

TUJUNGA WATERSHED PROJECT

Hydrology, Hydraulic, and Water Quality Model Summary v. 2

1. OVERVIEW

As part of the Tujunga Watershed Project, numerical models will be used as tools to evaluate and quantify flood protection, ground water recharge, and surface water quality under existing conditions and future alternatives. This document summarizes existing models and the modeling methodology developed for the Tujunga Watershed (TW). Section 2 describes existing surface water, water quality, and ground water models from prior studies that could be used for this project and summarizes the usage and conclusions of the models. Section 3 summarizes the applicability of the existing models for this study, as well as the modifications and updates to the models necessary to use the models for this study. Section 4 contains the proposed modeling approach to use the models to evaluate existing conditions and the alternatives.

2. EXISTING NUMERICAL MODELS

Previous surface water, water quality, and ground water models have been developed to simulate hydrologic, hydraulic, and water quality conditions in the Tujunga Watershed (TW). These models either focused on a portion of the TW or included the TW as part of a larger study area, such as the Los Angeles River (LAR) Watershed. A summary of these models is shown in Table 1 and the models are discussed below. No sediment transport model has been developed for the Tujunga Watershed, but a scour assessment was conducted based on The River Project (TRP) Hydrodynamic River Model.

Table 1 – Existing Models for the Tujunga Watershed

MODEL	MODEL TYPE	STUDY AREA	AGENCY
TRP Hydrodynamic River Model	Hydrodynamic	Tujunga Wash Subwatershed	TRP
Los Angeles River HEC Models	Watershed and Hydrodynamic	Los Angeles River Watershed	USACE and LACDPW
Los Angeles River EFDC Model	Hydrodynamic	Los Angeles River Watershed	LARWQCB
Los Angeles River WASP Model	Water Quality	Los Angeles River Watershed	LARWQCB
Los Angeles River LSPC Model	Watershed and Water Quality	Los Angeles River Watershed	LARWQCB
Los Angeles Basin Ground Water Augmentation Model	Runoff and Infiltration	Los Angeles Basin	Bureau of Reclamation and LASGRWC
LADWP Groundwater Model	Ground water	San Fernando Ground Water Basin	LADWP

2.1. The River Project (TRP) Hydrodynamic River Model

The TRP Hydrodynamic River Model used the hydrodynamic model MIKE 11 to establish a baseline for existing conditions and to evaluate modifications to the Tujunga Wash Channel. In addition, the MIKE 11 model river section for the Tujunga Wash Channel was translated to the Hydrologic Engineering Center’s River Analysis System (HEC-RAS) for use by parties without access to MIKE 11.

MIKE 11 is a one-dimensional hydrodynamic model developed by the Danish Hydraulics Institute (DHI). The computer executable and source codes are proprietary. The hydrodynamic component is an implicit, finite difference model that is capable of subcritical, supercritical, and mixed flow regimes. MIKE 11 can simulate hydraulic control structures including weirs, culverts, sluice gates, gated spillways, drop structures, pumps, bridges and dam breaks (DHI 2000).

HEC-RAS is a one-dimensional hydraulic model used to simulate steady and unsteady-state surface water flows in a network of natural and constructed channels. The executable code and documentation are public domain software developed by Hydrologic Engineering Center (HEC) for USACE. HEC-RAS is an implicit, finite difference model capable of subcritical, supercritical,

and mixed flow regimes. HEC-RAS is capable of simulating hydraulic control structures including bridges, culverts, weirs, gated spillways, drop structures, and other flood plain structures (USACE 2002). Neither MIKE 11 nor HEC-RAS are capable of simulating surface water infiltration; therefore, the effects of any reduction in flood flows associated with increased infiltration attributed to channel modification (e.g., concrete removal) were not included in the modeling simulations.

The TRP Hydrodynamic River Model domain was defined by cross sections of the Tujunga Wash Channel, Pacoima Drainage Channel, Branford Drainage Channel, Hansen Spreading Grounds, and Tujunga Spreading Grounds. The Tujunga Wash Channel between Hansen Dam and the confluence with the Los Angeles River cross sections were provided by USACE (1963 and 1990) and were verified with as-built construction plans dated September 1950, which were also provided by USACE. A total of 97 cross sections were used to define the 9.5-mile Tujunga Wash Channel. The Pacoima Drainage Channel between the Pacoima Spreading Grounds and the Tujunga Wash Channel confluence was defined by four cross sections over 2.9 miles. The Branford Drainage Channel was defined by two cross sections over 0.3 miles. The Hansen Spreading Grounds and Tujunga Spreading Grounds were each defined by two cross sections over 0.12 miles.

The upstream boundary controls were based on the Hansen Dam outflow, Pacoima Drainage Channel inflow, and Branford Drainage Channel inflow that were obtained from USACE (1991). Constant water level boundaries were used to represent diverted flows from the Tujunga Wash Channel to the Hansen Spreading Grounds and Tujunga Spreading Grounds. The downstream boundary condition for the TRP Hydrodynamic River Model was assumed to be critical depth at the confluence of the Tujunga Wash Channel and LAR that was simulated using a rating table (TRP 2002).

The TRP Hydrodynamic River Model of the existing Tujunga Wash Channel was used to simulate discrete flood events for the 2-, 5-, 10-, 25-, 50-, and 100-year flood events and seasonal discharge for the 1998 water year. The TRP study (2002) made the following conclusions for existing conditions.

- The existing Tujunga Wash Channel has little flow attenuation between Hansen Dam and the LAR confluence due to the lack of channel or floodplain storage, low frictional losses (i.e., very smooth channel surface), and a steep overall channel slope that results in supercritical flows.

