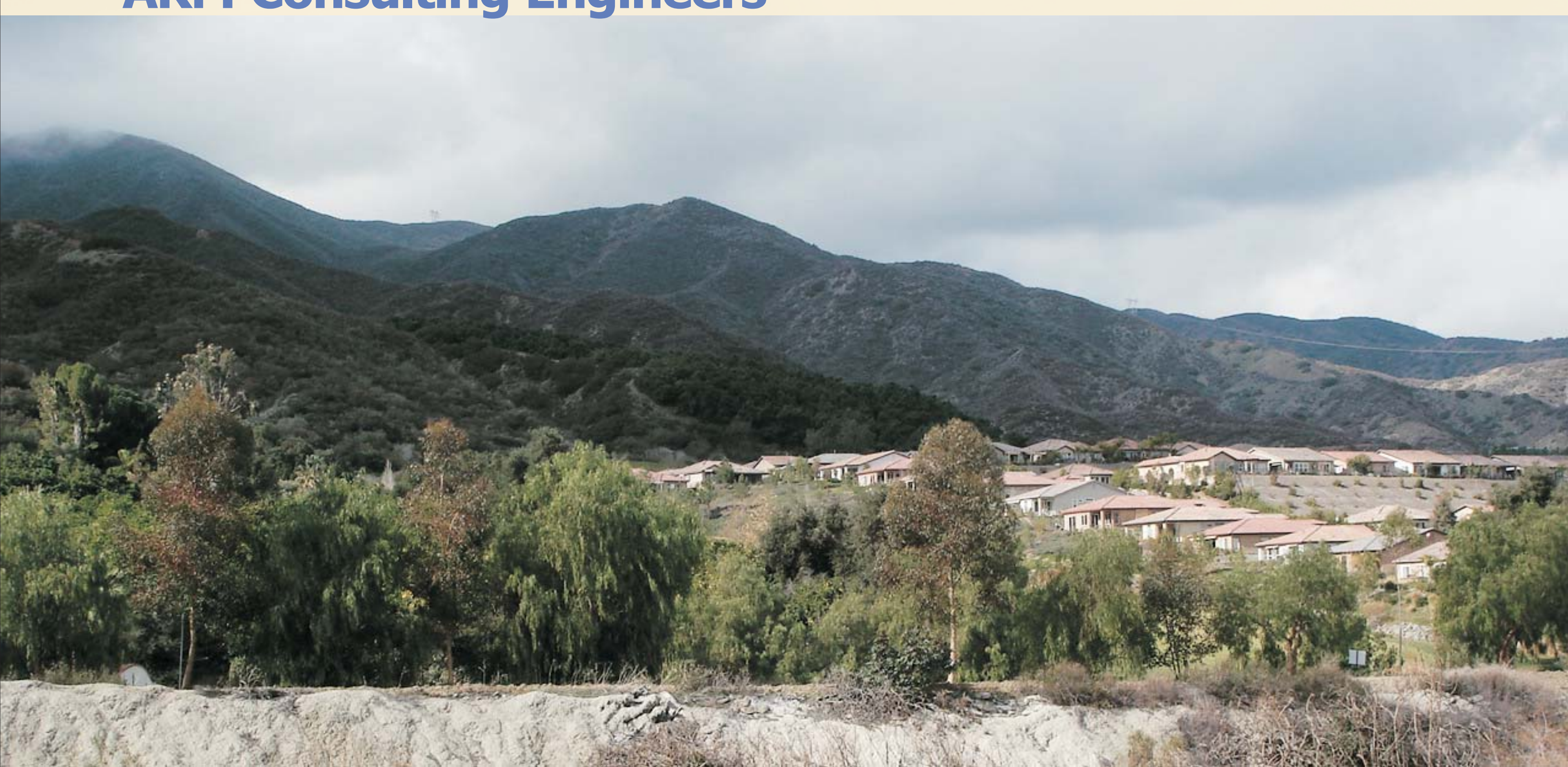
AB3030

# Groundwater Management Plan

**Prepared for**
**City of Corona**

**June 2008**

**Todd Engineers**
**AKM Consulting Engineers**



*Final*

# AB3030 Groundwater Management Plan

**Prepared for:**

**City of Corona**

**Department of Water and Power**

**755 Corporation Yard Way**

**Corona, CA 92880**

**Prepared by:**

**Todd Engineers**

**2490 Mariner Square Loop, Suite 215**

**Alameda, CA 94501-1080**

**AKM Consulting Engineers**

**553 Wald**

**Irvine, CA 92618**

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# Table of Contents

# List of Tables

Page No.



# List of Figures (following text)

## List of Appendices

# 1. Introduction

The City of Corona relies on three groundwater subbasins within their water service area for a portion of their water supply. In order to more actively manage this limited resource, the City and its technical consultants have prepared this Groundwater Management Plan (GWMP). The plan follows guidelines set forth in Assembly Bill (AB) 3030, which was promulgated in 1992 and allows local agencies to prepare and adopt GWMPs (California Water Code Sections 10750 through 10756). The bill was amended in 2002 by Senate Bill (SB) 1938, providing additional GWMP requirements. Such a plan allows the City to address issues of groundwater recharge and storage, critical components for effective management of the local subbasins and the City's water supply. This GWMP will be considered by the City for adoption on June 18, 2008 in accordance with AB3030 timelines (the press release for the public hearing is included in Appendix A).

## 1.1. GWMP Plan Goals and Objectives

The Goals of the GWMP include:

- Operate the groundwater basin in a sustainable manner for beneficial uses
- Increase the reliability of water supply for basin users

To support these goals, the City has determined the need to better understand the hydrogeology and groundwater conditions of the underlying basins and, based on this understanding, develop appropriate management objectives and strategies to achieve these goals.

The Plan area covers three groundwater subbasins within the City's water service area and sphere of influence. The City has conducted groundwater production and management activities in these subbasins for more than 40 years. These three subbasins, Temescal, Coldwater, and Bedford, are located in western Riverside County in the Santa Ana River Watershed as shown on Figures 1 and 2 (all figures are at the end of the text in this document).

## 1.2. Scope of Work

The City, along with input from Todd Engineers and AKM Consulting Engineers, developed a scope of work for the preparation of the GWMP including a series of nine tasks as listed below:

- Provide Public Outreach
- Identify Study Area and Compile Data
- Develop Data Management System

- Assess the State of the Basins
- Construct a Groundwater Model
- Develop Groundwater Basin Management Objectives (BMOs)
- Develop Groundwater Management Strategies
- Evaluate Management Alternatives
- Prepare a GWMP

The City took the lead on the public outreach process, described in more detail in the following section. The Study Area is defined as the groundwater subbasins underlying the City's water service area and covers approximately 30,000 acres (47 square miles) (Figure 3). To support the development of an AB3030 GWMP, relevant hydrologic and hydrogeologic data for the Study Area, as well as the contributing watersheds, were compiled and analyzed. The analysis provides for an historical assessment of available data as well as more detailed analysis over a 15-year Study Period.

Collectively, these analyses are used to describe the "state of the basins" with respect to groundwater use, water levels, quality, and storage. Based on this assessment, basin management objectives and management strategies to achieve those objectives were developed. The management strategies were further evaluated by the development, calibration, and application of a numerical groundwater flow model. The GWMP also includes a schedule for implementation of the management strategies.

## 1.3. GWMP Organization and Preparation

The organization of this GWMP generally follows the tasks described above. Tables are incorporated into the text and numbered within each chapter of the document. All figures are provided at the end of the text in a separate section to allow referencing throughout the text and to prevent duplication of figures. This introductory chapter provides the background and context for the GWMP. Chapter 2 describes the data compilation process for the analyses conducted. Chapter 3 describes the hydrogeologic assessment of the state of the groundwater basins. A brief description of the City's current and projected water demand, along with water sources, is included in Chapter 4 to provide context for the City's future reliance on groundwater as one of the sources of water supply. Basin Management Objectives and strategies to meet those objectives are provided in Chapters 5 and 6, respectively. Chapter 7 provides an implementation schedule for the GWMP. References are summarized in Chapter 8. Appendix A contains documentation of the stakeholder process. Appendix B summarizes the City's current monitoring program and makes recommendations for future improvement. Appendix C describes the development of a numerical groundwater model to assist with the evaluation of key management strategies. Appendix D contains a feasibility study for recycled water recharge in the Bedford

Subbasin conducted separately for Lee Lake Water District (LLWD) and included as part of this GWMP.

The development of the GWMP was a collective effort by the City and its technical consultants. The City provided key data and led the public outreach program. Todd Engineers led the data compilation and hydrogeologic assessment of the groundwater subbasins. Todd Engineers also constructed, calibrated, and applied a numerical groundwater model of the Temescal Subbasin for the analysis of selected groundwater management strategies. AKM assisted with details on the City's water supply and wastewater systems, future water demand, and the identification of key management strategies.

## 1.4. Public Outreach

In order to encourage public participation and keep local agencies informed, the City conducted a public outreach program associated with the GWMP. The City developed a stakeholder list to specifically invite interested parties to public meetings and inform them on plan preparation. Public notices, a Stakeholder List, and an adopted resolution to prepare the GWMP are provided in Appendix A. Public outreach activities are summarized in the following sections.

### 1.4.1. Notice of Intent to Prepare an AB3030 GWMP

On June 6, 2006, the City notified the public that a public meeting was scheduled to consider whether the City should prepare a GWMP. In the public notice, provided in Appendix A, the City invited all landowners and interested parties to attend the hearing and express their interest in the GWMP process. The City also made available advance copies of the resolution that was being considered. The notice described how interested parties could participate in the GWMP development by either attending the hearing or submitting a written request to the City.

At the public hearing on June 21, 2006, the City invited the public to comment on the GWMP process and pending resolution. No comments were made, and the Resolution of Intent to Prepare a Groundwater Management Plan was adopted. A copy of the signed resolution is provided in Appendix A.

### 1.4.2. Neighboring Agencies and Service Areas

Figure 4 shows the service areas of agencies in the region that provide water supply to the area. The City shares the three groundwater subbasins with the City of Norco, Home Gardens County Water District, Lee Lake Water District (LLWD), and Elsinore Valley Municipal Water District (EVMWD). LLWD is participating in the GWMP and is proposing a groundwater recharge project with recycled water in the Bedford Subbasin. This project is included as a groundwater management strategy in this GWMP and is evaluated separately in Appendix D.

### 1.4.3. Public Meetings

In addition to the public hearings held in accordance with the GWMP process, two public workshops were conducted on December 11, 2007 and May 20, 2008. At the December workshop, the assessment of the groundwater basin was presented along with preliminary basin management objectives (BMOs) and potential management strategies to achieve those objectives. Representatives from LLWD, Western Municipal Water District (WMWD), Orange County Water District (OCWD), EVMWD, Chandler's Sand and Gravel, Riverside County Waste Management Department (RCWMD), and other parties attended the workshop. GWMP information and a copy of the technical presentation were posted on the City's website prior to the meeting.

In the May workshop, the Draft GWMP was reviewed including the final BMOs, evaluation of the management strategies, and the implementation schedule. Representatives of WMWD, EVMWD, Santa Ana Watershed Protection Agency (SAWPA), Chandler's Sand and Gravel, Riverside County Flood Control and Water Conservation District (RFCWCD) and Inland Empire Waterkeeper attended the workshop. The Draft GWMP was posted on the City's website prior to the meeting. Written comments on the Draft GWMP were provided by WMWD, RFCWCD, RCWMD, and Inland Empire Waterkeeper. Those comments have been incorporated into this GWMP, or in some cases, marked for further review during the EIR process.

### 1.4.4. Meetings with Neighboring Agencies

Two informal meetings were also held with neighboring agencies on the GWMP process. On January 22, 2008, City consultants provided an update of the GWMP development to the Lee Lake Water District (LLWD) Board of Directors at their request. The City and consultants also met with consultants of the Chino Basin Watermaster at their request on March 18, 2008 to discuss the GWMP progress and mutual interests with respect to data sharing and groundwater modeling.

## *1.5. Environmental Review*

In compliance with the California Environmental Quality Act, the City has embarked on an environmental review of the GWMP. The process will evaluate the strategies included in the adopted GWMP in a Programmatic Environmental Impact Report (PEIR). The City has already retained the services of Environmental Science Associates (ESA) to prepare the PEIR, which will commence after the GWMP has been adopted. Preparation of the PEIR will involve public notification and hearings on potential environmental impacts of the GWMP. The City may decide to update or modify components of the GWMP in the future based on the environmental review process.

# 2. Data Compilation and Management

To support the development of an AB3030 GWMP for the City, relevant hydrologic and hydrogeologic data for the groundwater basins and contributing watersheds have been compiled. A Study Area and Study Period were defined early in the process to guide the data collection effort. The data collection process occurred mainly in 2006 and resulted in relatively complete data sets through 2004. In addition, data collected since 2006 are incorporated as noted throughout the GWMP. The City's water production and purchases are updated through the end of Calendar Year 2007 in Chapter 4. Other historical data were collected when available, but a focused effort was made to compile data covering an approximate 20-year period dating back to the mid-1980s.

A Data Management System (DMS) was designed to organize available data, support technical analyses, and identify data gaps. This system includes a relational database in Access format with individual tables for each data type. A project Geographical Information System (GIS) has also been maintained as a repository for regionally-available GIS files and for viewing and analyzing spatial data. The database and GIS were also used to facilitate the construction of a numerical model to assist in the evaluation of management strategies. Collectively, the GIS and project database provide a framework that will allow additional data to be incorporated and analyzed in the future. The Study Area, Study Period, and data collection efforts are described in the following sections.

## 2.1. Study Area

A Study Area for the Groundwater Management Plan was defined by the groundwater subbasins of interest, the contributing watersheds, and portions of the adjoining groundwater basins (Figure 3). The Study Area is larger than the groundwater subbasins to be managed in order to incorporate inflows from other groundwater basins and evaluate the subbasins of interest in a regional context.

Subbasin nomenclature and boundaries follow those included in the California Department of Water Resources (DWR) document, *California's Groundwater*, commonly referred to as DWR Bulletin 118 (DWR, 2003). Portions of Bulletin 118, including descriptions of individual groundwater basins, are updated periodically by DWR. The Study Area subbasins were updated on February 27, 2004 and those descriptions are used in this document (DWR February 27, 2004a; 2004b; 2004c). Subbasins and contributing watershed areas, as determined through GIS, are summarized in the table below.

**Table 2-1**
**Groundwater Basins and Watersheds**

| DWR Groundwater Basin (Basin No.)* | Subbasin (Basin No.)* | Subbasin Area (acres) | Contributing Watersheds (acres) | |
|---|---|---|---|---|
| | | | Western | Eastern |
| Upper Santa Ana Valley (8-2) | Temescal (8-2.09) | 23,500 | 13,999 | 12,549 |
| Elsinore (8-4) | Coldwater (none) | 2,176 | 9,525 | 0 |
| | Bedford (none) | 4,133 | 0 | 11,858 |
| | Total | 29,809 | 23,524 | 24,407 |

*DWR Bulletin 118, February 27, 2004a., b., c.

The Temescal Subbasin is a recognized subbasin in Bulletin 118. The Elsinore Groundwater Basin, the adjoining basin to the southeast, is not formally divided into subbasins in Bulletin 118. However, two areas within the northern portion of the Elsinore Basin, Coldwater and Bedford, have been designated as subbasins in past investigations (DWR, 1959). Because these subbasins can be readily defined as distinct from the remaining subbasins to the south, they are included as separate subbasins in the Study Area for the purposes of this GWMP.

### 2.1.1. Subbasin Boundaries

The Temescal Subbasin as defined by DWR is bounded on the west by the Santa Ana Mountains and the east by low-lying El Sobrante de San Jacinto and La Sierra hills. The subbasin is connected to three adjacent groundwater basins. The boundary with the Chino Subbasin (DWR Basin No. 8-2.01) to the north is generally marked by the Santa Ana River and a series of low-lying hills in the Norco area (Figure 3). Groundwater flows into the subbasin from the Riverside-Arlington Subbasin (DWR Basin No. 8-2.03) through the Arlington Gap, a restriction in the southwestern arm of the Riverside-Arlington Subbasin (Figure 3). The southern boundary of Temescal Subbasin is located at a constriction of the alluvium along Temescal Wash at Bedford Canyon where it connects with the Bedford Subbasin of the Elsinore Groundwater Basin (DWR Basin No. 8-4).

The subbasin also includes a small subarea west of the La Sierra Hills and east of the Santa Ana River (DWR, February 2004a). This northeastern arm of the Temescal Subbasin, referred to as the Norco area, consists of relatively low permeability alluvium and bedrock residuum flanked on the east and west by bedrock outcrops. Investigators in the Chino Subbasin include a portion of this area within the boundary of the Chino Basin (WE, July 2005). This division may be technically supported by a groundwater divide indicated by water level data in the Norco area with groundwater in the northern portion flowing toward the bluff along the Santa Ana River.

The Bedford Subbasin connects to the Temescal Subbasin near the base of Bedford Canyon. The connection occurs where the alluvium along Temescal Wash thins as the wash leaves the subbasin and traverses northward through bedrock (a reach referred to as Temescal Canyon) before entering Temescal Subbasin.

The Coldwater Subbasin connects to the Bedford Subbasin along a trace of the Glen Ivy Fault zone, a locally named fault related to the larger basin-bounding Chino-Elsinore Fault zone. Since the delineation between the two subbasins has historically been the surface trace of a groundwater-impeding fault, the fault trace mapped by the U. S. Geological Survey (USGS) was used as the subbasin boundary (USGS, 2004).

#### 2.1.2. Contributing Watersheds

The Temescal Subbasin receives runoff and recharge from almost 14,000 acres of uplands in the adjacent Santa Ana Mountains. Watersheds contributing runoff from the east are almost as large, but contribute less runoff because of lower elevations and corresponding precipitation. Watersheds contributing runoff to Coldwater and Bedford subbasins cover 9,525 acres and 11,858 acres, respectively, more than three times the area of the subbasins. Although the watershed contributing runoff to Bedford Subbasin is more than 2,000 acres larger than the Coldwater watershed, the Coldwater Subbasin receives more runoff due to the higher watershed elevations.

### *2.2. Study Period*

An initial review of documents and data was used to define a Study Period to guide ongoing data collection and the water balance. Study Period selection considered significant changes that may have an effect on the groundwater basin such as land use, population growth, imported water, and groundwater production. The availability and quality of historical data were also considered. Selecting a relatively recent period makes good use of available data and represents the current state of the basin, including changing land use and management.

Rainfall patterns and hydrologic cycles were also reviewed to select a representative Study Period. Average annual rainfall within the Temescal Subbasin, along with a cumulative departure curve is provided on Figure 5. Based on the data review and rainfall patterns, a Study Period from water year 1990 through water year 2004 (15-year period) was selected for focused data collection. This period contains a range of wet and dry cycles and approximates long-term average precipitation. The average annual rainfall for the Study Period is about 15 inches per year, in good agreement with the average of 15.7 inches per year at the Chase precipitation station (Figure 5). The Study Period begins in drought conditions when water levels in the basin are relatively stable. The period also contains a full wet and dry cycle (as indicated by the cumulative departure curve) to allow assessment of climatic variations in the water balance (Figure 5).

