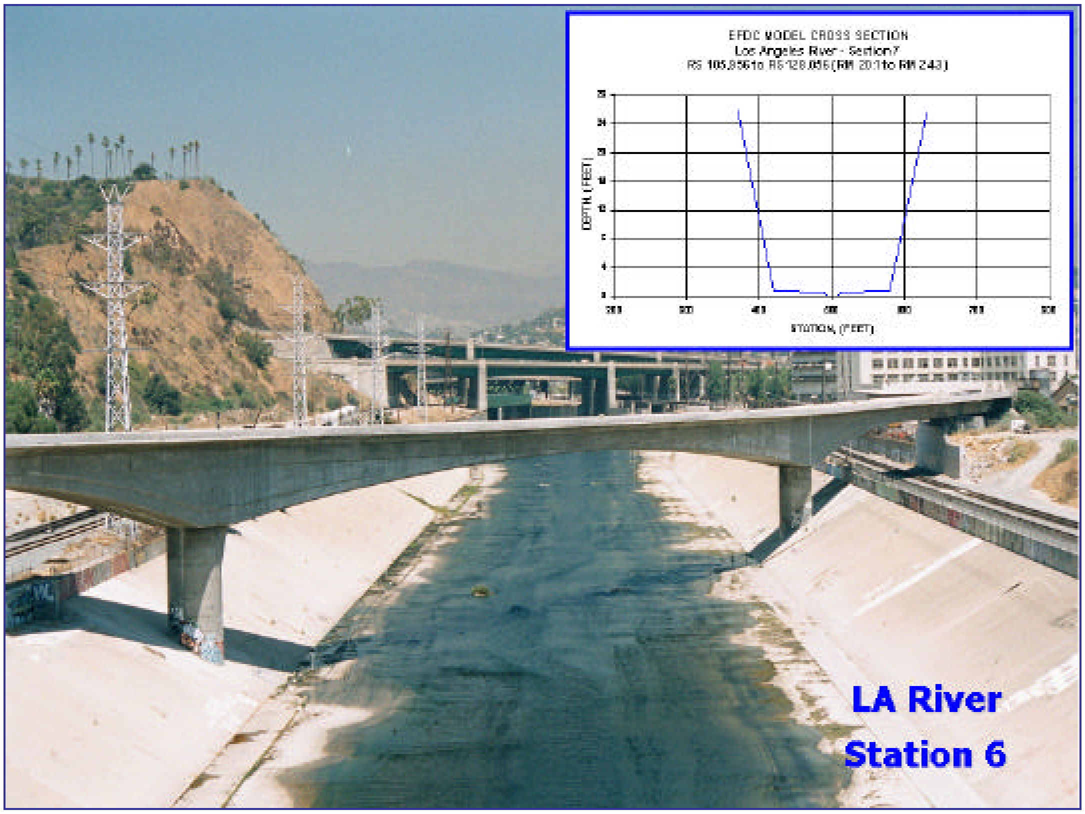


Figure 3-2d. Channel Cross-Section at LA River Station 6

Topography

The topography of the LA River watershed is represented by two distinct areas, the very steep mountain regions in the Santa Monica, Santa Susana and San Gabriel Mountains, and the low lying relatively flat sections in the San Fernando Valley and the lower LA River. Topographic data used in the model simulations were obtained from the USGS Digital Elevation Model (DEM) within the BASINS database with a resolution of 90 x 90 meters. Figure 3-3 presents the DEM data used in the model simulations. Elevations within the watershed range from near sea level at the lower reaches of the LA River to greater than 2,000 meters above sea level. Within the LA River model network, the DEM provided invert elevations and slopes for the channel sections where data were not available from the as built drawings. Details on the invert elevations used for the mainstem and the listed tributaries are presented in Appendix A.

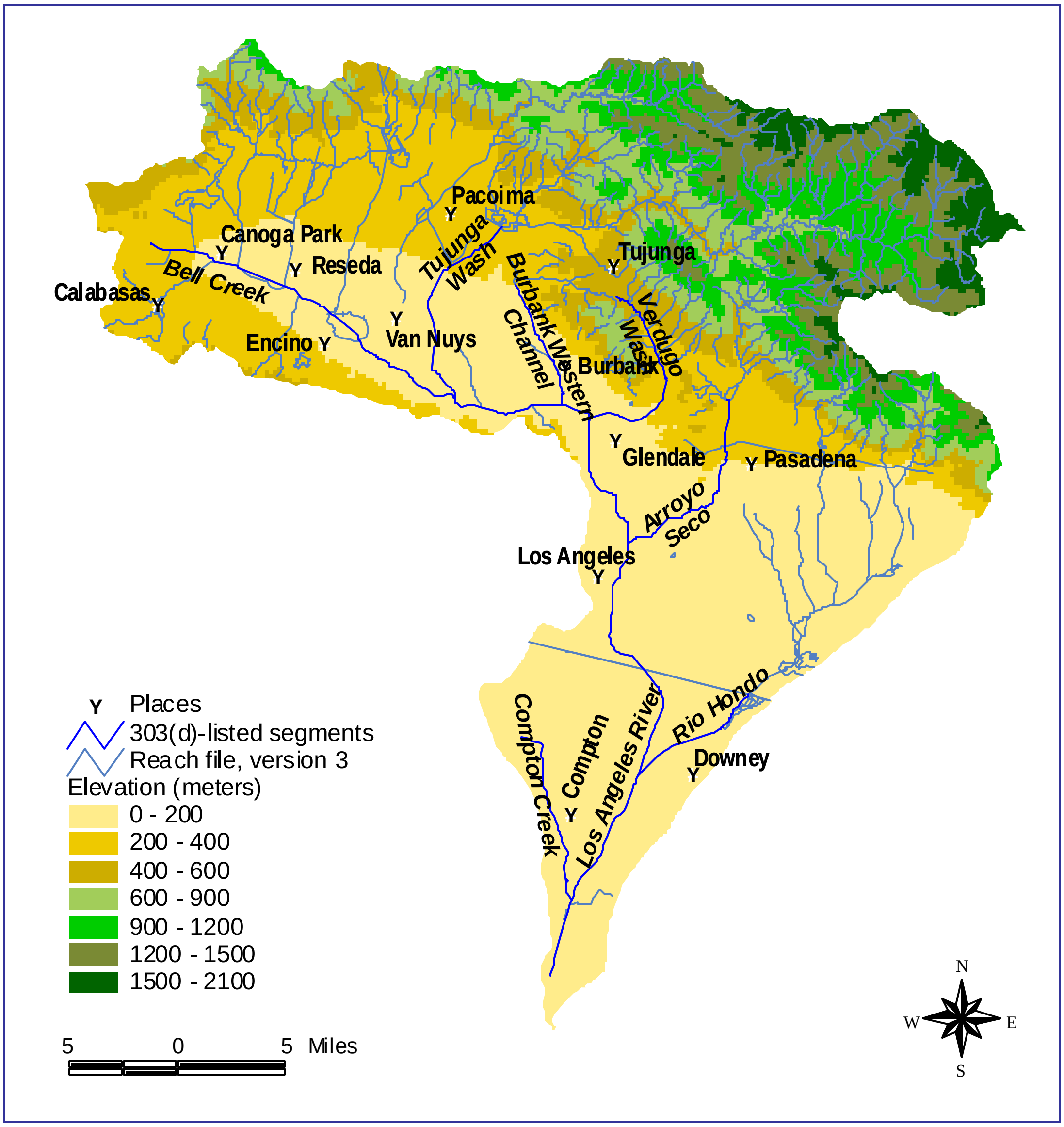


Figure 3-3. Topography in the LA River Watershed

Meteorological Data

Relevant meteorological parameters necessary for input into EFDC and WASP models are:

- Air Temperature
- Relative Humidity
- Wind Speed
- Wind Direction
- Solar Radiation
- Cloud Cover

The primary weather station located at the Los Angeles Airport provided the meteorological data used in the simulation of temperature in the EFDC hydrodynamic model. Given the nature of this type of data, a single station located at the airport was sufficient because spatial variability is not as critical for these parameters as it is to rainfall. Because the modeling evaluates dry-weather conditions with no rain-driven inputs, precipitation data are not a necessary input for the LA River low-flow modeling. However, all meteorological data were input to the models for completeness. Appendix D presents the measured meteorological data for the month of September 2000. The September 2000 data were also used during the model validation because these parameters do not have a significant impact on the modeling results during dry-weather simulations.

Source Representation

The setup of the modeling system also requires the initial representation of the various sources of flow and constituent loading to the system for the simulation time periods. This initial representation of the sources is based on a combination of historic monitoring and information gathering, targeted data collection, and mass balance analysis. For this application SCCWRP conducted targeted monitoring throughout the LA River watershed in September 2000 and July 2001 to better characterize sources of flow and metals to the LA River. This section discusses the supplemental data gathering, the analysis of the available data, and how this information was used to best represent sources in the models.

Examination of the LA River system indicates that the following potential sources and sinks of flow and constituent loading are present:

- Point Source Discharges
- Stormwater Inflows
- Tributary Inflows

The analysis of historic data was used to determine when various sources are active and the potential distribution of flow contributions. Examination of instream flow data from LACDPW and the City of Los Angeles was used to determine the flow distribution and patterns in the LA River system. Eleven stations had data available during the 1997 and 2000 water years (Figure 3-4). Of these 11 stations, all but one (F319-R) had data available at 15-minute intervals. Station F319-R had daily average data. Appendix C presents plots of the measured flow at all of these stations during the 1997 and 2000 water years.

Examination of historic flow records and point source discharge records confirm that a significant source of flows during low-flow periods are point source discharges. Presently there are six major permitted point source discharges to the LA River and its tributaries, and 29 minor permitted discharges. Table 3-2 presents a list of the major and minor dischargers along with their NPDES permit numbers and design flows and Figure 3-5 presents the locations of the major discharges.

If all of the major permitted facilities discharged at their design flow conditions, they would account for approximately 85 percent of the point source inputs to the LA River (Figure 3-6). Because many of the minors are stormwater-related, their contribution during dry periods is negligible. Additionally, examination of the design flows for the Glendale, Tillman, and Burbank WWRPs in relation to the other three majors shows that these three facilities account for over 80 percent of the major design discharge (Figure 3-6). Additionally, the Boeing and SC Edison discharges are primarily storm water and their contributions during dry weather are negligible. The Las Virgenes facility has a special permit that allows them to discharge to the LA River during high flow events. During the period used in the simulations, they did not exercise this option to discharge, and therefore the discharge from the Las Virgenes facility was not included in the model. Therefore the only point sources included in the low-flow simulations of the LA River system are the Glendale, Tillman, and Burbank WWRPs.

Analysis of the data showed that during the dry periods, point source discharges accounted for 60 to 100 percent of the total flow through the system. The remaining flows were attributed to groundwater inflow, discharge from dams upstream from the listed segments, and residential, commercial and industrial water uses. The gauged tributary data account for some of the additional 20 to 40 percent of the dry weather base flow on the mainstem LA River, but additional flow still remains unaccounted for based on these measurements.

To support the analysis of historic flow data, the in-stream model (EFDC) was also used to investigate potential sources of flow during the 1997 low-flow period. Evaluation of the mass balance of flow in the system during the 1997 model testing showed that up to 40 percent of the total flow in the system during low-flow conditions were unknown. Because no data were available to quantify the additional flows to the system (e.g., dry-weather stormwater inputs) during 1997, assumptions were made about the quantity and distribution of inflows to achieve reasonable comparison with the measured flows at the bottom of the system. The model testing for 1997 was not intended to calibrate the model to observed values, but rather to provide qualified estimates of the flow distribution in the system and help establish additional data needs.

Figure 3-7 present comparisons of the measured versus simulated flows at four stations throughout the system (see Figure 3-4 for station locations) for the 1997 low-flow period. The comparison stations represent four locations along the mainstem of the LA River. The simulated and measured flows range from 75 to 100 cfs at the upper most station (F300-R) to between 125 and 150 cfs at the lowest station (F319-R). The lowest station (F319-R) is below the confluence of all tributaries within the LA River and all simulated point source discharges. This station reflects the total water “mass balance” within the system under the relatively steady low-flow condition. This simulation was to provide a preliminary testing of the model to get results with similar patterns and magnitudes as observed data. Differences in flow are likely attributable to stormwater flows and other unknown flows that were not specifically included in this simulation.

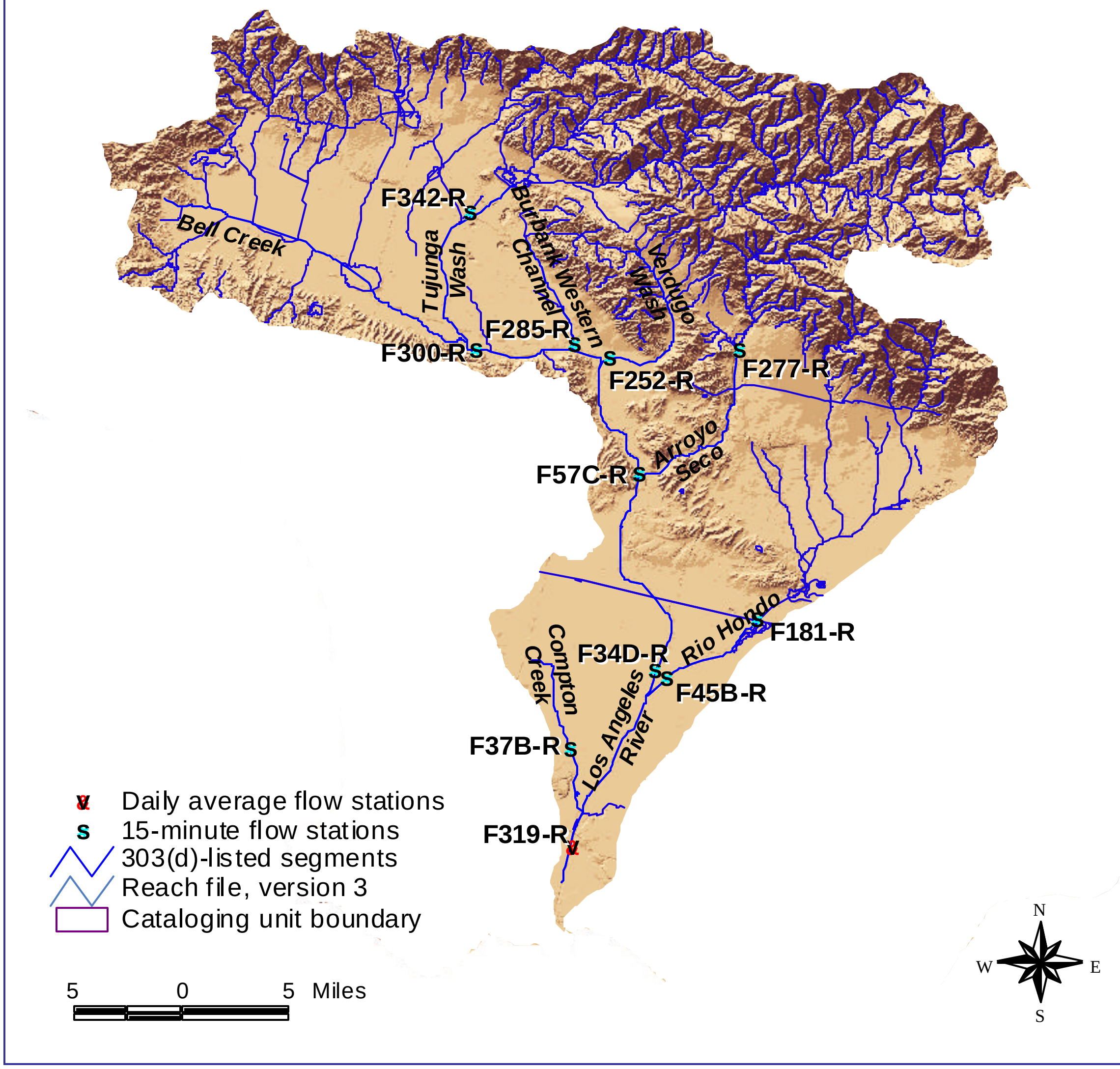


Figure 3-4. Flow Measurement Stations in the LA River and its Tributaries

Table 3-2. NPDES Permitted Major and Minor Discharges (LARWQCB, 2000)

