5. MODEL DESCRIPTION

Several models were used in combination to estimate the impacts of the proposed 100,000 acre-ft dry-year yield program. MODFLOW and MODPATH were used to estimate the groundwater and surface water response to the dry-year yield program. Other models and codes were used to support MODFLOW and MODPATH. Groundwater Vistas (Version 3) was the modeling software environment, and was used as a graphical design and analysis system for MODFLOW and MODPATH. ArcMAP 8.2 was used as a pre- and post-processing tool to manipulate input data and output results. The WLAM was used to estimate some of the hydrologic components and is discussed in Section 4.

5.1 MODFLOW

MODFLOW is a MODular three-dimensional finite-difference groundwater FLOW model. Several versions of MODFLOW have been developed by the USGS and released to the public domain. The most recent version is MODFLOW-2000, which is a major update that fully integrates parameter estimation. Comprehensive documentation of MODFLOW-2000 can be found on the World Wide Web at:

http://water.usgs.gov/software/modflow-2000.html

MODPATH, also developed by the USGS, is a three-dimensional, particle-tracking, post-processing code that works with output files from steady-state or transient ground-water flow simulations by MODFLOW. Comprehensive documentation of MODPATH can be found on the World Wide Web at:

http://water.usgs.gov/software/modpath.html

5.2 Groundwater Vistas

Groundwater Vistas (GV) is a groundwater modeling environment created for the Microsoft Windows platform by Environmental Simulations, Inc. In this investigation, it served as modeling design system and a graphical analysis tool for MODFLOW and MODPATH. GV can read and export Environmental Systems Research Institute (ESRI) shapefiles, which allowed for the creation of input data and the display of output results in ArcMAP 8.2. Comprehensive documentation of GV can be found on the World Wide Web at:

http://www.groundwatermodels.com/software/SoftwareDesc.asp?software_desc_id=19&software_id=6

5.3 Relationships between MODFLOW, other Models and Data

The complete modeling environment developed and used herein is referred hereafter as the 2003 Watermaster Model. Figure 5-1 shows the relationship between all the models and computer codes that were used in the 2003 Watermaster Model of the Chino Basin. The 2003Watermaster Model is a modeling system that incorporates complex hydrological processes, vast amounts of data, and sophisticated computer simulation programs.

A series of surface water hydrology models were used to estimate recharge through the land surface in areas where there is no dynamic interaction between surface water and groundwater. These surface water hydrology models are incorporated in the WLAM and include RUNOFF, ROUTER, and SOILH2O. These models estimate the surface water discharge, surface water recharge, and the deep percolation of precipitation and applied water. These models feed data into another program called RECHARGE INTEGRATOR that creates recharge files compatible with MODFLOW. Other data used by

RECHARGE INTEGRATOR include subsurface boundary flows from adjacent basins and the artificial recharge of imported and recycled water.

ArcMAP 8.2, FORTRAN, and SQL programs were created to manipulate Watermaster's database and files and convert them to files compatible with GV, MODFLOW, and MODPATH. The resulting data were combined with the data from RECHARGE INTEGRATOR and were assembled to create the input files for MODFLOW.

MODFLOW was then run and it produced output files that contain groundwater elevations and velocities for each cell, surface water discharge estimates, and water budget terms. The groundwater level, surface water discharge, and water budget terms were processed in ArcMAP 8.2 and Microsoft Excel. The groundwater velocity estimates were used in MODPATH.

MODPATH is a companion program to MODFLOW that uses a particle-tracking technique to predict the movement of water quality anomalies. The coordinates of water quality anomalies at the start of the simulation and the groundwater velocity estimates from MODFLOW were input to MODPATH. MODPATH subsequently estimates the movement of the water quality anomalies. The results of the MODPATH simulation were processed in ArcMAP 8.2.

5.4 Implementation of Conceptual Model

5.4.1 Calibration Period and Time Step

The calibration period was October 1989 through September 2001 a period of twelve years. This period was chosen for two reasons that include:

- Pumping data – the pumping data recorded by Watermaster during this period is more accurate than in past years due to more complete reporting by the agricultural producers.
- Recharge conditions – the availability and quality of data to estimate recharge from precipitation and applied water and storm water is greater than prior to this period.

As noted in Section 2, groundwater levels have been generally stable since the Judgment was implemented in 1978. Extending the calibration backward in time using data of lesser quality will not improve the calibration. Figure 5-2 shows cumulative departure from the mean precipitation for a long-term precipitation stations in Ontario and Fontana. Figure 5-2 also illustrates the period since the judgment and the calibration period. Statistics, relating the period of record to the calibration period, are summarized below.