- The Tujunga Wash Channel has an overall channel slope of 41 feet per mile and high average channel velocities, as high as 50 feet per second (ft/sec) at the Pacoima Wash Drainage Channel confluence.
- The existing Tujunga Wash Channel has little available capacity to accommodate additional runoff beyond the 100-year flood event.
- The widening of the Tujunga Wash Channel from 60 to 70 ft at the confluence with the Pacoima Wash Drainage Channel is required to maintain adequate conveyance capacity for flows greater than the 100-year flood event.
- The existing concrete channel can accommodate the supercritical flows without erosion.
- To allow a more natural channel, the channel must either be considerably enlarged or the flow must be considerably reduced (the latter being the only practical method).

The TRP HEC-RAS model domain was defined by the existing Tujunga Wash Channel between Hansen Dam and the confluence with the Los Angeles River. The channel cross sections were the same 97 cross sections used for the MIKE 11 model domain. The Pacoima Drainage Channel, Branford Drainage Channel, Hansen Spreading Grounds, and Tujunga Spreading Grounds were not included.

The TRP HEC-RAS model was used to simulate one steady-state simulation of existing conditions (note that HEC-RAS is capable of simulating unsteady-state conditions). The boundary condition was specified with three flows along the Tujunga Wash Channel, 22,000 cfs between Hansen Dam and the Pacoima Drainage Channel confluence, 29,000 cfs between the Pacoima Drainage Channel confluence and half way to the Los Angeles River confluence, and 30,000 cfs along the remaining portion.

A portion of the TRP Hydrodynamic River Model (MIKE 11) of the existing Tujunga Wash Channel model between Hansen Dam and the Sherman Way crossing was used to simulate the 100-year flood event for four alternative concepts: 1) Alternative A – a single floodplain terrace between Hansen Dam and Sherman Way, 2) Alternative B – two floodplain terraces between Hansen Dam and Sherman Way, 3) Alternative C – existing Tujunga Wash Channel with an adjacent braided channel between Glenoaks Boulevard and Sherman Way, and 4) MRCA Channel Concept – existing Tujunga Wash Channel with an adjacent unarmored channel

between Vanowen Street and Oxnard Boulevard. Various configurations (e.g., different channel widths) for each alternative were analyzed. In addition, initial volume estimates were made for using gravel pits to retain flood flows.

The following conclusions for the alternatives were made from the TRP study (2002).

- Alternative A would provide additional flood protection, enhanced habitat quality, and potential space for future recreational development. It reduces the existing 100-yr flood event channel velocities of 42 ft/sec to velocities between 24 and 33 ft/sec in the primary channel above the Pacoima Wash Drainage Channel confluence.
- Compared to Alternative A, Alternative B provides similar habitat and recreational benefits, but slightly less flood protection (e.g., storage and conveyance capacity) resulting in higher velocities, flow depths, and average shear stress. Alternative B would also require some channel bed and bank protection. Potential protection methods considered were derrick stones at selected cross-sections for the channel bed and bio-technical erosion prevention techniques for the channel bank.
- Alternative C does not alter the existing Tujunga Wash Channel and does not adversely affect existing flood conveyance conditions. Features (e.g., benched terraces or grade control structures) can be used to adjust channel geometries to attain target flow velocities and water surface elevations. The existing spreading grounds located adjacent to the channel are a potential pathway for the natural braided channel. Further refinement, development, and study of this concept are necessary to determine how this alternative might improve or impact infiltration and recharge operations of the spreading grounds.
- The new channel under the MRCA Channel Concept would not impact the existing channel and flood conveyance capacity. This concept is limited in extent regarding spatial modifications and hydrologic impact. Flow frequencies would depend on intake conditions from the Pacoima Channel and bed percolation losses in the newly created channel.
- Gravel pits should be considered in future flood flow management programs. A greater detailed study with field verification would be necessary.

The TRP study (2002) recommended a planning level feasibility study be conducted with the goal to develop these concepts (or new concepts) into more rigorously defined project alternatives. A more detailed hydrology and hydraulic analysis of project alternatives, socio-economic, land use zoning and availability, and other environmental considerations should be addressed.

The TRP study (2002) also included a scour assessment based on the flow conditions under Alternative A, which contained a range of channel width configurations. The average velocity of the 100-year event above the Pacoima Wash Drainage Channel confluence was determined for the various configurations of Alternative A. The velocities ranged between 24 and 33 ft/sec in the primary channel and 10 and 12 ft/sec in the terrace floodplain. The configuration with the smallest average velocity was used to determine the average bed shear stress. This bed shear stress would be sufficient to transport a sediment size of 200 mm (7.9 inches) or large cobbles. Alternative A would include some armoring of the channel bed with derrick stones, which are large concrete blocks.

2.2. Los Angeles River HEC Models

Several HEC Models were developed to evaluate alternatives for flood protection improvements within the LAR. The Los Angeles River HEC Models include the watershed model HEC-1 and reservoir storage model HEC-5, as well as the hydraulic flood flow model HEC-RAS (supersedes the HEC-2 model). The LAR HEC-1 and HEC-5 were used in the Los Angeles County Drainage Area (LACDA) Feasibility Study conducted by USACE in 1992. Los Angeles County Department of Public Works (LACDPW) used these HEC models in the Los Angeles River Alternative Study (LARAS) in 1997. In 2005, the USACE in cooperation with LACDPW developed detailed HEC-RAS models to update hydraulic flood modeling simulations for the upper LACDA, which includes the upper Los Angeles River and Tujunga Wash. The purpose of the HEC-RAS models is to establish present-day baseline hydraulic conditions, refine channel operation and maintenance procedures, evaluate permit requests for proposed changes to channel geometry, and evaluate future alternatives of LACDA.