NPDES#	Discharger	Facility	Design Q (mgd)	Class
CA0001309	The Boeing Company	Rocketdyne Div. - Santa Susana	15.000000	MAJOR
CA0052949	Southern California Edison	Dominguez Hills Fuel Oil Fac	4.320000	MAJOR
CA0053953	LA City Bureau of Sanitation	L.A.-Glendale WWRP, NPDES	20.000000	MAJOR
CA0055531	Burbank, City Of Public Works	Burbank WWRP, NPDES	9.000000	MAJOR
CA0056227	LA City Bureau of Sanitation	Tillman WWRP, NPDES	80.000000	MAJOR
CA0064271	Las Virgenes MWD	Tapia Park WWRP, NPDES	2.000000	MAJOR
CA0000892	Kaiser Aluminum Extruded Prod.	Kaiser Aluminum Extruded Prod.	0.125000	MINOR
CA0001899	Celotex Corporation	Asphalt Roofing Mfg, La	0.120000	MINOR
CA0002739	MCA / Universal City Studios	Universal City Studios	0.169000	MINOR
CA0003344	Kaiser Marquardt, Inc.	Ramjet Testing, Van Nuys	0.024000	MINOR
CA0056464	Owens-Brockway Glass Container	Glass Container Div, Vernon	0.408100	MINOR
CA0056545	Los Angeles City Of Rec&Parks	Los Angeles Zoo Griffith Park	2.010000	MINOR
CA0056855	Los Angeles City of DWP	General Office Building	1.500000	MINOR
CA0057274	Pabco Paper Products	Paperboard & Carton Mfg,Vernon	0.745800	MINOR
CA0057363	Edington Oil Co.	Long Beach Refinery - Rainfall	0.560000	MINOR
CA0057690	Bank Of America	Nt & Sa L.A. Data Center	0.015000	MINOR
CA0057886	Filtrol Corp.	Filtrol Corp.	0.897000	MINOR
CA0058971	Exxon Co., U.S.A.	Exxon Company U.S.A.	0.032000	MINOR
CA0059242	Consolidated Drum Recondition	Oil Drum Recycling, South Gate	0.008500	MINOR
CA0059293	Chevron U.S.A. Inc.	Van Nuys Terminal	0.050000	MINOR
CA0059561	Arco Terminal Services Corp.	East Hynes Tank Farm	0.190000	MINOR
CA0059633	Metropolitan Water Dist. Of SC	Rio Hondo Power Plant	0.050000	MINOR
CA0062022	Dial Corp, The	The Dial Corporation	0.028800	MINOR
CA0063312	3M Pharmaceuticals	3M Pharmaceuticals	0.144000	MINOR
CA0063355	Pasadena, City Of, DWP	Dept. Of Water & Power	0.411000	MINOR
CA0063908	McWhorter Technologies, Inc.	McWhorter Technologies, Inc.	0.075000	MINOR
CA0064025	Sta - Lube, Inc.	Sta - Lube, Inc.	0.150000	MINOR
CA0064068	Lincoln Avenue Water Co.	South Coulter Water Treatment	0.018500	MINOR
CA0064084	Mairoll, Inc.	Voi-Shan Chatsworth	0.014400	MINOR
CA0064092	Los Angeles County MTA	Metro Lines-Segments 1 & 2a	0.500000	MINOR
CA0064149	Los Angeles City of DWP	Tunnel # 105	0.005900	MINOR
CA0064190	Pacific Refining Co.	Former Western Fuel Oil	0.001200	MINOR
CA0064203	Los Angeles Turf Club	Santa Anita Park	12.700000	MINOR
CA0064238	Water Replenishment Dist Of S.C	West Coast Basin Desalter	2.200000	MINOR
CA0064319	Coltec Industries Inc.	Former Menasco Aerosystem Facility	0.014000	MINOR

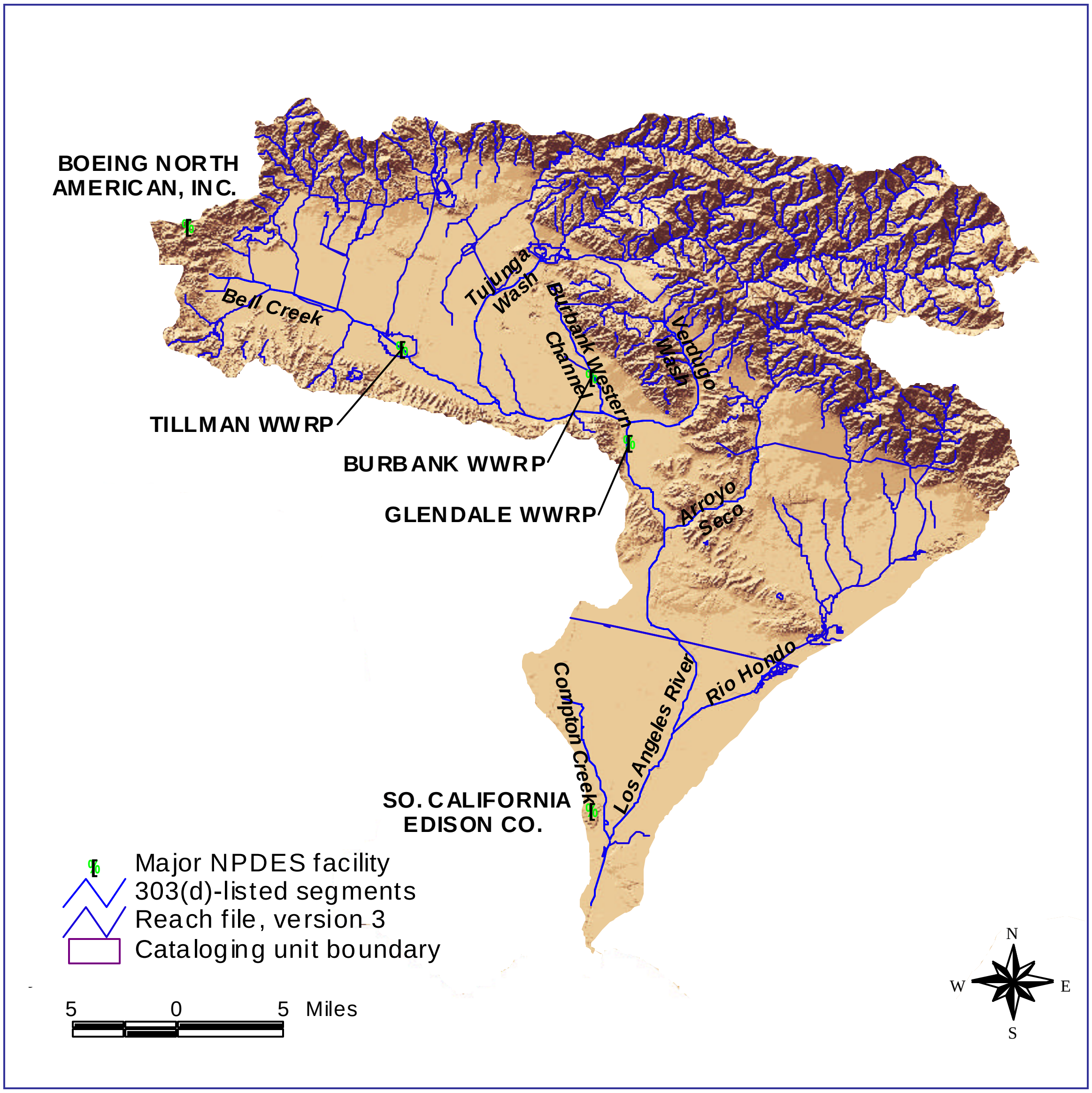


Figure 3-5. Major Wastewater Reclamation Plants within the LA River Watershed

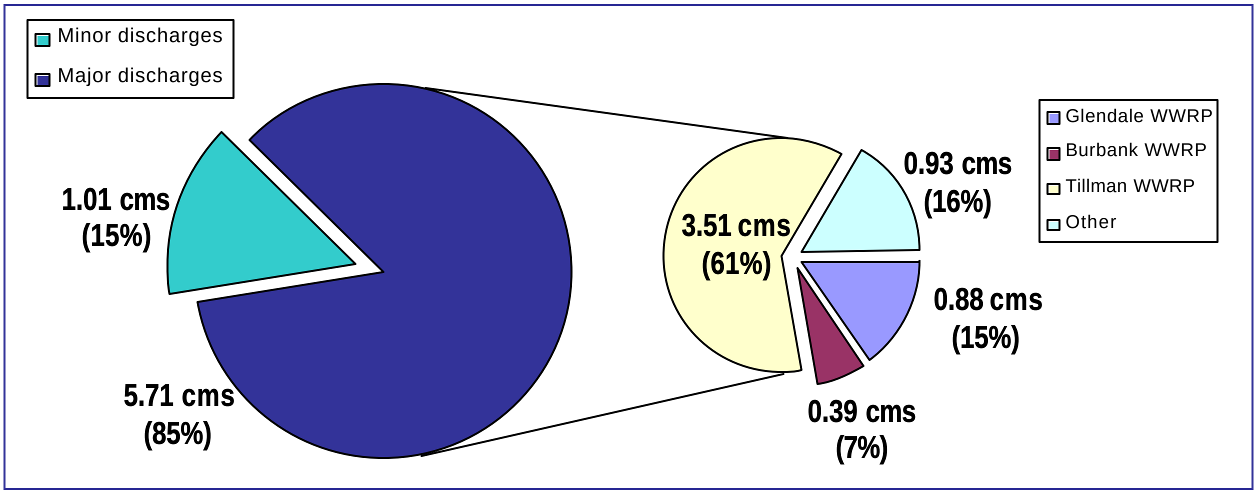


Figure 3-6. Distribution of Design Flows Between the Major and Minor Discharges

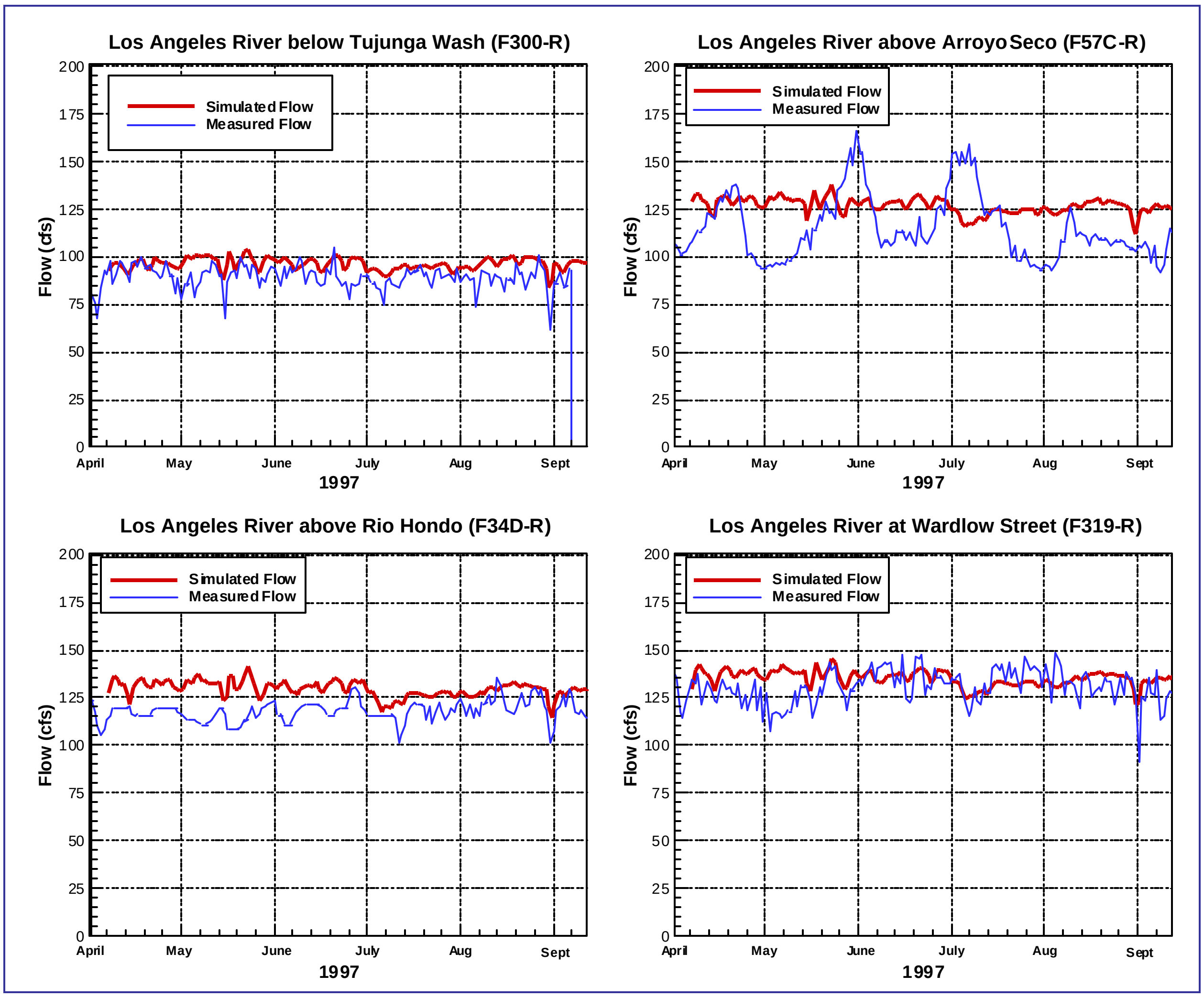


Figure 3-7. Simulated vs. Measured Dry Weather Flow, 1997 (EFDC)

Another important source of flow that could be a large portion of the "unknown" flow in the system is dry-weather inputs from stormdrains. Minor residential and commercial stormwater flows are typically a small portion of the total water budget during the wet-weather period, but can be a considerable percentage during the dry weather period. The stormwater inputs during dry-weather periods represent inflows from the stormwater conveyances throughout the system from sources such as golf courses, car washes or residential lawns. Data collected by SCCWRP in September 2000 and July 2001 indicated that stormdrain flows contributed 23 to 57 percent of the total copper load, 35 to 53 percent of the total lead load, and 14 to 46 percent of the total zinc load to the LA River on the monitored days. This information illustrates the importance of capturing the inputs from stormdrains in the models representing the LA River system. The 2000 and 2001 SCCWRP data were used to develop flow and water quality model inputs for dry-weather stormwater discharges in the watershed.

