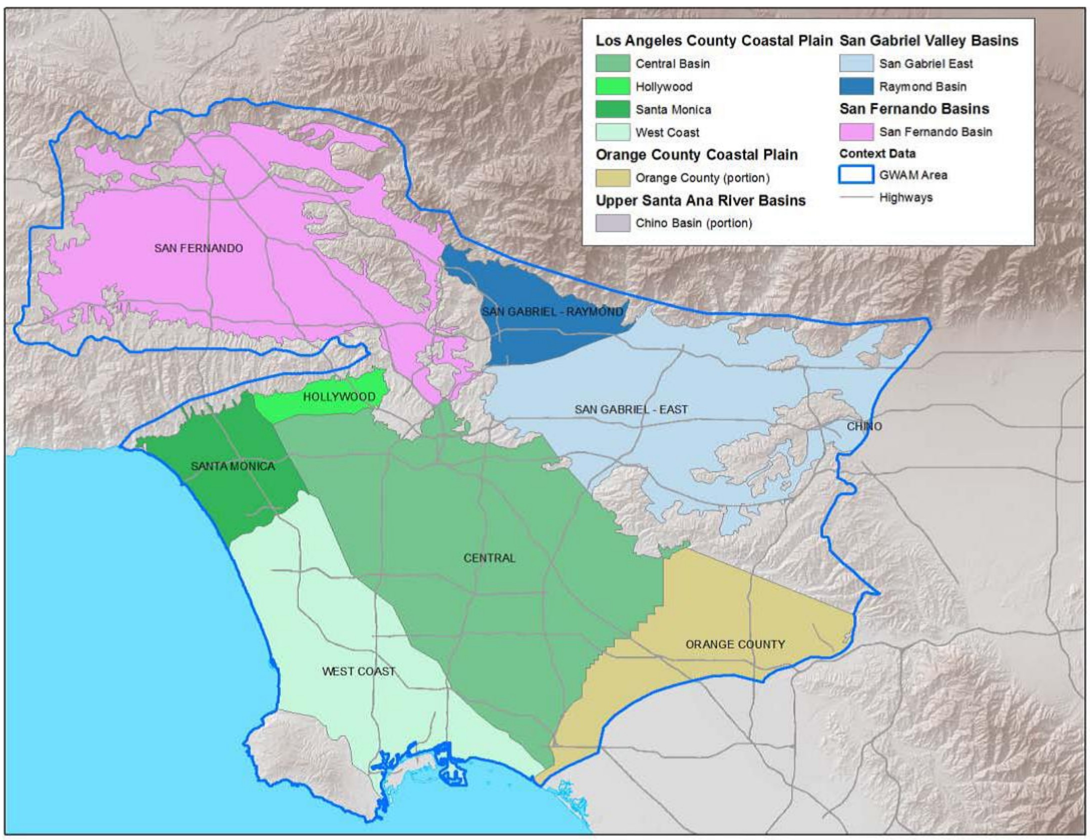
RECLAMATION

*Managing Water in the West*

# Los Angeles Basin Modeling Summary

## Los Angeles Basin Stormwater Conservation Study




U.S. Department of the Interior
Bureau of Reclamation
Engineering Services Office
Boulder City, Nevada

July 2014

## PROJECT INFORMATION

| | |
|---|---|
| PROJECT NUMBER: | **A10-1862-6019-135** |
| PROJECT NAME: | **Los Angeles Basin Modeling Summary** |
| PROJECT MANAGER: | **Douglas B. Blatchford, P.E.** |
| CLIENT: | **Southern California Area Office (SCAO)** |

## Project Staff

| | | |
|---|---|---|
| | Amy Witherall | SCAO |
| | Jack Simes | SCAO |
| Peer Reviewers | Scott Tincher, P.E. | ESO |
| | Tom Nichols, P.E. | ESO |

## Distribution List

## Project Summary

| | |
|---|---|
| Project Start Date | June 2010 |
| Project Completion Date | July 2014 |

# Contents

# Acronyms and Abbreviations

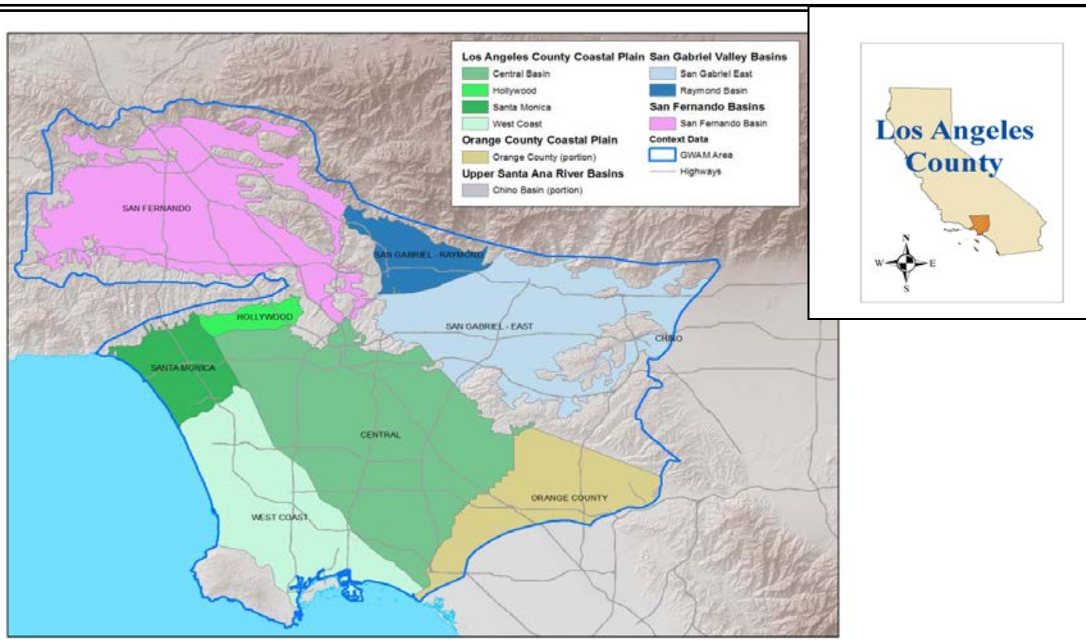
| | |
|---|---|
| CDM | Camp, Dresser and McKee, Inc. |
| GIS | Geographic Information Systems |
| GWAM | Ground Water Augmentation Model |
| IWL | Index Water Level |
| JMM | James M. Montgomery Consulting Engineers |
| LACDPW | Los Angeles County Department of Public Works |
| LACFD | Los Angeles County Flood Control District |
| LADWP | Los Angeles Department of Water and Power |
| LARWQCB | Los Angeles Regional Water Quality Control Board |
| MWD | The Metropolitan Water District of Southern California |
| MWH | Montgomery Watson Harza |
| PLASM | Prickett-Lonquist Aquifer Simulation Model |
| PVPA | Pomona Valley Protective Association |
| RBMB | Raymond Basin Management Board |
| SCCWRP | Southern California Coastal Water Research Project |
| SFBFS | San Fernando Basin Feasibility Study |
| SFV | San Fernando Valley |
| TDS | Total Dissolved Solids |
| TVMWD | Three Valleys Municipal Water District |
| ULARA | Upper Los Angeles River Area Model |
| USACE | United States Army Corps of Engineer |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| VCWPD | Ventura County Watershed Protection District |
| WMMS | Watershed Management Modeling System |
| WRDSC | Water Replenishment District of Southern California |