The Study Period also allows for evaluation of changes in water demand and supply. Although the City has grown steadily in population since its inception in 1896, significant population increases occurred between 1960 and 1970 and between 1985 and 1995. During each of these two decades, population doubled (AKM, April 2005). From 1985 to 2004, the population more than tripled, increasing from 45,750 to 144,274. Current population is approximately 149,400 (2008). Accompanying this growth was a change from predominantly agriculture to more urban land uses and a large increase in urban water demand. Much of the demand increase through the 1990s was met with an increase in imported surface water supplies. However, over the last five years, groundwater production increased from about one-third of the City's supply to about one-half, an increase contained within the Study Period.

Although the more quantitative assessments including the groundwater basin water balance and numerical modeling were conducted for the Study Period, additional historical data were also compiled. These documents and data provide useful information on the conceptual model of the three subbasins and changes in groundwater conditions over a relatively long time period.

## 2.3. Data Types and Sources

Data collected for the GWMP are summarized below by data type and are described in more detail in following sections.

- **Hydrologic** – Climatic data (e.g., precipitation and evapotranspiration), reservoir storage, and streamflow.
- **Land Use** – Land use maps over time indicating areas of agriculture, urban growth, and open space corresponding to changing water use, irrigation, and pumping patterns.
- **Geology** – Maps of geologic units and faults, lithologic information from wells, and soil types.
- **Groundwater** – Subbasin boundaries, well locations and construction, pumping tests, water levels, and ambient groundwater quality.
- **Water Quality** – Data included water quality analyses from municipal wells compiled from the City and the California Department of Public Health (DPH) (formerly the Department of Health Services). Data were also collected for Regulated Facilities in the Study Area. These data include water quality analyses conducted and compiled by the City as required by state regulations. Data were obtained from the Regional Water

Quality Control Board (RWQCB) and other local agencies relating to basin water quality from monitoring at commercial or industrial activities.

- **Water Supply** – Drinking water and other water uses from groundwater pumping (by the City and others), imported water, and recycled water.
- **GIS Base Maps and Layers** – Supporting physical and cultural information were compiled for use in the project GIS such as roads, freeways, city limits, parcels, sphere of influence, building footprints, digital elevation models, streams, rivers and lakes, and other data.

Primary sources of data for this GWMP were local and state public agencies including the City, County of Riverside, RWQCB, USGS, DWR, and the Santa Ana Watershed Protection Agency (SAWPA). SAWPA, in particular, was a helpful resource for filling key data gaps and acquiring physical and cultural data for the GIS base maps. SAWPA was first formed in 1968 as a planning agency, and reformed in 1972 with a mission to plan and build facilities to protect the water quality of the Santa Ana River Watershed (SAWPA, 2006). Within SAWPA, the Information Systems and Data Management team develops and maintains water-related data that are used by SAWPA staff for data analysis and dissemination. These data are available online through the Santa Ana Watershed Data Management System (SAW DMS, 2006).

## 2.4. Hydrologic Data

The main sources for hydrologic data in the Study Area included the California Irrigation Management Information System (CIMIS), County of Riverside, National Weather Service, and USGS as described in more detail below.

### 2.4.1. Climate Data

Precipitation data were available for four stations in the Santa Ana River Watershed as shown on Figure 2. Location data for each station are also included in the DMS. Data for the University of California Riverside Station # 44 were downloaded from the California Irrigation Management Information System (CIMIS) website. Data for the Chase, Norco, and Elsinore stations were obtained from the County of Riverside. Data are available monthly from June 1965 to the present for the three county stations (Chase, Norco, and Elsinore) and from June 1985 to the present for the CIMIS station.

The spatial distribution of average rainfall (isohyetal maps) in the Study Area was available from several sources. SAWPA files contained an isohyetal over the entire Santa Ana River Watershed (Figure 2). A long-term average isohyetal map was also obtained from the Oregon Climate Service (OCS) and Oregon State University using PRISM (parameter-elevation regressions on independent slopes model), a climate modeling and mapping system (OCS, January 8, 2007). The PRISM Group, supported by numerous agencies and used by DWR, models complex precipitation patterns over large areas to develop a more accurate predictive precipitation tool. This PRISM isohyetal map was used in the basin water balance and is shown on Figure 6.

Monthly evapotranspiration (ET) data were available from June 1985 to May 2006 for the CIMIS station. Long term pan evaporation data from 1948 to 2005 were compiled from an additional station in Riverside County (Riverside Citrus Exp. St. Station). These data, along with other information such as annual ET coefficients for various crops were downloaded from the DWR Division of Planning and Local Assistance (DPLA) website. The DWR DPLA divides the state into Detailed Analysis Units (DAU) for purposes of data reporting. The City is located in the North Riverside DAU. Both reference ET data and crop coefficients were added to the DMS.

### 2.4.2. Streamflow

Surface water gage data for Temescal Wash were available from the USGS National Water Information System (NWIS) as shown on Figure 7. Data from one active and several inactive gages were compiled. For the gage located along Temescal Wash between Bedford and Temescal subbasins (USGS Station no. 11072000), daily data were available from October 1928 to June 1980. For the active gage in the City near Main Street (11072100), daily flows from October 1980 to April 2007 were downloaded and added to the DMS as a separate table.

### 2.4.3. Reservoir Storage

Lake Mathews is used to store much of the imported water that supplies the City (Figure 3). Monthly reservoir storage data from October 1961 to May 2006 were downloaded from the California Data Exchange Center (CDEC) and included in the DMS.

## *2.5. Water System Data*

### 2.5.1. Pumping Data

The City provided numerous pumping summary tables in pdf format on a compact diskette (CD). This CD contained annual pumping data by well from 1964 to 1999 for City wells, with some data gaps (e.g., data for years 1994 to 1999 appear to only include Wells 1-4, 20, and 21). In addition to the annual data, monthly data were available for calendar year 1988 and from January 1990 through December 2004 (except for July 1996 through December 1996). Monthly data were summed to yield annual pumping by well and combined with the available annual data.

City production data were also available from a consulting firm, Water Master Support Services (WMSS), which compiles production data with the WMWD service area (including the City of Corona). These data were provided by the WMSS on a CD. Data included both tabulated reports in pdf format as well as an electronic table of production data in MS Access format. Data include pumping by the City and 56 other users in the Study Area from 1947 to 2004.

Production totals from the City tables were compared to production amounts contained in the WMSS data in acre-feet per year (AFY). Pumping totals were almost identical from 1995 to present, but varied somewhat in the earlier years (1964-1995). The total production error between these two data sets was judged to be relatively small when using known City wells (amounting to a discrepancy of a few percent of AFY produced), and the City's monthly pumping data were used when available.

The largest discrepancy in the WMSS data was the large number of production wells that were allocated to the water supply system, but are not necessarily City wells. This discrepancy was more prevalent during the early portion of the Study Period than later years. Research conducted on several of these wells indicated that they were irrigation wells at parks throughout the City and/or older wells previously owned by others that were subsequently obtained by the City and abandoned. For example, two older wells thought to be previously owned by Orange Heights Water System (and designated MAIN 3 and MAIN 4) were on the property obtained by the City for the construction of City Hall. While there were no records to independently verify historical production totals from these wells, locations and pumping totals were reviewed for reasonableness and generally left unmodified in the production database.

### 2.5.2. Imported Water Data

The City imports water through WMWD from the Colorado River and the State Water Project. Data on imported water volumes at the main treatment plants and system interties were provided by the City for this project. Annual data were provided from 1964 through 1999 and monthly data were available from 1990 through 2004. These data are included in the DMS with the pumping data.

### 2.5.3. Water Demand

The City's 2005 update of its Urban Water Management Plan (UWMP) contains statistics on water demand (including population, number of housing units, and population per household) in 5-year increments from 1970 to 2003 (AKM, December 2005). Population data for various time periods from 1900 to 1960 are also available in the UWMP.

### 2.5.4. Wastewater Treatment Plant (WWTP) Data

Information from the City of Corona's three WWTPs and the volume of discharge to ponds and Temescal Creek were provided by the City from 1997 to present. Earlier data were apparently destroyed accidentally and were estimated for this GWMP using verified methods and City information on discharge locations. Additional operation and location information was available in the National Pollutant Discharge Elimination System (NPDES) permits issues by the RWQCB.

## 2.6. Groundwater Data

Groundwater data were compiled from multiple sources including DWR, SAWPA, Riverside County, and the City. Groundwater data available from SAWPA includes groundwater elevations, general analytical chemistry, and well construction information compiled from 37 local agencies (water districts, cities, counties). However, complete data, including well construction and water levels or quality, were available for only a few wells in the Study Area.

### 2.6.1. Basin and Watershed Boundaries

DWR publishes maps and descriptions of California groundwater basins in DWR Bulletin 118. This document and the accompanying basin descriptions are updated periodically. Basin descriptions for the Study Area were updated in February 2004. The last update for the basin map was in 2003. Groundwater basin boundaries are available in GIS-compatible data files and were obtained from DWR for groundwater basins in the Study Area. Since Temescal is a DWR-defined subbasin, the delineation of this subbasin was available in the files and has been used unmodified in this study.

Because Coldwater and Bedford subbasins are not delineated in the DWR files, GIS shape files were created for these subbasins. Subbasin boundaries were based on previously-defined boundaries and the location of geologic faults (DWR, 1959; MWH, 2004; USGS, 2004). The Coldwater Subbasin was delineated from the larger Elsinore Groundwater Basin boundaries on the west, north and south, and the location of the North Glen Ivy fault on the east as mapped by USGS (2004). The Bedford Subbasin boundaries are coincident with the Elsinore Groundwater Basin boundaries on the north and east and the North Glen Ivy fault on the west. The southern boundary was based on the narrowing of Temescal Wash through surface bedrock outcrops, and checked for similarity to boundaries previously published (DWR, 1959). These modified subbasin boundaries are shown on Figures 1 and 3 and used in calculating subbasin areas in this GWMP.

The contributing watershed areas for the subbasins in the Study Area were delineated digitally by Todd Engineers, using GIS software to create shape files of the defined watersheds. Watershed delineation relied on electronic USGS Digital Elevation Models (DEM) (10-meter resolution) and topographic elevation contours of the Santa Ana quadrangle provided by USGS (2004). DEM files were processed in ArcView to provide shaded relief maps, slope percentage maps, slope aspect maps, and elevation contour maps at varying contour intervals. These maps were combined with the USGS elevation contours, hydrologic features, and DWR groundwater basin boundaries to manually delineate watershed boundaries. Watersheds were defined to include those areas that could potentially contribute surface runoff to the three main Study Area subbasins and are shown on Figure 3.

### 2.6.2. Well Data

Well locations and construction information tie key data (e.g., pumping, water levels, and water quality) to spatial and vertical locations within the groundwater basin. Sources of well locations and construction include SAWPA, DWR, the City, and Riverside County.

SAWPA provided a list of 312 wells in the Study Area, 174 of which contained detailed location data (latitude/longitude) and 60 of which contained some well completion information (e.g., depth, screen intervals, and casing). SAWPA well data were included in the DMS as a separate table maintaining the format from the original data source.

A database was created by Todd Engineers of selected DWR Driller's Log data for approximately 325 wells. These data are included as a separate table in the DMS. Completion dates for these wells range from 1905 to 2004, but approximately half of these wells were drilled after 2000. Locations of 131 of the wells with Driller's Logs were estimated using the state well number and added to the DMS. The Master Well table within the DMS contains a field for each record indicating the method used to locate the well. The method of the DWR wells location is noted as "manual" to indicate the approximate nature of the placement. An older DWR document (1959) lists 112 wells in the Temescal, Coldwater, and Bedford subbasins that were drilled before 1959, most of which are listed as irrigation or domestic wells. The earliest completion date is 1912, but completion dates are unavailable for most wells in the document. Because key hydrologic and hydrogeologic data cannot be tied to these individual wells, these well data have not been included in the electronic DMS.

Construction information for the City's 31 wells (including inactive and abandoned wells) were compiled from several documents including the Water Master Plan (AKM, April 2005), the Drinking Water Source Assessment and Protection Plan (DSWAP) (Kennedy/Jenks, 2002), and a focused hydrogeologic assessment document prepared for the City's desalter facility (Fox/Roberts, 2004). Data were entered into Excel spreadsheets and re-formatted into a separate table in the DMS.

The U.S. Geological Survey compiles and publishes well information such as well location, construction, and available water level data through a web based portal, the National Water Information System (NWIS). The system was queried for wells in the Study Area, and 18 wells with location data were identified and added to the DMS.

Well construction data were also available from a limited database that Riverside County initiated in 1990. Any well drilled after 1990 in the County is included in the database and earlier wells are being added as resources become available. The County database contains 683 wells in the Corona area, most of which are relatively shallow monitoring wells (551 wells or 81 percent). The remaining 132 wells are listed as municipal (2 percent), domestic (5 percent), irrigation (3 percent), or unknown (9 percent) wells. The County well database was also included as a table in the DMS.

Well location and construction data from all sources were compiled into one table in the DMS. Some wells may be duplicated in this table as it difficult to match wells between sources. Data from each source were also retained as a separate table in the DMS for updating and archiving purposes.

### 2.6.3. Water Level Data

Water level data in the Study Area were available from SAWPA and the City. Approximately 100 wells contain at least one water level measurement ranging from June 1919 to September 2004. The number of groundwater elevation measurements per well varies from 1 to 1,083 distinct monitoring events. Each well with water level data has been assigned a unique ID that links the water level data to other well information, such as location and construction, if available. Water level data were also available for City wells from 1998 to 2005. Water level data from both SAWPA and the City were re-formatted and entered into the DMS.

No historical water level contour maps could be found in previously published documents that covered the Study Area. A few water level contour maps were available for relatively small portions of the Study Area for a few time periods. The earliest available water level contour map is a DWR map for March 1957 water levels (DWR, 1959). The map covers the northern portion of the Study Area and small sections of the Elsinore Groundwater Basin to the south. Wells used to construct the map are provided in a summary table, but actual water level measurements in each well were not included in the report and therefore are not included in the DMS.

### 2.6.4. Water Quality Data

Ambient groundwater quality data were available from the City, SAWPA, and DPH. SAWPA water quality data were available from 101 wells. The number of monitoring events per well varied from 1 to 180. The average number of constituents analyzed per event per well ranged from 2 to 50.

DPH requires water quality sampling of drinking water systems larger than six connections. The Division of Drinking Water and Environmental Management (DDWEM) compiles these data into a statewide database. The database was obtained from DPH and queried for all wells, surface water, and intermediate system connections in the Corona area. Water quality data were available for 69 stations, 39 of which were operated by City of Corona. Other owners include the City of Norco, Glen Eden, Home Gardens, and California Rehabilitation Center. The number of monitoring events per well ranged from 1 to 567. Most monitoring events included the full suite of Title 22 drinking water constituents.

### 2.6.5. Regulated Facilities

Potential threats to groundwater quality are regulated by RWQCB, Department of Toxic Substance Control (DTSC), and the Riverside County Department of Environmental Health. A review of the RWQCB database identified 30 major sites that are regulated for possible environmental releases in the Corona area and approximately 75 Underground Storage Tank (UST) investigations. Of non-UST sites, 18 are regulated by the Spills, Leaks, Investigations, and Cleanup (SLIC) Program at the Santa Ana RWQCB and two are landfills. The remaining 10 sites are regulated by DTSC.

Data collection has focused on facilities whose discharge is regulated by the RWQCB, sites that are being investigated for impacting groundwater, and leaking underground storage tank sites. Data include location, site characterization, water quality, and other information.

A file review was conducted at the Santa Ana RWQCB in July 2006. Groundwater quality and other environmental data were copied from 11 sites. Electronic databases were unavailable and data were evaluated from paper copies and not hand entered into the DMS. Water quality data for four UST investigations are available from the State Water Resources Control Board (SWRCB) online through their data management system, Geotracker. These data were included as a table in the DMS.

#### 2.6.6. Land Use Data

Land use maps in the form of GIS shape files were available from the DWR DPLA and the Department of Conservation Division of Land Resource Protection (DC DLRP). DWR DPLA conducts complete land use surveys approximately once every ten years for the Upper Santa Ana River Drainage Area. The most recent survey, 1993, was available from the DWR website as a GIS shape file. A summary table of this map, which includes the total area by land use type within the basin and watershed area, was added to the DMS. Additional surveys (years 1957, 1964, 1975, 1984) were available on paper from DWR, but were not converted to electronic format and are not included in the DMS.

In addition to land use data, DWR DPLA also publishes data on applied irrigation rates for specific crop types in each DAU. Data were available on the DWR website for 1998 through 2001. A table of the water use (AFY per acre) for each crop type for the North Riverside DAU was included in the DMS.

The Farmland Mapping and Monitoring Program (FMMP) of the DC DLRP determines the area of farmland in the state on a biennial basis. In Riverside County, maps showing farmland and urban areas are available for the even years 1984 to 2004 in GIS (shape file) format. Summary tables with the total amount of agricultural land by year for DWR and FMMP are included in the DMS.

The City provided a detailed parcel map for the project GIS with information regarding the zoning of each parcel. These parcels, differentiated by zoning type, were compared with the other sources of land use to confirm areas of urban and agricultural land.

## 2.7. Geologic Data

USGS data provided the primary source of geologic units and faulting in the Study Area. Additional documents and data were used as described below.

### 2.7.1. Geology Maps

A digital geologic map of the Santa Ana 30’ x 60’ quadrangle was obtained from USGS (2004) and imported into GIS. A summary table, including the total area of each geologic unit, was added to the DMS.

### 2.7.2. Lithologic Data

Subsurface lithologic data were available from DWR Driller’s Logs (400 paper logs compiled), available City well-completion reports, and geophysical logs for six City wells. Lithologic information was also available for 10 wells in the SAWPA database.

### 2.7.3. Soils Data

Soil type and the respective soil moisture holding capacity governs the amount of recharge and runoff that occurs in an area. Digital soil maps and a database of physical properties for soils in Riverside and Orange counties were downloaded from the Natural Resources Conservation Service’s (NRCS, formally the Soil Conservation Service) website. In addition, the NRCS also provides a methodology for estimating the amount of runoff that occurs based on land use type. A summary table of the acreage associated with each soil type was added to the DMS.

## 2.8. GIS Files and Layers

The City maintains a GIS and provided numerous shape files in support of this project including parcels, city limits and sphere of influence, roads, storm detention basin locations, production well locations, and a high resolution aerial photograph. In addition, numerous GIS files were obtained from the Santa Ana Watershed Project Authority (SAWPA) from an online user system. These files included physical and cultural features as well as limited groundwater data sets such as water levels and water quality. Additional GIS files were downloaded from various sources as previously mentioned.