At times, comparison of the flows from the three major point source discharges exceeded the total flow measured at the stations downstream of all of the inflow points (Stations F57C-R, F34D-R, and F319-R). During these time periods three possible explanations exist for the conditions:

- Errors in the gauging stations in measuring very low-flow conditions
- Evaporative losses within the system
- Losses due to groundwater recharge

It may be that during these time periods all three of these processes are occurring and the result is a net loss of water from the system.

The models were set-up to account for all of the potential sources of flow and nutrients in the LA River system. The following sections discuss the data used to represent the hydrodynamics and water quality of each of the major sources—WWRPs, tributaries, dry-weather stormwater and groundwater.

Hydrodynamic Data Used for Source Representation

The EFDC hydrodynamic model was calibrated and validated for application to the LA River system. The model was calibrated to observed data collected during the monitoring effort on September 10 and 11, 2000. After the model was calibrated, model validation was performed using the data set collected on July 29 and 30, 2001.

For each of these hydrodynamic simulations, it was necessary to characterize the sources of flow as closely as possible to the conditions occurring during the simulation period. Table 3-3 presents a summary of the representation of inflows in the models and the following sections provide more details on the data used as input for the model calibration and validation, including data used to characterize and represent inputs to the LA River from the main sources of flow—WWRP, tributary, stormwater and groundwater flows. Section 3.3 presents and discusses the results of the testing, calibration and validation.

WWRP Flow

Point source discharges provide a substantial portion of the LA River system's flow. Therefore it is necessary to include inputs in the model to represent discharges from the major point sources Glendale WWRP, Burbank WWRP, and Tillman WWRP. The following discusses how the WWRP discharges were represented in the EFDC hydrodynamic model for the model calibration and validation.

Table 3-3. Summary of hydrodynamic representation of sources in the LA River system

Source Inflows	Representation in Calibration	Representation in Validation
WWRP	Constant flow based on measured daily average flow of WWRP effluent on September 10-11, 2000	Constant flow based on measured daily average flow of WWRP effluent on July 29-30, 2001
Tributaries	Constant flows based on flows measured at tributary headwaters on September 10-11, 2000	Constant flows based on flows measured at tributary confluences on July 29-30, 2001
Dry-weather stormwater	Constant flows based on measured flows of 48 identified stormwater flows on September 10-11, 2000	Constant flows based on measured flows of 69 identified stormwater flows on July 29-30, 2001
Groundwater	Infiltration, based on mass balance evaluation	Not included, based on mass balance evaluation

Flow data obtained from the three major WWRPs (Tillman, Glendale and Burbank) were used as input to EFDC for model calibration and validation. Daily average flows measured by the WWRPs for September 10 and 11, 2000, were used as constant flows representing their respective discharges in the EFDC model calibration and flow data from the WWRPs for July 29 and 30, 2001, were for model validation.

The Glendale WWRP had only one discharge location, the Burbank WWRP had two outlets, both discharging to Burbank Western Channel, and the Tillman WWRP effluent is discharged to the LA River through the following four outlets:

- Direct discharge to the LA River
- Discharge to the Wildlife Lake with eventual outflow to the LA River
- Discharge to the Recreation Lake within the Sepulveda Basin with eventual outflow to the LA River
- Discharge to the Japanese Tea Gardens, with eventual feedback to the direct discharge

Table 3-4 presents the WWRP flows used in the model for calibration and validation. These values are used as constant flow values in the model to represent the discharges from the WWRPs to the LA River system.

Table 3-4. Flow Data from the Three Major Point Source Discharges Used in Model Calibration and Validation

Point Source Discharge		Flows used in Calibration[1]		Flows used in Validation[1]	
		Flow (cms)	Flow (mgd)	Flow (cms)	Flow (mgd)
Tillman WWRP	Direct Discharge	1.507	34.4	0.407	9.3
Tillman WWRP	Japanese Gardens	0.210	4.8	0.197	4.5
Tillman WWRP	Recreation Lake	0.762	17.4	0.762	17.4
Tillman WWRP	Wildlife Lake	0.258	5.9	0.250	5.7
Tillman WWRP	TOTAL	2.737	62.5	1.617	36.9
Glendale WWRP		0.407	9.3	0.403	9.2
Burbank WWRP		0.403	9.2	0.269	6.2

[1]Based on discharge monitoring data provided by the WWRP

Tributary Inflows

In addition to flow contributions from the WWRPs, the LA River system receives flow from tributary inflows and baseflows during low-flow periods. These flows are included in EFDC with a representative constant flow value that was defined using monitoring data or evaluation of a mass balance when monitoring data were unavailable. Table 3-5 presents the values used to represent tributary inflows in the model setup, calibration and validation, and the following paragraphs provide further discussion on the identification of these flow values. All flows were input to the uppermost cell of each segment (e.g., mainstem, Compton Creek) as constant flows.

Table 3-5. Measured Tributary Inflows Used for Model Calibration and Validation

Location	Flows Used in Calibration[1] (cfs)	Flows Used in Validation[2] (cfs)
Mainstem LA River	10.59	Not included
Compton Creek	2.97	1.80
Rio Hondo	NO FLOW	NO FLOW
Arroyo Seco	0.00	3.32
Verdugo Wash	1.36	2.20
Burbank Channel	1.41	9.51
Tujunga Wash	0.67	0.37
Bell Creek	1.20	2.65

[1]Based on data collected at headwater stations by SCCWRP on September 11-12, 2000.
[2]Based on data collected at confluence stations by SCCWRP on July 29-30, 2001.

SCCWRP monitoring data were used to identify model inputs for the tributary inflows for the hydrodynamic model calibration and validation. SCCWRP included monitoring in the upper reaches of all the listed tributaries as part of the September 10-11, 2000, intensive monitoring. Figure 3-8 shows the locations of the headwater monitoring stations. Table 3-5 presents the measured headwater flow data for the LA River and its tributaries. These values were used in the model calibration to characterize the flow contributions from the tributaries as constant discharges.

During the July 2001 data collection, SCCWRP measured flows at the upper reaches of all of the listed tributaries as well as at their confluence with the LA River. The locations of the headwater stations were the same as those used in the 2000 dataset (Figure 3-8). Because the model is steady-state, if there are no additional inflows to a tributary (e.g., stormwater inputs), the modeled flow at the bottom of the tributary (i.e., at the confluence) is equal to the input flow at the headwaters. To better represent the inflows from the tributaries, 2001 confluence flows were used to define the tributary flows for the model validation instead of the headwater flows. Table 3-5 presents the flows measured at the confluences of each of the tributaries and the LA River and used as constant flow inputs in the model to represent flow contributions from tributaries for model validation.

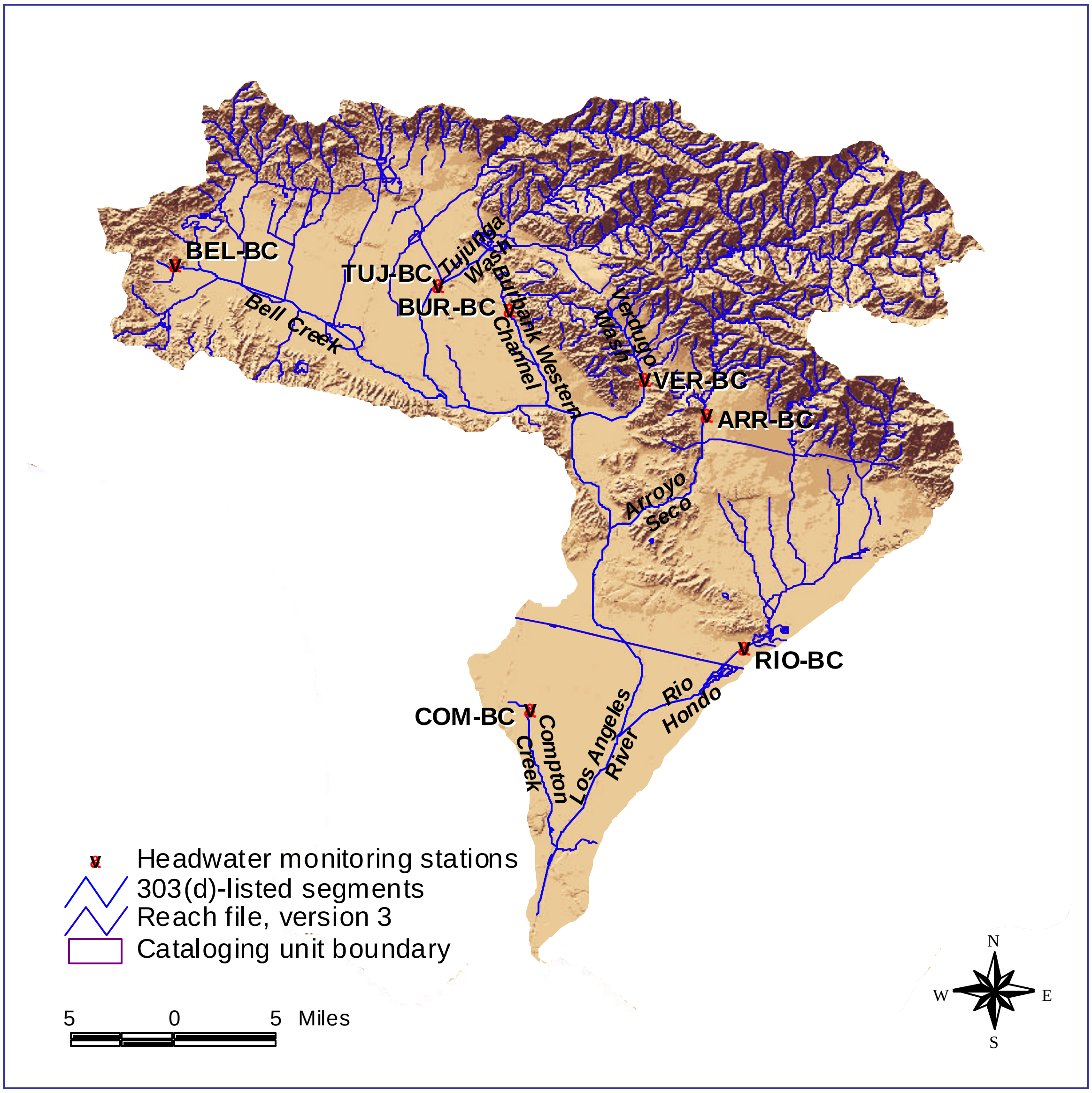


Figure 3-8. Headwater Flow Monitoring Stations

Stormwater Inflow

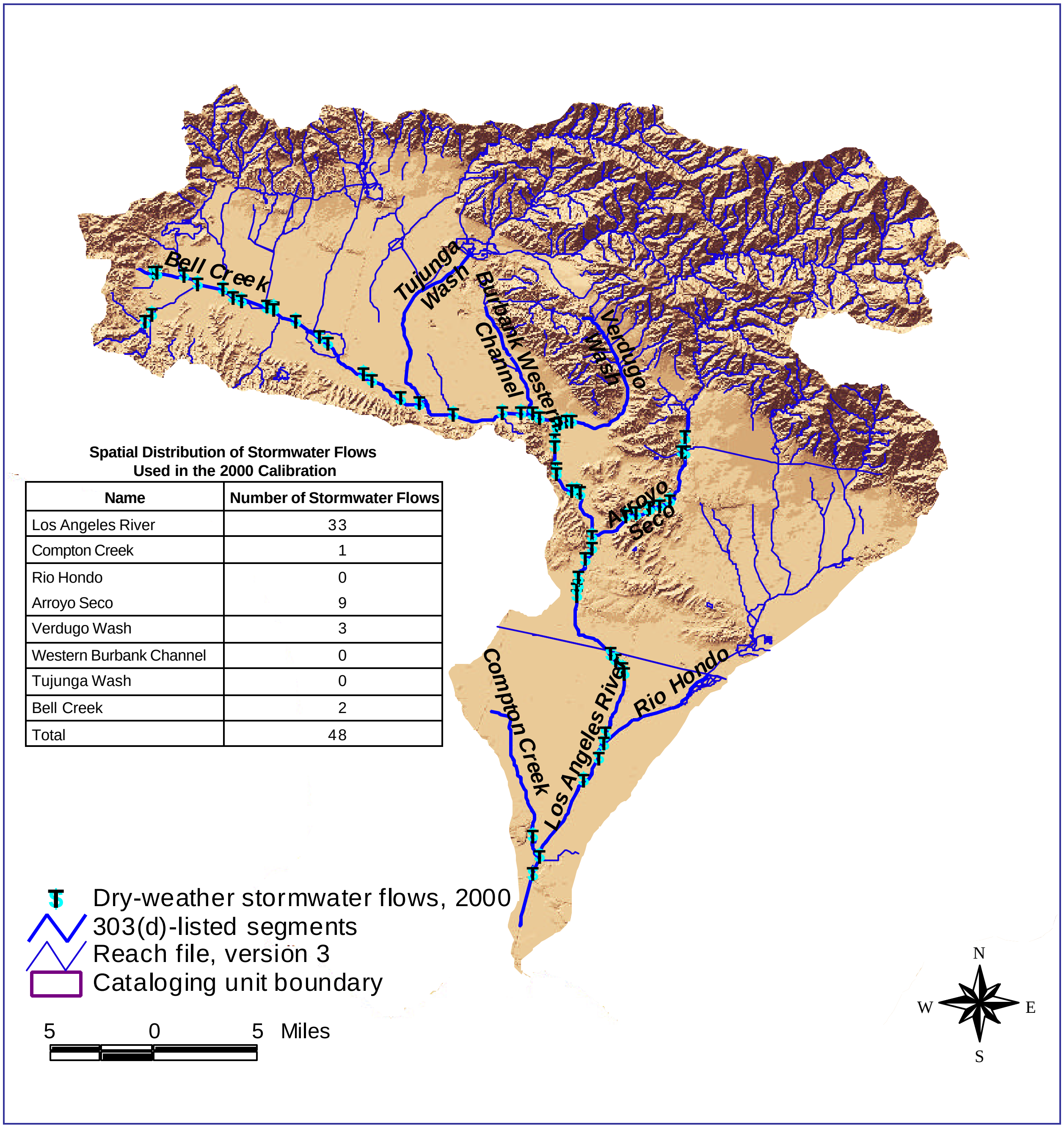
Another source of flow contributions to the LA River system are dry-weather stormwater flows. Minor stormwater flows are typically a small portion of the water budget during wet-weather periods but can be a considerable percentage during dry weather periods. During the 2000 data collection by SCCWRP, 67 dry-weather stormwater flows were identified in the LA River and its tributaries (Figure 3-9). Flow was measured at 48 of the 67 total flows identified and input into the hydrodynamic model to represent flow contributions from dry-weather stormwater during the calibration period. The remaining identified stormwater flows represent locations where the flows could not be measured (e.g., the flows were too small or had already moved downstream) and were therefore not included as inputs to the model. Figure 3-9 presents the locations of the dry-weather stormwater inflows during the September 2000 sampling event with a summary of their spatial distribution. Table 3-6 presents a summary of the totals of the individual dry-weather stormwater flows included in the model by listed reach. Appendix E presents the model inputs for the individual dry-weather stormwater flows used in model calibration, including their associated flow, water quality values, and corresponding model cell information.