# Introduction

This report is a brief summary of major water quality, groundwater hydrology, and surface water hydrologic and hydraulic models in the Los Angeles County, California, area. Models that were summarized include the Ground Water Augmentation Model (GWAM), the Watershed Management Modeling System (WMMS), the Main San Gabriel Model, the Raymond Basin Model, Six Basins Model, Upper Los Angeles River Area (ULARA) Model, United States Army Corps of Engineer (USACE) models, and Central and West Coast Basins models associated with the Water Replenishment District of Southern California. The Bureau of Reclamation's Engineering Services Office in Boulder City, Nevada, was tasked by Reclamation's Southern California Area Office to provide a brief summary that includes both the background and need for model development. This background summary also includes a brief technical summary that generally describes simulated outcomes, model characteristics, ownership, which agency uses the model, and other information.

The models identified are not necessarily all inclusive, but do encompass the majority of the efforts being performed in the region.

# Ground Water Augmentation Model



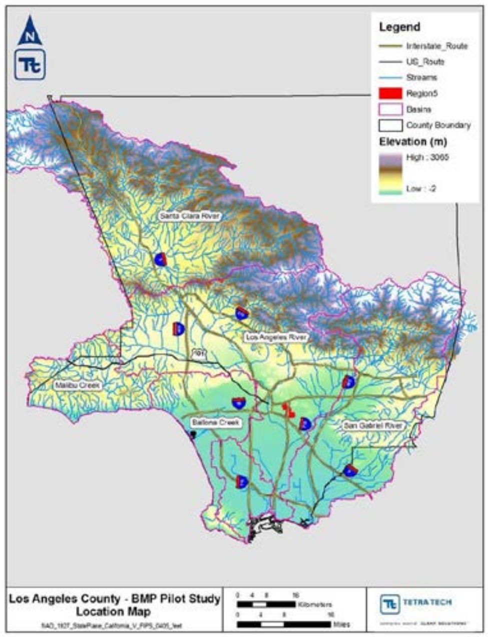

**Model Summary**

Since 2000, the Bureau of Reclamation has been engaged in partnership with the Los Angeles and San Gabriel Rivers Watershed Council and other agencies in a Water Augmentation Study. The purpose of the study is to explore the potential for increasing local water supplies and reducing urban runoff pollution by increasing infiltration of storm water runoff. This infiltration water will potentially augment local groundwater supplies by capturing and recharging storm water runoff that otherwise would flow unused to the ocean. Long-term goals of this effort include quantification of the benefits, costs, and risks of supply augmentation through infiltration, characterization of appropriate and optimal conditions for infiltration, providing a comprehensive assessment of the potential for augmenting water supply, reducing water pollution, and providing additional environmental and social benefits through infiltration in combination with other management strategies [9][27].

The Groundwater Augmentation Model (GWAM) estimates that 16 percent or 194,000 acre-feet of the precipitation in the greater Los Angeles area percolates past the root zone. A large percentage of the local precipitation is underutilized, and routed through storm drain systems after removing pollution and contaminants.  The model was developed through a collaboration of the Bureau of Reclamation and the Los Angeles and San Gabriel Rivers Watershed Council. It provides an estimate of runoff, infiltration and deep percolation under current conditions, but can be adjusted to accommodate greater groundwater recharge strategies. This is a GIS based model that functions with Microsoft Access. The model estimates baseline runoff-recharge conditions for the region, and shows the potential benefits of making changes to how urban runoff is handled by the infrastructure [9][27].

| | |
|---|---|
| Model /Interface | Customized GUI interface |
| Model characteristics | GWAM operates on a daily time step and is highly dependent on information provided to it from ARC/INFO coverages and time series data contained in ASCII files. The model operates in an integrated Microsoft Access and ARC/INFO GIS environment and was written in FORTRAN 95, C, PERL, ARC MACRO Language and Microsoft Visual Basic and runs on a Microsoft XP platform. |
| Simulated outcomes | The model computes infiltration as a residual after runoff based on the SCS curve number procedure. Reclamation's soil moisture accounting model simulates the root zone (field scale) with a daily time step for the historical period from January 1951 through December 2002. The root zone is segmented into a number of uniformly sized cells that were used to represent several soil profile types. These were derived through discrete interpolation of moisture accounting for representative areas in the basin. |
| Agencies using the model | Los Angeles and San Gabriel Rivers Watershed Council |
| Owner/Operator | Los Angeles and San Gabriel Rivers Watershed Council |
| Other | The geographic extent of the model includes the Los Angeles Basin, roughly from the foothills of the San Gabriel Mountains to the ocean including the San Fernando Valley to the west and the San Gabriel Valley to the east. |