HEC-1 is a watershed model, which is public domain software developed by HEC for USACE. HEC-1 is used to determine surface runoff based on a precipitation within a watershed. The model is capable of simulating streams, reservoirs, and dam breaks. Limitations include single flood simulations (i.e., successive floods cannot be simulated), results are in terms of flow not

stage, and reservoir routing is not applicable for controlled reservoir releases using gates (USACE 1998a).

HEC-RAS, the public domain software developed by the USACE HEC, is a one-dimensional hydraulic model used to simulate surface water flows in a network of natural and constructed channels. A detailed description of the model capabilities and limitations are provided in Section 2.1.

HEC-5 is a reservoir routing model, which is public domain software developed by HEC for USACE. HEC-5 is used as a tool to assist in sizing flood control and conservation (e.g., hydropower) storage facilities. HEC-5 can account for reservoir release operations, maximum reservoir outflow, minimum channel flows, and flow diversions (USACE 1998b).

The HEC-1 model domain of the LAR watershed used in the LACDA study included the Tujunga Watershed, which was divided into seven subwatersheds. Each subwatershed included data for watershed area, soil infiltration rates, and percent impervious cover. Infiltration rates ranged from 0.25 to 0.35 inches per hour and percent impervious cover ranged between 0 and 33%. HEC-1 was used to simulate 24-hour precipitation events for various return periods and determine the corresponding flood hydrographs within the LAR. The HEC-5 model was then used to determine the corresponding flood plains and evaluate alternatives for flood protection along the LAR and portions of the Rio Hondo and Compton Creek. The modified Puls routing technique was used for reservoirs and channel reaches and it was assumed that debris and reservoir were full at the initiation of the flood event.

The LACDA study (USACE 1992) determined that the lower portion of the Tujunga Wash Channel (below the Pacoima Wash Drainage Channel confluence) is not sufficient to convey the 100-year flood (a.k.a. regulatory flood). In addition, the use of the Pacoima Spreading Grounds and Tujunga Spreading Grounds as detention basins were determined to be infeasible due to high costs and localized effects relative to flood improvement in the lower LAR. No recommendations were made for changes within the Tujunga Watershed, as the recommended plan increased the flood protection to the 133-year design level in the lower LAR (Rio Hondo and LAR below the Rio Hondo confluence) (LACDPW 1997).

The LARAS evaluated alternatives to reduce the 133-year flood peak within the LACDA project area. Alternatives with modifications within the Tujunga Watershed that were evaluated included re-operation of Hansen Dam and peak flow detention using Pacoima Spreading Grounds. Both alternatives were found to have localized improvements, but negligible effects

on the lower LAR. No recommendations were made for areas within the Tujunga Watershed since this study did not address changes within the TW (LACDPW 1997).

The model domain of the USACE HEC-RAS models covers the upper LAR above Rio Hondo and Tujunga Wash, which are divided into three separate HEC-RAS models. The Reach 2 HEC-RAS model contains the LAR between Sepulveda Flood Control Basin and Fletcher Drive and Tujunga Wash Channel between Hansen Dam to LAR confluence, which also included a portion of the Pacoima Drainage Channel. The Tujunga Wash Channel cross sections and bridge dimensions were based on as-built drawings and site visits were conducted to verify the channel cross sections and bridge and pier measurements. The 9.3-mile channel was defined by 217 rectangular cross sections with an additional 606 interpolated cross sections. Cross sections below Magnolia Boulevard show a low flow channel. The Pacoima Drainage Channel was represented by nine cross sections over 360 feet. The Tujunga Wash Channel included 26 bridges. Initial analyses indicated pressure flow conditions (water elevation reaches the bridge soffit) for a number of these bridges, but not along the LAR. All bridges along the Tujunga Wash Channel were artificially raised by 10 feet (USACE 2005).

The USACE HEC-RAS model was used to conduct a steady-state simulation of design discharges. The upstream boundary conditions for the Tujunga Wash Channel and Pacoima Drainage Channel were specified as constant water elevations based on the design discharges. A total of three design flows were used for the Tujunga Wash Channel, 22,000 cfs between Hansen Dam and Beachy Avenue, 29,000 cfs between Beachy Avenue and Vanowen Street, and 30,000 cfs between Magnolia Blvd and the LAR confluence. The downstream boundary conditions were specified as stream junctions. The starting water elevations were specified as supercritical (USACE 2005).

Results along the Tujunga Wash Channel indicate no channel overtopping for design discharge conditions. However, these results were based on a simulation with all bridge soffits artificially raised by 10 feet. Comparisons of the modeled water elevations to stream gage measurements and other pertinent data were also included in the study. Pertinent data of water surface elevation and invert elevation profiles were compared along the entire length of the Tujunga Wash Channel. Gage data of flow and corresponding water elevation taken at Tujunga Wash below Hansen Dam showed the model predicted water elevations within one-foot of the gage data (USACE 2005).

The USACE study (2005) also developed a procedure for evaluating proposed changes in the channel using the HEC-RAS models based on the current USACE Los Angeles District permit

process. The process includes assessing appropriate model use and changes to design water surfaces or flow conveyance characteristics, determining mitigation, and documenting changes to the HEC-RAS models (submit model control files). HEC-RAS model changes would become official when a permit is issued. USACE and LACDPW would be the bearer of the current models of record (USACE 2005).