## 2.9. Data Management System (DMS)

The DMS includes one main relational database in Access format with individual tables for data types summarized above. A summary of the tables included in the DMS relational database is provided on Table 2-2 below. This database provides a flexible framework, allowing additional data to be incorporated as available. The project GIS was populated with shape files generated from selected data sets as well as selected publicly- or commercially-available GIS layers as described above.

**Table 2-2**
**Data Tables in the Data Management System (DMS)**

| DMS Table Name | Description | Source(s) |
|---|---|---|
| Geo_Geology | A summary table for the geologic map containing formation names and area in subbasins and watersheds | USGS |
| Geo_Lithology | Lithologic information for select wells in the area | SAWPA |
| Geo_Soils | A summary table of the soils map containing soil types and associated areas within the subbasins and watersheds | NRCS |
| GW_AB County | Abandoned wells as documented by Riverside County | COUNTY |
| GW_County Wells | Wells from the Riverside County Well Database | COUNTY |
| GW_DWRLOGS | Information from DWR Driller's Logs | DWR |
| GW_Master Wells | A composite table of wells from all available sources. Includes a unique ID for each well and location information | DWR, COUNTY, SAWPA, CITY, WATERMASTER |
| GW_Water Quality | Ambient groundwater quality for select wells in the area | SAWPA |
| GW_Well Construction | Well construction information for wells in the area | SAWPA, CITY |
| GW_Well_Perf | Screened interval information for select wells in the area | SAWPA |
| GW_WL_ALL | Groundwater elevations for select wells in the area | SAWPA, CITY |
| HY_ET_CIMIS | Monthly reference evapotranspiration data | CIMIS |
| HY_ET_K | Annual evapotranspiration and crop coefficients for the DAU | DWR DLPA |
| HY_Precip | Monthly precipitation data from 4 stations | CIMIS, COUNTY |
| HY_Precip_Stations | Location information for the precipitation stations | CIMIS, COUNTY |
| HY_Res_Storage | Monthly reservoir storage in Lake Mathews | CDEC |
| HY_Streamflow_Temescal | Streamflow on Temescal Wash | USGS |
| LU_Applied Water Use | Applied water use (AFY/acre) for crop types in the North Riverside DAU | DWR |
| LU_DWR_SUMMARY | A summary table of the DWR 1993 land use map containing land use areas within the subbasins and watersheds | DWR DPLA |
| LU_Summary_Farm Mapping | A summary table of the farmland mapping program land use maps, contains land use areas with the basin and watershed by year | DC |
| RF_Locations | Location data for regulated facilities in the area | RWQCB |
| WS_Annual Pumping | Annual pumping from the City of Corona by well | CITY |
| WS_Monthly Pumping | Monthly pumping from the City of Corona by well | CITY |
| WS_Watermaster_Pumping | Annual pumping for the groundwater basins | WATERMASTER |

This process was the City's first effort to compile numerous types of hydrologic and hydrogeologic data into a comprehensive database for future updating, revision, and use. Numerous inconsistencies and duplicative data types were noted as data were compiled from various sources. Data sets were evaluated for quality control as needed, but only minimal deletions or modification have been made to preserve data that may be potentially important in the future.

# 3. State of the Groundwater Basins

The groundwater subbasins of the Study Area have undergone significant changes since groundwater development began in the early 1900s (DWR, 1959). Since that time, the groundwater subbasins have supported a variety of uses including extensive agricultural irrigation (especially citrus), industrial demand from mining and citrus packaging, and increasing urban use. Early agricultural activities in the subbasins were supplemented by diversions of surface water imported into the basin. Agricultural reliance on groundwater increased through the 1940s and 1950s, apparently peaking in the early 1960s but continuing into the 1970s. Increasing urban use has replaced most of that early agricultural demand.

The Study Area subbasins occupy a small portion of the upland Santa Ana River watershed, which covers more than 1.5 million acres in San Bernardino and Riverside counties (Figure 2).The Study Area subbasins cover about 47 square miles (about 30,000 acres) in western Riverside County (Figures 2 and 3) and include portions of townships/ranges 3S/6W, 3S/7W, 4S/6W, 4S/7W, and 5S/6W. The subbasins and the local watersheds that contribute runoff are contained within an approximate 400-square mile area outlined in Figure 3.

## *3.1. Land Use*

Current and historical land use in the Study Area is shown on the land use maps on Figure 8. Two maps, one from 1984 and one from 2004 illustrate changes in land use over the last 20 years. As shown on Figure 8, land use on the Study Area subbasins, especially Temescal Subbasin, is predominantly urban (shown by the pink color). The urbanization has progressed mainly over the last 35 years as population in the subbasin has risen and agriculture has moved out. A comparison of the two maps on Figure 8 illustrates the change from agriculture (green) to urban (pink) land use for large portions of Temescal, Coldwater, and Bedford subbasins.

In the 1950s and 1960s, the subbasins consisted mainly of irrigated agricultural lands with a variety of crops, especially citrus. In 1957, approximately 7,000 acres of Temescal Subbasin were under cultivation, 1,100 of which were devoted to citrus and avocado production near Corona (DWR, 1959). During that year, approximately 17,000 acre-feet per year (AFY) of groundwater were pumped from the basin, primarily for irrigation and citrus processing facilities with some municipal use (DWR, 1959). At that time, less than 10,000 people lived in the subbasin.

Agriculture and native vegetation were the predominant historical land uses in both Coldwater and Bedford subbasins. In 1957, about 1,700 acres were irrigated in the two subbasins. Although some urbanization has occurred in both subbasins, much of the land remains undeveloped. Sand and gravel mining has been the predominant industrial land use in Coldwater Subbasin, an activity that continues today.

Groundwater production data suggest that the peak of agricultural pumping in Temescal Subbasin was from about 1959 through about 1966, but irrigation continued through most of the 1970s. By about 1980, most of the growers and citrus processors had left the basin. The 1984 land use map on Figure 8 suggests that large portions of southern Temescal Subbasin continue to be used for agriculture, but most of this land was likely fallow or non-irrigated pasture by 1984. Groundwater production totals for the 1980s indicate that irrigation had decreased significantly in the subbasin.

The contributing watersheds that surround the subbasins consist mostly of native vegetation or grasslands used for grazing. With the exception of urbanization of the small watershed on the northeastern side of Temescal Subbasin, land use on the contributing watersheds has not changed significantly over the last 20 years.

The northern edge of the Study Area contains a portion of the Prado Dam Management Area, shown as native on the land use maps (see also Figure 7). The management zone, operated by the U.S. Bureau of Reclamation, is a 6,800-acre area generally defined by a ground surface elevation of 560 feet above mean sea level (msl) and serves as flood control for the Santa Ana River at Prado Dam.

## *3.2. Physical Setting*

The groundwater basins are in a high desert setting in the rain shadow of the Santa Ana Mountains in western Riverside County. The basins are at the downstream portion of the Santa Ana River watershed.

### 3.2.1. Topography

The elevation of the ground surface in the Study Area ranges from below 500 feet msl at Prado Dam to more than 5,600 feet msl at the highest peak in the Santa Ana Mountain watersheds west of Coldwater Subbasin. The floor of Temescal Subbasin slopes from about 1,500 feet msl along the base of the Santa Ana Mountains in the southwest to about 500 feet msl in the northwest. The ground surface elevation in the city center is about 650 feet msl. In Coldwater Subbasin, elevations along the western mountain front are about 1,500 feet msl, similar to the Temescal Subbasin mountain front. The Coldwater Subbasin floor slopes to an approximate elevation of 1,000 feet msl near the eastern subbasin boundary along the Elsinore-Glen Ivy Fault zone. Bedford Subbasin slopes from about 1,100 feet msl on the south and west to about 850 feet msl on the northeast where Temescal Wash exits the subbasin (Figure 3).

Surface elevations increase significantly from the mountain front at the groundwater basin boundaries (about 1,500 feet msl) to the higher elevations in the contributing watersheds.

For the contributing watersheds in the Santa Ana Mountains to the west, elevations range from about 2,500 feet msl in the north to more than 5,600 feet msl in the south. The watershed west of Coldwater Subbasin rises above 5,600 feet msl. Watersheds east of the subbasins are significantly lower in elevation and rise only to about 1,800 feet in the highest areas east of Bedford and Temescal subbasins.

### 3.2.2. Precipitation and Evapotranspiration (ET)

Annual precipitation varies from below 12 inches to more than 26 inches over the Study Area. As shown on the isohyetal map on Figure 6, long-term average annual rainfall is between 12 and 14 inches per year on the basin floor and increases to more than 20 inches along the top of the local watersheds in the Santa Ana Mountains to the west.

The variability of rainfall on an annual basis is illustrated by the rainfall records from the Chase precipitation station, located in the southwestern portion of Temescal Subbasin (Figure 6). Over the last 40 years, annual rainfall at the Chase Station has ranged between about 4 inches per year to 34 inches per year with an average of 15.7 inches per year (Figure 5). Although the average rainfall of 15.7 inches per year since 1965 is slightly higher than predicted by the long-term isohyets on the figure, the Chase Station data illustrate the variability of rainfall in the Study Area. Annual rainfall totals range from less than 5 inches per year to more than 30 inches per year. Rainfall patterns indicate several wet and dry cycles persisting from about 4 to 8 years.

Data from the Chase Station are plotted as a cumulative departure curve on the lower portion of Figure 5. The graph relates annual rainfall to average rainfall as a percentage and indicates dry cycles with downward slopes and wet cycles with upward slopes. This plot more clearly demonstrates the wet and dry cycles that have occurred since 1965 and shows that only a few time periods can be characterized as average rainfall conditions.

Long term pan evaporation data from 1948 to 2005 were compiled from a station in Riverside (Riverside Citrus Exp. St. Station). These data indicate an annual potential evaporation of 75.66 inches per year ranging from 3.03 inches per month in December to 10.88 inches per month in July.

### 3.2.3. Streamflow

Temescal Wash (also referred to as Temescal Creek) is the primary surface water drainageway traversing from south to north across the Study Area draining the Temescal Valley (Figure 7). Originating south of the Study Area, the wash flows north through Bedford Subbasin, cuts through bedrock outcrops in Temescal Canyon, flows through Temescal Subbasin, and discharges to the Santa Ana River near Prado Dam. Streamflow in Temescal Wash is fed by storm water runoff and discharges from wastewater treatment plants within and upstream (south) of the Study Area. For example, Lee Lake Water District is currently allowed to discharge up to about 1,000 AFY of tertiary treated wastewater (although some is recycled for reuse) (RWQCB, September 6, 2001).

Temescal Wash is lined through most of the Corona city limits. The concrete lining begins around Magnolia Avenue, about 1.5 miles after Temescal Wash enters the Temescal Subbasin (from Temescal Canyon to the south, see Figure 7). The lined portion of the channel is indicated on Figure 7 and continues from Magnolia Avenue to the City's wastewater treatment ponds near the Prado Management Area. The only unlined portion in Temescal Subbasin is the 1.5-mile area where the wash emerges from Temescal Canyon. This area is characterized by high groundwater, likely the result of infiltration of streamflow and relatively fine-grained surficial deposits. Other than limited infiltration in this narrow section of the subbasin, Temescal Wash does not contribute significant recharge to the Temescal Subbasin.

The Study Area is also crossed by numerous drainageways originating in the surrounding watersheds to the east and west of the groundwater subbasins and draining toward the basin center. Drainageways originating in the Santa Ana Mountains west of the Study Area carry relatively large amounts of runoff into the subbasins.

Runoff from the Santa Ana Mountains into Temescal Subbasin has only limited opportunity for percolation into the groundwater basin. Drainageways are lined across the subbasin floor and funnel runoff into the lined portion of Temescal Wash. From there, runoff generally leaves the basin and provides surface discharge at Prado Dam. Some infiltration occurs in two large detention basins used for flood control near the western Temescal Subbasin boundary (Figure 7). These two basins, operated by the Riverside County Flood Control and Water Conservation District (RCFCWCD) and referred to as the Oak Avenue and Main Street detention basins, detain peak runoff from large storm events and allow for some infiltration to groundwater. Runoff into Coldwater Subbasin has the opportunity to percolate into the relatively permeable surface sediments. In addition, berms along washes, diversions of surface water, and the presence of large gravel pits enhance groundwater recharge of runoff in Coldwater Subbasin.

Stream gage data exist along Temescal Wash but are insufficient to document inflows and outflows at each of the subbasin boundaries. Streamflow data were available at only three locations along Temescal Wash within the Study Area as shown on Figure 7. The southernmost gage is an inactive USGS gage that measures flow in Temescal Wash in the bedrock outcrop between Bedford Subbasin and Temescal Subbasin. The northernmost stream gages are located in northern Corona before Temescal Wash enters the Prado Management Area.

Although currently inactive, the stream gage in the bedrock south of Temescal Subbasin (Site No. 11072000, Figure 7) provides data on the amount of runoff available for infiltration into the groundwater basin north of the gage. Daily measurements from October 1928 through June 1980 indicate an average annual discharge of 4,062 AFY. Annual averages vary significantly from less than 80 AFY during dry periods to more than 8,000 AFY. Discharge during several more recent wet and dry cycles (water years 1966 through 1979) averaged 4,488 AFY, in general agreement with the long-term average.

An active stream gage in the City of Corona (Site No. 11072100, Figure 7) measures runoff in the lined portion of Temescal Wash after additional stormwater discharge has entered the culvert. As such, flows at this gage are significantly higher than streamflow recorded to the south. Average discharge for the entire gaged period (1980-2006) is 19,575 AFY. This runoff leaves the subbasin and contributes to surface water outflow at Prado Dam.

### 3.2.4. Geology

The Study Area is located within one of the structural blocks of the Peninsular Ranges of Southern California. The groundwater basins occur in a linear low-lying block, referred to as the Elsinore-Temecula trough, between the Santa Ana Mountains on the west and the Perris Plain on the east (Norris and Webb, 1990). The trough extends from Corona to the southeast some 30 miles and was formed along an extensive northwest-southeast trending fault zone including the Elsinore, Chino, and related faults. The Elsinore and Chino fault zones bound the subbasins on the west and trend along the mountain front.

The oldest rocks in the Study Area crop out in the Santa Ana Mountains. These uplands are composed principally of volcanic (including the Santiago Peak Volcanics) and metamorphic rocks (including the Bedford Canyon Formation) of Jurassic and Cretaceous age. A thin rim of younger sedimentary units of Tertiary age crops out along the mountain front generally lying between the Elsinore and Chino faults. This zone of sedimentary units broadens to the north and contains numerous mapped formations of Cretaceous and Tertiary age. The northeastern side of the valley is flanked primarily by granitic rocks of Cretaceous age. Erosion of these units has filled in the trough over time resulting in quaternary-age alluvial fan, channel, and other deposits making up the permeable portions of the groundwater subbasins.

The geologic map on Figure 9 shows the distribution of these units in the Study Area. The original map was constructed by the USGS (2004), but several similar geologic units have been combined on Figure 9 to simplify the display. The main surficial deposits on the floor of Temescal Subbasin include younger and older alluvial fans deposited from the erosion of volcanic rocks and Bedford Canyon Formation to the west. These units prograde across the basin to the northeast and are truncated by channel deposits along Temescal Wash.

The Coldwater Subbasin is also composed of alluvial fan deposits, mainly from the Bedford Canyon Formation and adjacent granitic rocks. Volcanic rocks are essentially absent from the uplands adjacent to Coldwater Subbasin so the character of the deposits and groundwater chemistry differ from the alluvial fans to the north. The alluvial fan deposits in Coldwater Subbasin continue into Bedford Subbasin and appear to have been disrupted by faulting. Channel deposits along Temescal Wash define the eastern boundary of Bedford

Subbasin. In northern Bedford Subbasin, a variety of Tertiary sedimentary units crop out including the Silverado (Paleocene), Vaqueros (Miocene), Topanga (Miocene), and Puente (Miocene) formations.

## 3.3. Aquifers and Hydrostratigraphy

The basin-fill alluvial deposits and, to some extent, the underlying sedimentary units make up the aquifers in the basin. The thicknesses of these units vary significantly across the Study Area.

To further evaluate aquifer thickness and basin geometry, the base of the unconsolidated sediments was mapped as part of this GWMP. Lithologic descriptions from driller's logs were reviewed for evidence of consolidated sedimentary or igneous units (generally referred to in this document as bedrock) throughout the Study Area. These data were plotted in GIS and evaluated with surface topography and geologic outcrops to estimate a depth to bedrock beneath the subbasins. This surface was produced as a GIS raster file and color coded according to depth. The resulting map is shown on Figure 10.

As shown on the figure, the thickest portion of the alluvial basin (the deepest depth to bedrock) occurs in the central-west portions of the subbasins. The formation of a trough along the Elsinore-Chino Fault zone is indicated by the asymmetric basin geometry. The deepest depths occur along this zone as indicated by the orange and red colors. Unconsolidated sediments are estimated to be more than 1,000 feet thick in this area. Bedrock is much shallower in the eastern portion of the basin as indicated by the blue color on Figure 10. A slight deepening of the basin is indicated in the Arlington Gap by the lighter blue to green color. Here, unconsolidated sediments are approximately 250 feet thick. This area is interpreted to have been eroded by a branch of the ancestral Santa Ana River, accounting for the deeper base. Sediments throughout most of the Bedford Subbasin and in the Norco area are about 100 feet thick. Outcropping bedrock in the northern and eastern portions of the Bedford Subbasin is further evidence of the thin alluvial sediments.

Aquifer packages composed of various geologic units have been defined for this study based on depositional environment, degree of consolidation, groundwater production, and location throughout the Study Area. Three aquifer packages provide water supply to wells in Temescal Subbasin: the Channel Aquifer, the Alluvial Fan aquifers, and, to a lesser extent, consolidated sandstone aquifers. The thickness and geometry of these units were evaluated through the construction of hydrostratigraphic cross sections through the Study Area. The locations of five of the sections are shown on Figure 11. Three cross sections in Temescal Subbasin are provided on Figures 12 through 14 (A-A' through C-C') and two cross sections covering portions of Coldwater and Bedford subbasins (D-D' and E-E') are provided on Figure

15. Each of the aquifer units and the cross sections on which they are illustrated are described in more detail below.

### 3.3.1. Channel Aquifer

A package of relatively homogeneous and highly permeable sands approximately 200 feet thick have been encountered in many of the City wells in the northern half of Temescal Subbasin. This sand package is interpreted as channel deposits of an ancestral arm of the Santa Ana River and, as such, is referred to as the Channel Aquifer in this document. The alignment of the aquifer suggests that an ancestral river channel had entered the Temescal Subbasin at Arlington Gap, eroding the sedimentary units and possibly older alluvial fan deposits in the area. Permeable channel sands were deposited in the eroded channel over time. From the gap, the Channel Aquifer meanders northwest toward Prado Dam. The Channel Aquifer is limited in extent and is not present in the Coldwater or Bedford subbasins. The general extent of Channel Aquifer is shown by the dashed line on Figure 16, which also shows the distribution of hydraulic conductivity in various aquifer units.