# Los Angeles County Watershed Management Modeling System

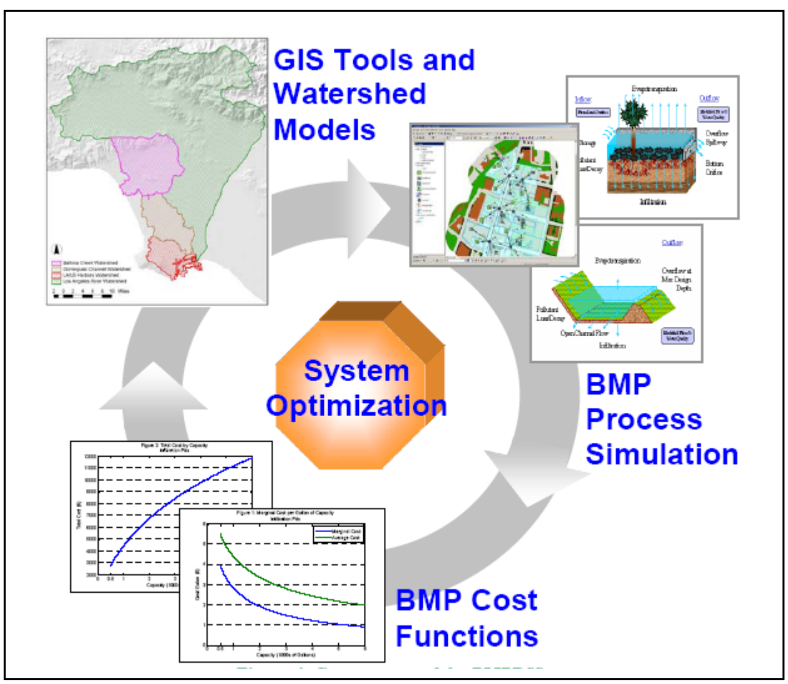




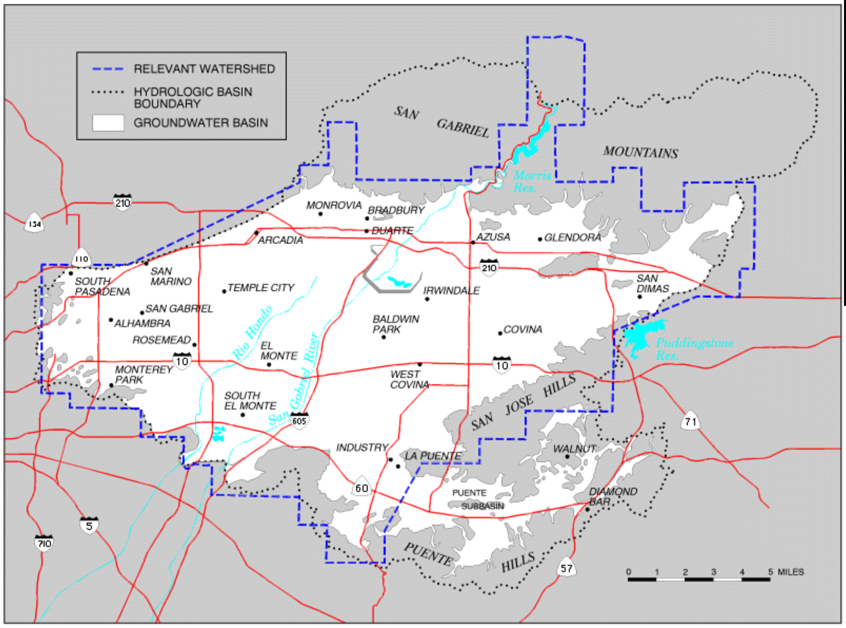
**Model Summary**

The Los Angeles County Flood Control District Watershed Management Modeling System (WMMS) identifies cost-effective projects through an integrated, watershed based approach. Using WMMS, collective impact of a variety of pollutant sources from point to nonpoint is evaluated and thereby comprehensive, long-term strategies for overall water quality improvement of the entire watershed are planned. In addition, the WMMS will be used as an integrated watershed management tool for future planning of projects that achieve multiple benefits besides water quality such as water conservation, flood control, and open space development. This would eventually allow for an effective storm water resource management. Improving the quality of urban runoff and storm water in the Los Angeles County's coastal watersheds is challenging. Thousands of separately permitted discharges with multiple Total Maximum Daily Loads flow into the same receiving water bodies simultaneously. This makes it necessary and economical to address many different pollutant sources concurrently [20][21].

| | |
|---|---|
| Model characteristics | Primarily used to develop Best Management Practices for improving storm water quality in the greater Los Angeles area. |
| Simulated outcomes | Low flow and peak discharge related to storm water response to rainfall events. |
| Agencies using the model | Los Angeles County Flood Control District (LACFCD), United States Environmental Protection Agency (USEPA), Los Angeles Regional Water Quality Control Board (LARWQCB), Southern California Coastal Water Research Project (SCCWRP), Ventura County Watershed Protection District(VCWPD), United States Corp of Engineers (USACE). |
| Owner/Operator | LACFCD |
| Other | Includes six overall watersheds, namely: 1) San Gabriel River, 2) Los Angeles River, 3) Dominguez Channel, Ballona Creek/Coastal, Malibu Creek, and Santa Clara River. 530 miles of open channel, 2800 miles of storm drain, 3100 sq miles of watershed areas, 23 TMDL's, 5600 NPDES permits, MS4 permit for LA County. |