2.3. *Los Angeles River EFDC Model*

The Los Angeles River EFDC Model was developed by the Los Angeles Regional Water Quality Control Board (LARWQCB) to support the development of a dry weather metals TMDLs for the LAR. The Environmental Fluid Dynamics Code (EFDC) is a hydrodynamic model that can be executed as a one-, two-, or three-dimensional model. EFDC was originally developed at the Virginia Institute of Marine Science and is currently a public domain model maintained by the U.S. Environmental Protection Agency (USEPA). EFDC is an implicit, finite difference model with options to use HEC-type cross sections for one-dimensional applications. EFDC is capable of simulating hydraulic control structures using rating curves, but is not capable of simulating supercritical flow.

The LAR EFDC model domain was a one-dimensional representation of the LAR that included the Tujunga Wash Channel as a major tributary. The Tujunga Wash Channel was defined between Hansen Dam and the LAR confluence. Hansen Dam, Pacoima Wash, and the spreading grounds were not simulated. The LAR channel cross sections were based on the LACDA Operation and Maintenance Manual (USACE 1999) and were represented with 302 grid cells with each cell having a length about 600 meters (LARWQCB 2004b). The channel invert elevations were based on the U.S. Geological Survey (USGS) 7.5-minute quad map and ranged from an upstream invert elevation of 990 ft, NGVD to a downstream invert elevation of 566 ft, NGVD. An assumed low flow channel was also included through the entire reach (LARWQCB 2004b).

The LAR EFDC model was calibrated and verified for hydrodynamics conditions based on flow, water surface elevation, and velocity data collected on two separate occasions. The Tujunga Wash Channel was simulated as a tributary with a constant dry weather flow determined by field measurements. No storm drain flows for the Tujunga Wash Channel were measured (LARWQCB 2004b).

No conclusions or recommendations were made for areas within the Tujunga Watershed since the model was calibrated and verified at locations along the mainstem of the LAR and not within the Tujunga Watershed.

2.4. Los Angeles River WASP Model

The Los Angeles River Water Quality Analysis Simulation Program (WASP) Model was developed by the LARWQCB to support the dry weather metals TMDLs for the LAR. WASP is a public domain model maintained by USEPA. WASP is a dynamic water quality model that can be executed as a one-, two-, or three-dimensional model to simulate aquatic systems including the water column and underlying benthos. The model is capable of simulating time-variable exchange coefficients, advective flows, waste loads, water quality boundary conditions, and user-specified kinetic processes. WASP simulates water quality constituents as either a conventional pollutant with reactions involving dissolved oxygen, biochemical oxygen demand, nutrients, and eutrophication or a toxic pollutant, such as organic chemicals, metals, and sediment (USEPA 2001).

The LAR WASP Model was linked to the one-dimensional LAR EFDC Model, which was used to simulate the hydrodynamic conditions. WASP was used to simulate metal concentrations (total copper, total lead, and total zinc) as a conservative constituent (i.e., no chemical or biological reactions). No calibration or validation was performed due to limited supporting data and the simulation of metals as a conservative constituent, but comparisons of model predicted concentrations were made to observed data. The conservative constituent inputs were defined by two grab samples taken on two occasions and were used to simulate two steady-state scenarios with constant loads (LARWQCB 2004b).

Comparisons for total copper, total lead, and total zinc were made for one scenario at the Tujunga Wash Channel below the Pacoima Wash Drainage Channel. The model predicted total copper was about twice the measured concentration. The model predicted total lead matched the measured concentration and the model predicted total zinc was about four times that of the measured concentration. No other conclusions or recommendations were made (LARWQCB 2004b).

2.5. Los Angeles River LSPC Model

The Los Angeles River LSPC Model was developed by the LARWQCB to support the wet weather metals TMDL for the LAR. The Loading Simulation Program C++ (LSPC) is a proprietary watershed model developed by Tetra Tech, Inc. LSPC integrates GIS data storage and management capabilities, a dynamic watershed model, and a data analysis/post-processing system into a PC-based windows interface. The watershed model component is a re-coded version of a portion of the watershed model Hydrological Simulation Program – Fortran (HSPF), which is a public domain model maintained by USEPA. LSPC contains algorithms for simulating hydrology, temperature, sediment, and general water quality constituents. LSPC does not contain the HSPF features for the agricultural chemicals (e.g., nitrogen, phosphorus, and pesticides) and does not simulate the complex chemical interactions. The LSPC capabilities include simulation of point and non-point sources for flow, sediment, and simple sediment and water associated constituents (e.g., nonpoint sources of constituents are determined based on sediment loading) from pervious and impervious land uses.

The Los Angeles River LSPC Model domain of the LAR Watershed included the Tujunga Watershed. The Tujunga Watershed was divided into seven subwatersheds, which were based on existing stream networks and topography (e.g., digital elevation models [DEMs]). The Pacoima Wash Subwatershed was divided into three subwatersheds defined by Pacoima Creek above Lopez Dam, Pacoima Creek above Pacoima Spreading Grounds, and Pacoima Creek below Pacoima Spreading Grounds and Pacoima Drainage Channel. The remaining four subwatersheds were split as Big Tujunga Creek above Little Tujunga Creek, Little Tujunga Creek, Tujunga Wash Channel between Little Tujunga Creek and Pacoima Drainage Channel confluence, and Tujunga Wash Channel between Pacoima Drainage Channel confluence and LAR confluence. Land uses in the LAR watershed were derived from two datasets, LACDPW 1994 land use dataset and the 1993 USGS Multi-Resolution Land Characteristic dataset. Land uses were designated into seven general categories: residential, commercial, industrial, open, agriculture, water, and other. The percent of imperviousness associated with the different land uses were based on typical impervious percentages from the LACDPW Hydrology Manual. Soil type data were obtained from the State Soil Geographic Data Base (STATSGO), which divides soil type into four groups. The Tujunga Watershed is mostly characterized by group D soil, which has high runoff potential and low infiltration rates. The river and channel network were defined from the National Hydrography Dataset (NHD) for the USGS hydrologic unit code 18070105.