The Channel Aquifer is illustrated on cross sections A-A', B-B', and C-C' on Figures 12, 13, and 14, respectively. Cross Section A-A' extends from the Santa Ana Mountains to the northeast across Temescal Wash to the bedrock high in the northeast. As shown on the section, the Channel Aquifer occurs in the northeastern portion of the subbasin and has a saturated thickness that ranges from 125 to 150 feet along this section. As illustrated on the section, Channel Aquifer sediments lie directly above granitic bedrock beneath Temescal Wash and above the Sandstone Aquifer in other areas (Figure 12).

Cross-section B-B' is located north of A-A' and extends from the Santa Ana Mountains through the Norco area (Figure 13). The Channel Aquifer is shown on the western side of the section southeast of the Prado Management Area. Similar to Cross Section A-A', the saturated thickness of the Channel Aquifer is about 100 to 150 feet thick. The cross section also shows the absence of the Channel Aquifer in the Norco area and illustrates the shallow depth to bedrock there (generally less than 100 feet). The saturated thickness of alluvial sediments in Norco is generally less than 50 feet. Also indicated on the section is a groundwater divide in the Norco area (near well 53-499) indicating possible groundwater outflow from the Norco area to the Santa Ana River (Figure 13).

The Channel Aquifer at Arlington Gap is shown on Cross Section C-C' (Figure 14). Here the saturated thickness is approximately 200 feet and well data indicate a thick and permeable sand package. The Channel Aquifer is underlain by the Sandstone Aquifer throughout most of this area.

Figure 16 shows estimated values of hydraulic conductivity (K) derived from test data on driller's logs and/or City well aquifer testing data. The K value is an indicator of the aquifer's permeability and is expressed in gallons per day per square foot (gpd/$ft^2$) or feet per day (ft/day). As shown in the figure, the wells within the limits of the Channel Aquifer have the highest hydraulic conductivity values in the Study Area (Figure 16). The lower K values shown within the extent of the Channel Aquifer area on Figure 16 are generally from deeper wells tapping the underlying Sandstone Aquifer. The average K value of City of Corona production wells screened solely in the Channel Aquifer (Wells 7A, 8A, 9A, 17, 25, and 28) is 2,062 gpd/$ft^2$ (276 ft/day).

### 3.3.2. Alluvial Fan Aquifers

Both older and recent alluvial fans have been deposited through time along the mountain front on the western edge of the subbasins. These fans have prograded across both Temescal and Coldwater subbasins from west to east (Figure 9). Although these deposits are relatively thick, the entire unit is heterogeneous and cannot be considered one single aquifer. Rather, sand lenses within the deposits collectively form the Alluvial Fan Aquifers. Lithologic data from wells are insufficient to map out the extent of the aquifers or characterize the deposits. Limited data indicate relatively fine-grained textures throughout much of the area, especially with depth.

The geometry of these units in the subsurface, including the contact with the Channel Aquifer, is illustrated on Cross Section A-A’ on Figure 12. The section illustrates the alluvial fan deposits that have infilled the basin. The fans have prograded across the basin and a thin veneer of these deposits likely overlies the Channel Aquifer at the surface (not shown on the section). Wells that penetrate the entire thickness of the Channel Aquifer in the east do not appear to encounter alluvial fan deposits on top of the Sandstone Aquifer. The total thickness of the deposits is unknown, but appears to exceed 1,400 feet in the central subbasin.

Only limited data exist for estimating K values in the alluvial fan deposits of Temescal Subbasin. Sparse data from a few wells indicate a K value of generally less than 50 gpd/$ft^2$ in the Alluvial Fan aquifers and in the Norco area (Figure 16). Specific capacity data from a City of Corona production well (Well 27), drilled in the Alluvial Fan, indicated a lower K value of about 7 ft/day (PBS&J, 2004).

Alluvial fan deposits in the Coldwater and Bedford subbasins are shown on Figure 15. The cross section on the left side of the figure shows the subbasin geometry and separation at the North Glen Ivy fault. The section on the right side is a north-south profile through the main portion of the Coldwater Subbasin where much of the subbasin production is located (Figure 11).

As shown on Figure 15, alluvial fan deposits in the Coldwater Subbasin range up to approximately 800 feet in thickness (consistent with the depth to bedrock map on Figure 10). Although the alluvial fan deposits here originate from the same mountain range as those in Temescal Subbasin, sediments have been eroded from different source rocks and have different textures and water quality. These alluvial fan aquifers are interpreted to be more permeable overall than the fan deposits in Temescal Subbasin and contain less mineralized groundwater.

However, aquifers are not as permeable as the Channel Aquifer in Temescal Subbasin. Hydraulic conductivity values for the Coldwater Alluvial Fan aquifers are generally less than 100 gpd/$ft^2$ (Figure 16).

### 3.3.3. Sandstone Aquifer

Some of the sedimentary units underlying the alluvial basin provide sufficient well yields to categorize them as aquifers. Although generally grouped with other bedrock units, the subsurface sedimentary rocks of Tertiary age in northeast Temescal Subbasin contain sandstone layers that are screened in several City wells (see Corona 24 on Figure 12). The estimated K value is 22 gpd/$ft^2$ (3 ft/day) for one City of Corona production well (Well 24) screened solely in the Sandstone Aquifer (below the Channel Aquifer). Due to the limited production, small areal extent, increasing depths, and relatively low permeability in most areas, the Sandstone Aquifer is not considered a primary source of water supply.

## *3.4. Water Supply*

For more than 100 years, Study Area subbasins have been an important component of water supply. More than 650 wells have been drilled in the Study Area dating back to the early 1900s according to various DWR and Riverside County documents. Well uses include irrigation and domestic pumping, municipal wells, and shallow monitoring wells associated with commercial and industrial environmental investigations. A DWR study conducted in 1959 lists 112 wells in the Temescal, Coldwater, and Bedford subbasins, almost all of which were used as irrigation or domestic wells. Only limited data are available from the older wells and it is unknown if historical wells still exist. Riverside County files indicate that a large percentage of existing wells have been drilled as shallow monitoring wells in the Study Area, but files do not contain location or construction data for most of these wells, limiting their use for this study.

The City has operated as many as 31 municipal wells in the Study Area over time. Some of the older wells were purchased from the Temescal Water Company, a former irrigation water provider in the basin. Over the last few years, the City has obtained its groundwater supply from about 18 active wells. Most of the Temescal Subbasin wells are screened in the Channel Aquifer (generally shallower than 300 feet deep), but three wells also produce groundwater from the deeper Sandstone Aquifer. Three wells are located in the Coldwater Subbasin and produce groundwater from the local Alluvial Fan aquifers.

### 3.4.1. Pumping

A groundwater production database was developed from City records and data from a private firm, Water Master Support Services (WMSS). The WMSS data included production records from WMWD (including the City of Corona) and 56 other producers in the three subbasins from 1947 to 2004. Data are provided as annual totals, but monthly pumping totals were available for City wells from 1990 (with missing data in 1996). Total groundwater production by subbasin from 1947 to 2004 is shown on Figure 17. The location of pumping wells is shown on Figure 18.

As shown on the graph on Figure 17, groundwater pumping has varied over time and by subbasin. In the late 1940s, the total amount of groundwater pumping in the Study Area was about 20,000 AFY. That amount increased to between 25,000 AFY and 32,000 AFY from the late 1950s to the mid-1970s. Total groundwater pumping decreased to below 20,000 AFY in the 1980s and early 1990s due to a decrease in agricultural irrigation, but has increased to about 25,000 AFY in recent years due to municipal pumping. Most of the pumping occurred in Temescal Subbasin. Production in Coldwater Subbasin increased and accounted for more than one-half of Study Area production during a few years in the 1970s and 1980s, but has been less than 25 percent in recent years. Bedford Subbasin production is relatively minor and has decreased somewhat over time.

Most of the historical groundwater production (extending into the 1970s) was used for irrigation. During that time, groundwater supply was also supplemented with surface water and groundwater from adjacent basins conveyed by irrigation water companies. Data on sources and amounts of imports were generally unavailable, but some summary data were documented in an older DWR study (1947). After about 1980, agriculture lands had decreased significantly and almost all of the Study Area pumping was used for municipal supply.

Since 1980, the City has been the largest producer and currently pumps about 80 percent of all groundwater extracted from Study Area subbasins. The City also imports surface water from various sources to supplement the groundwater supply. The City has increased both groundwater production and imported supply over time, especially over the last 20 years, to meet increasing demands. The City's increase in groundwater and imported water supply is illustrated on Figure 19. As shown on the graph, the total water supply from 1964 to 1984 remained relatively consistent at an average of 10,138 AFY, with about 72 percent from groundwater (average 7,296 AFY) and 28 percent from imported water (2,842 AFY). From 1984 to 2004, groundwater pumping has averaged about 12,000 AFY, but has generally increased along with total supply. Since 2002, total water demand has been over 40,000 AFY, with groundwater production at about 20,000 AFY.

In addition to City pumping, approximately 56 other well owners have produced groundwater in the Study Area since 1947. The largest producers are listed on the following table.

**Table 3-1**
**Major Groundwater Users**
**Data Review Period 1947-2004**

| Well Owner | Number of Wells | Last Year of Production | 2004* Production (AFY) |
|---|---|---|---|
| City of Corona** | 39 | current | 20,435 |
| Ellsinore Valley Municipal Water District | 19 | current | 2,344 |
| Foothill Ranch | 15 | 2000 | 0 |
| Sunkist Growers Lemon Product | 12 | 1980 | 0 |
| City of Norco | 6 | current | 1,856 |
| Home Gardens County Water District | 5 | current | 272 |
| Henry Smith | 5 | 1999 | 0 |
| Cold Water Aggregates | 3 | current | 360 |
| Joy Water Company | 3 | 2000 | 0 |

Source: WMSS Data 1947-2004
*Calendar Year
**Includes several inactive park irrigation wells and other non-municipal supply wells. As noted in subsequent sections and in Table 4-2, the City's production in 2007 was 22,317 AFY

#### 3.4.1.1. Pumping in Temescal Subbasin

The graph on Figure 20 re-plots the pumping totals from Temescal and Coldwater Subbasins (from Figure 17) separately to examine pumping in each subbasin more closely. As shown on the graph, production exceeded 15,000 AFY in Temescal Subbasin from 1951 to 1978 in support of agriculture irrigation with peak production occurring from 1959 through 1964. Production declined generally to below 10,000 AFY by 1979 and averaged about 9,419 AFY over the next 17 years (1979-1996). During this time period, agriculture pumping had significantly declined, but municipal pumping had not yet increased. Since 2002, pumping has exceeded 20,000 AFY for the first time since the 1960s peak irrigation totals.

Almost all of this recent pumping is for municipal use. Industrial groundwater pumping is conducted by three companies in Temescal Subbasin (Minnesota Mining, Dart Container, and All American Asphalt) and accounts for about 700 AFY. There has been almost no agriculture pumping in Temescal Subbasin over the last few years.

#### 3.4.1.2. Pumping in Coldwater Subbasin

As shown on Figure 20, groundwater production in Coldwater Subbasin has generally ranged from less than 3,000 AFY to more than 10,000 AFY. Since 1980, production has averaged 7,018 AFY.

There have been relatively few pumpers in Coldwater Subbasin over time. Most of the production has been by the City and EVMWD, the only municipal pumpers in the subbasin. Historically, City and EVMWD production has averaged 61 percent (3,538 AFY) and 31 percent (1,932 AFY), respectively, of the total subbasin production. Most of the production in the basin is exported for out-of-basin use.

Coldwater Aggregates extracts water to support sand and gravel mining and is the only industrial pumper in the subbasin. Their pumping amounts have ranged from about 100 AFY to 300 AFY, except for a period of increased production from 1975 through 1980 when production averaged about 450 AFY.

A few well owners have also produced small amounts of groundwater to support agriculture and domestic use. Until the last few years, agriculture pumping was relatively consistent, averaging about 200 AFY since 1947. However, there has been no agriculture pumping recorded in Coldwater Subbasin since 2001. Agriculture pumping occurred mainly in the foothills along the western edge of the subbasin. Municipal and industrial pumping is clustered along the basin-bounding fault on the eastern side of the subbasin (Figure 18).

#### 3.4.1.3. Pumping in Bedford Subbasin

As shown on Figure 17, production from Bedford Subbasin has been less than in Temescal or Coldwater subbasins. Since 1947, Bedford production has ranged from 373 AFY to 4,658 AFY and has declined slightly over time with decreasing agriculture land use. Several pumping wells exist at the mouth of Bedford Canyon, just north of the subbasin boundary (Figure 18). These wells are just outside of the Temescal subbasin boundary and are included in Bedford Subbasin pumping for convenience.

Most of the early production in Bedford Subbasin supplied irrigation on local ranches. In the late 1940s, agricultural pumping represented more than 70 percent of the total subbasin pumping. Since 1984, irrigation pumping has accounted for less than 20 percent (average 421 AFY) of total production. EVMWD has been the largest single pumper over the last 20 years, producing about two-thirds of the water extracted from the subbasin (or just outside the subbasin boundary, at Bedford Canyon on Figure 18). The City has also produced small quantities of groundwater in that area (abandoned City Well 4 east of Bedford Canyon). Historically, production associated with Bedford Subbasin by the City and EVMWD has averaged 194 AFY and 1,200 AFY, respectively. Almost all of the municipal production occurs just outside of the northern edge of the subbasin at Bedford Canyon (Figure 18).

### 3.4.2. Imported Water

The City imports water through WMWD, a member agency of the Metropolitan Water District of Southern California (Metropolitan). Water is supplied from both the Colorado River and the State Water Project (SWP). Figure 19 shows the annual amount of water imported over time. From 1964 to 2004, water demand has increased by a factor of four and imported water has been an increasingly important component of the City's water supply. Since 2000, an average of 23,126 AFY has been imported, accounting for more than one-half of the City's total water supply. Additional information on the City's water supply is provided in Chapter 4.

LLWD also imports water from WMWD for potable supply in Bedford and Coldwater subbasins. In 2004, LLWD provided 1,174 AFY of imported supply to local residential customers.

### 3.4.3. Wastewater

For more than 40 years, industrial and municipal wastewater discharge has occurred in the northern portion of the Temescal Subbasin. Prior to 1963, Sunkist Growers was discharging about 790 AFY of wastewater to land along Temescal Wash in the northern portion of the subbasin (DWR, 1965), a discharge that apparently continued into the 1970s. Since the 1950s, the City has been discharging municipal wastewater effluent into ponds along the wash or directly into Temescal Wash in compliance with their wastewater discharge permits (RWQCB December 19, 2001; September 26, 2001; April 17, 1998a). From 1955 to 1963, discharges averaged about 1,000 AFY (DWR, 1965).

The City operates three wastewater treatment plants (WWTPs), two of which provide recharge to groundwater in the Temescal Subbasin. WWTP No.1 and No. 2 are located in the northern portion of the subbasin. Prior to 1997, all of the wastewater effluent was discharged to one or more of 13 percolation ponds, 10 of which were at the western end of Rincon Street in the vicinity of the Corona Airport and three of which are located along Temescal Creek between Lincoln Avenue and Cota Street. Discharge to the ponds near the Airport have been discontinued and only the three ponds referred to as the Lincoln, Cota North, and Cota South ponds are currently in use for discharge percolation (Figure 7). After 1997, WWTP No. 1 also discharged a portion of the wastewater into Temescal Wash. Beginning in 2002, the City began recycling a portion of the tertiary treated wastewater from WWTP No. 1 for landscape irrigation, reducing the overall discharge. WWTP No. 3 is located at the southeastern corner of Temescal Subbasin and provides recycled water for irrigation. The plant also discharges a small amount of tertiary treated effluent into Temescal Wash when effluent exceeds the irrigation demand.

Detailed data on wastewater volumes discharged to Temescal Wash and Lincoln and Cota ponds were available only dating back to 1997. According to City personnel, earlier records are no longer available. Files at RWQCB only date back to 1993, and efforts to recover historical RWQCB file archives were unsuccessful. As such, historical amounts of discharge to the groundwater basin were estimated using a factor of wastewater generation per household as described below.

Population data, provided in five-year increments in the City's Water Master Plan (AKM, April 2005), were evaluated on an annual basis from 1984 using a linear extrapolation. An average household was assumed to be 3.3 persons. Based on current wastewater generation, a factor of 270 gallons per day (gpd) per household was used (AKM, September 2005). This method was applied to years where actual data existed to evaluate the accuracy of the methodology. The difference between estimated and actual total wastewater generation during those years was less than three percent, verifying the method for predicting total wastewater from 1984 through 1996. Operational information provided by the City indicated that all wastewater generated before 1997 was discharge to percolation ponds only. The decline from 1996 to 1997 reflects the beginning of discharge to Temescal Wash.

Using this methodology for historical estimates and recent City data, the amount of wastewater discharged to the ponds was graphed from 1984 to 2004 as shown on Figure 21. Over this time period, wastewater discharge to the ponds averaged 6,574 AFY.

## 3.5. Groundwater

Groundwater occurs under unconfined conditions in the unconsolidated sediments of the subbasins including the Channel Aquifer and Alluvial Fan Aquifers. Water level data from the underlying consolidated sedimentary units are limited, but groundwater is likely more confined in the deeper units. Water levels and groundwater flow in the subbasins are described in the following sections.

### 3.5.1. Water Levels

Groundwater data dating back to 1916 were compiled into a water level database from multiple sources, including DWR, SAWPA, USGS, Riverside County, and the City. At least five water level measurements in the Study Area were available for each year since 1924 with one or two measurements in 1916, 1919, and 1922. Hydrographs were generated for most of the wells containing five or more measurements to examine water level trends and fluctuations throughout the basin. Three key hydrographs were selected to represent long term water levels in each subbasin. Locations of the three wells used to construct the key hydrographs are shown on Figure 22 and hydrographs are presented on Figures 23, 24, and 25. A discussion of water level trends and fluctuations in each subbasin is provided below.

#### 3.5.1.1. Water Levels in Temescal Subbasin

Water level changes in the Temescal Subbasin from 1953 to 2004 are shown on the long-term hydrograph on Figure 23. The graph shows the time period 1947 through 2004 for easy comparison to the pumping graph on Figure 20. The hydrograph combines water level data recorded during both pumping and static conditions in City Well No. 8, resulting in the somewhat spiking nature of the data, especially since 1987. Recent data from the City identified levels recorded during or immediately after pumping, but most of the data were not so designated. Filtering out designated pumping water levels removed data that appeared consistent with static conditions and left many data points remaining that appeared to be lower than static water levels. As such, all levels are shown on Figure 23 to preserve the overall trend.