# Main San Gabriel Model





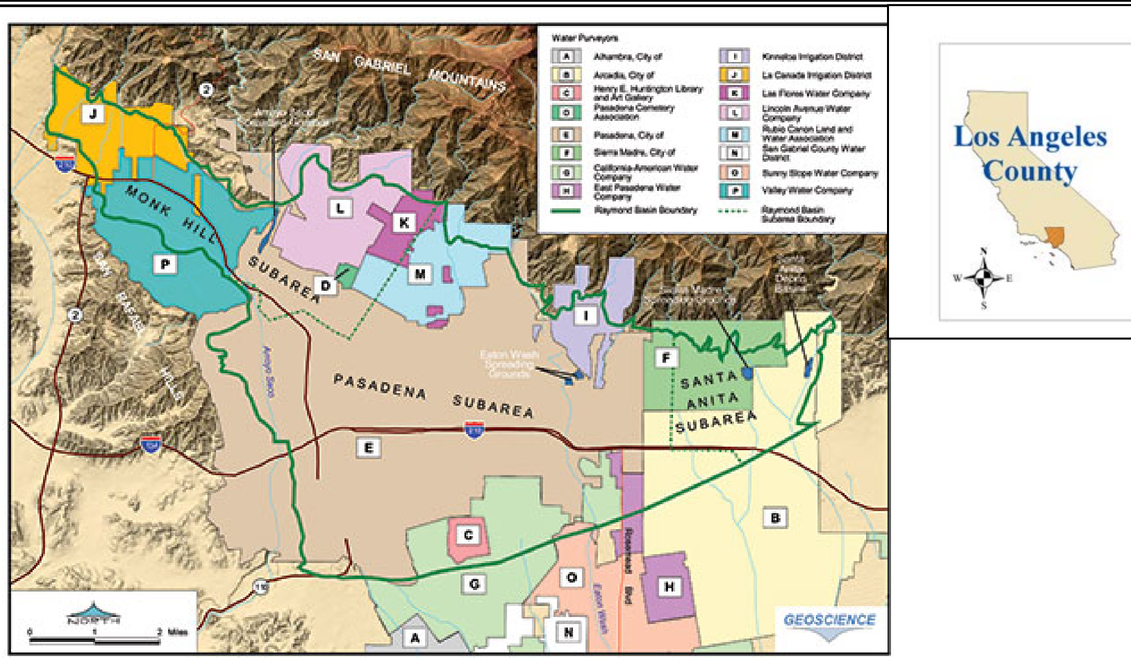
## Model Summary

The Main San Gabriel Basin lies in eastern Los Angeles County, California. The hydrologic basin or watershed coincides with a portion of the upper San Gabriel River watershed, and the aquifer or groundwater basin underlies most of the San Gabriel Valley. The groundwater basin is bounded by the San Gabriel Mountains to the north, San Jose Hills to the east, Puente Hills to the south, and by a series of hills and the Raymond Fault to the west. The watershed is drained by the San Gabriel River and Rio Hondo, a tributary of the Los Angeles River.

Surface area of the groundwater basin is approximately 167 square miles. The fresh water storage capacity of the basin is estimated to be about 8.6 million acre-feet. The Watermaster's Groundwater Basin Flow was developed by Stetson Engineering in 1997. The model is a two dimensional finite-difference model that uses a modified version of the Prickett-Lonquist Aquifer Simulation Model (PLASM) code. The model has a 400 foot by 400 foot grid node. The model layer thickness is a uniform 500 feet. Model documentation and user's manual are described in a separate reference document [6][10][14][22].

| | |
|---|---|
| Model /Interface | ASCII |
| Input Parameters: | Aquifer geometry and characteristics; recharge components and discharge components |
| Output Parameters: | Groundwater elevations |
| Agencies using the model | Main San  Gabriel Basin Watermaster |
| Constraints | For groundwater flow, only partial calibration was achieved |
| Owner/Operator | Main Basin Watermaster/Stetson Engineers |
| Last Updated | 2010 |
| User Manual | Yes |
| Federal Agencies Involved | None |

# Raymond Basin Model



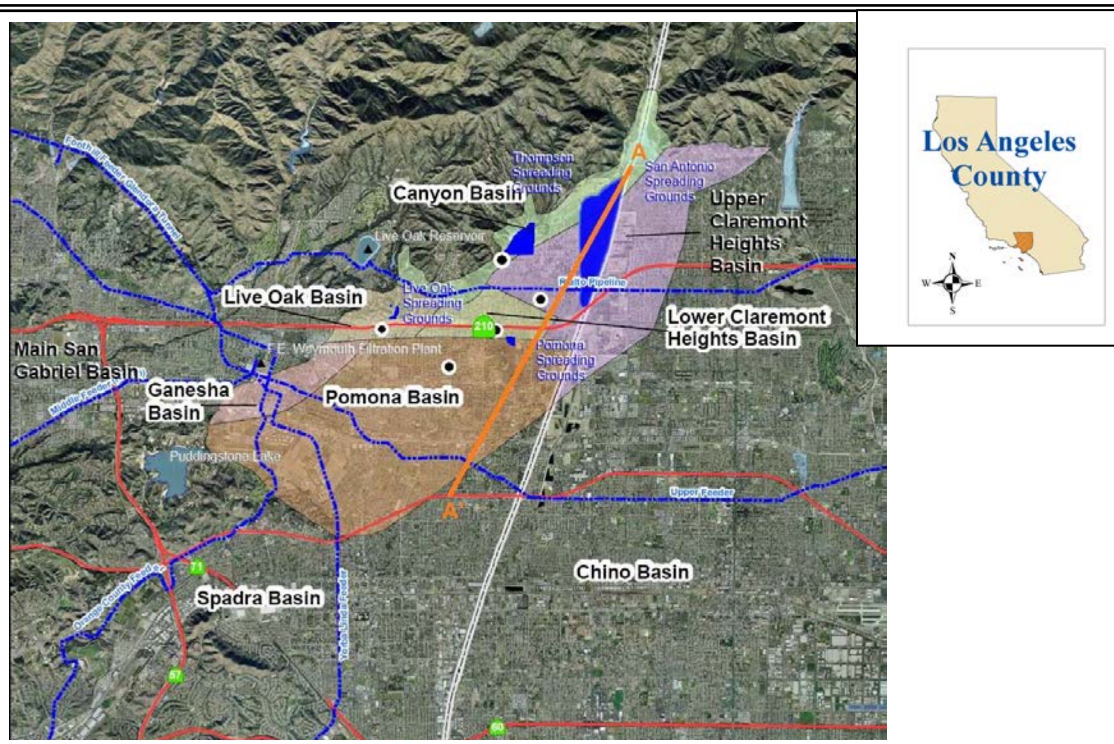

## Model Summary

The Raymond Basin is located in the northwestern portion of the San Gabriel Valley in Los Angeles County. The Raymond Basin includes the communities of Sierra Madre, Arcadia, Pasadena, La Cañada Flintridge and unincorporated areas of Los Angeles County, and includes 16 separate water purveyors. The Raymond Basin underlies the service areas of the Foothill Municipal Water District (Foothill MWD), Upper San Gabriel Valley Municipal Water District (Upper District), City of Pasadena and City of San Marino. The City of Sierra Madre is a member agency of San Gabriel Valley Municipal Water District, a State Water Project Contractor.