Meteorological data were obtained from the National Climatic Data Center (NCDC). Precipitation in the Tujunga Watershed was based on Station CA3751 at Hansen Dam, while weather data were from the Los Angeles International Airport. Major NPDES point source dischargers were included, although none were located in the Tujunga Watershed. Model water quality parameters were based on calibrated model parameters from the Ballona Creek Watershed. Both hydrologic and water quality parameters were simulated with constants value (i.e., no seasonal variations in parameters were used).

The Los Angeles River LSPC Model was calibrated and verified for hydrodynamic conditions between October 1989 and March 1998 at various LACDPW monitoring locations along the main stem of the LAR. The model calibration at two locations showed the model under-predicted flows in the LAR, specifically for flood events occurring in the winter of 1992-92 and 1994-95. This was attributed to localized rainfall that was not captured at the NCDC precipitation gages. Verification of the model at six other locations over the same period showed better model performance. The model calibration and validation also showed less accurate prediction during dry weather conditions. The Los Angeles River LSPC model was then used to simulate sediment and metal concentrations between for flood events in 2001. Metals were simulated as a general water quality constituent associated with sediment. Comparisons were made for total suspended solids, copper, lead, and zinc at four locations along the LAR with wet weather pollutograph data. The Los Angeles River LSPC model was then used to simulate conditions from October 1989 through September 2001, which was used to generate TMDL load duration curves for copper, lead, and zinc (LARWQCB 2004a).

No conclusions or recommendations were made for areas within the Tujunga Watershed, as the model was calibrated and verified at locations along the mainstem of the LAR and not within the Tujunga Watershed.

2.6. *Los Angeles and San Gabriel Watersheds Ground Water Augmentation Model*

The Los Angeles Basin Ground Water Augmentation Model (GWAM) is an infiltration model used to estimate the potential runoff and infiltration rate for ground water recharge of the Los Angeles, San Gabriel River, and Santa Monica Bay Watersheds. GWAM was developed by the U.S. Department of the Interior, Bureau of Reclamation and the Los Angeles and San Gabriel Rivers Watershed Council as part of a Water Augmentation Study, which is a study to determine the potential for increasing local water supplies and reducing urban runoff by increasing infiltration of storm water runoff. GWAM utilizes a GIS interface and soil moisture accounting

model to compute the portion of precipitation for runoff and infiltration into the upper soil (root zone). The model also accounts for additional water from irrigation and loss through evapotranspiration. Evapotranspiration, which is based on the U.S. Department of Agriculture's Soil and Water Assessment Tool (SWAT) algorithms, is calculated using data from the California Irrigation Management Information System (CIMIS). The model then calculates the amount of water that percolates into the vadose zone, which is available for ground water recharge. The GIS interface stores information for vegetation type, surface use (subcategory of vegetation type), irrigation, root zone parameters for each surface use, soil properties, runoff curve numbers used to determine runoff, and land use. The data are specified for each land use based on the Southern California Aerial Land Use Consortium, which contain 100 land use codes (Bureau of Reclamation 2005).

The GWAM model domain represents the ground water basins below the San Gabriel Mountains, which include the Los Angeles, Santa Monica, Ballona, Dominguez, and San Gabriel Watersheds, with 65,000 polygons in the GIS interface. Although the model can calculate infiltration and runoff, the model does not route runoff (i.e., does not transfer runoff from one polygon to another polygon), so results are limited to each individual polygon. The model also contains weather data between 1951 through 2002.

2.7. LADWP Ground Water Model

The LADWP Ground Water Model was developed as part of the remedial investigation of ground water contamination in the San Fernando Ground Water Basin, which has been designated as a superfund site. The ground water model MODFLOW was selected.

MODFLOW is a three-dimensional finite difference ground water model to determine flow in porous media. This public domain model is maintained by USGS. MODFLOW is capable of simulating confined and unconfined aquifers and flow from wells, aerial recharge, evapotranspiration, drains, and streams (USGS 1988).

The LADWP Ground Water Model domain encompassed the San Fernando Ground Water Basin and its natural hydrogeologic boundaries. The model domain does not include the Sylmar Basin, Verdugo Basin, or Eagle Rock Basin. The ground water basin is modeled with four vertical layers. The Tujunga Watershed lies within the coarser portion of the model grid, which means this model may not be sufficient for applications beneath the Tujunga Watershed without grid modifications.

Inflows simulated were subsurface flows from adjacent basins (e.g., Sylmar Basin and Verdugo Basin), recharge from hill and mountain runoff, recharge from precipitation on the valley floor, artificial recharge from spreading grounds, return flow from delivered water, and recharge from the Los Angeles River. Outflows simulated were subsurface outflow, ground water extractions, and ground water flow to the Los Angeles River. The model was calibrated based on one steady state simulation and one transient simulation (LADWP 1992).

The LADWP Ground Water Model was not calibrated and verified at locations within the Tujunga Watershed, as the model emphasis was on the Superfund Site (southeast portion of the San Fernando Ground Water Basin). The deviation between the steady-state simulated ground water levels and actual ground water levels in the Tujunga Watershed area varied between 20 and 60 ft. None of the key wells used in the transient calibration simulation were located within the Tujunga Watershed, although two of the wells were in close proximity.

3. APPLICABILITY OF EXISTING MODELS

Existing conditions and the alternatives will be evaluated to determine the level of flood protection and analyze retention of storm water for increased infiltration to ground water. A surface water model will be used to analyze flood protection issues and a watershed model will be used to analyze water quality, ground water infiltration, and ground water storage.

The following section summarizes the applicability of existing models to evaluate flood protection and infiltration and the modifications and updates to existing models necessary to utilize the models for applications in the TW.