During the July 29-30, 2001, monitoring effort, SCCWRP again measured dry-weather stormwater flows to be included in the models, this time for model validation. Unlike the September 2000 data collection, dry-weather stormwater inflows were collected only on the LA River and not on the tributaries. Because September 2000 data suggested that dry-weather stormwater inflows on the tributaries were insignificant during the low-flow period, more effort was spent on quantifying dry-weather stormwater inflows on the LA River. During the 2001 data collection, 105 dry-weather stormwater flows were identified in the LA River (Figure 3-10). Flow was measured at 69 of the 105 total flows identified and input in the model. The remaining 36 flows represent flows that could not be measured and are not included in the model. Figure 3-10 presents the locations of the dry-weather stormwater inflows during the July 2001 sampling event with a summary of their spatial distribution throughout the mainstem. The tables in Appendix F list all of the 69 individual stormwater flows included in the model validation with their associated model inputs (e.g., flow values, water quality conditions and model cell information). Table 3-6 provides a summary of the stormwater flows represented in the model, presenting the total of the individual flows into each listed reach.

Table 3-6. Totals of Measured Dry-Weather Stormwater Inflows to the Listed Reaches in the LA River Watershed

	Total of Individual Dry-Weather Stormwater Flows (cfs)	
Location	**Used in Calibration[1]**	**Used in Validation[2]**
Mainstem LA River	25.58	64.19
Compton Creek	0.10	Not Measured
Rio Hondo	NO FLOW	Not Measured
Arroyo Seco	3.72	Not Measured
Verdugo Wash	1.46	Not Measured
Burbank Channel	0.00	Not Measured
Tujunga Wash	0.00	Not Measured
Bell Creek	3.09	Not Measured

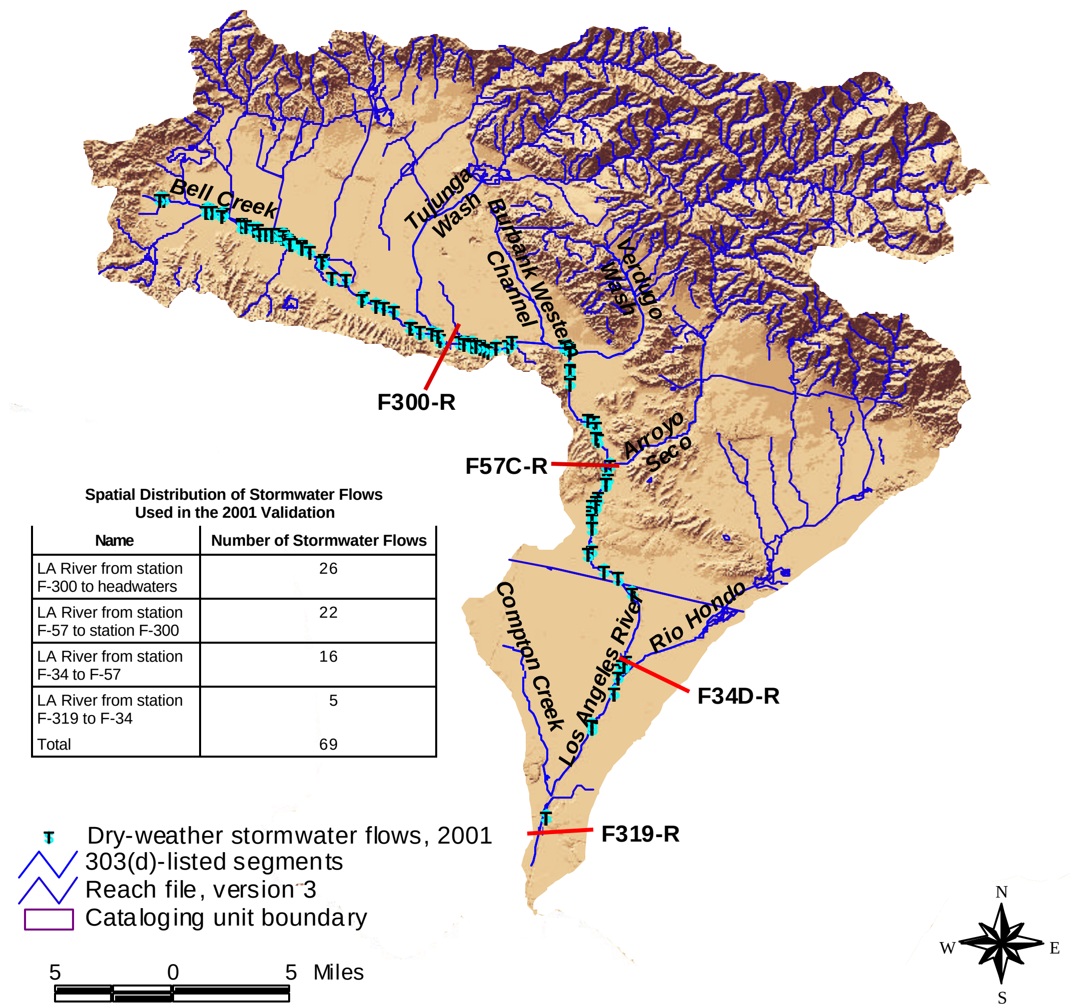
[1]Based on data collected by SCCWRP on September 11-12, 2000.
[2]Based on data collected by SCCWRP on July 29-30, 2001.



Spatial Distribution of Stormwater Flows Used in the 2000 Calibration

Name	Number of Stormwater Flows
Los Angeles River	33
Compton Creek	1
Rio Hondo	0
Arroyo Seco	9
Verdugo Wash	3
Western Burbank Channel	0
Tujunga Wash	0
Bell Creek	2
Total	48

Figure 3-9. Stormwater Inflow Measurements during September 10-11, 2000



Name	Number of Stormwater Flows
LA River from station F-300 to headwaters	26
LA River from station F-57 to station F-300	22
LA River from station F-34 to F-57	16
LA River from station F-319 to F-34	5
Total	69

Figure 3-10. Stormwater Inflow Measurements during July 29-30, 2001

Groundwater

Groundwater recharge can add water to the system while infiltration can cause a flow loss. While data are not available to directly measure the groundwater component of the LA River system, the net groundwater contribution can be estimated using a mass balance of known flows in the system. Although it is likely that groundwater is a small portion of the flow budget in the system, the mass balance was used to estimate its magnitude and it was assumed that the “leftover” flow input or loss necessary to achieve mass balance is the groundwater component in the system. Mass balances were performed for the time periods of the model calibration and validation to identify the gain or loss attributed to groundwater and to account for this flow component in the model. Adjustments included the following:

- For the low-flow simulations for the model calibration the base flows within the LA River and the tributaries were based on the flow measurements at the upstream end of the tributaries and the measurement of intermittent stormwater flows coming into the system on September 10-11, 2001.

The groundwater interaction at Glendale Narrows was assumed to be a net decrease of water (infiltration) into the unlined portion of the river at the Narrows. The total flow at station F57-R (Los Angeles River at Arroyo Seco), which is located just below the Glendale Narrows, was approximately 0.52 cms less than the measured data. This difference was input into the hydrodynamic model as infiltration for the model calibration.

- During the 2001 validation period, the total flow measured at station F-319 (Los Angeles River at Wardlow Rd) showed that during the two days of data collection, the sum of the measured flows fell within the range measured at station F-319. This indicates that a mass balance was achieved, and infiltration or recharge was not input into the model for the validation period.

Water Quality Data Used for Source Representation

The WASP model results were compared to water quality data collected by SCCWRP on September 10 and 11, 2000, and July 29 and 30, 2001. Table 3-7 presents a summary of the model representation of water quality inputs from sources of metals to the LA River system—WWRPs, tributaries, and stormwater concentrations. Following is a discussion of the data used to characterize the inputs for the WASP water quality comparisons.

Table 3-7. Summary of Water Quality Representation of Sources in the LA River System

Source Inflows	Representation in 1st Comparison	Representation in 2nd Comparison
WWRP	Metals concentrations based on measurements of WWRP effluent on September 10-11, 2000	Metals concentrations based on measurements of WWRP effluent on July 29-30, 2001
Tributaries	Metals concentrations based on water quality measurements at tributary headwaters on September 10-11, 2000	Metals concentrations based on water quality measurements at tributary confluences on July 29-30, 2001
Dry-weather stormwater	Metals concentrations based on water quality measurements in 48 identified stormwater flows on September 10-11, 2000	Metals concentrations based on water quality measurements in 69 identified stormwater flows on July 29-30, 2001
Groundwater	Infiltration, based on mass balance evaluation	Not included, based on mass balance evaluation

WWRP Water Quality

The Tillman, Glendale and Burbank WWRPs represent a significant portion of the flow and metals contributions to the LA River system. The WWRPs in the LA River watershed routinely monitor their discharge effluent. Water quality data for the three major WWRPs collected on September 11, 2000, were used as input into the WASP model for the first model comparison and effluent measurements from July 30, 2001, were used as input for the second model comparison. Table 3-8 presents the water quality data used to represent WWRP discharges in the model comparisons.

The Tillman plant does not discharge directly to the LA River, but first passes through three other discharges—Japanese Gardens, Recreation Lake and Wildlife Lake. The four discharges were included in the model with individual characteristics (Table 3-8).

Table 3-8. Water Quality Characteristics of WWRP Inputs for Model Comparisons

	Point Source Discharge	Copper (mg/L)		Lead (mg/L)		Zinc (mg/L)	
		Com[1]	Com[2]	Com[1]	Com[2]	Com[1]	Com[2]
Tillman WWRP	Direct Discharge	0.013	0.013	0.005	0.005	0.039	0.051
Tillman WWRP	Japanese Gardens	0.013	0.005	0.005	0.005	0.039	0.035
Tillman WWRP	Recreation Lake	0.013	0.015	0.005	0.005	0.039	0.067
Tillman WWRP	Wildlife Lake	0.013	0.005	0.005	0.005	0.039	0.035
Glendale WWRP		0.005	0.021	0.005	0.005	0.030	0.043
Burbank WWRP		0.018	0.016	0.005	0.005	0.052	0.070

[1] Based on data collected on September 11-12, 2000
[2] Based on data collected on July 29-30, 2001

Tributary Water Quality

Water quality data collected by SCCWRP at the upstream boundaries of major tributaries were used to define metal inputs from tributaries for model comparisons. Data were collected on September 10-11, 2000, and July 29-30, 2001, at the headwater stations shown in Figure 3-11. The data at each boundary consisted of three composite samples. Three grab samples were taken to create each composite sample. A third of each grab sample was then combined into one bottle forming the composite sample. The purpose of this method was to eliminate the variability that occurs in sampling, as well as the variability that occurs in the river. Table 3-9 presents the water quality data used to represent tributary inflows in the model comparisons. The data were input into the model as metals concentrations at the upstream boundary of each tributary.

Table 3-9. Water Quality Concentrations of Inflows from Tributaries for Model Comparisons

Tributary	Copper (mg/L)		Lead (mg/L)		Zinc (mg/L)	
	Com[1]	Com[2]	Com[1]	Com[2]	Com[1]	Com[2]
Compton Creek	0.005	0.009	0.005	0.005	0.011	0.025
Rio Hondo	No Flow					
Arroyo Seco	0.005	0.005	0.005	0.005	0.005	0.011
Verdugo Wash	0.014	0.018	0.019	0.005	0.041	0.025
Western Burbank	0.018	0.016	0.005	0.005	0.052	0.070
Tujunga Wash	0.018	0.032	0.005	0.005	0.016	0.018
Bell Creek	0.015	0.007	0.005	0.005	0.005	0.005

[1] Based on data collected on September 11-12, 2000
[2] Based on data collected on July 29-30, 2001

Dry-Weather Urban Runoff Water Quality

SCCWRP measured flow and water quality at 48 dry-weather stormwater inputs on the LA River and tributaries during the September 2000 data collection and at 69 dry-weather runoff inputs on the LA River mainstem during the July 2001 data collection (Figures 3-9 and 3-10). The data collected by SCCWRP were used to assign representative flow and metals concentrations to each of the individual runoff discharges, characterized as inputs to the model cells corresponding to their measurement location. The data used in the first water quality comparison (September 10-11, 2000) are included in Appendix E and the data used in the second water quality comparison (July 20-30, 2001) are included in Appendix F.

During the 2000 and 2001 data collections, many stormdrain samples were measured as "non-detects" or "less than detection limits". This means that when analyzing the sample, the true concentration was below the detection limits of the test being performed. Therefore, each sample measured as a non-detect value was input into the model at half the detection limit of each metal (0.005 mg/L). A sensitivity analysis of this assumption is performed in section 3.4.