A two-layer MODFLOW model was constructed for the entire Raymond Basin area, including a portion of the Main San Gabriel Basin. The model covers approximately 120 square miles and consists of 162 nodes (e.g. model cell) in the north-to-south direction (i-direction) and 230 nodes in the west-to-east direction (j-direction), for a total of 74,520 nodes. Each model cell represents an area of two acres (300 ft x 300 ft) [13].

| | |
|---|---|
| Model/Interface | MODFLOW and Groundwater Solute Transport Model: MT3DMS. GUI interface is Groundwater Vistas and ArcMap. |
| Input Parameters: | Model input parameters include initial groundwater levels, top and bottom elevations of model layers, hydraulic conductivity, storativity, vertical leakance between model layers, hydraulic characteristic of groundwater flow barriers, parameters for general head boundary to simulate underflow from Verdugo Basin and underflow to Main San Gabriel Basin, initial TDS and nitrate-nitrogen concentrations, dispersivity, recharge from mountain front runoff, deep percolation from precipitation, artificial recharge, return flow, groundwater injection, and groundwater pumping. |
| Output Parameters: | Model output parameters include cell-by-cell model-calculated groundwater levels, TDS and nitrate-nitrogen concentrations and groundwater budgets. |
| Agencies using the model | Raymond Basin Management Board use the model to develop the conjunctive use management plan and to evaluate the groundwater level and water quality impacts from the proposed Stormwater Capture Program. |
| Constraints | The RBMB groundwater flow and solute transport models are useful tools for evaluating water levels and water quality of the aquifer systems. However, it is a simplified approximation of a complex geohydrologic system. The accuracy of a model prediction is dependent upon the assumptions used. For example, the TDS concentration in the urban area was assumed to be 25 mg/L (precipitation's concentration) plus an urban increment of 250 mg/L and then adjusted by a factor of four for concentrating effects. These mass-loading assumptions may not represent actual conditions due to the lack of field data. The model simulations were not expected to predict the future TDS concentrations with a high degree of accuracy. Rather, they were intended to allow relative comparisons between predictive model scenarios. |
| Owner/Operator | Raymond Basin Management Board own the model/Geoscience Support Services |
| Last Updated | August 2011 |
| User Manual | None |
| Federal Agencies Involved | U.S. Army Corps of Engineers is involved with the stormwater capture study and conjunctive use plan |

# Six Basins Model




### Model Summary

The first model was created in 1983 on behalf of the Pomona Valley Protective Association (PVPA) by James M. Montgomery Consulting Inc., now Montgomery Watson Harza (MWH). MWH was later contracted again in 1993 to develop a groundwater model and spreadsheet model to assist PVPA in spreading operations. The PVPA spreadsheet plan used three basic components to evaluate groundwater levels:

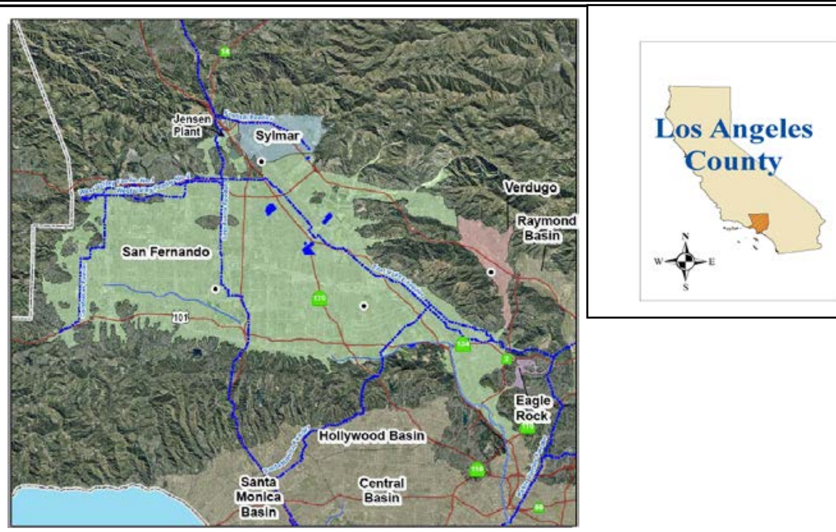
- The groundwater elevation (above mean sea level) at five key wells: Mountain View No. 4, Upland Foothill No. 3, College No. 1, Miramar No. 3, and Tunnel Well No. 3
- The quantity of water spread in the San Antonio, Thompson Creek, and Pomona Spreading Grounds, and
- The actual and projected extractions within the basins.

Subsequently, in 1997, PVPA retained Camp Dresser & McKee Inc. (CDM) to update the Montgomery model and provide additional components to the model. During the basin adjudication process, the geologic interpretation of the basins was revisited and a new groundwater model developed and calibrated based on this interpretation [12][23].

In August 2002, six existing wells were retrofitted with transducers to record static water levels in the various basins. Three new monitoring wells were constructed and equipped with transducers in 2004. These wells provided additional hydrogeological information from areas where knowledge of geological conditions was limited. Data collected by the transducers is transmitted directly to the Three Valleys Municipal Water District (TVMWD) central telemetry system. The water level data collected is used to create historical hydrographs of the monitoring wells. The information gained was integrated in the updated groundwater model completed by CDM in late 2006.

As part of the model update conducted by CDM, a new version of the spreadsheet model was developed for the basins above the Indian Hill Fault. Information collected from the nine monitoring wells is used in the spreadsheet model to compute an Index Water Level (IWL). The IWL is one of the tools used by the Six Basins Watermaster to assess whether additional spreading of local surface water should take place in the area above the fault [12][23].