3.1. *Surface Water Models*

Flood protection will be evaluated using a surface water (hydrodynamic) model based on the water flows, surface elevations, and velocities on a flood event basis (e.g., 100-year return period). Model requirements include the following: varying channel dimensions and characteristics, bridges, flow control structures (e.g., weirs and culverts), and sub- and super-critical flow regimes. The model domain should be defined to sufficiently represent the channel dimensions, channel alignment, and flow control structures.

Existing surface water models are TRP Hydrodynamic Model, Los Angeles River HEC Models, and Los Angeles River EFDC Model. Applicability of each model was determined based on required model capabilities and model domain.

The TRP Hydrodynamic Model consists of the MIKE11 and HEC-RAS hydrodynamic models. Both models have the necessary capabilities for application to this study, but HEC-RAS would be the preferred model since it is a public domain model and it is accepted by USACE and LACDPW for permitting purposes. Modifications to the TRP HEC-RAS model required to simulate existing conditions include grid modifications, review of boundary conditions, and data conversion of boundary conditions. The model domain would need to be extended to include the Pacoima Drainage Channel, Branford Drainage Channel, Hansen Spreading Grounds, and Tujunga Spreading Grounds. A review of the inflow and downstream boundary conditions would be conducted to select appropriate boundary conditions. In addition, the boundary conditions, specifically the flood hydrographs of the 2-, 5-, 10-, 25-, 50-, and 100-year return periods for the Tujunga Wash Channel, Pacoima Drainage Channel, and Branford Drainage Channel, would need to be converted from the MIKE 11 format to a HEC-RAS acceptable format.

The Los Angeles River HEC Models include the HEC-5 reservoir routing model, which is typically applied for reservoir operations. HEC-5 is not capable of simulating flood control structures, thus this model will not be used for this study. The HEC-RAS model (Reach 2) has better resolution of the Tujunga Wash Channel than the TRP HEC-RAS model. For this study, the USACE HEC-RAS cross sections (USACE 2005) can be used to update the modified TRP HEC-RAS model.

The Los Angeles River EFDC Model is not suitable for this application since the EFDC model cannot simulate super critical flow, which is very likely to occur during flood events. Thus, the model will not be considered for this study.

3.2. Watershed, Infiltration, and Water Quality Models

Infiltration for ground water recharge will be evaluated using a watershed model. The selected model capabilities required include precipitation, evapotranspiration, runoff, infiltration, land uses, vegetation, soil types, soil moisture, as well as short- and long-term simulation ability. The model domain requires sufficient resolution to define subwatersheds, sites for infiltration (e.g., spreading grounds), and general channel characteristics.

Existing watershed or infiltration models are the Los Angeles River HEC Models, the Los Angeles River LSPC Model and the Los Angeles and San Gabriel Watersheds Ground Water Augmentation Model (GWAM). Applicability of each model was determined based on required model capabilities and model domain.

The Los Angeles River HEC Models include the HEC-1 watershed model. HEC-1 is typically used for flood event runoff, not infiltration and cannot simulate successive flood events (i.e., cannot account for soil moisture). Thus, the existing Los Angeles River HEC-1 model was not considered for use in this study.

The Los Angeles River LSPC Model has the necessary capabilities to simulate sediment associated constituents (e.g., metals) in the Tujunga Watershed. In addition, hydrologic, sediment, and metal related parameters have been defined based on the prior application in the LAR watershed. It would be assumed that the watershed calibrated parameters are sufficient and that metals are linearly related to sediment since prior model applications with these assumptions were for regulatory purposes (e.g., Ballona Creek and LAR metals wet weather TMDLs). However, the Los Angeles River LSPC Model itself would not be sufficient for the Tujunga Watershed due to the division of the subwatersheds. A new LSPC model for the Tujunga Watershed with different subwatersheds would be created using higher resolution data including topography, watershed boundaries, land uses, soil types, and stream networks.

The GWAM has limited capabilities compared to a watershed model, but can provide estimates in infiltration rates based on precipitation. The suitability of the model domain for applications in the Tujunga Watershed would need to be verified upon acquisition of the model.

3.3. Existing Ground Water Model

The LADWP Ground Water Model is the only known, existing ground water model that includes the San Fernando Valley Ground Water Basin beneath the Tujunga Watershed. The ground water model would require linkage to the watershed model via the infiltration rates as an input to the ground water model. LADWP has determined that no model grid modifications will be necessary.

4. PROPOSED MODELING APPROACH

The modeling approach was developed based on the applicability of existing models to determine runoff and infiltration. The modeling approach will be used to evaluate existing conditions and alternatives based on the following objectives:

- Maintain or enhance flood protection (e.g., inundation and erosion)
- Increase ground water recharge
- Minimize adverse movement of existing ground water contaminants
- Improve surface water quality

The modeling approach, shown as a flow chart in Figure 1, consists of four components (input data, models, model output, and objectives) each highlighted by a different color. The figure illustrates the use of input data (yellow), models (green), and linkages between the model outputs (blue), and the ultimate objectives to be quantified (red). The ground water portion of the modeling approach, shown in the flowchart within the dash-lined box, is to be conducted by LADWP. The remaining portion of the flowchart covers the watershed and hydraulic modeling. This modeling approach will be used for both short-term events (e.g., 100-year flood event) and long-term (e.g., water year) conditions.

The watershed model will be used to simulate rainfall and evapotranspiration to determine runoff, infiltration, and water quality parameters, while accounting for topography, land use, vegetation, soil moisture, and BMPs. The TW portion of the existing LAR LSPC Model will be updated as previously mentioned. The LSPC model of the TW will be used to output runoff, infiltration, and water quality parameters.