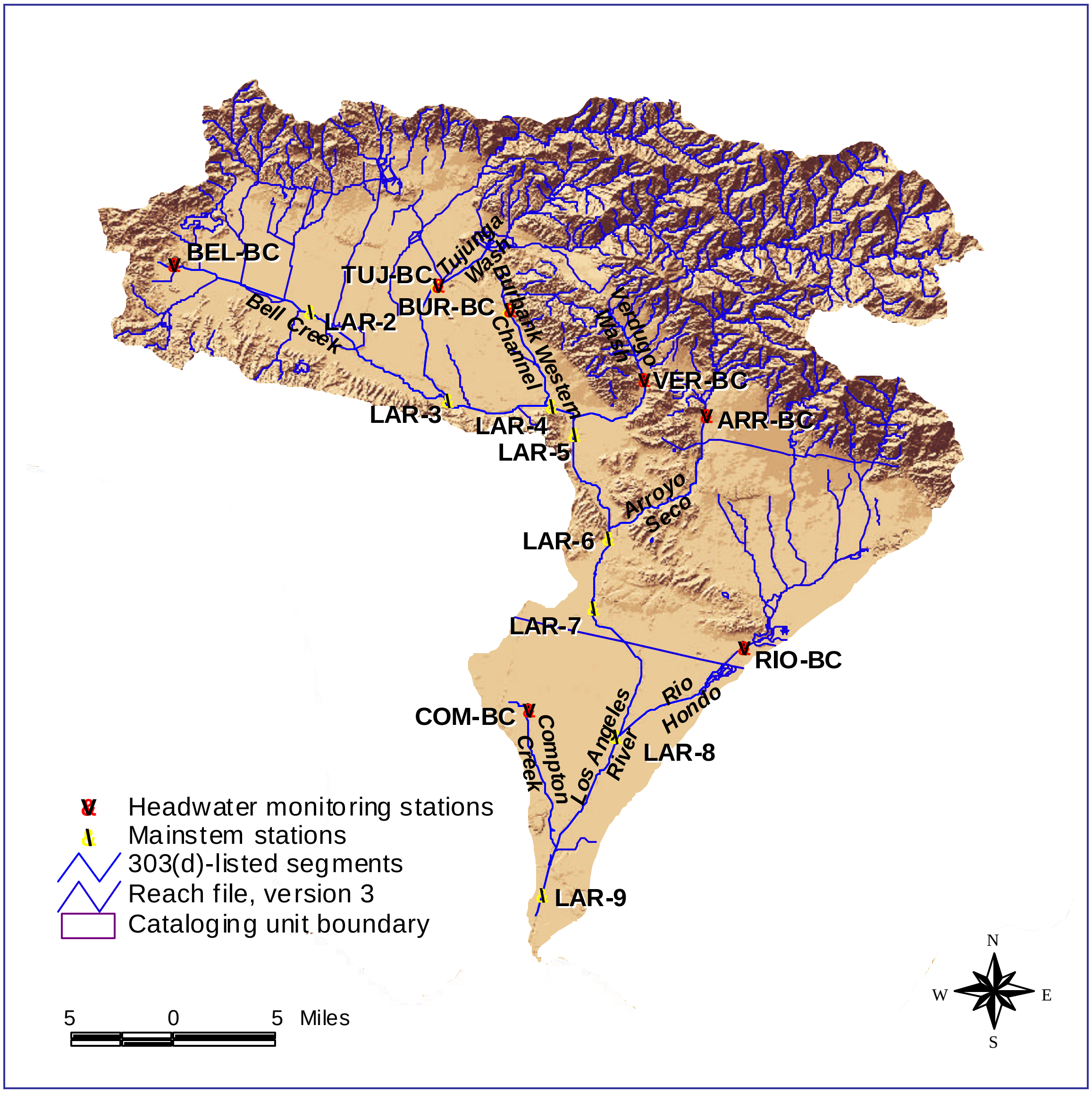


Figure 3-11. Location of Tributary and Instream Water Quality Measurements

3.2 Hydrodynamic Model Calibration and Validation

Model calibration is a critical component of the TMDL modeling analysis. Calibration consists of comparing model results to observed data to evaluate the accuracy of the model simulations and adjusting relevant parameters to obtain simulations that appropriately represent the behavior of the system. Once the calibration provides acceptable results, a model validation is conducted. The validation includes application of the calibrated model to a data set that is independent of the calibration data set (e.g., data from a different time period) to evaluate the ability of the calibrated model to appropriately simulate the system under different conditions or time periods.

The LA River hydrodynamic model was calibrated for low-flow conditions measured on the dates of the first intensive data collection (September 10 and 11, 2000) and then validated to the flow conditions measured during the second monitoring effort (July 29-30, 2001). The following sections present the results of the calibration and validation of the hydrodynamic model of the LA River system.

3.2.1 Hydrodynamic Calibration (September 10 and 11, 2000)

EFDC was calibrated to observed data collected on September 10 and 11, 2000. The dataset represents a snapshot picture of the flow distribution in the LA River. The hydrodynamic model was calibrated to this snapshot by simulating constant headwater flows, point source discharges, and urban runoff flows and reaching an equilibrium condition. The model was then adjusted to match the longitudinal distribution of the measured flow and water surface elevation. The transport was calibrated by matching the modeled velocities to those measured by SCCWRP during the September 2000 time-of-travel studies.

The only model parameter that was adjusted during calibration of the EFDC hydrodynamic model to alter the flow is the Manning's *n* value for each segment. Calibration was used to determine the final Manning's *n* values that were used in subsequent simulations for model validation. Appendix B presents a table of the hydrodynamic values for each segment including the final Manning's *n* values determined through calibration.

Figure 3-12 presents a longitudinal plot of flow in the LA River, the minimum and maximum flow values measured on September 11, 2000, and the locations of the Tillman and Glendale WWRPs. The measured flows range from 50 to 120 cfs at the upper most station (mile 38) to about 135 to 200 cfs at the lowest station (mile 4). The lowest station (F319-R) is below the confluence of all tributaries in the LA River and all simulated point source discharges. Figure 3-16 shows that the model simulated the upper range of the measured data at three of the four stations.

During summer 2000, SCCWRP also performed three dye studies within the mainstem of the LA River—downstream of the Bell Creek confluence, downstream of the Glendale WWRP, and near the 4th Street Bridge. The data from these dye studies were to be used in calibrating the model for velocity. Data from the dye studies indicated that at two of the sites (Bell Creek and 4th Street Bridge) there was a loss of dye from the drop point to the measurement point. This indicates that while the dye was traveling downstream, some of it escaped into the flood plain and did not reenter the low-flow channel, causing inaccurate calculations of the velocity in the river. Therefore, data were not used from the Bell Creek or the 4th Street dye studies and only the results of the dye study downstream of the Glendale WWRP were used for calibration of the modeled velocity. Figure 3-13 presents the simulated longitudinal plot of velocity with the measured and simulated velocity at the dye study location.

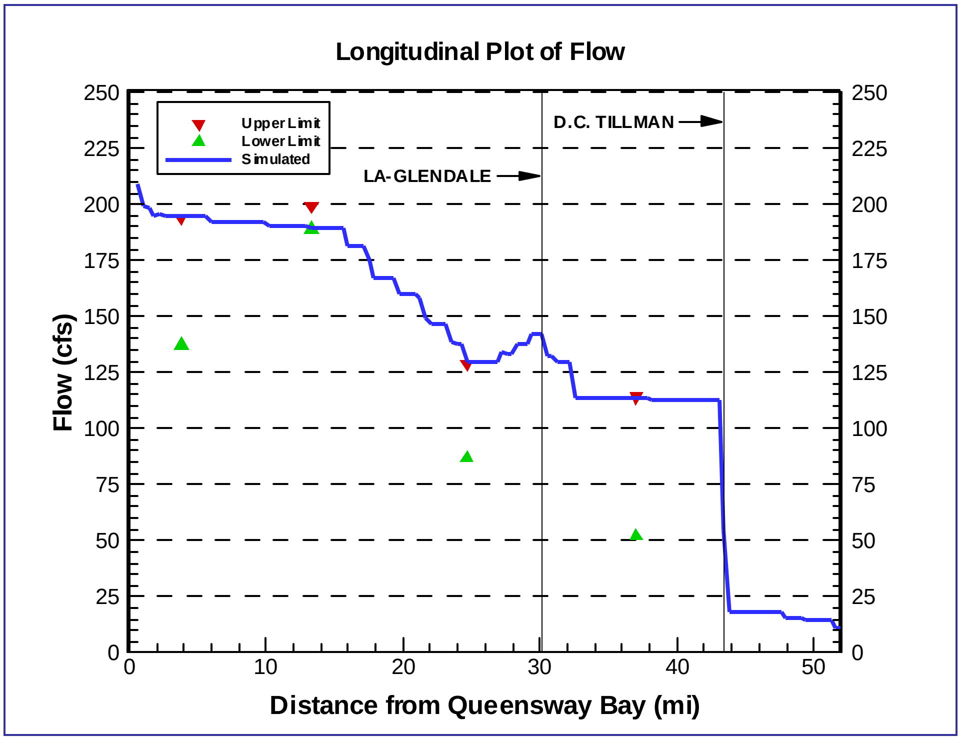


Figure 3-12. Simulated vs. Measured Flow During 2000 Low-Flow Period

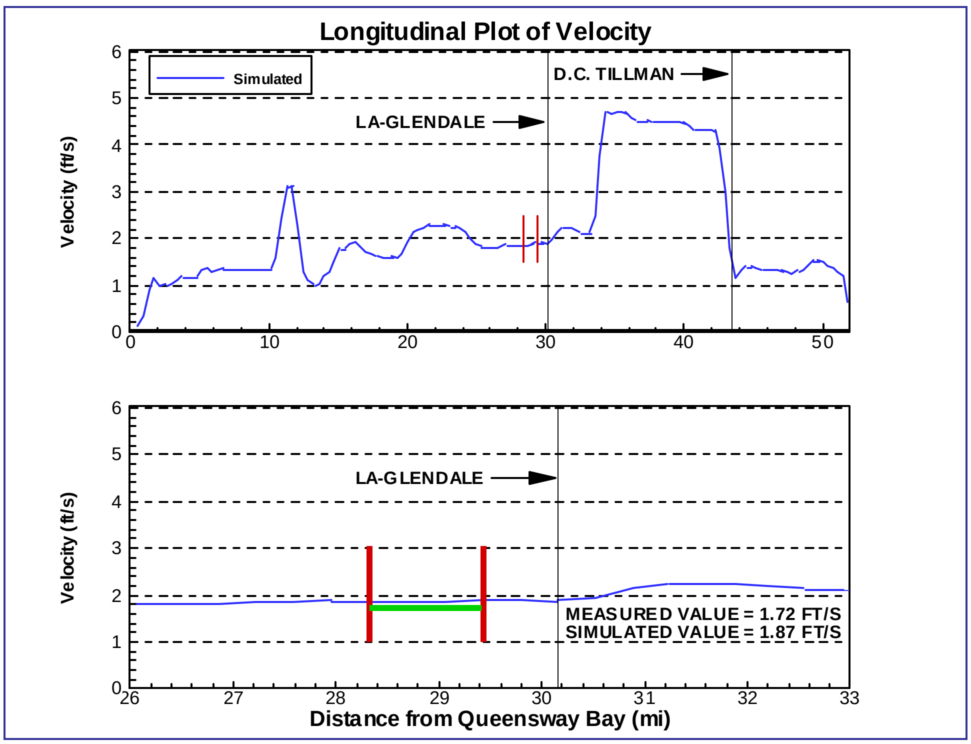


Figure 3-13. Simulated vs. Measured Velocity During 2000 Low-Flow Period

3.2.2 Hydrodynamic Validation (July 29 and 30, 2001)

After the model was calibrated, model validation was performed using the data collected on July 29 and 30, 2001. As with model calibration, this the hydrodynamic model was validated to this snapshot picture of the flow distribution by simulating constant values of the headwater, point source discharges and urban runoff inflows and reaching an equilibrium condition.

Figure 3-14 presents a longitudinal plot of flow in the LA River, the minimum and maximum flow values measured on July 30, 2001, and the locations of the Tillman and Glendale WWRPs. The measured flows range from 30 to 47 cfs at the upper most station (mile 38) and 108 to 129 cfs at the lowest station (mile 4). Mass balance was achieved at the lowest station (F-319), indicating that the quantification of flows by the model for the July 29-30, 2001, validation acceptably simulated the observed data.