Station ID Location	SBC 1026 Ontario		SBC 2194 Fontana	
Period of Record	1934 to 2001	1990 to 2001	1926 to 2001	1990 to 2001
Average (inches)	16.62	15.42	16.71	16.55
Maximum (inches)	37.22	32.38	37.84	32.28
Minimum (inches)	6.10	6.36	3.98	7.64
Standard Deviation (inches)	8.14	7.68	7.59	8.35
Coefficient of Variation	49.01%	49.82%	45.45%	50.45%

The statistics for the period of record and the calibration period are reasonably close; however, it is apparent from Figure 5-2 that the historical record contains periods that are substantially wetter and drier than in the calibration period. Section 7 will present a technique to develop an expected value recharge hydrology that incorporates the range of historical precipitation over the Chino Basin area and future land use and drainage conditions.

The time step used in MODFLOW was 91.3 days or one-quarter of a year. This time step corresponds to the production reporting time period used by Watermaster.

5.4.2 Geometry

5.4.2.1 Grid Size and Layout

Figure 5-3 shows the 2003 Watermaster grid orientation relative the Chino Basin. The model grid consists of cells arranged in rows and columns as required by MODFLOW. Each cell is square and 200 feet on edge.

5.4.2.2 Effective and Ineffective Cells

Not all the cells are used in the model. Cells located outside of the modeled area of the Chino and Temescal Basins are "turned off" and are called inactive or ineffective – the model does not compute heads or groundwater flux at these cells. The cells located in the Chino and Temescal Basins are "turned on" and are called active or effective cells. Figures 5-4, 5-5 and 5-6 show the locations of effective cells for Model Layers 1, 2 and 3, respectively. Recall from Section 2, that Layer 1 is the top layer and that Layer 3 is the bottom layer.

5.4.2.3 Stream Representation

The sources of surface water in Chino Basin include storm water runoff, urban dry-weather runoff, and non-tributary discharges that include: publicly-owned treatment works (POTW) discharges, Lake Elsinore overflows through Temescal Creek, Arlington desalter discharges through Temescal Creek, and State Water Project (SWP) water through San Antonio Creek. With the exception of the Santa Ana River inflow to the Chino Basin at Riverside Narrows, all storm water estimates were made with the WLAM. The non-tributary inflows were estimated from discharge data provided by the dischargers and the USGS. The Santa Ana River inflow to the Chino Basin at Riverside Narrows was estimated from USGS data. The locations of these discharge points are shown in Figure 5-7.

The streams represented in the 2003 Watermaster Model include San Antonio, Chino, West Cucamonga, Cucamonga, Mill, Deer, Day, Etiwanda, San Sevaine and Temescal Creeks and their tributaries, and the Santa Ana River. Regulating structures including dams, debris basins, detention basins, recharge basins, and diversion works have been incorporated into the simulation.

Stream reaches where dynamic stream and groundwater interaction could occur are delineated in Figure 5-7. These reaches are located in the southern part of the Chino Basin and Temescal Basin where the groundwater levels are near the streambed. In these reaches, recharge and rising water are a function of stream discharge, water level in streams, and underlying groundwater levels. Recharge and rising water discharges are estimated by MODFLOW in these stream reaches.

The remaining stream segments and associated recharge facilities are also shown in Figure 5-7. These reaches are located north of the Santa Ana River and where groundwater levels are sufficiently below the land surface so that groundwater levels have no effect on recharge. In these reaches, recharge estimates were developed from the WLAM and USGS stream gage data on a daily time step and were aggregated to the 91.3-day time step required used in the groundwater model.

5.4.2.4 Initial Aquifer Properties

The aquifer properties included in the model are horizontal hydraulic conductivity, vertical hydraulic conductivity, storage coefficient, and specific yield. The reader is referred to *Groundwater* (Freeze and Cherry, 1979) and/or other textbooks covering groundwater for descriptions of these properties and their physical meaning. Initial estimates of these aquifer properties are necessary to start the calibration. Initial estimates were developed from Watermaster's *Rapid Assessment Model* and the modeling work done to support the design of the Chino-1 Desalter expansion and Chino-2 Desalter (Geoscience, 2001). Subsequently, the values of the properties were changed through calibration. The final values of the aquifer properties are discussed in *Section 6 Model Calibration*.

5.4.3 Recharge and Discharge

Recharge and discharge in the model area were described in Section 4. The recharge components, with the exception of stream recharge in the Santa Ana River and its tributaries that are simulated directly in the model, were assigned to specific model cells.

Similarly, the discharge components, with the exception of groundwater discharge to the Santa Ana River and its tributaries that are simulated directly in the model, were assigned to specific cells. The assignment of pumping from a well to specific layers and the cell within each layer was based on the screened interval and depth of the well, and the hydraulic conductivity of the layers in which the well was screened.

5.4.4 Initial Conditions

The initial condition for the model corresponds to October 1989 and consists of groundwater levels for effective cells in the model domain. A groundwater elevation map was prepared for the Chino Basin for October 1989 and is shown in Figure 5-8. The resulting groundwater levels were assigned to individual cells of the model. For a given location, the groundwater levels were assumed the same in each layer at the start of the calibration.