# Upper Los Angeles River Area Model



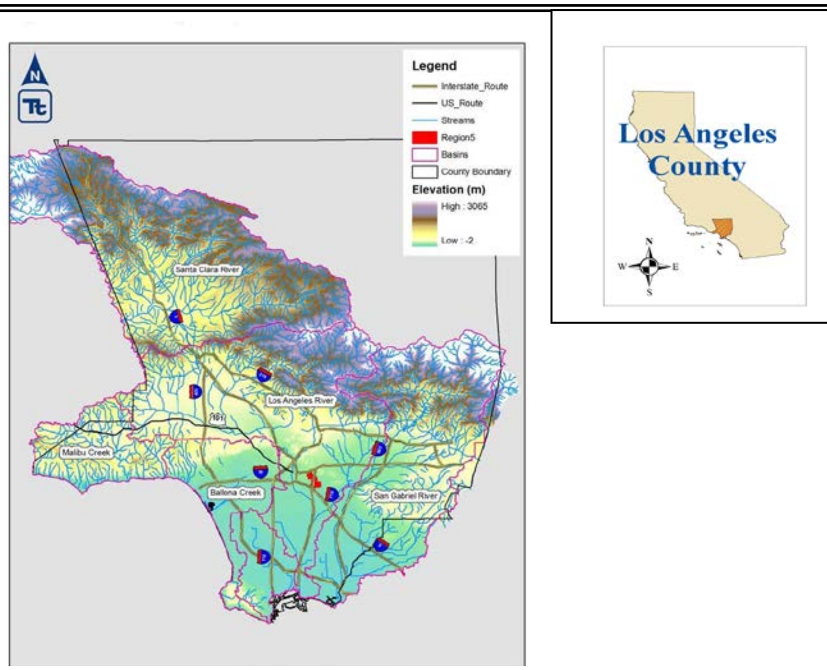

**Model Summary**

James M. Montgomery Consulting Engineers (JMM) originally developed a groundwater flow model (JMM, 1992) for the San Fernando Valley (SFV) groundwater basin under cooperative agreement with the U.S. Environmental Protection Agency (EPA) and the Los Angeles Department of Water and Power (LADWP). The model was developed using the MODFLOW modeling application and was subsequently revised in 1994 by CH2M HILL (under contract with EPA) to support a feasibility study of groundwater cleanup for the San Fernando basin. This version of the model was referred to as the San Fernando Basin feasibility study (SFBFS) groundwater flow model and is documented in the San Fernando Basin Groundwater Model Documentation [2]. An updated version of the SFBFS model was developed in 1998 [3]. The resulting model was designated as the SFBFS-A model and documented in the Draft San Fernando Basin Groundwater Model Update and Revision Report [3]. Updates and revisions to the original model include the following [7][17]:

- Translation of the model into a graphical user interface (Visual MODFLOW)
- Enhanced particle tracking capabilities using MODPATH
- Extension of the simulation period through water year 1997
- Transition to deep percolation with temporal variability
- Changes to hydraulic conductivity in the Glendale area as a result of detailed modeling by Camp, Dresser, and McKee in the Glendale area
- Implementation of the MODFLOW rewetting package (SURFACT)
- The SFBFS-A model was revised in 2001 to yield the SFBFS-B model.

| | |
|---|---|
| Model /Interface | Visual MODFLOW |
| Model characteristics | Block centered finite difference model, as described in MODFLOW user's manual. |
| Simulated outcomes | Piezometric surfaces for ULARA groundwater area, including the San Fernando Valley |
| Agencies using the model | ULARA, Los Angeles Department of Water and Power (LADWP), The Metropolitan Water District of Southern California (MWD) |
| Owner/Operator | ULARA |
| Other | Models all ULARA basins, including the San Fernando, Sylmar, Verdugo, and Eagle Rock groundwater basins. |

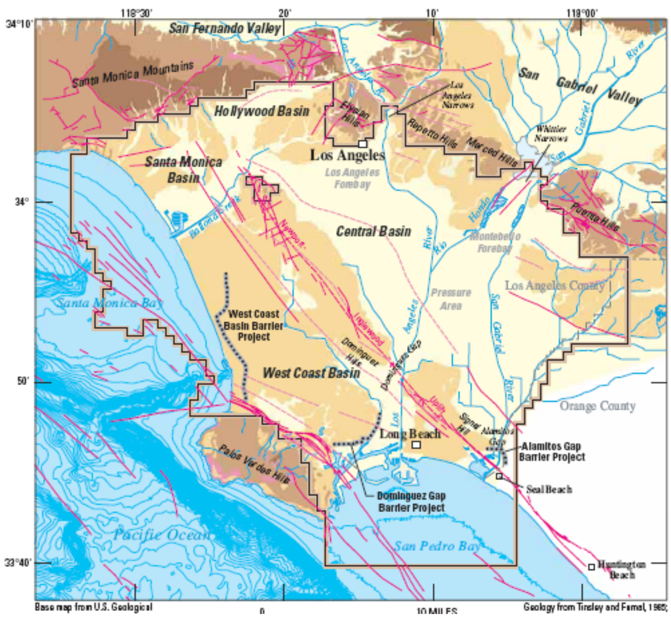
# USACE Models




The U.S. Corps of Engineers (USACE) Los Angeles District has various hydrologic and hydraulic modeling capabilities. The USACE models the Los Angeles River, Ballona Creek, and Malibu Creek watersheds using Hydrologic Engineering Center (HEC) HEC-HMS, HEC-GeoHMS, HEC-RAS and HEC-GeoRAS. HEC-HMS and HEC-RAS are hydrologic and hydraulic watershed models developed by the USACE at the HEC. Water management at the USACE is managed through the Corps Water Management System (CWMS), regulating river flow through reservoirs and other water control structures. The USACE currently has an existing hydraulic model of the Los Angeles River for specific reaches only in HEC-RAS.