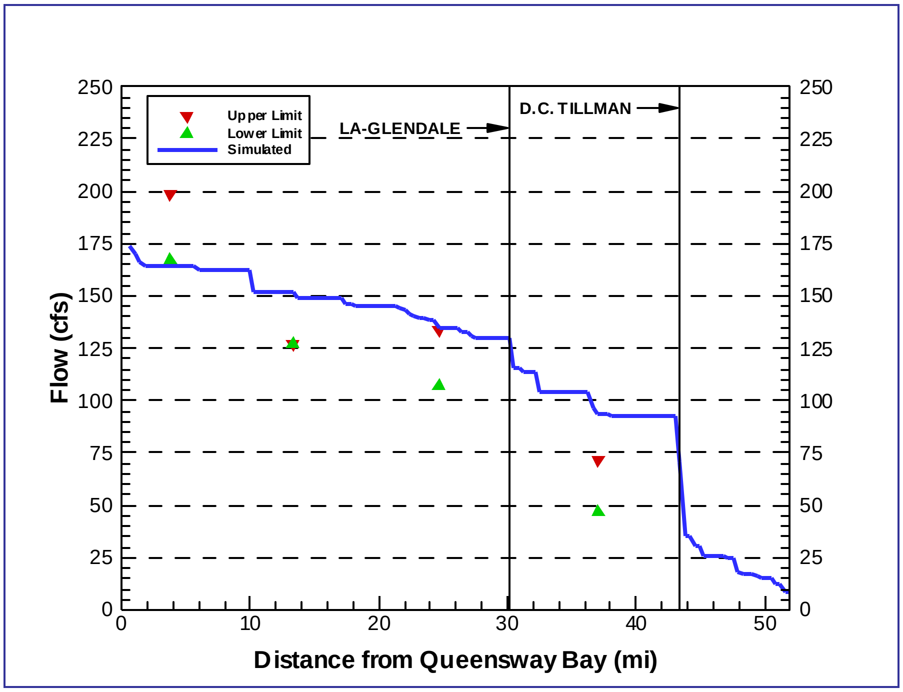


Figure 3-14. Simulated vs. Measured Flow During 2001 Low-flow Period

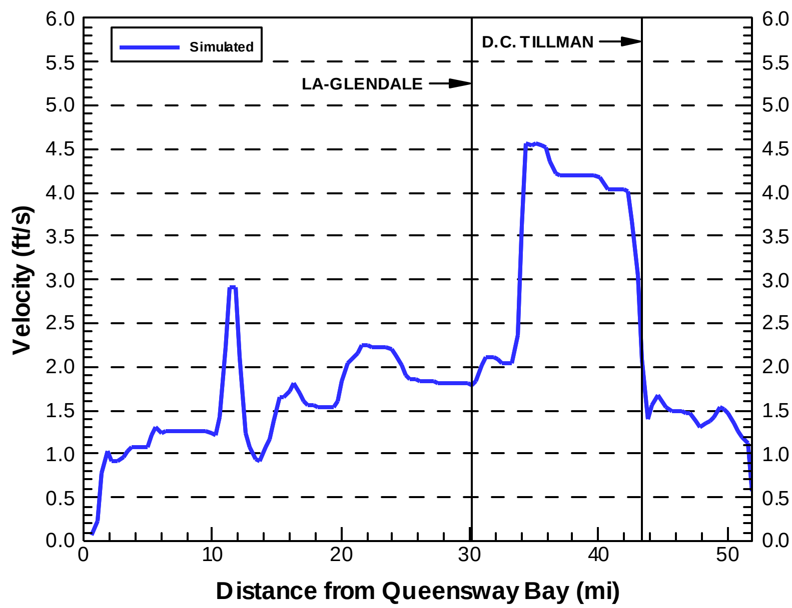


Figure 3-15. Simulated Velocity During 2001 Low-flow Period

3.3 Water Quality Model Comparison

Although the hydrodynamic model was calibrated and validated, similar calibration and validation of the WASP water quality model was not performed. Rather, model results were compared to observed data, with no modification of modeling parameters to improve comparison. Lack of water quality calibration and validation was due to limited supporting data and the simulation of metals as conservative substances with no losses or decay. As conservative substances, processes affecting water quality are limited to dilution and transport, which depend on results of the previously calibrated and validated hydrodynamic model and loading set with measured data. Boundaries of the WASP water quality model were defined by measured data. The simulated metals concentrations were then compared to observed instream data. The WASP model was run for both the datasets (September 10 and 11, 2000, and then July 29 and 30, 2001) under steady state conditions with constant loads and forcing functions. For each metal, comparison was considered successful if magnitudes and trends in simulated data were reflected in the observed data.

Before performing the model comparison, the 2000 and 2001 SCCWRP water quality data were evaluated to better understand the water quality conditions during the simulation periods. Figures 3-16 through 3-18 provide comparisons between the measured longitudinal distributions of copper, lead and zinc within the mainstem LA River between the 2000 and 2001 low-flow measurements. Figure 3-19 presents the effluent concentrations from the Glendale, Tillman and Burbank plants to provide an understanding of the relative magnitude to instream concentrations.

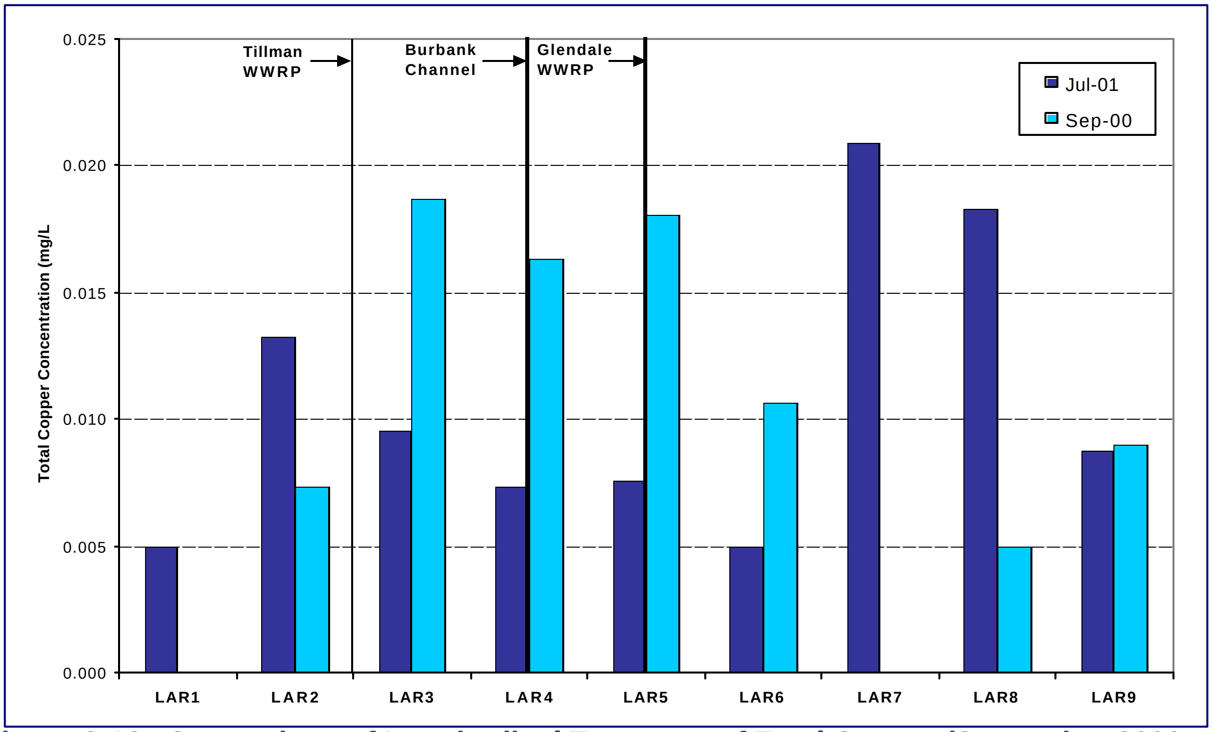


Figure 3-16. Comparison of Longitudinal Transects of Total Copper (September 2000 vs. July 2001)

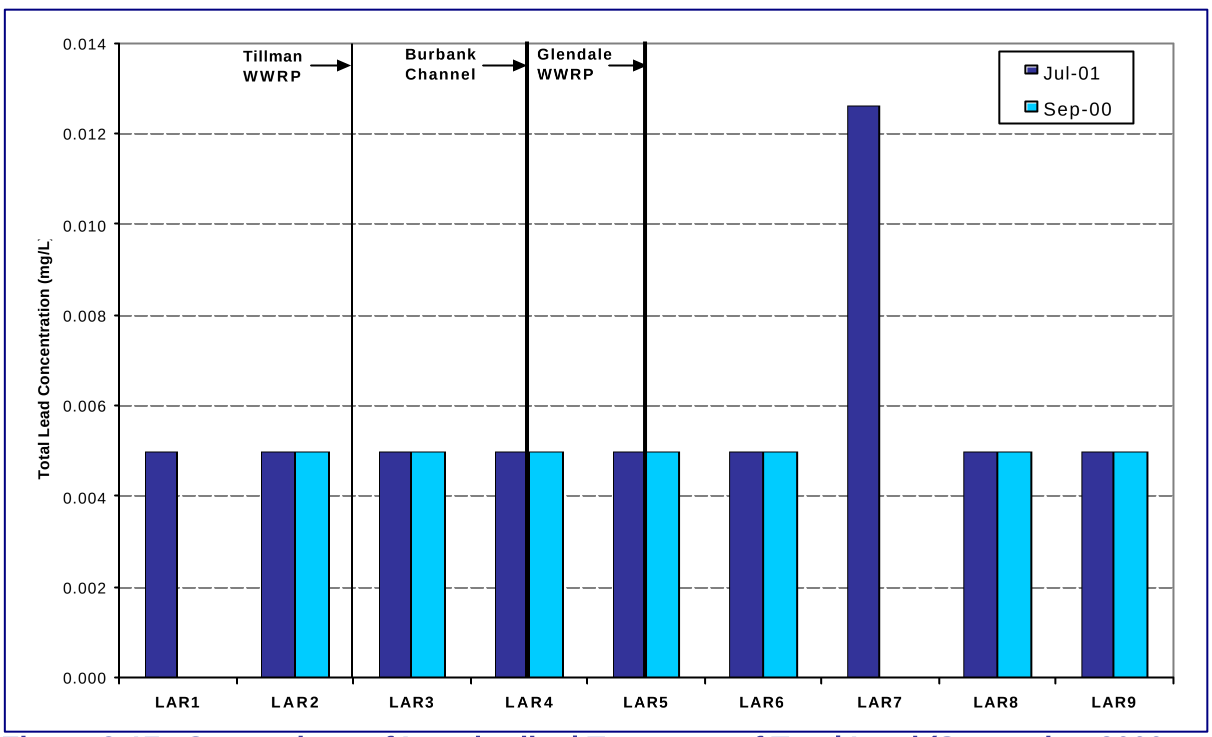


Figure 3-17. Comparison of Longitudinal Transects of Total Lead (September 2000 vs. July 2001)

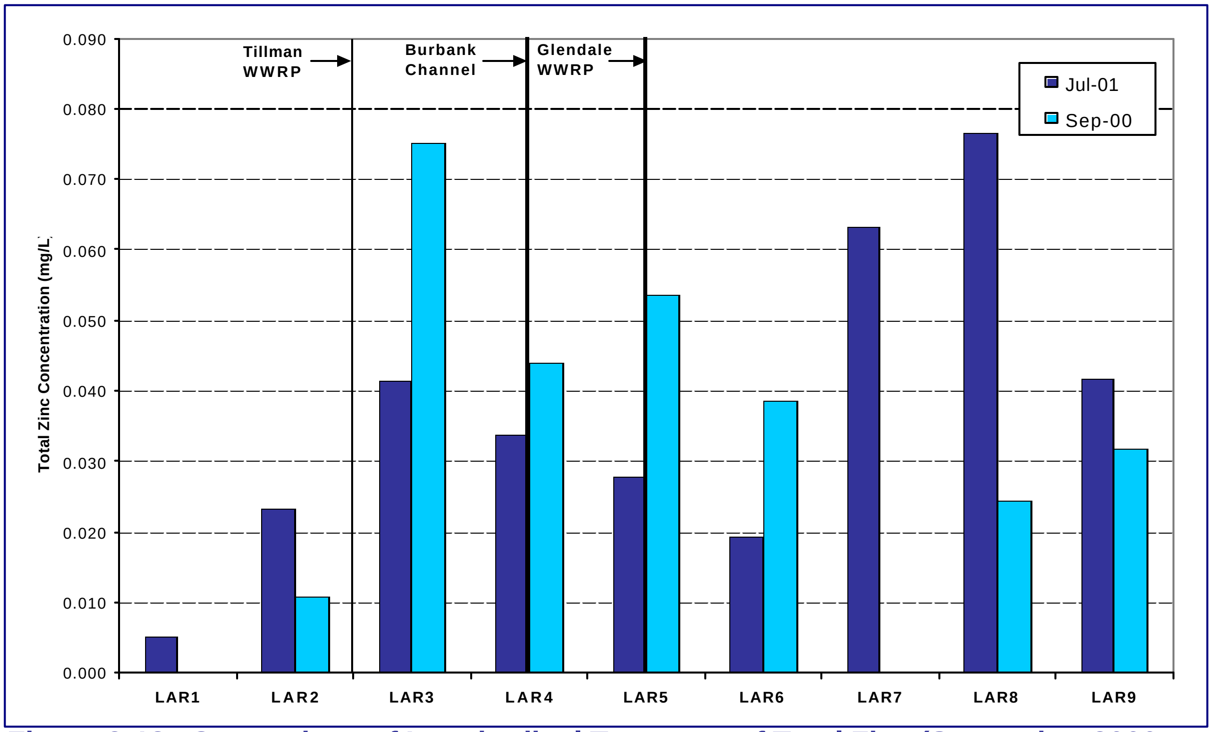


Figure 3-18. Comparison of Longitudinal Transects of Total Zinc (September 2000 vs. July 2001)

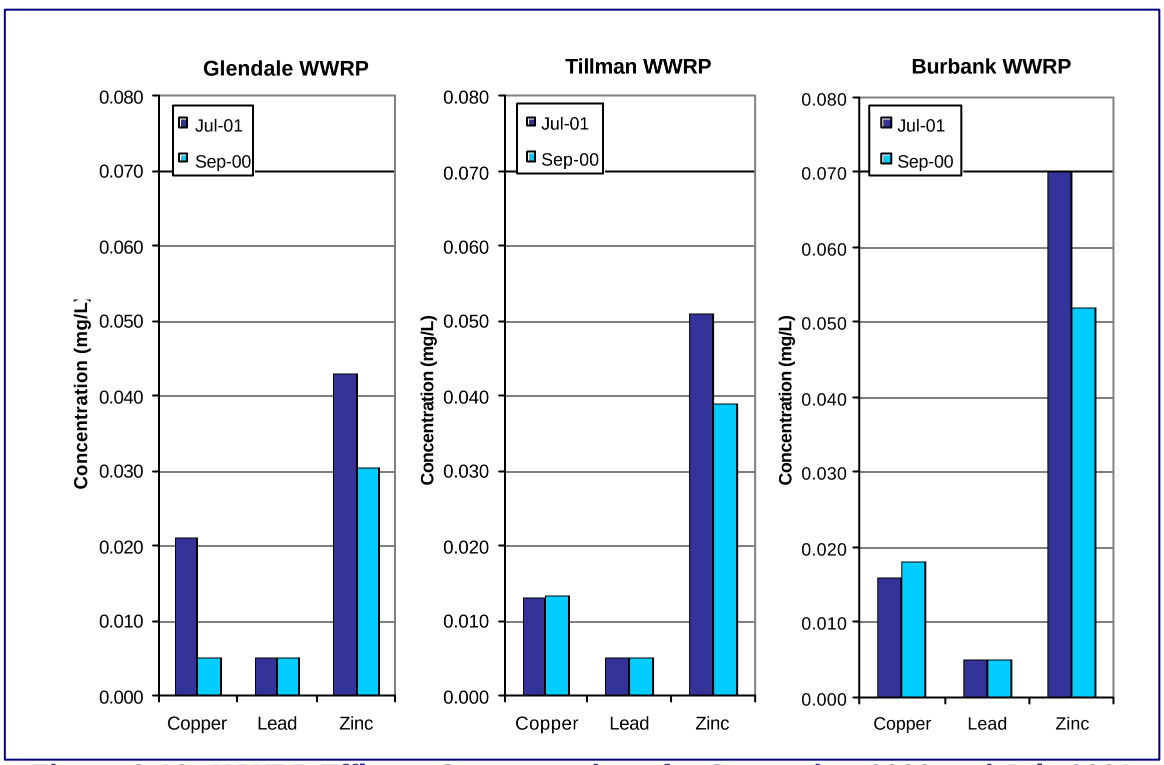


Figure 3-19. WWRP Effluent Concentrations for September 2000 and July 2001

Observed copper and zinc concentrations follow a similar pattern within the system. Concentrations spike in 2000 at LAR3, just downstream of the Tillman WWRP. The concentrations then generally decrease moving downstream. In 2001, concentrations seem to be diluted by the inflow of the point source discharges. Copper concentrations then spike at LAR7, while zinc spikes at LAR8. These spikes are due to large loadings from non-point sources. Measured lead concentrations were below detention limits at all instream stations for both years, except for a spike at LAR7 in 2001.