Since 1953, water levels have fluctuated a total of about 45 feet, from an elevation of 580 feet msl to about 535 feet msl (assuming the spikes below that level are influenced by local drawdown in the pumping well). In general, water levels correlate to wet and dry hydrologic cycles as shown by annual precipitation on Figure 5. The highest water levels were measured in the early 1980s in response to a wet hydrologic cycle that began in 1978. These higher levels also correlate to a period of relatively low pumping in the subbasin (Figure 20). During a later wet cycle from 1992 to 1998, water levels did not recover to 1980s levels, likely due in part to an increase in subbasin pumping (Figure 20).

Current levels appear to be near record lows with levels falling below 540 feet msl over the last few years. With precipitation data indicating near-average conditions in the basin, the declining water levels may be indicative of over-pumping conditions in the subbasin.

#### 3.5.1.2. Water Levels in Coldwater Subbasin

Water levels in the Coldwater Subbasin are illustrated by the hydrograph from City Well No. 3 on Figure 24. As shown on the graph, water levels have fluctuated dramatically over the last 40 years in response to wet and dry cycles in the basin. In contrast to the 45-foot water level fluctuations noted in Temescal Subbasin, water levels in Coldwater Subbasin have varied more than 300 feet over approximately the same time period. The highest water level was recorded during 1983 at an elevation of 1,112 feet msl within 20 feet of the ground surface. During 2004, water levels fell below 800 feet msl for the first time in at least 40 years, possibly representing an all-time low water level for the subbasin.

The wide water level fluctuations over time in Coldwater Subbasin reflect the relatively small footprint and compartmentalization of the subbasin (Figure 21). The basin covers only about 2,000 acres and is surrounded on the west, north, and south by bedrock. In addition, communication with the adjacent Bedford Subbasin is impeded by the North Glen Ivy fault (associated with the Elsinore-Chino fault zone). Although the subbasin is capable of receiving large amounts of recharge from mountain runoff, it has a relatively limited storage capacity. However, it is unknown whether the recent steep decline in City Well No. 3 is reflective of water level conditions on a subbasin basis. Water level data are mainly available only in or near active pumping wells in the subbasin.

#### 3.5.1.3. Water Levels in Bedford Subbasin

An analysis of groundwater conditions in Bedford Subbasin was conducted in support of a recycled water feasibility study conducted for LLWD and provided in Appendix D. This analysis incorporates and builds on data presented in the main portion of the GWMP. The recharge project is a groundwater management strategy for potentially increasing subbasin yield.

As described in detail in Appendix D, very few wells in the Bedford Subbasin contain a sufficient water level record to analyze long term trends. However several wells near the northeast outflow of the subbasin allow for an analysis of water levels at that location (Figure 22). One well, City No. 4, is located about 950 feet north of the northeast corner of Bedford Subbasin at the mouth of Bedford Canyon. Wells pumping in this area receive recharge from runoff in adjacent Bedford Canyon (Temescal Subbasin) as well as surface and subsurface outflow from Bedford Subbasin. The location is also downgradient from any subsurface outflow that occurs from Coldwater Subbasin (Figure 22). As such, water levels in this area are indicative of the total groundwater and surface water discharge where Temescal Wash temporarily leaves the subbasins. A hydrograph from this Bedford Canyon well is shown on Figure 25.

As shown on the hydrograph, water levels have fluctuated only about 60 feet over the last 40 years. The hydrograph is plotted at the same scale as the Coldwater Subbasin hydrograph (Figure 23) for comparison to the 300 feet of change seen just south of this well. In the Bedford Canyon well, water levels have been recorded as high as 782 feet, but have remained above about 770 feet for most of the period of record. Water levels dropped to around 720 feet during the relatively dry cycle from 1987 to 1995.

The ground surface elevation at this well is reported to be about 791 feet msl (Figure 24) indicating that water levels are within 10 feet of the ground surface during times of high water levels. Downstream ground surface elevations are around 780 feet, similar to water levels in the well. These surface elevations indicate the level at which the groundwater basin is likely discharging to Temescal Wash as the Wash leaves the subbasins and traverses north across consolidated sediments in Temescal Canyon. Production wells in this area are expected to reduce surface flows in Temescal Wash, but do not appear to have significantly impacted groundwater in any of the subbasins.

### 3.5.2. Groundwater Flow Directions

Groundwater flow in the Study Area is generally from the surrounding uplands toward Temescal Wash and then north and northwestward toward the groundwater and surface water discharge location at Prado Dam.

Only a few water level contour maps exist in available documents and none of them covers the entire area of the subbasins. As such, water level data were plotted for various time periods to analyze groundwater flow directions over time. Water level contour maps are presented on Figures 26 and 27 for representative periods of low water levels and high water levels in the basin, respectively. These maps are discussed in more detail below.

#### 3.5.2.1. Groundwater Flow – Spring 1964

Figure 26 shows a water level contour map based on water levels from Spring 1964 and represents a time period when water levels were at relatively low levels in each of the subbasins as indicated on the key hydrographs (Figures 23, 24, and 25). Very few data points were available in Bedford or Coldwater subbasins during this time period, and water levels there are highly interpretive. In addition, almost no water level data are available in the alluvial fan deposits in southwestern Temescal Subbasin, so contours have been interpreted to mirror topography.

In the Bedford Subbasin, groundwater flows northward in the thin alluvial sediments. Given the narrow alluvial constriction at the southern corner of the subbasin, there is unlikely to be significant subsurface inflow of groundwater into the Study Area from the south. Almost no water level data are available from the central portion of the subbasin and contours were interpreted using geology and ground surface elevations.

Groundwater in Coldwater Subbasin flows from recharge areas in the west toward the North Glen Ivy fault that separates Coldwater and Bedford subbasins. Outflow does not likely occur during times of low water levels when significant differences in water levels are noted across the fault. When groundwater outflow does occur from Coldwater Subbasin, flow likely follows subsurface channels beneath the surface water drainageways at the central portion of the subbasin boundary. Dissected outcrops of older, semi-consolidated deposits indicate a few pathways of incised surface water drainages emanating from Coldwater Subbasin and crossing Bedford Subbasin in this area. Once in Bedford Subbasin, both groundwater and surface water flow continue northward to the subbasin boundary where flow converges with groundwater flow out of Bedford Canyon. Here water levels rise and partially discharge to Temescal Wash as it enters Temescal Canyon.

An area of uncertainty is in southeastern Temescal Subbasin north of Bedford Canyon where a groundwater divide may be present. Highly dissected alluvial fan deposits and bedrock outcrops of various Miocene-age formations indicate complex geology and thin alluvial deposits north of Bedford Canyon (Figures 9 and 10). A groundwater divide is interpreted in this area, defined by northerly flow north of the divide and northeasterly flow in Bedford Canyon south of the divide.

In the southwestern portions of the Temescal Subbasin, groundwater flows northeast in alluvial fan deposits toward the area of the Channel Aquifer. Groundwater then flows northwesterly toward the subbasin outflow at the Prado Management Area. Groundwater rises and leaves the basin as surface water discharge at Prado Dam.

#### 3.5.2.2. Groundwater Flow - Spring 1984

Groundwater elevation contours estimated for conditions in Spring 1984 are shown on Figure 27. Spring 1984 represents the end of an extended wet hydrologic cycle and water levels are at relatively high water levels throughout the Study Area. In general water levels in northern Temescal Subbasin are about 25 to 40 feet higher than in 1964. In Coldwater Subbasin, water levels are almost 200 feet higher than in 1964. In Bedford Subbasin, water levels appear to be similar to 1964, constrained somewhat by the ground surface elevations. Groundwater discharge to Temescal Wash is likely occurring in northern Bedford Subbasin during times of high water levels. Groundwater flow directions are generally similar to those in 1964. However, outflow from Coldwater Subbasin is likely occurring in 1984, adding recharge to the Bedford Subbasin.

### 3.5.3. Groundwater Quality

Groundwater quality data for this study were sourced from SAWPA, the California DPH Drinking Water Program (DHS DDWEM, July 2006), and the City of Corona. Data were combined into a comprehensive database and used to identify the chemical signature of groundwater and concentrations of constituents of concern within the Study Area.

#### 3.5.3.1. Inorganic Groundwater Chemistry

Inorganic water quality data from 102 wells in the Temescal, Bedford, and Coldwater subbasins were used to evaluate the general groundwater chemistry across the Study Area. Well locations are shown on Figure 28 and are color-coded by general areas of similar water quality. The water quality in these areas may be impacted by inflows from different source areas based on the hydrogeologic analysis of the Study Area. These areas are summarized on the following table.

**Table 3-2**
**Groundwater Areas for Water Quality Assessment**

| Subbasin | Groundwater Areas | Number of Wells |
|---|---|---|
| Temescal | Southwestern Alluvial Fan | 6 |
| | Arlington Gap | 15 |
| | Norco Area | 16 |
| | Upgradient (southeast) of Norco | 16 |
| | Downgradient (southwest) of Norco | 33 |
| | Temescal Wash - Bedford Canyon | 5 |
| Coldwater | Coldwater Subbasin | 10 |
| Bedford | Bedford Subbasin | 1 |

To characterize groundwater quality in these various areas, water quality data were evaluated using a geochemical plotting technique known as a Trilinear Diagram (Piper, 1944). This technique plots the major anions and cations in percent milliequivalents per liter (% meq/L) to characterize inorganic water chemistry and differentiate samples of varying water quality. Cations in % meq/L are plotted on the lower left triangle and anions in % meq/L are plotted in the lower right triangle. Data are projected onto the central diamond to evaluate overall water type.

Water samples of similar quality plot together in a cluster. Water samples that are a mix of two different source waters plot between the two source type end members.

Figures 28 and 29 show trilinear diagrams of the groundwater chemical signatures in Coldwater and Temescal subbasins, respectively. Only the most recent reported groundwater quality data for each well are plotted. This methodology combines data from 1953 to 2005, but a comparison of historical and recent data indicates no significant changes in inorganic water chemistry over time.

Overall, most of the water quality data indicate similar inorganic chemistry. As shown on the figures, data points for most of the wells generally cluster in the central portion of the diamond (shaded areas on the plots on Figures 28 and 29), indicating primarily a sodium/calcium-bicarbonate water type. However, variability of water types can be correlated to specific areas and indicate the following relationships:

- Groundwater in the Coldwater Basin (Figure 28) has a relatively high calcium-to-sodium ratio compared to groundwater in Temescal Subbasin (with the exception of groundwater in the western alluvial fan). This relationship is likely caused by the chemical interaction of rainfall and outcropping granitic bedrock (and the lack of outcropping volcanic bedrock) in the Coldwater Basin watershed.
- Groundwater in wells located in the Bedford Canyon portion of Temescal Wash or Temescal Canyon (Figure 28) has a higher ratio of calcium-to-sodium and sulfate-to-chloride than wells located in Arlington Gap. Relative cation concentrations indicate that groundwater in the Temescal Wash area upgradient of the Norco area is a mixture of waters from both the Temescal Canyon area and Arlington Gap, but are most similar to the water in Arlington Gap.
- Groundwater in wells located in the Norco area has a lower ratio of calcium-to-sodium and sulfate/bicarbonate-to-chloride than most other areas.
- Groundwater in wells located in the southwestern alluvial fan has the highest ratio of calcium-to-sodium and sulfate-to-chloride/bicarbonate compared to groundwater in other areas. The water type in the alluvial fan may result from geochemical interaction between rainfall runoff and the outcropping Santiago Peak volcanics in the western catchment area of Temescal Subbasin prior to aquifer recharge along the base of the mountains.
- Cation concentrations indicate that groundwater in wells located in Temescal Wash downgradient of the Norco area appear to be mixtures of groundwater from three sources: Temescal Wash upgradient of the Norco area, Arlington Gap, and the western alluvial fan.

This water quality source assessment indicates the major sources of water by analyzing the blending of different water quality from different areas. Identifying major areas of inflow and outflow is critical in developing a strong conceptual model of the aquifer. Based on water quality type, the groundwater in the Channel Aquifer appears to be derived mainly from Arlington Gap and to lesser extent Temescal Wash. In addition to these sources, the western Channel Aquifer also receives inflow from the Alluvial Fan.

#### 3.5.3.2. Total Dissolved Solids (TDS) Concentrations in Groundwater

Groundwater in the Study Area tends to be highly mineralized. Figure 30 shows the range of total dissolved solids (TDS) concentrations across the Study Area. Data represent the most recent concentration of TDS from 89 wells. The map indicates that groundwater in the Temescal Subbasin generally exceeds the secondary maximum contaminant level (MCL) of 500 mg/L for drinking water. TDS concentrations greater than 1,000 mg/L are observed beneath Temescal Wash and in the Norco area. Groundwater in the Norco area is also characterized by elevated hardness.

TDS concentrations in the Coldwater and Bedford subbasins are generally lower in TDS and range from 300 to 650 mg/L. Average TDS concentrations for each subbasin are summarized below.

**Table 3-3**
**Total Dissolved Solids in Groundwater**

| Subbasin | Number of Wells | TDS (mg/L) | |
|---|---|---|---|
| | | Range | Geometric Mean |
| Temescal | 80 | 307 - 1,950 | 894 |
| Bedford | 1 | 630 | 630 |
| Coldwater | 8 | 300 - 650 | 477 |

#### 3.5.3.3. Nitrate Concentrations in Groundwater

Elevated nitrate concentrations have been documented in the Temescal Subbasin since at least the 1950s. The latest reported nitrate concentrations (as $NO_3$) for 78 wells in the Study Area are shown on Figure 31. Water quality data indicate nitrate concentrations ranging from 0.3 to 124 mg/L. Although the average nitrate concentration in the subbasin is 41 mg/L, nitrate concentrations in 28 of the 72 subbasin wells do not meet the primary MCL standard of 45 mg/L for drinking water. The highest nitrate concentrations are those associated with wells at the Arlington Gap where concentrations of groundwater entering Temescal Subbasin exceed 100 mg/L. Elevated nitrate concentrations are also generally located along Temescal Wash and on the western alluvial fan.

Groundwater quality in City wells typically does not meet federal or state drinking water standards for nitrate (45 mg/L). Nitrate concentrations (as $NO_3$) measured in the City production wells typically range from 4.0 to 110 mg/L. Most wells require treatment and/or blending to meet regulatory requirements.

In the Coldwater Subbasin, groundwater nitrate concentrations (as $NO_3$) for six water supply wells range from 0.4 to 6.5 mg/L, significantly below the MCL. Although data were generally unavailable for the Bedford Subbasin, DWR reports historical elevated nitrate and sulfate concentrations in the area (DWR, 1959). However, one recent sample (2007) from a Bedford Subbasin well indicated a relatively low nitrate (as N) concentration of 1.2 mg/L (LLWD, 2007).

#### 3.5.3.4. Additional Water Quality Concerns

As urbanization has increased in the Study Area, the potential for groundwater quality impacts from anthropogenic (human-influenced) sources has also increased. Numerous underground storage tanks (USTs), dry cleaners, and industrial facilities are located across the subbasins and in adjacent basins. Potential impacts from historical anthropogenic sources are also a concern. For example, years of wastewater discharge by citrus processing facilities occurred in areas where locally elevated chloride concentrations have been detected. In addition, the U.S. Navy operated an ordnance laboratory in the Norco area in 1957 (DWR, 1959). Data were compiled from regulatory agencies in the Study Area to identify areas of concern.

**Regulated Facilities**

Potential threats to groundwater quality are regulated by RWQCB, Department of Toxic Substance Control (DTSC), and the Riverside County Department of Environmental Health (DEH). A review of the RWQCB database identified 30 major sites that are regulated for possible environmental releases in the Corona area and approximately 75 Underground Storage Tank (UST) investigations. These sites are shown on Figure 32. Regulated facilities and USTs that overlie the areal extent of the Channel Aquifer are of highest concern, given the permeable nature, shallow depth, and the reliance on the aquifer for water supply.

**Corona Sanitary Landfill**

One regulated facility, the Corona Sanitary Landfill, has impacted local groundwater quality and remains a potential threat to existing city wells and the Channel Aquifer. Riverside County Waste Management Department (RCWMD) operates the closed sanitary landfill on an 80-acre site identified on Figure 32. Groundwater impacted by trichloroethene (TCE) has been mapped offsite and downgradient of the landfill. The TCE plume, as interpreted in a 1999 study, indicates that elevated TCE concentrations are migrating toward City wells (RCWMD, 1999). The study also concludes that more than one source of TCE exists in the area.

Three City wells downgradient of the landfill plume have already detected low concentrations of TCE in micrograms per liter (ug/L) as summarized in the following table. One additional nearby well not has not yet detected TCE, but does not appear to be directly downgradient from the TCE-impacted groundwater.

**Table 3-4**
**TCE Detections in City Well Samples**
**Data Review Period 1999-2002**

| City Well | Number of Detections | Highest TCE Concentration |
|---|---|---|
| Well 6 | 7 | 1.0 ug/L |
| Well 7 | 12 | 2.2 ug/L |
| Well 17 | 10 | 2.4 ug/L |

Although none of the detections have exceeded the MCL of 5 ug/L, the occurrence of TCE at the wells indicates a continuing threat to water quality. Strategies developed for this GWMP consider options to address specific water quality concerns.

## 3.6. Water Balance

Preliminary water balances have been prepared for the two subbasins that provide City water supply, Temescal and Coldwater, to evaluate current conditions and future sustainability of the groundwater resource. Data are generally inadequate for a rigorous assessment, and many simplifying assumptions have been made; nonetheless, the water balances presented here provide useful information for basin management and address the sustainability of the groundwater resource.

Data gaps and uncertainties associated with the Bedford Subbasin limit the ability to quantify inflows and outflows. In addition, Bedford Subbasin is relatively shallow, characterized by thin alluvial sediments and relatively high water levels with very little water use. Only one groundwater management strategy was identified with the Bedford Subbasin (groundwater recharge by LLWD) and that strategy was analyzed based on water level data and did not require a detailed water balance.  Further analysis of the Bedford Subbasin in a feasibility study of the LLWD management strategy is provided in this document as Appendix D.

The water balances for Temescal and Coldwater subbasins are useful beyond application to GWMP management strategies. The evaluation provides a tool to improve the understanding of the groundwater system and to refine the conceptual model. It also supports improved monitoring in the basin, identifying where additional data would be most useful. The water balance will continue to be refined and updated in the future as additional data become available. In addition, the water balance provided a foundation of the development of the numerical model used to assess some management scenarios.

The water balance relies on data presented in the previous sections of the GWMP. Groundwater subbasin conditions and analyses are not repeated in this section, but previous figures are referenced where applicable. A more complete explanation of each figure is contained in the section where each was first introduced.