4.1. *Runoff*

The runoff from the watershed model will be linked to the surface water (hydrodynamic) model. The hydrodynamic model will use runoff, channel properties, and dam operations to simulate water levels and velocities in the stream channel system. The TRP Hydrodynamic Model (HEC-RAS) and USACE HEC-RAS will be used upon completion of modifications mentioned

previously. The modified hydrodynamic model will be used to determine flood (e.g., 100-year) flow conditions (e.g., water level, velocity, and water depth) within the channel, which will be used to evaluate flood protection. The evaluation of flood protection will verify that flood protection under alternatives is maintained relative to existing conditions.

The high velocities of flood flows can also cause erosion, thus a potential scour assessment will be conducted to determine if the velocities are sufficient to scour or erode the channel bed. The potential scour assessment is commonly used as an initial screening tool and will be based on guidelines developed by USACE for using empirical methods to determine potential channel instability and sedimentation effects (USACE 1994a, 1994b, and 2001), as well as to determine if channel stabilization measures would be necessary under the alternatives.

The flood flow conditions from the hydrodynamic model will be used to determine the bed shear stress, which is adjusted for local variability and the channel type (e.g., straight or sinuous channel). The stability of the channel bed is then determined based on empirical relationships between bed shear stress and sediment grain size (typically Shield's diagram). If the channel conditions are not stable, a suitable channel lining material or stabilization measure would be selected. These can be rigid, such as concrete or gabions, or flexible, such as soils with different grain sizes, vegetated banks (with or without rolled erosion control products), or rock riprap. Flexible channel lining would permit infiltration and a more natural appearance, but would have limitations in the flow without erosion occurring. The use of soils with varying grain sizes, such as large grained gravel-clay-silt mixtures, provide greater resistance to erosion. Examples of vegetation used in bank stabilization are willows, grasses, and reeds. Another channel stabilization measure is increasing the sinuosity of the channel to reduce channel velocities. The scour assessment procedure is repeated to account for the selected channel stabilization method (i.e., recompute hydraulic conditions and confirm channel stability).

4.2. Infiltration

The infiltration from the watershed model will be used to determine the ground water recharge (i.e., volume rate of supply to the aquifer). The evaluation of ground water recharge will quantify the potential reduction in water imports under the alternatives.

The infiltration rate to ground water will be linked to the ground water model as an additional input (e.g., water source). Monthly infiltration rates and infiltration areas for existing conditions and alternatives will be provided to LADWP. The LADWP Ground Water Model, which accounts

for aquifer properties, ground water extractions/injections, and subsurface inflows/outflows, will be used to determine the long-term changes to ground water elevation and flows. These will be used to evaluate ground water movement and contaminant plume movement under the alternatives.

4.3. *Water Quality*

The watershed model will also be used to determine water quality parameters, which include loadings and/or concentrations of pollutants within the channel, spreading grounds, and infiltration basins (e.g., gravel pits). The Tujunga Wash Channel between Hansen Dam and the LAR is 303(d) listed for ammonia, coliform, copper, scum, odors, and trash. The watershed model will be used to simulate the water quality parameters copper and ammonia to assess water quality improvements under the alternatives.