Other models the USACE utilizes include HEC-ResSim which is a Reservoir Simulation System with the capability of modeling one or more reservoirs for a variety of operational goals and constraints. HEC-EFM and HEC-GeoEFM is an ecosystem functions model designed to determine ecosystem responses to changes in the flow regime of a river or connected wetland. The HEC-FIA (Flood Impact Analysis) software package analyzes the consequences from a flood event by calculating damage to structures and content, loss to agriculture, and loss of life. HEC-RPT (Regimen Prescription Tool) is designed to facilitate entry, viewing, and documentation of flow recommendations in real-time, public settings. The USACE Los Angeles District may also utilize such models as Flo-2D, a two dimensional surface water hydraulic model developed outside the USACE [24][25].

# Central and West Coast Basins - Water Replenishment District of Southern California





**Model Summary**

Historical groundwater development of the Central and West Coast Basins in Los Angeles County, California through the first half of the 20th century caused large water-level declines and induced seawater intrusion. Because of this, the basins were adjudicated and numerous groundwater management activities were implemented, including increased water spreading, construction of injection barriers, increased delivery of imported water, and increased use of reclaimed water. In order to improve the scientific basis for these water management activities, an extensive data collection program was undertaken, geohydrological and geochemical analyses were conducted, and groundwater flow simulation and optimization models were developed. As part of this project, extensive hydraulic, geologic, and chemical data were collected from new multiple-well monitoring sites. On the basis of these data and data compiled and collected from existing wells, the regional geohydrologic framework was characterized. For the purposes of modeling, the three-dimensional aquifer system was divided into four aquifer systems—the Recent, Lakewood, Upper San Pedro, and Lower San Pedro aquifer systems. Most pumpage in the two basins is from the Upper San Pedro aquifer system[1][8][15][16][18][19][26][28][30][31].

| | |
|---|---|
| Model /Interface | No GUI – developed with GIS |
| Model characteristics | 4 layers; Orange County boundary condition |
| Time Step | |
| Simulation Period (existing) | Steady state simulation period: 1971-2000 |
| Simulation Period (future) | Transient state simulation from 2001 -2025 of two scenarios.<br>• Scenario 1 simulates continued pumping at average current rates.<br>• Scenario 2 simulates increased pumping from most wells in the Central Basin. |
| Simulated outcomes | • Scenario 1: Stable or slightly increasing water levels<br>• Scenario 2: Declining water levels, i.e., 25 to 50 feet in the Central Basin |
| Agencies using the model | US Geological Survey, Los Angeles County Department of Public Works (LACDPW), Water Replenishment District of Southern California (WRDSC) |
| Owner/Operator | USGS |
| Last Update | September 2003 |
| User Manual | MODFLOW and related users manuals |
| Link to documentation | http://pubs.usgs.gov/wri/wrir034065/wrir034065.pdf |
| Other | Models water chemistry and particle tracking; currently in the process of being updated by the USGS. Other MODFLOW models exist for the Water Replenishment District, including 1) Montebello Forebay, 2) West Coast Barrier, 3) Dominguez Gap Barrier, and 4) Alamitos Barrier. |

# References

[1] CBMWD. "Central Basin Municipal Water District." Accessed October 30, 2014 from: http://www.centralbasin.org/en/.

[2] CH2MHill, and U.S. Environmental Protection Agency, Region IX. 1994. "San Fernando Basin Groundwater Model Documentation: San Fernando Valley Superfund Site, Los Angeles County, California". CH2MHill. Accessed November 2014 from: http://books.google.com/books/about/San_Fernando_Basin_Groundwater_Model_Doc.html?id=QV2mHAAACAAJ.

[3] CH2MHill, and United States Environmental Protection Agency Region IX. 1998. "Draft San Fernando Basin Groundwater Model Update and Revision Report, San Fernando Valley Superfund Site, Los Angeles, California". CH2MHill.

[4] Chieh, James, Jay Pak, and Rene Vermeeren. 2010. "Hydrologic/Hydraulic Modeling of Westminster Watershed – Orange County, California". 2nd Joint Federal Interagency Conference. Accessed November 2014 from: http://acwi.gov/sos/pubs/2ndJFIC/Contents/8F_Chieh_3_01_10.pdf.

[5] Fong, Moira T., Charles Downer, and Aaron Byrd. 2007. "A GSSHA Model of the Perris Basin of the San Jacinto River Watershed, Riverside County, California" USACE. Accessed November 2014 from: http://chl.erdc.usace.army.mil/library/publications/chetn/pdf/chetn-iii-76.pdf .

[6] Harris, Jonathan, Sumant Gupta, Mike Bitner, and Mike Broten. 1989. *San Gabriel Basin Groundwater Flow Analysis - Integrated Use of GIS and Finite Element Modeling* Manual. CH2MHill. Accessed November 2014 from: http://info.ngwa.org/GWOL/pdf/890149630.pdf.

[7] James M. Montgomery (JMM) Consulting Engineers, Inc. 1992. "Remedial Investigation of Groundwater Contamination in the San Fernando Valley, Remedial Investigation Report".

[8] Land, Michael, Rhett R. Everett, and Steven M Crawford. 2002. *Geologic, Hydrologic, and Water-Quality Data From Multiple-Well Monitoring Sites in the Central and West Coast Basins, Los Angeles County, California, 1995–2000* Open-File Report 01-277 United States Geological Survey. Accessed November 2014 from: http://pubs.usgs.gov/of/2001/ofr01277/ofr01277.pdf.

[9] Los Angeles & San Gabriel Rivers Watershed Council. 2010. *Ground Water Augmentation Model Demonstration Report A Component of the Water Augmentation Study*. Accessed November 2014 from: http://www.usbr.gov/lc/socal/reports/LASGwtraugmentation/AppC.pdf .

[10] "Main San Gabriel Basin Watermaster." 2013. Accessed October 30, 2014 from http://www.watermaster.org/.

[11] Metropolitan Water District of Southern California. 2007a. "Summary of Groundwater Basin Management." *Groundwater Assessment Study*. Accessed October 30, 2014 from: http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/groundwater/PDFs/FINALAppendixB.pdf

[12] ———. 2007b. "Chapter IV – Groundwater Basin Reports San Gabriel Valley Basins – Six Basins ."*Groundwater Assessment Study*. Accessed October 30, 2014 from: http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/groundwater/PDFs/SanGabrielValleyBasins/SixBasins.pdf.