### 3.6.1. Approach

The water balance for Study Area subbasins examines inflow into the subbasins, outflow from the basins, and change in groundwater storage in the basin, recognizing the following relationship:

*Inflows – Outflows = Change in Storage*

To examine how these components change through time with varying amounts of recharge and pumping, the balance was conducted over a 15-year period, 1990 through 2004, covering a full hydrologic cycle of wet and dry conditions as well as significant changes in groundwater pumping. Change in groundwater storage over that time period was estimated independently using water level data, and compared to the net difference between estimated inflows and outflows to check for inconsistencies and to identify simplifying assumptions or data gaps of concern. For the Temescal Subbasin, the balance was further evaluated with the construction and calibration of a numerical groundwater model. These steps allow for a reasonable range of values to be determined for each element of the water balance and highlight the sensitivity of the water balance to specific elements.

To evaluate water balance components, the contributing watersheds and subbasins were subdivided and designated as water balance units to assist in the analysis. These units are shown on Figure 33 and allow for grouping areas together of similar land use, soil type, and/or other water balance factors within each unit. The delineation of similar areas within the water balance units are referred to in this document as water balance elements. These elements are shown on Figure 34 and represent areas of similar land use, soil type and precipitation zones.

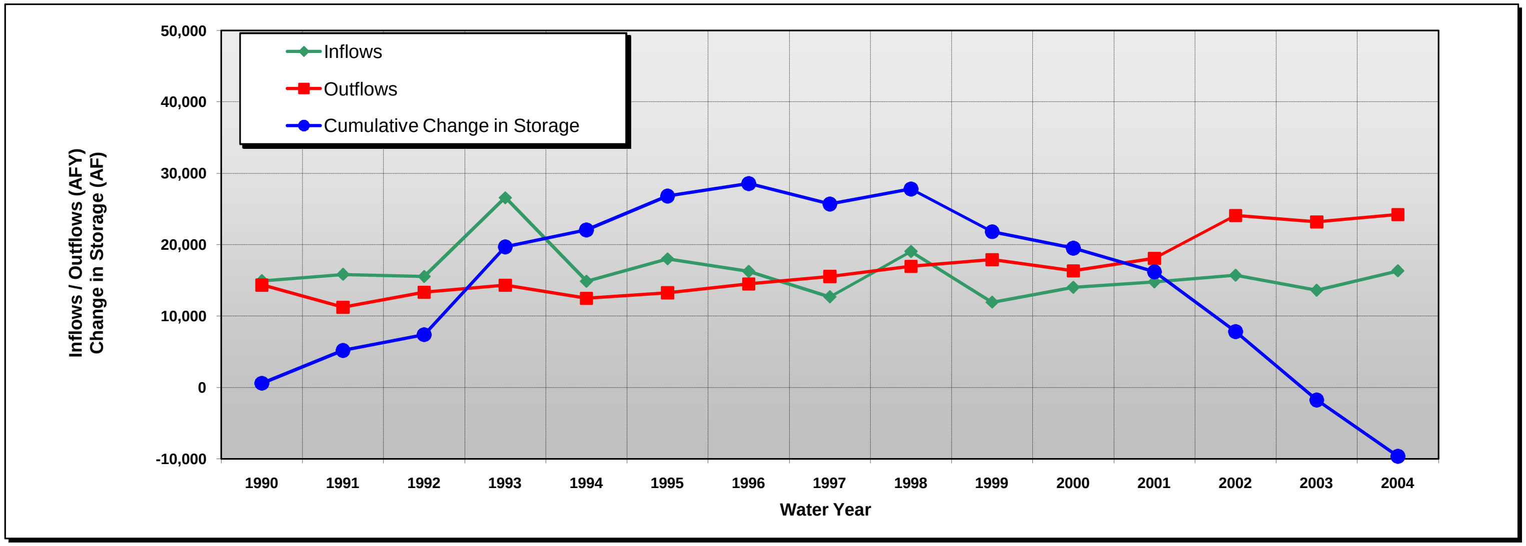
Throughout this report, areas are shown to the nearest acre, and water budget items are shown to the nearest AF. As a result, large numbers may appear to be accurate to four or five significant digits, which is not the case. Values for data that are measured directly, such as water levels, streamflow, and groundwater pumping, are probably accurate to two or possibly three significant digits. Values for data that are estimated, such groundwater storage changes and groundwater inflows and outflows, are probably accurate to only one or two significant digits. All digits are retained in the text and tables to preserve correct column totals in tables and to maintain as much accuracy as possible when converting units or conducting subsequent calculations.

### 3.6.2. Temescal Subbasin Water Balance

The water balance for the Temescal Subbasin was initially conducted through an independent evaluation of the different components of inflow and outflow from the subbasin. The resultant change in storage was checked for reasonableness by estimating the change in storage indicated by water level fluctuations over the Study Period. These inflows and outflows were then incorporated into a numerical groundwater model based on the hydrogeologic conceptual model of the basin. Inflows and outflows were adjusted during calibration to provide a better fit to measured water levels in key areas of the basin. The methodology for each of these steps is summarized in the following sections. Table 3-5 summarizes the water balance results as modified through groundwater model calibration. Documentation of the development of the groundwater model is provided in Appendix C.

## Table 3-5
## Water Balance Summary for Temescal Subbasin

| Water Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INFLOWS** | | | | | | | | | | | | | | | | |
| Deep Percolation from Precipitation | 0 | 653 | 1,122 | 12,694 | 0 | 1,766 | 0 | 0 | 3,753 | 0 | 0 | 1,714 | 3,076 | 608 | 913 | **1,753** |
| Infiltration of Runoff in Detention Basins | 478 | 478 | 482 | 478 | 478 | 478 | 482 | 478 | 478 | 478 | 482 | 478 | 478 | 478 | 482 | **479** |
| Recharge from Wastewater Discharge | 6,978 | 7,380 | 7,797 | 8,214 | 8,629 | 9,056 | 9,474 | 5,238 | 7,812 | 3,650 | 6,104 | 6,072 | 6,289 | 5,994 | 7,997 | **7,112** |
| Subsurface Inflow Subtotal | 5,602 | 5,828 | 4,603 | 3,643 | 3,983 | 4,945 | 5,407 | 4,717 | 4,806 | 5,097 | 4,695 | 4,068 | 3,173 | 3,778 | 4,186 | **4,569** |
| - Arlington Gap | 4,654 | 4,880 | 3,652 | 2,695 | 3,035 | 3,997 | 4,456 | 3,769 | 3,858 | 4,149 | 3,745 | 3,120 | 2,225 | 2,830 | 3,235 | 3,620 |
| - Temescal Wash (Temescal Canyon) | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 |
| - Bedrock in Watershed | 783 | 783 | 785 | 783 | 783 | 783 | 785 | 783 | 783 | 783 | 785 | 783 | 783 | 783 | 785 | 783 |
| - Norco | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 |
| Return Flows Subtotal | 1,897 | 1,506 | 1,545 | 1,575 | 1,780 | 1,790 | 902 | 2,262 | 2,207 | 2,716 | 2,749 | 2,455 | 2,712 | 2,760 | 2,760 | **2,108** |
| **TOTAL INFLOWS (AFY)** | **14,956** | **15,844** | **15,549** | **26,605** | **14,871** | **18,035** | **16,264** | **12,696** | **19,057** | **11,940** | **14,030** | **14,788** | **15,728** | **13,618** | **16,338** | **16,021** |
| | | | | | | | | | | | | | | | | |
| **OUTFLOWS** | | | | | | | | | | | | | | | | |
| Groundwater Pumping | 10,248 | 7,294 | 9,378 | 10,302 | 8,465 | 9,233 | 10,470 | 11,492 | 12,889 | 13,847 | 12,251 | 13,981 | 19,986 | 19,073 | 20,112 | **12,601** |
| Subsurface Outflow to Santa Ana River | 4,104 | 3,944 | 3,973 | 4,019 | 4,028 | 4,040 | 4,050 | 4,061 | 4,074 | 4,074 | 4,096 | 4,102 | 4,123 | 4,121 | 4,114 | **4,062** |
| **TOTAL OUTFLOWS (AFY)** | **14,352** | **11,238** | **13,351** | **14,321** | **12,494** | **13,273** | **14,520** | **15,553** | **16,963** | **17,920** | **16,347** | **18,082** | **24,109** | **23,194** | **24,227** | **16,663** |
| | | | | | | | | | | | | | | | | |
| **Cumulative Change in Storage (AF)** | **604** | **5,210** | **7,408** | **19,692** | **22,069** | **26,831** | **28,575** | **25,718** | **27,812** | **21,832** | **19,514** | **16,220** | **7,839** | **-1,737** | **-9,627** | |



#### 3.6.2.1. Inflows to Temescal Subbasin

Inflows to the Temescal Subbasins include the following:

- deep percolation from rainfall on the basin floor
- return flows from urban and agriculture irrigation
- infiltration of runoff from surrounding uplands
- stormwater infiltration at flood control basins
- discharge at wastewater recharge ponds
- subsurface inflow from adjacent subbasins.

Each inflow component is estimated on an annual basis over the Study Period from 1990 through 2004. Methodology, assumptions, and results are discussed below.

##### *Deep Percolation from Precipitation*

Deep percolation from precipitation is the amount of precipitation (rainfall) that falls on the floor of the groundwater basin and infiltrates through the soil to the underlying water table. The volume of deep percolation is influenced by factors including the amount and timing of precipitation, soil type, geology, topography, vegetation cover, and extent of impervious areas (e.g., pavement and buildings). In the Study Area, deep percolation is limited due to the large impervious area of urban development that covers the basin floor, especially over the productive Channel Aquifer. In this area, a large portion of rainfall is funneled to lined storm drains and prevented from recharging groundwater. Nonetheless, deep percolation represents a significant portion of the subbasin inflow in wet years. It contributes almost no inflow in dry years.

Deep percolation was calculated over the Study Area using two steps: a runoff analysis and a soil moisture balance. The runoff analysis used the SCS Curve Number method to estimate the amount of precipitation resulting in runoff based on land use type, soil type, and precipitation amount. The soil moisture balance examines the precipitation that does not result in runoff and determines the amount available for groundwater recharge.

To account for the factors that vary spatially, the Study Area was divided into unique elements. This was accomplished by overlaying spatial maps to create elements each with a single soil hydrologic classification, soil moisture capacity value, precipitation multiplier, and land use category. Because the land use changes over time, a set of elements was created for each year that a land use map was available (i.e., even years from 1984 - 2004). For each year without a land use map (odd years), it was assumed that the land use remained the same as the previous year. The elements created for 2004 are shown on Figure 34.

For each element, the runoff analysis and soil moisture balance were applied to estimate deep percolation. Elements within the groundwater basin are applicable to deep percolation, while elements in the contributing watershed were analyzed as part of the evaluations of infiltration of runoff and subsurface inflow, respectively, which are addressed in subsequent sections.

#### Runoff Analysis

The Curve Number runoff analysis was developed by the SCS (Soil Conservation Service, now the U. S. Natural Resources Conservation Service, NRCS). The method is described in the document *Technical Release 55* from the U.S. Department of Agriculture (USDA, 1986). Direct runoff is calculated as a relationship between *rainfall*, the potential maximum *initial abstractions* and the *retention* after runoff begins.

*Rainfall* was estimated for each element and each month using historical rainfall data from the Elsinore station and the PRISM isohyetal map (see Figure 6). For watershed areas with substantially higher rainfall than Elsinore, monthly rainfall amounts were estimated by applying a rainfall-elevation factor based primarily on the PRISM map. Land use also was considered. Information on land use types and the portion of impervious area by housing type (provided in the Riverside County Flood Control and Water Conservation District Hydrology Manual) were used to derive a weighted average percent impervious area, 56 percent, which was used for all urban types. All precipitation falling on these impervious areas was assumed to become runoff that was captured by storm water collection systems (and removed from the water balance).

*Initial abstractions* include water that is captured before runoff. This initial abstraction includes plant interception, initial infiltration, and surface storage associated with ground cover and can be expressed as a percentage of the maximum retention. For the purposes of this study, initial abstractions were assumed to be 20 percent of the maximum retention, the recommended default value from the NRCS.

The *potential maximum retention* is estimated using a coefficient, or curve number. The curve number is based on information on land use and soil hydrologic classification, obtained primarily from the Hydrology Manual. The manual provides maps showing soil hydrologic groups (e.g., Group A – high infiltration through Group D – very slow infiltration) and provides the curve numbers for specific land use types and soil hydrologic groups. For this analysis, curves representing moderate runoff potential were used to calculate direct runoff on a monthly basis. These runoff values then were subtracted from actual precipitation to derive the *effective precipitation.* The effective precipitation is assumed available to meet ET demands, to contribute to soil water capacity, and to provide deep percolation to groundwater.

#### Soil Moisture Balance

Once the effective precipitation was calculated in the Curve Number analysis, it was input to the soil moisture balance. The soil moisture balance accounts for soil moisture storage and provides an estimate of ET; the remaining water is assumed to recharge the aquifer as deep percolation.

Soil moisture holding capacity values were derived using the Riverside County and Orange County soil surveys performed by the NRCS (2006). Soil moisture capacity for each soil type was derived from the weighted average of the moisture capacity over the entire rooting depth. The soil types then were divided into four categories based on soil moisture holding capacity: low, medium, high, and very high capacity. These categories were overlain with the soil hydrologic groups (A through D). Figure 35 shows the distribution of the resulting soil types; soils without soil moisture holding capacity data (unknown-UNK or not available-NA) are indicated.

The soil moisture balance was applied to each element to evaluate deep percolation. In brief, the soil moisture balance computes deep percolation on a monthly time step as the residual of the equation:

*Effective precipitation - ET - soil moisture storage = deep percolation.*

The rate of percolation was then applied to each area to calculate the total volume of recharge from deep percolation. This analysis resulted in a range of recharge estimates from less than one AFY of recharge in years of very low precipitation such as 1999 and 2002 to almost 10,000 AFY in 1993, the wettest year of the Study Period. These numbers were adjusted upward slightly (about 2 percent) in the groundwater model during model calibration as documented in Appendix C. Final recharge values for the purposes of the water balance are provided in the first row of inflows in Table 3-5.

As shown in the table, deep percolation of precipitation averages 1,753 AFY for the Temescal Subbasin, accounting for about 11 percent of the total average subbasin inflow and about 7 percent of average precipitation over the Study Period. During that time period, recharge from deep percolation ranged from 0 AFY to 12,694 AFY.

### *Return Flows*

When land is irrigated, either for agricultural or urban landscape uses, most of the water is consumed through ET, but some water typically percolates to the underlying water table (depending on irrigation efficiency). Urban return flows may also include leakage from septic systems, municipal pipelines, or other urban uses. Figure 8 shows general land uses in the Study Area for 1984 and 2004. For the purposes of this analysis, any area that currently receives water from a municipality is considered part of the urban area.

#### Urban Return Flows

The analysis of urban return flows involved evaluation of 1) the amount of municipal water used outdoors and 2) the portion of outdoor water that percolates to groundwater. Urban outdoor water use generally involves landscape irrigation, with different customer types (e.g., single family homes, multiple family homes, commercial/industrial, and landscape irrigation) using a different portion of water outdoors. The distribution of customer types in Corona was obtained from the City's Urban Water Management Plan (AKM, December 2005) and the amount of water served to each customer type was totaled. Estimation of the portion of water used outdoors for different customer types was derived from online DWR data on indoor/outdoor use for the North Riverside Detailed Analysis Unit from 1998-2004. While the relative portions of indoor and outdoor water use varied significantly from year to year, representative apportionments of 40 percent water use indoors and 60 percent water use outdoors was selected for multiple family homes. The apportionments for commercial customers and single family homes were similar. Applying these apportionments to the customer types and total water use, the portion of the total water supply used outdoors was estimated at 62.7 percent.

The urban return flow is the portion of applied irrigation water that exceeds the ET demands of the landscaping. For the purposes of this analysis, it was assumed that landscape irrigation water is not typically allowed to run off. Assuming that the average irrigation system is 90 percent efficient, then 10 percent of the applied water results in return flows to groundwater. Thus for each year, 10 percent of the water used outdoors returns to the aquifer as percolation.

A similar calculation addresses additional urban areas served by the City of Norco and Home Gardens County Water District. Assuming that water use has a similar indoor/outdoor apportionment as in Corona, the same portion (62.7 percent) of total water supply used outdoors was assumed. Similarly, it was assumed that 10 percent of the outdoor use would contribute to return flows.

Using this methodology, urban return flows average 1,960 AFY related to the City water supply and an additional 86 AFY associated with other urban water suppliers.

#### Agricultural Return Flow

Estimation of agricultural return flows was based on the total amount of applied water and the consumed fraction, which represents the portion of applied irrigation that is consumed by the crop through ET. According to the DWR website, the average consumed fraction for citrus crops in the North Riverside DAU from 1998 to 2002 was approximately 74 percent. The remaining 26 percent, assuming no runoff, represents agricultural return flow.

Although agricultural areas are now mostly urbanized, some agricultural areas were persistent in early portion of the Study Period. However, these agricultural return flows are small and average about 61 AFY, or less than one percent of total inflows to the groundwater subbasin. Total return flows for both urban and agriculture for Temescal Subbasin average about 2,108 AFY, about 13 percent of total inflows (Table 3-5).

### *Infiltration of Runoff*

Although large amounts of natural runoff are generated in the Santa Ana Mountains west of the subbasin, most of this runoff is captured by the City's stormwater management system and is unavailable for infiltration into the groundwater basin. Two large flood control (detention) basins, the Oak Avenue Basin and the Main Street Basin, have been constructed on two main drainageways along the mountain front. These basins are owned and operated by the Riverside County Flood Control and Water Conservation District (RCFCWCD). The locations of these basins are shown on Figure 7. The Oak Avenue and Main Street detention basins together cover 28 acres and hold 240 AF of water at full capacity (about 120 AFY each) (PBS&J, 2004). The basins are operated to only detain peak flows and only a small amount of runoff is estimated to infiltrate the basin floor. Almost all of the flow is diverted into lined canals that drain to a lined portion of Temescal Wash, which ultimately conveys the runoff out of the subbasin. The only other large drainageway that provides significant runoff to the subbasin is Bedford Wash in the south. Runoff on this drainage is also lost from the Temescal Subbasin as it flows into Temescal Wash.

A variety of methodologies were examined to estimate the potential annual recharge through the Oak Avenue and Main Street detention basins, resulting in a wide range of possible values from several hundred AF to several thousand AF. The evaluation considered the potential wetted area, potential infiltration rates, variations in annual runoff, and anecdotal information on the number of days that water is observed in the basins. It was determined from this review that reasonable ranges of potential infiltration varied considerably. However, since the basins are operated only to detain peak flows for a very short duration, it was determined that a conservative average of infiltration would be appropriate for the water balance. As such, an estimated infiltration volume of 480 AFY is used. This is equivalent to about 240 AFY for each basin and assumes that an amount equal to twice the total basin capacities infiltrates to groundwater each year. This is considered a conservative amount and represents only about five percent of the runoff that could potentially reach the detention basins. The 480 AFY is maintained for every year in the Study Period. (The slightly different amount of 478 to 482 shown on Table 3-5 reflects rounded values extracted from detailed groundwater model budget outputs).