3.3.1 Water Quality Comparison (September 10 and 11, 2001)

The first comparison of the WASP water quality model was conducted for September 10 and 11, 2001. Modeled results were compared to observed data for the listed tributaries as well as the mainstem of the LA River. The following sections present the results for the tributary and the LA River mainstem.

Tributary Water Quality Comparison

The water quality comparisons for the tributaries are presented in Figures 3-20 through 3-22. The model results for each of the listed tributaries were compared to observed data at their confluence with the LA River. The measured data consisted of a single sample collected on September 11, 2000, not allowing for evaluation of temporal variability in water quality.

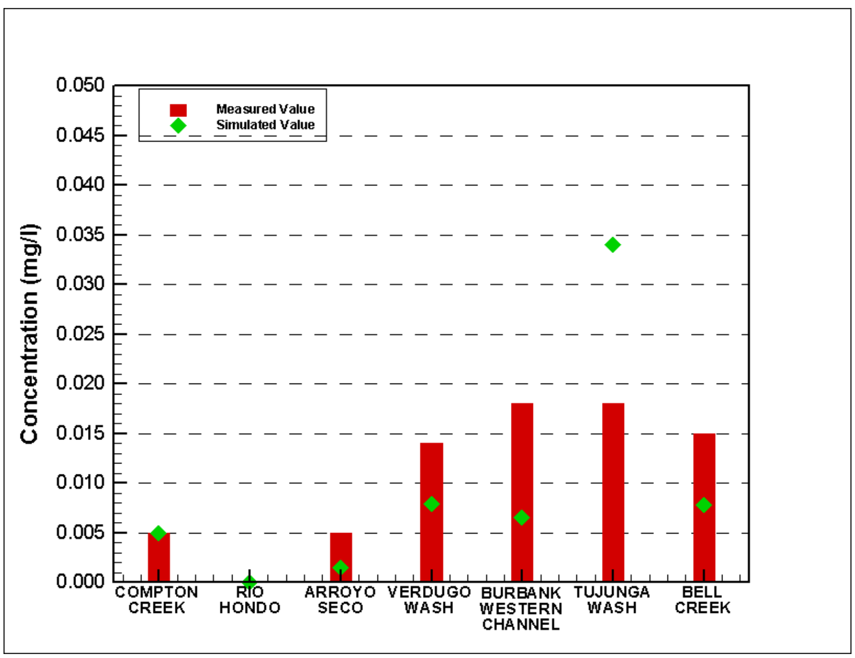


Figure 3-20. Simulated vs. Measured Total Copper for the 2000 Low-Flow Period

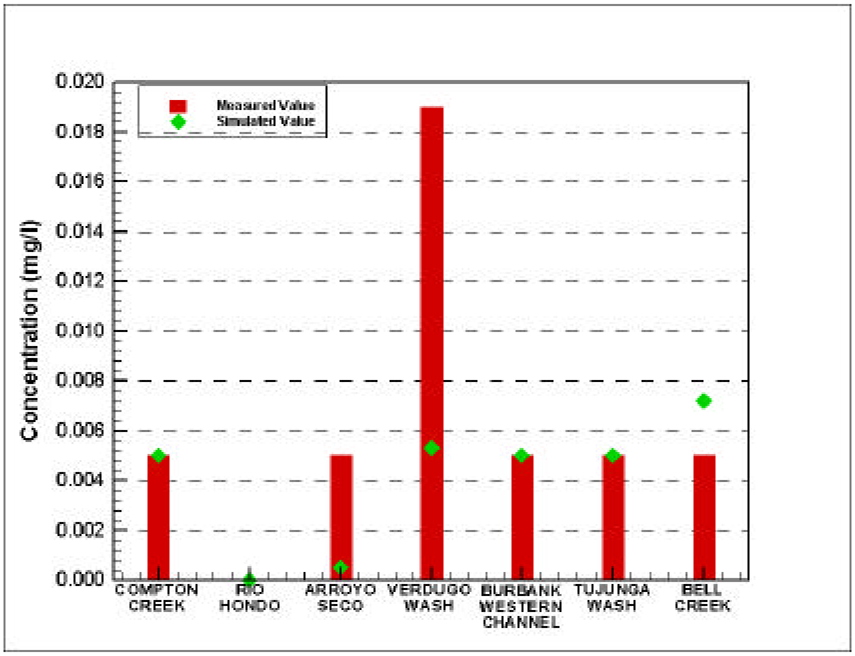


Figure 3-21. Simulated vs. Measured Total Lead for the 2000 Low-Flow Period

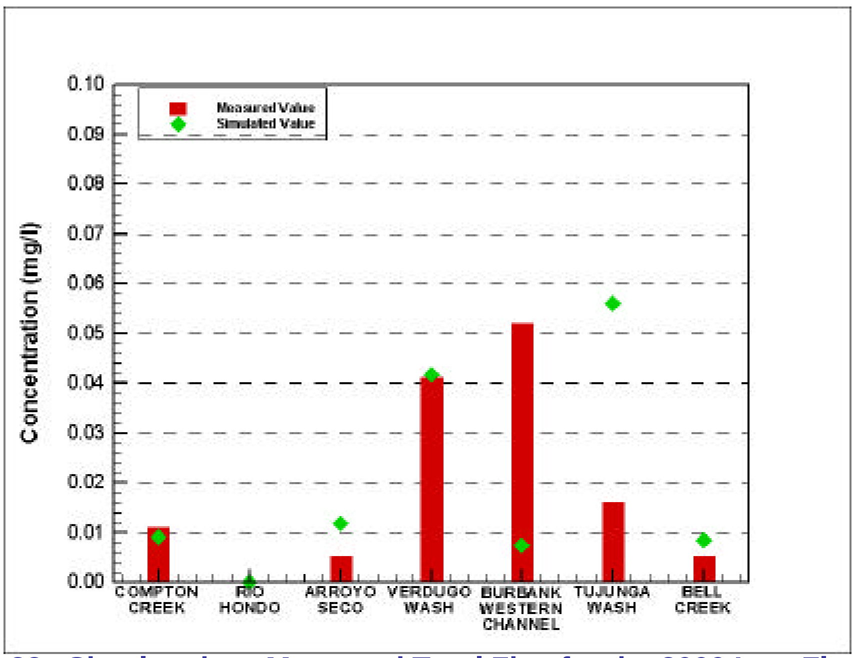


Figure 3-22. Simulated vs. Measured Total Zinc for the 2000 Low-Flow Period

Los Angeles River Mainstem Water Quality Comparison

The water quality comparisons for the metal constituents for the LA River are presented in Figures 3-23 through 3-25. The comparison points for the LA River consisted of seven composite samples collected along the river on September 11, 2000. The seven composite samples reflect a quasi-steady state condition that provided a longitudinal pattern for model comparison.

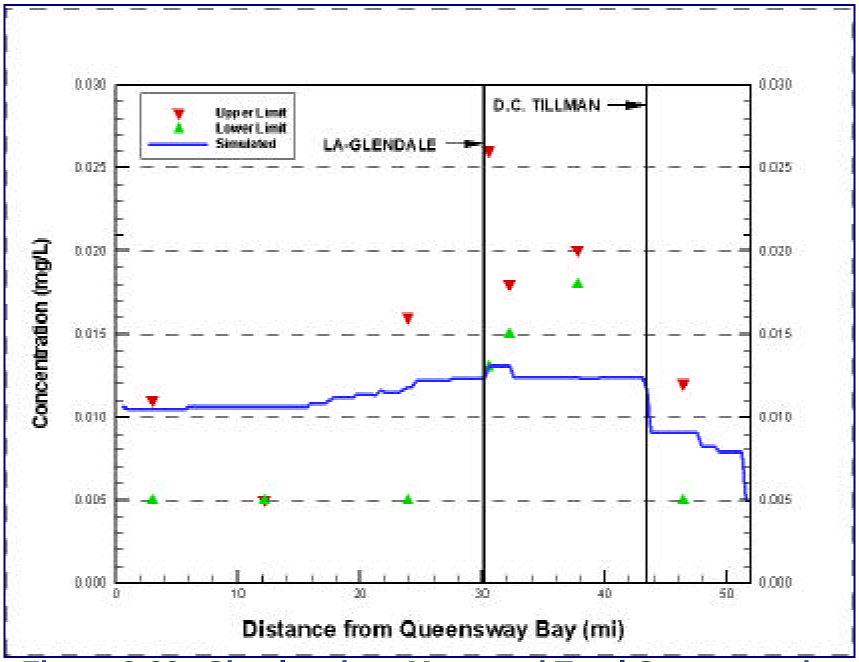


Figure 3-23. Simulated vs. Measured Total Copper on the LA River for the 2000 Low-flow Period

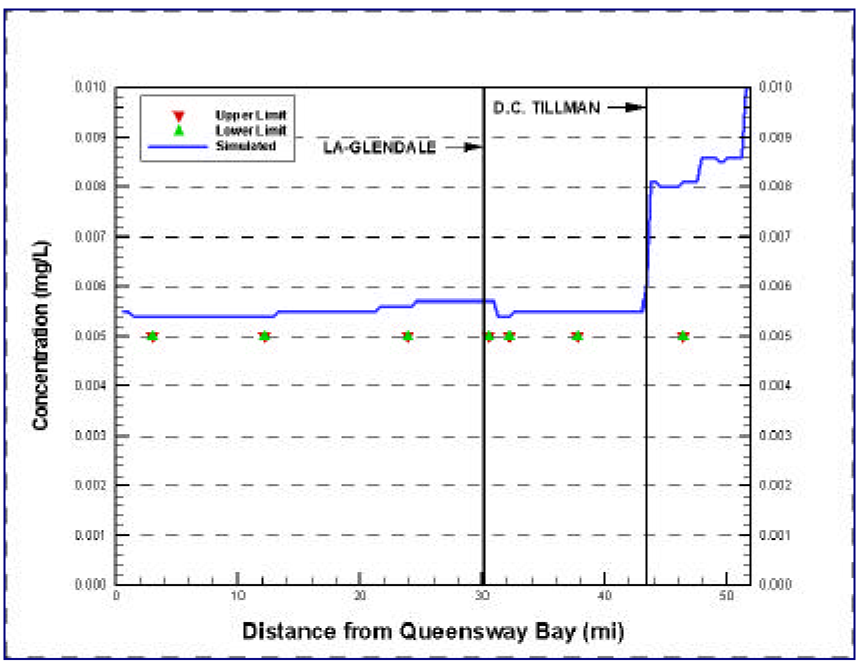


Figure 3-24. Simulated vs. Measured Total Lead on the LA River for the 2000 Low-flow Period

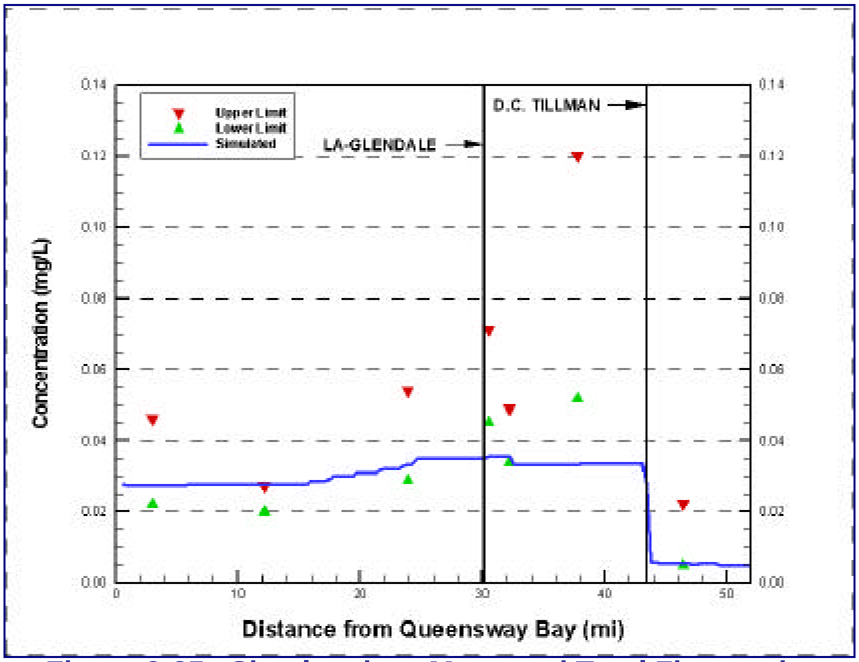


Figure 3-25. Simulated vs. Measured Total Zinc on the LA River for the 2000 Low-flow Period

3.3.2 Water Quality Comparison (July 29 and 30, 2001)

The comparison points for the LA River consisted of nine composite samples that were collected along the river on July 30, 2001. The results of water quality comparisons for the LA River are presented in Figures 3-26 through 3-28. Similar to the 2000 dataset, for each parameter, comparison was considered successful if the model simulated relative trends reflected in the observed data.