[13] ———. 2007c. "Chapter IV – Groundwater Basin Reports San Gabriel Valley Basins - Raymond Basin ."*Groundwater Assessment Study*. Accessed October 30, 2014 from: http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/groundwater/PDFs/SanGabrielValleyBasins/RaymondBasin.pdf.

[14] ———. 2007d. "Chapter IV – Groundwater Basin Reports San Gabriel Valley Basins - Main San Gabriel and Puente Basins."*Groundwater Assessment Study*. Accessed October 30, 2014 from: http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/groundwater/PDFs/SanGabrielValleyBasins/SanGabrielandPuenteBasins.pdf.

[15] ———. 2007e. "Chapter IV – Groundwater Basin Reports Los Angeles County Coastal Plain Basins – West Coast Basin." *Groundwater Assessment Study*. Accessed October 30, 2014 from: http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/groundwater/PDFs/LACountyCoastalPlainBasins/WestCoastBasin.pdf.

[16] ———. 2007f. "Chapter IV – Groundwater Basin Reports Los Angeles County Coastal Plain Basins – Central Basin." *Groundwater Assessment Study*. Accessed October 30, 2014 from: http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/groundwater/PDFs/LACountyCoastalPlainBasins/CentralBasin.pdf.

[17] ———. 2007g. "Chapter IV – Groundwater Basin Reports San Fernando Valley Basins - Upper Los Angeles River Area Basins." Accessed October 30, 2014 from: http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/groundwater/PDFs/SanFernandoValleyBasins/UpperLARiverAreaBasins.pdf.

[18] Ponti, Daniel J., Brian J. Wagner, Michael Land, and Matthew K. Landon. 2014. *Characterization of Potential Transport Pathways and Implications for Groundwater Management Near an Anticline in the Central Basin Area, Los Angeles County, California* Open-File Report 2014–1087. USGS. Accessed November 2014 from: http://pubs.usgs.gov/of/2014/1087/pdf/ofr2014-1087.pdf .

[19] Reichard, E.G, S.M. Crawford, R.R. Everett, D.J Ponti, T.A Johnson, T Nishikawa, M Land, et al. 2003. *Geohydrology, Geochemistry, and Ground-Water Simulation-Optimization of the Central and West Coast Basins, Los Angeles County, California*. Water Resources Investigations 03-4065. Los Angeles, California. Accessed October 30, 2014 from: http://pubs.usgs.gov/wri/wrir034065/wrir034065.html.

[20] Sim, Y, S Carter, J Riverson, and J Zhen. 2010. "Urban Runoff and Stormwater Quality Management Using the Los Angeles County Flood Control District's Watershed Management Modeling System: A Pilot Application ." *World Environmental and Water Resources Congress 2010*, 3462–73. doi:10.1061/41114(371)354.

[21] Sim, Youn. 2009. "Development of Watershed Management Modeling System: The Los Angeles County Flood Control District's Watershed Based Approach for Urban Runoff and Stormwater Quality."*World Environmental and Water Resources Congress 2009: Great Rivers*, Conference Proceeding Paper. Accessed November 2014 from: doi:http://dx.doi.org/10.1061/41036(342)165).

[22] Smead, Kevin R. 2005. *California Domestic Water Company Urban Water Management Plan*. Stetson Engineers Accessed November 2014 from: http://www.water.ca.gov/urbanwatermanagement/2005uwmps/CaliforniaDomesticWaterCompany/CaliforniaDomesticWaterCompany2005UWMP.pdf

[23] Three Valleys Municipal Water District. 2012. "Development and Use of a Numerical Groundwater-Flow Model of the Six Basins". Local Groundwater Assistance Program, Attachment 4 Project Description. Accessed November 2014 from: http://www.water.ca.gov/lgagrant/docs/applications/Three%20Valleys%20Municipal%20Water%20District%20(201209870026)/Att04_LGA12_TVMWD_ProjD_1of1.pdf.

[24] USACE. 2014. Hydrologic Engineering Center (HEC). Accessed November 2014 from http://www.hec.usace.army.mil

[25] USACE. 2011. "Peer Review Plan Los Angeles River Ecosystem Restoration Feasibility Study Los Angeles District", USACE. Accessed November 2014 from: http://www.spl.usace.army.mil/Portals/17/docs/review_plans/LARiver_FEB2011.pdf.

[26] Warne, William E. 1961.*Planned Utilization of the Ground Water Basins of the Coastal Plain of Los Angeles County* Bulletin 104 Appendix A Ground Water Geology. State of California Department of Water Resources. Accessed October 30, 2014 from: http://www.water.ca.gov/waterdatalibrary/docs/historic/Bulletins/Bulletin_104/Bulletin_104-A__1961.pdf.

[27] Weghorst, Paul, Jack Cunningham, and Tom Bellinger. 2007. *Los Angeles Basin Ground Water Augmentation Model Version 4.1.10 User's Manual and Technical Documentation*. User's Manual and Technical Memorandum Version 4.1.10. Bureau of Reclamation .

[28] "West Basin Municipal Water District." Accessed October 30, 2014 from http://www.westbasin.org/.

[29] Williams, Dennis E. 2013. *Hydrogeological Analysis of Underground Retention Time and Recycled Water Contribution from Proposed Recharge Sites in the Vicinity of La Canada High School*. Technical Memorandum. Geoscience for Foothills Municipal Water District. Accessed November 2014 from: http://www.fmwd.com/resources/documents/fmwd%20rwp/RWP-Draft-Hydrogeologic-Report-(5-6-13).pdf.

[30] "WRD Technical Bulletin Volume 4, Summer 2005." 2014. *An Introduction to the Central and West Coast Groundwater Basins*. Accessed October 30, 2014 from: http://www.wrd.org/engineering/introduction-groundwater-basins-los-angeles.php.

[31] WRDSC. 2014. "Water Replenishment District of Southern California." Accessed October 30, 2014 from: http://www.wrd.org/.