Another area for potential infiltration of runoff exists on the eastern side of Temescal Subbasin where Temescal Wash enters the subbasin from Temescal Canyon (Figure 7). Here, surface water is allowed to infiltrate along a short segment of the subbasin before entering a lined culvert near Magnolia Avenue (lined portion shown on Figure 7). The area available for recharge has historically been characterized by high groundwater, apparently from surface water infiltration and fine-grained soils at the surface. As such, infiltration from the wash is thought to be small and has been calculated by applying Darcy's Law to the subsurface area of Temescal Wash. This method results in an estimate of about 113 AFY of recharge, on average. In the absence of data that would be needed to allow this number to vary within a reasonable range of values, the average amount is applied to the water balance for each year of the Study Period as shown on Table 3-5.

### *Wastewater Recharge*

Since the 1950s, the City has discharged treated wastewater into unlined ponds in northern Temescal Subbasin. The current locations of the percolation ponds are indicated on Figure 33 and a graph of wastewater discharge to the ponds is provided on Figure 21. The three ponds, referred to as Lincoln, Cota North, and Cota South, range in size from 2.95 acres to 6.81 acres, and together total 16.51 acres. Since 1984, effluent volumes have ranged between 3,649 AFY and 9,476 AFY (Figure 21).

A 2006 wastewater pond investigation documented high historical percolation rates, ranging up to 25 feet per day (AKM, 2006). During the time of the investigation, percolation had decreased to less than 1 foot per day due to the buildup of clogging particles and organic material on the bottom of the ponds. As recommended in the investigation report, removal of fines and other pond rehabilitation methods were implemented and the higher percolation rates were restored. The amount of evaporation from the ponds is estimated to be small, given the high percolation rates and observations by City staff (perhaps about 30 inches or 40 AFY) and was not incorporated into the recharge amounts. As such, recharge to Temescal Subbasin from the wastewater discharge ponds is estimated to range from about 3,650 AFY to 9,474 AFY and averages 7,112 AFY as shown in Table 3-5.

A portion of the wastewater from WWTP No. 1 is now treated to tertiary levels and used for park irrigation. This change in operation occurred late in the Study Period (2002) and adds only a small amount of additional return flows for 2003 and 2004. As such, it is considered to have a negligible effect on the water balance.

The City operates a third WWTP, located at the southeast corner of Temescal Subbasin. Wastewater is used for local irrigation, with a small percentage discharged to Temescal Wash. Any addition of wastewater does not affect the water balance as the recharge from Temescal Wash is limited by lined channels and has been estimated at 113 AFY as described above.

### *Subsurface Inflow*

Subsurface inflow contributes to the Temescal Subbasin from adjoining basins. In addition, some inflow likely occurs along the entire circumference of the Study Area from adjacent bedrock. General areas where subsurface inflows and outflows occur are indicated conceptually by arrows on Figure 33 and described in more detail below.

#### Subsurface Inflow at Arlington Gap into Temescal Subbasin

Water level contour maps indicate that groundwater enters the Temescal Subbasin from the Riverside-Arlington Basin through a narrow arm of the alluvial basin referred to as the

Arlington Gap (Figure 33). To estimate the volume of subsurface inflow across Arlington Gap, a calculation applying Darcy's Law was conducted using the cross-sectional area of water-bearing sediments, estimated hydraulic conductivity values, and a measured hydraulic gradient of 0.0028 ft/ft across the subbasin boundary. This amount was used as a preliminary target for inflow at this boundary in the groundwater model. Inflow amounts estimated by the model are provided on Table 3-5 and average 3,620 AFY. The methodology of the initial Darcy's Law calculation is described below.

As shown on cross-section C-C' (Figure 14), the saturated aquifer thickness at Arlington Gap (as defined by DWR Well 193583) is about 400 feet and includes both the Channel Aquifer and underlying Tertiary-age sandstones. Applying a K value of 1,500 gpd/ft$^2$ (200 ft/day) to the Channel Aquifer and 100 gpd/ft$^2$ (13 ft/day) to the Sandstone Aquifer results in an estimated average annual subsurface inflow through Arlington Gap of 4,869 AFY, of which 95 percent is represented by groundwater flow through the Channel Aquifer. This volume is in close agreement with a previous estimate by DWR of 3,000 AFY (DWR, 1947).

This value was tested in the groundwater flow model. As described in Appendix C, the boundary condition at the Arlington Gap was simulated with a specified head tied to water level data in a production well operated by Home Gardens Water District and located near the gap. As shown on Table 3-5, groundwater modeling indicated that inflow at the gap averaged 3,620 AFY over the Study Period and ranged from about 4,880 AFY to 2,225 AFY. Inflow decreased over the last few years in the Study Period in response to declining water levels in the well.

#### Subsurface Inflow from Surrounding Bedrock

Although limited by permeability, the bedrock surrounding the groundwater subbasin is recharged by small amounts of local precipitation. This bedrock groundwater system is in direct hydraulic communication with the groundwater in the alluvial basin over a relatively large area in the subsurface. Assuming that bedrock recharge and subsurface inflow will vary with precipitation, a soil moisture balance was calculated on the watershed area and the resulting groundwater recharge was used to approximate subsurface inflow. This amount was adjusted upward during model calibration.

Using these methods, about 783 AFY on average is estimated to provide subsurface inflow to the Temescal Subbasin from adjacent bedrock areas (Table 3-5). Although the amount was assumed to vary somewhat with precipitation, the lag time for inflow is unknown. Therefore a simplifying assumption was made using the average amount of inflow for each year in the Study Period as shown on Table 3-5. This inflow is relatively small and represents less than one percent of total precipitation in the watershed.

**Subsurface Inflow from Norco Area**

Although most of the Norco area is included within the Temescal Subbasin boundaries as provided by DWR, there are significant unknowns associated with the area. Alluvial sediments appear to be thin and interrupted by bedrock highs. In addition, a groundwater divide is indicated by the data, with some groundwater flow indicated to the north toward the Santa Ana River and exiting the subbasin. The area that contributes groundwater flow to the Temescal Subbasin is uncertain. As such, the area was simulated in the groundwater model as providing a specified flow into the subbasin, derived from a simple calculation of subsurface inflow using Darcy's Law. That calculation indicated an inflow of approximately 52 AFY, an amount that was held constant as an annual subsurface inflow for Temescal Subbasin water balance (Table 3-5).

#### 3.6.2.2. Outflows from Temescal Subbasin

Two outflows from the subbasin have been accounted for in the water balance. The largest of these is groundwater pumping, mostly from the City's production wells. The other outflow component is the amount of groundwater that rises to surface water and contributes to the Santa Ana River outflow at Prado Dam. The incorporation of these components in the water balance is described below.

***Pumping***

Water pumped from the subbasin supplies water for urban, agricultural, and industrial uses. During the Study Period (1990 -2004), municipal uses account for 94 percent of the production. Pumping totals from the DMS were input into the water balance and the groundwater model. The monthly distribution of pumping used in the groundwater model was determined from the time period when monthly data were available and average monthly percentages were applied to annual totals.

As shown on Table 3-5, pumping represents the primary outflow in the water balance. During the Study Period, production in Temescal Subbasin averaged 12,601 AFY and ranged from 7,294 AFY to more than 20,000 AFY. In general pumping has increased during the Study Period with a significant increase beginning in 2002 when pumping exceeded 19,000 AFY. From 1990 to 2002, pumping averaged 10,821 AFY. From 2002 through 2004, average pumping increased more than 80 percent to 19,724 AFY. Section 3.4 provides a more complete discussion of pumping in the Study Area.

***Subsurface Outflow***

Subsurface outflows from the Temescal Subbasin are interpreted to occur at two main locations: contribution to baseflow at the Santa Ana River and contribution to Temescal Creek baseflow near Bedford Canyon. Methodology was similar to the calculations for subsurface inflow previously described.

### Subsurface Outflow from Temescal Subbasin at Santa Ana River

Groundwater level contours in the Study Area (Figures 26 and 27) indicate that groundwater flows out of the Temescal Subbasin in the Prado Management Area (flood control basin) of the Santa Ana River (northern portion of the Study Area). Groundwater rises and discharges from the valley via surface water flow at Prado Dam. However, to incorporate subsurface data and provide a more reliable estimate of this amount, the outflow calculation was initially estimated at a location judged to be just upgradient of groundwater discharge to surface water.

To estimate the annual volume of subsurface outflow from Temescal Subbasin, the same methodology and K values were applied as those used for the Channel Aquifer and Tertiary deposits in the Arlington Gap inflow calculation. A hydraulic gradient of 0.0009 ft/ft was measured across the northwestern boundary of Temescal Subbasin, and an average saturated thickness of 600 feet was assumed for the Tertiary deposits. Results of the calculation using Darcy's Law indicate that the estimated annual subsurface outflow from Temescal Subbasin is 4,352 AFY, of which 90 percent is represented by groundwater outflow through the Channel Aquifer. This volume is within the previously estimated range of 3,000 to 9,000 AFY made by USGS in a study of groundwater outflow to Prado Management Area (French, 1972).

In order to analyze the variability of this outflow, output from the calibrated groundwater model was reviewed. This boundary was simulated as a general head boundary based on elevation of the pool at Prado Dam. Details of this boundary condition are provided in Appendix C. The model output agrees closely with the estimates from the calculations described above. These amounts are provided as outflow from the basin and are listed in Table 3-5. As shown in the table, average outflow to surface water is estimated at 4,062 AFY and varies within a relatively narrow range from 3,944 AFY to 4,123 AFY.

### Subsurface Outflow from Temescal Subbasin along Bedford Canyon

Subsurface outflow from Temescal Subbasin at the subbasin southeast corner is interpreted to occur in the alluvial sediments of Bedford Canyon. According to hydrographs in this area (e.g., Figure 25 with location on Figure 22), groundwater discharge to surface water occurs in this area as Temescal Wash enters Temescal Canyon. Runoff contributing to infiltration along Bedford Wash is not accounted for in the water balance and is assumed to exit the subbasin as either groundwater or surface water. Because this area does not impact the remaining portions of the water balance, inflows and outflows are not included for this area.

## *Total Outflows*

As shown on Table 3-5, total outflows from Temescal Subbasin, including pumping and subsurface outflow, average 16,663 AFY, about 642 AFY larger than average inflows. Outflows were generally less than inflows on an annual basis for most of the early years of the Study Period.

In recent years, outflows have exceeded inflows, especially in 2002-2004 when pumping amounts increased to about 20,000 AFY.

#### 3.6.2.3. Change in Groundwater Storage in Temescal Subbasin

Groundwater in storage refers to the volume of groundwater in the saturated aquifers from the water table down to a level where groundwater extraction is limited by factors such as deteriorating water quality, insufficient permeability, or excessive lift costs. The amount of groundwater in storage changes from year to year with climatic variation and basin operation (i.e. pumping). The water balance provides a regional assessment of the change in storage by estimating how much water is entering and leaving the groundwater basin on an average basis and serve as an initial guide to the average amount of groundwater that can be extracted without significant depletion of groundwater. The balance is only an initial indication; changes in groundwater storage from pumping are controlled by pumping locations, boundary conditions, and the ability of pumping to capture inflows and outflows in the basin.

The change in groundwater storage predicted by the water balance is the subtraction of outflows from inflows. Although this calculation can be made annually, the change in storage over the Study Period is more representative of groundwater basin response to variable hydrologic conditions over time. The cumulative change in storage over the Study Period is also tabulated on Table 3-5 and represented by the graph at the bottom of the table.

For the Temescal Subbasin, the change in groundwater storage over the Study Period is estimated at -9,627 AF, an average deficit of about -642 AFY. The graph on Table 3-5 tracks the cumulative change in groundwater storage for each year of the Study Period (blue line on the graph on Table 3-5). The change in storage became negative only in the last two years of the Study Period, a time when average inflows were a little less than average (especially in 2003), but outflows increased more than 40 percent from average outflows due to increased pumping.

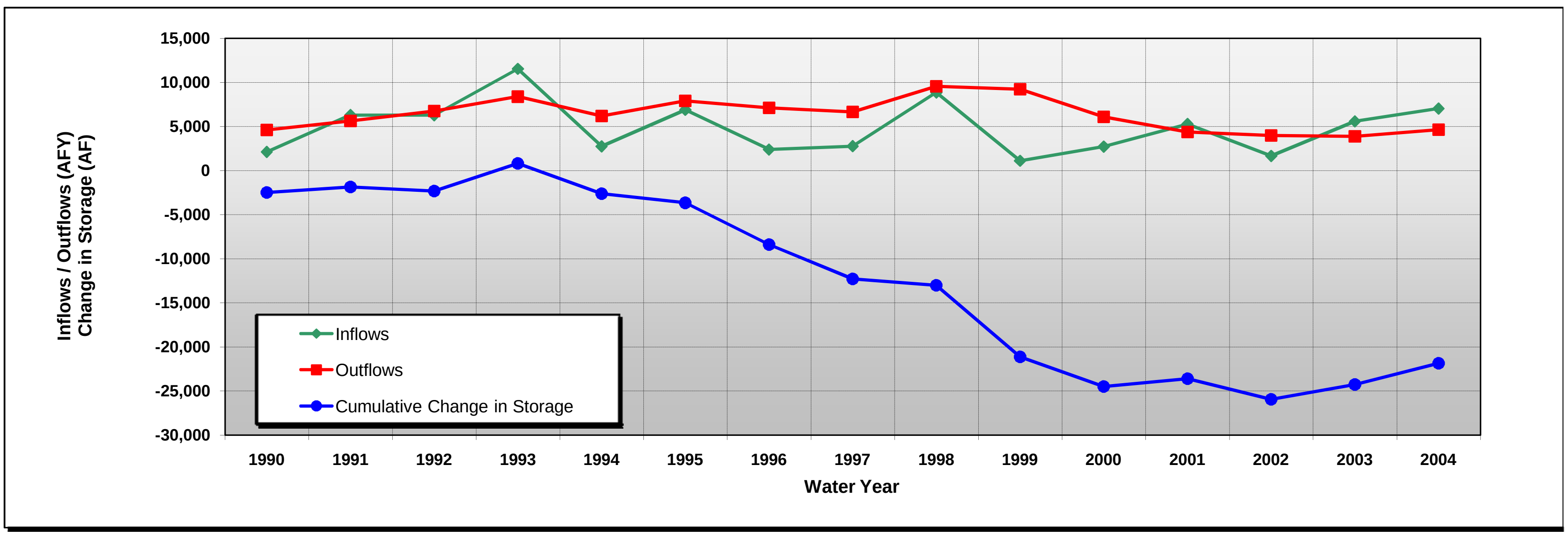
The deficit in cumulative change in storage is judged reasonable given that water levels have generally declined from 1990 to 2004. However, given that the pumping is primarily in the Channel Aquifer in the northern portion of the subbasin (Figures 16 and 18), the decline in water levels has not likely occurred on a basin-wide basis. Hydrographs in the Channel Aquifer indicate a water level decline of about 10 feet over the Study Period (e.g., Figure 23). The Channel Aquifer extends over about 3,000 acres and has an estimated specific yield of about 20 percent. Using these data and assuming an aquifer-wide water level decline, the change in storage is estimated at about -6,000 AFY. This amount is reasonably close to the average estimated change in storage in the water balance of -9,627 AFY (Table 3-5).

### 3.6.3. Coldwater Subbasin Water Balance

The water balance for the Coldwater Subbasin was initially conducted through an independent evaluation of the different components of inflow and outflow from the subbasin. The resultant change in storage was checked for reasonableness by estimating the change in storage indicated by water level fluctuations over the Study Period. The methodology for each of these steps is summarized below. Table 3-6 summarizes the water balance.

## Table 3-6
## Water Balance Summary for Coldwater Subbasin

| Water Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INFLOWS** | | | | | | | | | | | | | | | | |
| Deep Percolation from Precipitation | 69 | 434 | 548 | 1,424 | 111 | 623 | 55 | 96 | 891 | 29 | 138 | 435 | 49 | 375 | 544 | **388** |
| Subsurface Inflow from Watersheds | 4 | 13 | 28 | 576 | 1 | 24 | 1 | 3 | 42 | 0 | 3 | 27 | 1 | 11 | 14 | **50** |
| Return Flows | | | | | | | | | | | | | | | | |
| - Agriculture | 33 | 42 | 45 | 46 | 49 | 50 | 53 | 21 | 47 | 54 | 3 | 12 | 0 | 0 | 0 | **30** |
| - Urban | 127 | 159 | 169 | 149 | 135 | 121 | 165 | 166 | 200 | 162 | 160 | 143 | 121 | 118 | 160 | **150** |
| - Industrial | 226 | 183 | 149 | 112 | 95 | 98 | 124 | 132 | 143 | 210 | 42 | 129 | 158 | 189 | 324 | **154** |
| Infiltration from Runoff | 1,554 | 5,362 | 5,245 | 9,130 | 2,252 | 5,870 | 1,888 | 2,242 | 7,429 | 555 | 2,273 | 4,435 | 1,227 | 4,788 | 5,890 | **4,009** |
| Glen Ivy Hot Springs Discharge | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| **TOTAL INFLOWS (AFY)** | **2,102** | **6,283** | **6,273** | **11,525** | **2,733** | **6,876** | **2,376** | **2,751** | **8,843** | **1,099** | **2,709** | **5,270** | **1,645** | **5,571** | **7,023** | **4,872** |
| | | | | | | | | | | | | | | | | |
| **OUTFLOWS** | | | | | | | | | | | | | | | | |
| Pumping | 4,600 | 5,630 | 6,758 | 8,100 | 6,066 | 7,746 | 7,073 | 6,646 | 9,461 | 9,231 | 6,082 | 4,377 | 3,984 | 3,877 | 4,635 | **6,284** |
| Subsurface Outflow to Bedford Subbasin | 0 | 0 | 0 | 280 | 110 | 160 | 50 | 0 | 90 | 0 | 0 | 0 | 0 | 0 | 0 | **46** |
| **TOTAL OUTFLOWS (AFY)** | **4,600** | **5,630** | **6,758** | **8,380** | **6,176** | **7,906** | **7,123** | **6,646** | **9,551** | **9,231** | **6,082** | **4,377** | **3,984** | **3,877** | **4,635** | **6,330** |
| | | | | | | | | | | | | | | | | |
| **Cumulative Change in Storage (AF)** | **-2,498** | **-1,845** | **-2,329** | **816** | **-2,627** | **-3,657** | **-8,404** | **-12,299** | **-13,007** | **-21,140** | **-24,513** | **-23,619** | **-25,958** | **-24,264** | **-21,876** | |



#### 3.6.3.1. Inflows to Coldwater Subbasin

### *Deep Percolation from Rainfall*

Deep percolation was calculated over the Study Area using two steps: a runoff analysis and a soil moisture balance, using the same methodology described for the Temescal Subbasin water balance. As shown in Table 3-6, deep percolation of precipitation is estimated to average 388 AFY for the Coldwater Subbasin, or about 8 percent of the total inflows. The amount is variable from year to year and is most significant during wet years (e.g., 1,424 AFY in 1993). The amounts are slightly higher than would be anticipated for average rainfall due to the open pits, permeable surface soils, and relatively un-vegetated industrial area of gravel mining in the southern portion of the subbasin.