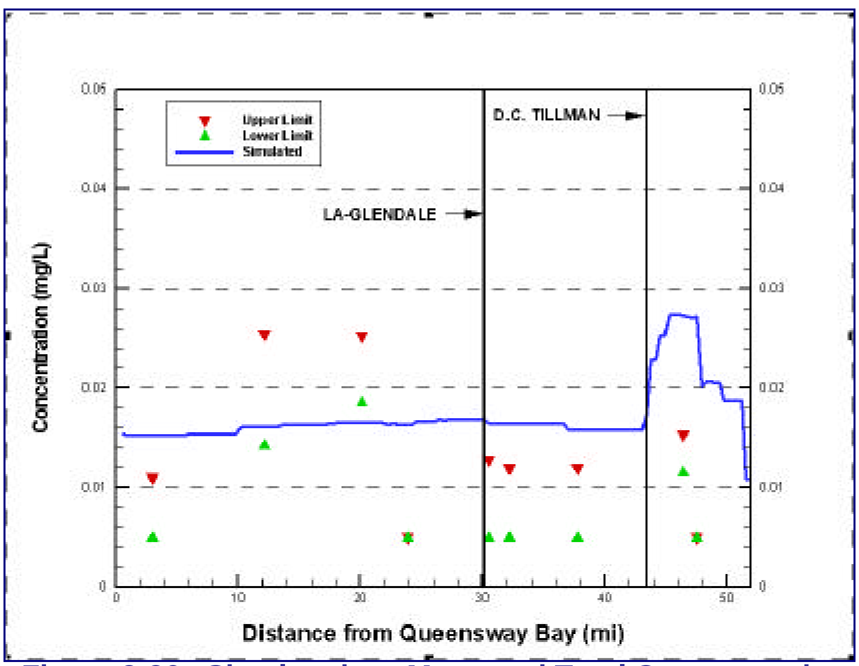


Figure 3-26. Simulated vs. Measured Total Copper on the LA River for the 2001 Low-flow Period

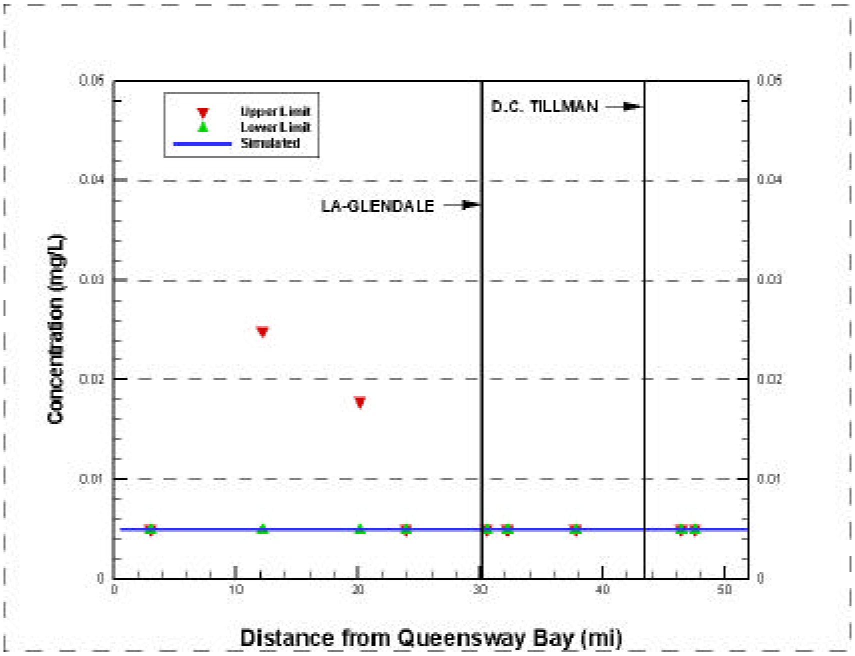


Figure 3-27. Simulated vs. Measured Total Lead on the LA River for the 2001 Low-flow Period

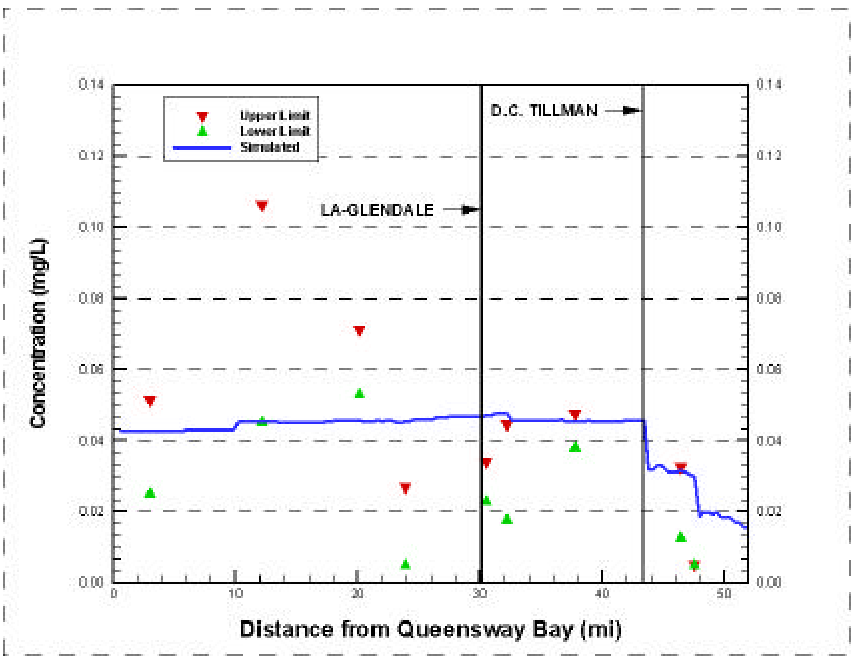


Figure 3-28. Simulated vs. Measured Total Zinc on the LA River for the 2001 Low-flow Period

3.3.3 Summary of Water Quality Comparisons

As shown in Figures 3-23 through 3-28, the model appears to be simulating the water quality constituents in a consistent manner. The simulated results generally follow the same pattern and have the same magnitude as the observed water quality. This indicates that during the two data collections, a good quantification of the sources and their loads was performed. Even though the water quality model was not "calibrated", and constituents were simply modeled as a conservative substance, this seems to be an appropriate assumption. Overall, it appears that the model is a valuable tool to predict water quality trends and magnitudes for evaluation of sources and water quality impacts in the system.

3.4 Sensitivity Analysis

During the 2000 and 2001 data collections, many stormdrain samples were measured as "non-detects" or "less than detection limits". This means that when analyzing the sample, the true concentration was below the detection limits of the test being performed. Since the true concentration of the sample was not known, a sensitivity analysis was performed on the 2000 dataset by adjusting the input concentrations for those particular samples. To perform sensitivity analyses, each sample with a non-detect value was first input into the model at half the detection limit of each metal (0.005 mg/L). The concentration was then adjusted by +/- 10, +/- 25 and +/- 50 percent and input into the model. The results of each scenario are presented in Figures 3-29 through 3-31.

As can be shown in the figures, adjusting the concentrations of non-detect samples does not significantly affect the results of the simulation, particularly above the Glendale WWRP. This is most likely due to the fact the at this point and above, the dominant source of flow to the system are the three WWRPs. Below the Glendale WWRP, as more stormdrains enter the system the three point sources begin to have a smaller percentage of the overall load to the system. Therefore the results of the analysis begin to show some minor deviation.

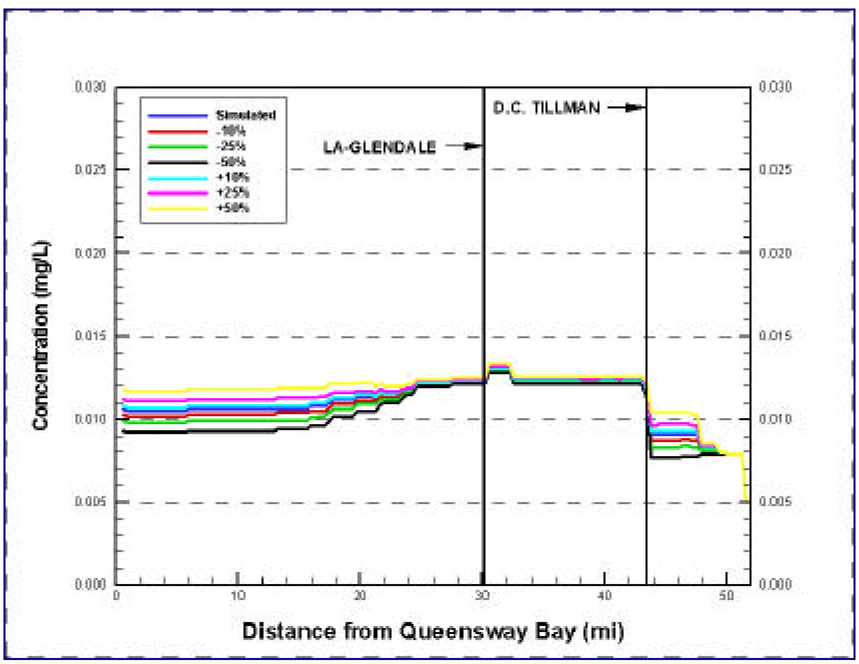


Figure 3-29. Sensitivity Analysis on Non-Detect Samples for Total Copper in the LA River

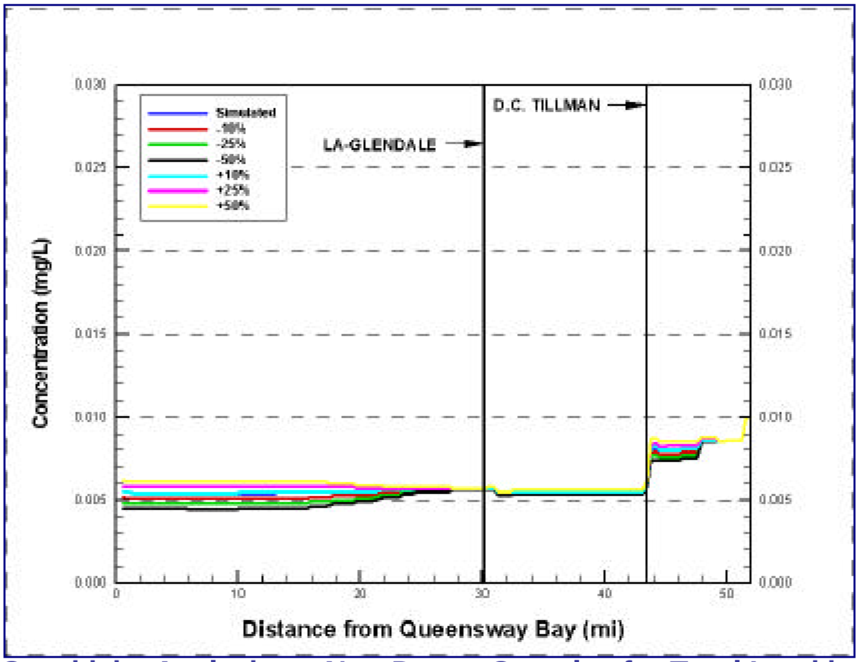


Figure 3-30. Sensitivity Analysis on Non-Detect Samples for Total Lead in the LA River

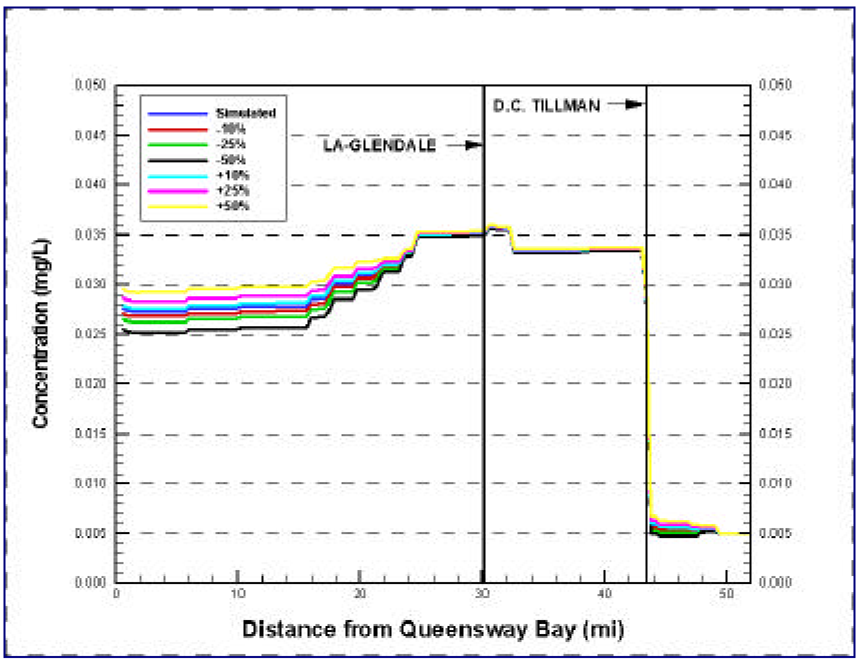


Figure 3-31. Sensitivity Analysis on Non-Detect Samples for Total Zinc in the LA River

References

Ambrose, R.B. et al. 1988. *WASP4, A Hydrodynamic and Water Quality Model--Model Theory, User's Manual, and Programmer's Guide*. U.S. Environmental Protection Agency, Athens, GA. EPA/600/3-87-039.

Caupp, C.L., Brock, J.T., and Runke, H.M. 1991. *Application of the dynamic stream simulation and assessment model (DSSAM III) to the Truckee River below Reno, Nevada. Model formulation and program description*. Prepared by Rapid Creek Water Works for Nevada Division of Environmental Protection, Carson City and Washoe County Department of Comprehensive Planning, Reno, NV.

Connolly, J.P., and Winfield, R. 1984. *A User's Guide for WASTOX, a Framework for Modeling the Fate of Toxic Chemicals in Aquatic Environments. Part 1: Exposure Concentration*. U.S. Environmental Protection Agency, Gulf Breeze, FL.

DiToro, D.M., Fitzpatrick, J.J., and Thomann, R.V. 1981, rev. 1983. *Water Quality Analysis Simulation Program (WASP) and Model Verification Program (MVP) - Documentation*. Hydroscience, Inc., Westwood, NY, for U.S. Environmental Protection Agency, Duluth, MN, Contract No. 68-01-3872.

Hamrick, J.M. 1996. *A User's Manual for the Environmental Fluid Dynamics Computer Code (EFDC)*. The College of William and Mary, Virginia Institute of Marine Science, Special Report 331, 234 pp.

LARWQCB. 1998. *Los Angeles River Watershed Water Quality Characterization*. First Edition. April 1998. California Regional Water Quality Control Board, Los Angeles Region, CA.

NDEP. 1982. *Water Quality Management (208) Plan for the Carson River Basin, Nevada*. Nevada Division of Environmental Protection, Department of Conservation and Natural Resources.

Thomann, R.V., and Mueller, J.A. 1987. *Principles of Surface Water Quality Modeling and Control.* Harper & Row, New York. 644 pp.

Warwick, J.J, Cockrum, D., and Horvath, M. 1997. Estimating Non-Point Source Loads and Associated Water Quality Impacts. *Journal of Water Resources Planning and Management.*

Whitford, L.A., and Schumacher, G.J. 1964. "Effect of current on respiration and mineral uptake in Spirogyra and Oedogonium." *Ecology*, 45, 168-170.