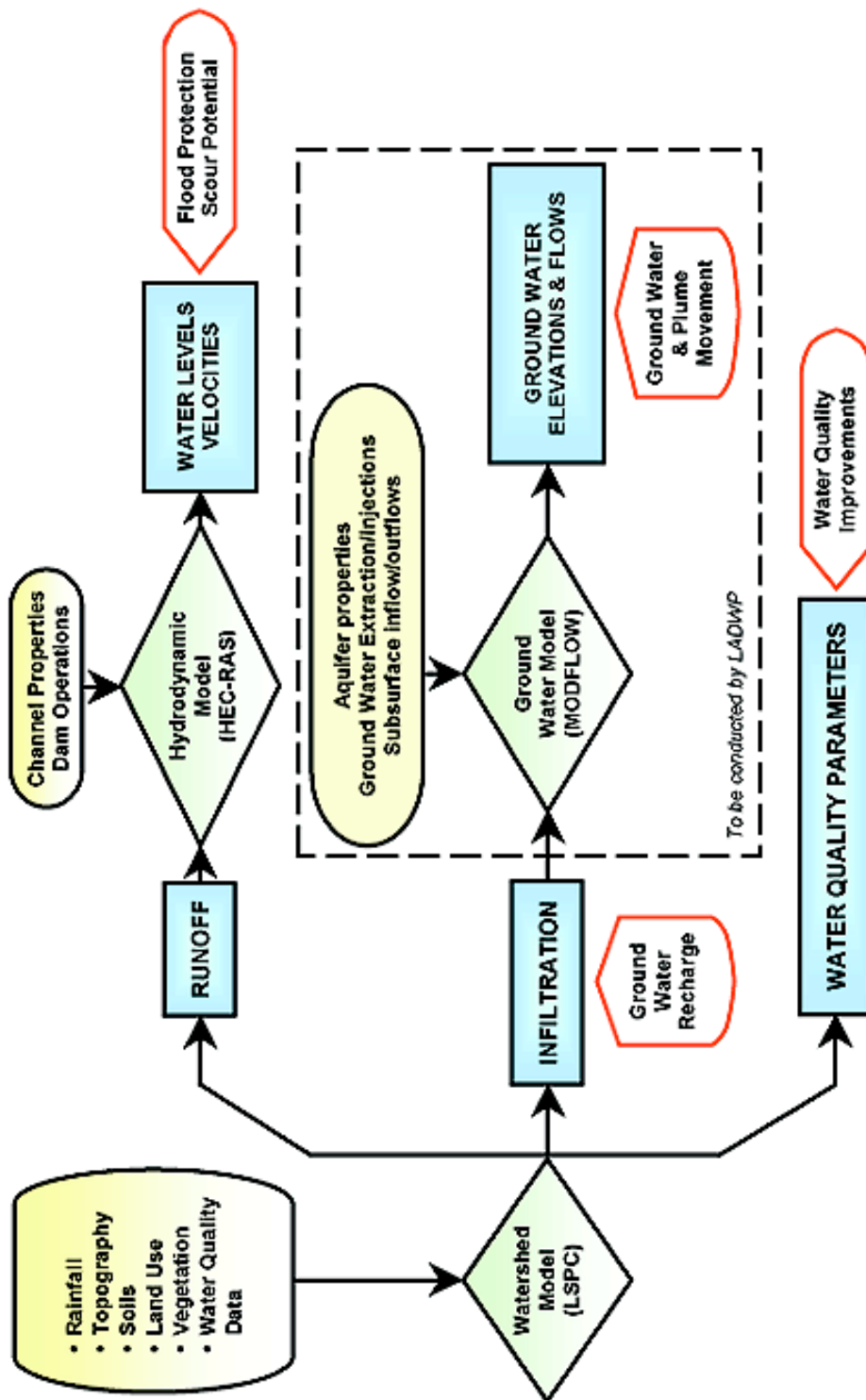


Figure 1 – Modeling Approach Flowchart

References

Bureau of Reclamation. 2005. Los Angeles and San Gabriel Watersheds Ground Water Augmentation Model Draft User's Manual. Prepared by Bureau of Reclamation Technical Services Center Water Resources Division and Los Angeles and San Gabriel Rivers Watershed Council.

DHI. 2000. MIKE 11 A Modeling System for Rivers and Channels Reference Manual. DHI Water & Environment. May 2000.

LACDPW. 1997. Los Angeles River Alternative Flood Control Study Volume I: Baseline Conditions. Prepared by Simons, Li & Associates, Inc. Prepared for County of Los Angeles Department of Public Works.

LADWP. 1992. Remedial Investigation of Groundwater Contamination in the San Fernando Valley. Prepared for City of Los Angeles Department of Water and Power. Prepared by James M. Montgomery, Inc. December 1992.

LARWQCB. 2004a. Model Development for Simulation of Wet-Weather Metals Loading from the Los Angeles River Watershed. Prepared by TetraTech, Inc. Prepared for U.S. Environmental Protection Agency Region 9 and Los Angeles Regional Water Quality Control Board. May 2004.

LARWQCB. 2004b. Modeling Analysis for Development of TMDLs for Metals in the Los Angeles River and Tributaries. Prepared by TetraTech, Inc. Prepared for U.S. Environmental Protection Agency Region 9 and Los Angeles Regional Water Quality Control Board. July 2004.

TRP. 2002. Hydrodynamic Study for Restoration Feasibility of the Tujunga Wash. Prepared by The River Project, WaterCycle Inc., and Philip Williams & Associates, Ltd. Prepared for California Coastal Conservancy and Los Angeles & San Gabriel Rivers Watershed Council.

USACE. 1963. Summary of Pertinent Hydraulic Data for Tujunga Wash. U.S. Army Corps of Engineers.

USACE. 1990. Water Control Manual Hansen Dam Tujunga Wash, Los Angeles County, California. U.S. Army Corps of Engineers, Los Angeles District, Reservoir Regulation Section. November 1990.

USACE. 1991. Los Angeles County Drainage Area Final Feasibility Interim Report, Part 1: Hydrology Technical Report. U.S. Army Corps of Engineers. 1991.

USACE. 1994a. Channel Stability Assessment for Flood Control Projects. U.S. Army Corps of Engineers. EM 1110-2-1418.

USACE. 1994b. Hydraulic Design of Flood Control Channels. U.S. Army Corps of Engineers. EM 1110-2-1601.

USACE. 1998a. HEC-1 Flood Hydrograph Package User's Manual. U.S. Army Corps of Engineers Hydrologic Engineering Center. June 1998.

USACE. 1998b. HEC-5 Simulation of Flood Control and Conservation Systems User's Manual Version 8.0. U.S. Army Corps of Engineers Hydrologic Engineering Center. October 1998.

USACE. 1999. Operation, Maintenance, Repair, Replacement, and Rehabilitation Manual, Los Angeles County Drainage Area. U.S. Army Corps of Engineers. December 1999.

USACE. 2001. Stability Thresholds for Stream Restoration Materials. U.S. Army Corps of Engineers Research and Development Center, Environmental Laboratory. ERDC TN-EMRRP-S-29.

USACE. 2002. HEC-RAS River Analysis System User's Manual Version 3.1. U.S. Army Corps of Engineers Hydrologic Engineering Center. November 2002.

USACE. 2005. Los Angeles County Drainage Area, Upper Los Angeles River and Tujunga Wash, HEC-RAS Hydraulic Models, Final Report. U.S. Army Corps of Engineers, Los Angeles District, Engineering Division, Hydrology and Hydraulics Branch, Hydrology and Hydraulics Section. August 2005.

USEPA. 2001. Water Quality Analysis Simulation Program (WASP) Version 6.0 Draft User's Manual. Prepared by Tim A. Wool, Robert B. Ambrose, James L. Martin, and Edward A. Comer. Prepared for U.S. Environmental Protection Agency, Region 4.

USGS. 1988. A Modular Three-Dimensional Finite-Difference Ground Water Flow Model. Michael G. McDonald and Arlen W. Harbaugh. U.S. Geological Survey. Techniques of Water-Resources Investigations Book 6 Chapter A1. TWRI 06-A1. 1998.