**Infiltration of Runoff**

For Coldwater Subbasin, large amounts of runoff are generated in the Santa Ana Mountains adjacent to the basin and, unlike Temescal Subbasin, are not funneled into concrete lined culverts. The amount of water available for recharge varies annually with changes in rainfall and runoff amounts. Runoff was estimated from the contributing watershed using the same Curve Number methodology described in the Temescal Subbasin water balance.

Runoff into the Coldwater Subbasin is subject to ET, infiltration, or continued surface flow to the local drainageway of Temescal Wash. The contributing watershed to Coldwater Subbasin is comprised of about six individual watersheds. From south to north these are Mayhew Canyon, Coldwater Canyon, Anderson Canyon, Bixby Canyon, Brown Canyon, and smaller drainages south of Bedford Canyon. The northern subbasin is more developed and contains a stormwater control system. Therefore, it was assumed that runoff from the northern watersheds (i.e., Anderson, Bixby, Brown, and smaller drainages) do not significantly contribute to groundwater recharge. Runoff from Coldwater and Mayhew canyons, however, are diverted and managed for recharge and, as such, contribute significant amounts of inflow into the subbasin. Runoff from these two individual watersheds was based on the percentage of the entire contributing watershed area represented by Coldwater and Mayhew watersheds.

Runoff from Coldwater and Mayhew canyons is captured and diverted to gravel pits or spreading areas for groundwater recharge in the subbasin (MWH, 2004). The City has constructed berms and in-stream diversion structures along Coldwater Wash (assisted by Chandler Inc., the operator of the adjacent sand and gravel mining operation). Numerous berms capture streamflow and allow for infiltration into the permeable gravels of the streambed. EVMWD diverts varying amounts of surface water runoff along Mayhew Wash to gravel pits for enhanced groundwater recharge. Some portion of the diverted water may also provide irrigation to agriculture users in the subbasin, but the amount dedicated to such use is not documented (MWH, 2004).

Although most of the Coldwater and Mayhew runoff is conserved, wet years generate large amounts of water that bypass the recharge structures and flow to Temescal Wash (in some years causing flooding of local roads). For purposes of the water balance, in years with a total of more than 6,000 AFY of runoff it was assumed 85 percent of the runoff from Coldwater and Mayhew basins infiltrate to the groundwater system leaving about 5,000 AF over the study period that could not be captured. In years generating less than 6,000 AFY, 100 percent of the runoff was assumed to infiltrate, although some large storms may not be fully captured. In addition, the ET demands of the land cover were already taken into account in the runoff calculations. The total runoff resulting in groundwater recharge is estimated to average 4,009 AFY (Table 3-6). Runoff and recharge vary significantly from year to year with changes in precipitation.

#### Subsurface Inflow from Surrounding Bedrock

Subsurface inflows from bedrock were estimated for the Coldwater Subbasin using a similar methodology as the Temescal Subbasin water balance. Inflow is estimated to average only about 50 AFY (Table 3-6). This component represents the only subsurface inflow component applicable to Coldwater Subbasin.

#### Wastewater Recharge

Glen Ivy Springs operates a spa facility in the Coldwater Subbasin. The facility discharges approximately 90 AFY (per their NPDES permit) to a diversion channel that funnels discharge into Coldwater Wash (RWQCB, 2004). This flow is retained by the City's in-stream berms and is assumed to infiltrate to the groundwater. No other discharge of wastewater is known to exist in the Coldwater Subbasin.

### *Return Flows*

Water supply available for return flows in the Coldwater Subbasin originates from several water sources. Total water supply includes groundwater pumping within the subbasin, imported water from LLWD (purchased from WMWD through Metropolitan), imported non-potable water by EVMWD from Corona Lake, and imported water from deep pumping by Glen Ivy Hot Springs (below the potable groundwater subbasin). A portion of the subbasin pumping is exported and not available for return flows within the subbasin. Groundwater pumping by the City of Corona is exported to the Temescal Subbasin. In addition, a portion of the EVMWD pumping provides water supply to the Butterfield Estates trailer park, just outside of the subbasin. The amount of exported pumping was not included in the return flow estimates for the subbasin.

#### Urban Return Flow

Urban return flows were estimated for the Coldwater Subbasin using the same methodology as used in the Temescal Subbasin. Land use data from DWR were used to identify changing urban areas during the Study Period. Urban water use was derived from total pumping plus imported water less basin exports. These exports include pumping by the City of Corona and

EVMWD, who provides water supply to Butterfield Estates located just outside of the subbasin boundary. Assuming that water use has a similar distribution as in the City of Corona, the same portion (62.7 percent) of total water supply used outdoors was assumed. Similarly, it was assumed that 10 percent of the outdoor use would contribute to return flows. As shown in Table 3-6, this methodology indicates that urban return flows in the Coldwater Subbasin average about 150 AFY.

#### Agriculture Return Flow

As documented in Table 3-6, agricultural return flows contribute only minor amounts of inflow to groundwater due to decreases in agriculture land use. Agriculture return flows in Coldwater Subbasin averages 30 AFY, but is thought to be higher prior to the beginning of the Study Period (before 2000).

#### Industrial Return Flow

Some industrial return flows are anticipated from sand and gravel mining use of groundwater. Groundwater is used to wash fines from the excavated sediments, and a portion of this water is returned to the gravel pits. Gravel mining operations are active in Coldwater Subbasin during the entire Study Period; however, pumping totals are small relative to pumping amounts by the City and EVMWD. Evaporation from the gravel pits and other losses associated with the mining operation are estimated to be small compared to the amount of water allowed to infiltrate back to the groundwater system. It was assumed 90 percent of industrial pumping becomes return flows.

### *Total Inflows*

Total inflows for the Coldwater Subbasin are much lower than inflows into the Temescal Subbasin due to the smaller areal extent and relatively closed nature of the subbasin. Accounting for all of the inflows discussed above, total inflows are estimated to range from 1,099 AFY to 11,525 AFY and average 4,872 AFY over the 2,176 acres in the subbasin (Table 3-6).

### 3.6.3.2. Outflows from Coldwater Subbasin

Outflows from the subbasin include groundwater pumping and subsurface outflow to the Bedford Subbasin under certain conditions. Pumping represents the primary outflow in the water balance (Table 3-6). During the Study Period, production in Coldwater Subbasin averaged 6,284 AFY (Table 3-6). Section 3.4 provides a more complete discussion of pumping in the Study Area. Assumptions regarding the outflow to Bedford Subbasin are described below.

#### Subsurface Outflow from Coldwater Subbasin to Bedford Subbasin

The North Glen Ivy fault forms the subbasin boundary between Coldwater and Bedford subbasins. Details of where and under what conditions groundwater moves across the fault are not well understood. However, it is likely that when groundwater outflow occurs, it does so in the central portion of the subbasin, based on natural surface water drainageways, topography, and the incised nature of shallow sediments and bedrock in the area. Estimates of subsurface outflow across the fault have been made by MWH (2004), which were interpreted to occur only in times of relatively high water levels. Those estimates were determined to be reasonable for this water balance and are incorporated for years in which outflow is estimated to occur (Table 3-6). These outflows are estimated to range between 50 AFY and 280 AFY and average only 46 AFY over the Study Period (Table 3-6). Declining water levels have resulted in a relatively closed basin over the last few years and it is assumed that during this time, subsurface outflow does not occur.

As shown on Table 3-6, total outflows from the Coldwater Subbasin are estimated to average 6,330 AFY over the Study Period. This amount exceeds inflows by an average of 1,458 AFY.

#### 3.6.3.3. Change in Groundwater Storage in Coldwater Subbasin

The change in storage in the Coldwater Subbasin indicates a larger deficit in storage (Table 3.6) than occurred in Temescal Subbasin over the Study Period. The water balance indicates a cumulative loss of groundwater storage of about -21,876 AFY, an average deficit of about -1,629 AFY. To compare this deficit with declining water levels, a groundwater storage change was computed using water levels and subbasin hydrographs (e.g., Figure 24). These graphs indicate a decline in water levels of about 100 feet from 1990 to 2004, likely concentrated in the western subbasin where pumping occurs. Using a specific yield of 20 percent in the sediments where the decline has occurred and applying the deficit over approximately one-half of the subbasin, the change in storage over the Study Period is estimated at -21,760 AF. This estimate is consistent with the deficit predicted from the water balance. In addition, the graph on Table 3.6 showing the cumulative change in storage mimics the shape of the water level hydrograph on Figure 24 for the Study Period. This agreement provides additional confirmation of the average water balance estimates.

### 3.6.4. Water Balance Discussion

The results of the water balances indicate a negative change in storage at average pumping conditions in both Temescal and Coldwater subbasins over the Study Period. This indicates that more water is being withdrawn from the subbasins than will be naturally replenished over time, a condition referred to as overdraft. The water balances also provide a preliminary assessment for the operational range of the subbasins. Assuming no other significant changes in the water balance, average pumping totals of about 12,000 AFY in Temescal Subbasin indicate no significant loss of groundwater storage. For Coldwater Subbasin, average pumping totals around 4,500 AFY also indicate no significant loss of groundwater storage. These estimates are simplistic and do not take into account other changes in the water balance resulting from pumping decreases (such as potential increases in subsurface outflow or reduced return flows). Nonetheless, they provide a preliminary estimate for guiding management scenarios.

Although the Study Period is conservative, containing slightly below-average precipitation and ending with drought conditions, neither the Temescal or the Coldwater subbasin appears to be sustainable at the average pumping amounts unless additional recharge (natural or enhanced) can be captured. With an expected increase in demand associated with City build out, management strategies will be necessary to use the groundwater resource in a sustainable manner. An evaluation of current and future water demand as well as additional sources of water supply are provided in the following section.

# 4. City of Corona Water Demand and Supply

In order to manage the groundwater resource and provide for planned growth associated with build out, the City has examined current and future demand as well as water supply from other sources. Demand increases are categorized by water use type through 2030. The City is also taking measures for water conservation and demand management. Collectively, these data are summarized in previous City evaluations presented in their Water Master Plan (AKM, April 2005) and their Urban Water Management Plan (AKM, December 2005) and have been updated for this GWMP.

## *4.1. Current and Future Demand*

The City has a wide array of water users, classified by sectors: residential single-family, residential multi-family, commercial, industrial, institutional/governmental, landscape, and agricultural. Total current water demand is 45,600 AFY (not including water transfers wheeled to the City of Norco and Western Municipal Water District in Calendar Year 2007). This represents a 15 percent increase from 2000 usage of 39,634 AFY.

Ultimately the City anticipates a total demand of 51,631 AFY by the year 2020 (projected City build out). In addition to use demand, the City must also account for spent filter backwash (from the Lester and Sierra del Oro water treatment plants) and brine reject (from the Temescal Desalter), which is currently 2,300 AFY. This amount is expected to increase to 2,954 AFY by 2020. A brief summary of the categories of water users and expected changes in the future are described below and summarized on Table 4-1.

**Residential – Single-Family**

In the City of Corona, a single family residential customer averages 3.5 persons per connection. Corona is a suburban community with approximately 30 percent of its acreage comprised of residential use. Total system consumption for this sector was 22,863 AF in 2000. Current consumption levels are at 28,000 AFY and are expected to ultimately increase 16 percent by year 2020 to 32,471 AFY. At build out, the single family residential water use will represent 63 percent of the total demand.

**Residential – Multi-Family**

Multi-family residential customers average 3.35 persons per household. Like the single-family residential sector, the multi-family sector is expected to experience significant growth over the next 15 years, but total demand is significantly less than for the single family sector. Currently the multi-family residential sector is using 4,000 AFY from 1,600 connections and is expected to increase to a total sector usage of 9,048 AFY with 3,601 connections by 2020.

#### Commercial

The City has a large mix of commercial customers that are categorized as general commercial, office professional, and downtown commercial. General commercial accommodates many commercial uses that service the community such as department stores, banks, supermarkets, and retail stores. Office professional includes general business, finance, insurance, real estate, and medical offices. Downtown commercial is intended to create a pedestrian-oriented street environment with such uses as retail shops, offices, services, cultural facilities, entertainment, and civic and public uses. Current commercial water use has grown about 18 percent to 1,700 AFY since the year 2000 and will ultimately grow to 1,980 AFY by 2020.

#### Industrial Sector

Corona has a large industrial base that is centered on high-tech and manufacturing. The industrial sector has increased water usage by 19 percent from 2000 to present and accounts for 3,200 AFY. This usage is expected to grow to 3,679 AFY by 2020.

#### Institutional/Governmental

The City has a stable institutional and government sector, primarily local government, schools, visitor services, and a public hospital. This sector will keep pace with the growth of the city.

#### Landscape

Landscape water use would be expected to increase with the growth of the city, fueled mainly by residential development. But increased efficiency and landscape conversions occurring at existing parks, golf courses, and cemeteries should help offset new demand and result in decreased water use in the future. Additional information on the City's water conservation and demand management efforts are described in Section 6.1.9 (management strategy 25).

#### Agriculture

Agricultural water demand has declined over the past 20 years, but is projected to remain fairly constant over the next 20 years. The City's General Plan reflects local citizen interest in space, quality of life, environmental values, and the long-term maintenance of a diverse economic base. It is projected that these objectives will be met with urban uses and open space rather than with agricultural land.

**Table 4-1**
**City Current and Future Demand (AFY)**

| Year | Water Use Sectors | Single Family | Multi-Family | Comm. | Ind. | Special Acct. | Instit./ Gov. | Land-scape | Ag. | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | No. of accounts | 33,616 | 1,355 | 277 | 515 | 3 | 9 | 583 | 35 | 36,393 |
| | Deliveries AFY | 22,863 | 3,405 | 1,443 | 2,679 | 666 | 82 | 3,230 | 480 | 39,634* |
| 2005 | No. of accounts | 38,164 | 1,538 | 315 | 584 | 3 | 11 | 662 | 40 | 41,317 |
| | Deliveries AFY | 25,956 | 3,866 | 1,638 | 3,042 | 756 | 93 | 3,668 | 545 | 45,000* |
| 2010 | No. of accounts | 42,593 | 3,213 | 339 | 631 | 3 | 10 | 485 | 34 | 47,308 |
| | Deliveries AFY | 28,968 | 8,072 | 1,766 | 3,282 | 740 | 79 | 2,686 | 468 | 46,062 |
| 2015 | No. of accounts | 44,140 | 3,329 | 352 | 654 | 3 | 10 | 502 | 35 | 49,026 |
| | Deliveries AFY | 30,020 | 8,366 | 1,831 | 3,401 | 767 | 82 | 2,783 | 485 | 47,735 |
| 2020 | No. of accounts | 47,743 | 3,601 | 380 | 707 | 4 | 11 | 543 | 38 | 53,028 |
| | Deliveries AFY | 32,471 | 9,048 | 1,980 | 3,679 | 830 | 89 | 3,010 | 524 | 51,631 |
| 2025 | No. of accounts | 47,743 | 3,601 | 380 | 707 | 4 | 11 | 543 | 38 | 53,028 |
| | Deliveries AFY | 32,471 | 9,048 | 1,980 | 3,679 | 830 | 89 | 3,010 | 524 | 51,631 |
| 2030 | No. of accounts | 47,743 | 3,601 | 380 | 707 | 4 | 11 | 543 | 38 | 53,028 |
| | Deliveries AFY | 32,471 | 9,048 | 1,980 | 3,679 | 830 | 89 | 3,010 | 524 | 51,631 |

*Total deliveries include sales/transfers to the City of Norco and WMWD.

## *4.2. Water Conservation and Demand Management*

The City recognizes the importance of continuing current efforts for conserving water and decreasing demand. As such, they became a signatory to the California Urban Water Conservation Council (CUWCC) MOU in 1996 and are committed to implementing the 14 Best Management Practices (BMPs) in the MOU. The City has retained a Water Conservation Coordinator to lead these efforts.

The City and the Water Conservation Coordinator have developed and implemented an extensive water conservation education system, including a dedicated education center at the City's treatment plant. Materials and information on water conservation have been prepared and presented in schools (K-12) across the City. Last month alone, the Coordinator interacted with about 500 children in connection with numerous education programs, a total representative of a typical month. These programs not only provide basic information to younger children (typical of many programs), but also specifically develop material to target grades 6 through 12. It is more difficult and time-consuming to prepare materials for the older grade levels because much more detail is required. However, targeting the older children provides a higher level of education and potentially more benefits in promoting good stewardship of their water resource.

The City also sponsors numerous events that are focused on water. In May, the City held their third annual Water Festival, an event that attracts about 1,500 attendees. The City has also developed a Water Wise landscape award that is publicized to encourage residential responsibility. In addition to their own events and programs, the City participates in water conservation programs developed by Metropolitan and WMWD.

Since the single-family and multi-family residential sectors represent the largest growth in demand over the next 15 years, the City of Corona has implemented a water use efficiency program to offset increasing water demands. The program strives to increase water use efficiency by supporting water use surveys for residential and public facilities, ultra low flush toilet replacement, and educational/informational programs. Increased efficiency and landscape conversions occurring at existing parks, and golf courses should help offset new demand and result in decreased future water use for landscape irrigation.

## 4.3. Supply

The City water system contains potable water from two sources: local groundwater and imported water. The groundwater source includes the three groundwater subbasins described in this GWMP. The source of the imported water is the Colorado River and State Water Project water supplied by Metropolitan and purchased through WMWD. The supply obtained from each groundwater well and imported water sources from 1990 through 2007 is summarized in Table 4-2 and discussed in the following sections.

**Table 4-2**
**Water Production and Purchases (AFY)**

| Source of Supply | Well # | 1990 | 1995 | 2000 | 2002 | 2004 | 2007 |
|---|---|---|---|---|---|---|---|
| **Coldwater Basin** | 1 | 1,062 | 1,685 | | 0 | 0 | 0 |
| | 2 | 0 | 1,191 | | 0 | 0 | 0 |
| | 3 | 1,024 | 1,391 | 506 | 0 | 380 | 1,083 |
| | 20 | 0 | 0 | 0 | 0 | 0 | 430 |
| | 21 | _ | _ | 3,493 | 2,579 | 2,400 | 2,004 |
| | *Subtotal* | *2,086* | *4,267* | *3,999* | *2,579* | *2,780* | *3,517* |
| **Temescal Subbasin (including Well 4 in Bedford Subbasin)** | 4 | 253 | 173 | 0 | 0 | 0 | 0 |
| | 6 | 535 | 588 | 436 | 27 | 0 | 0 |
| | 7 | 531 | 654 | 876 | 12 | 0 | 0 |
| | 7A | 0 | 0 | | 15 | 1,202 | 1,149 |
| | 8 and 8A | 1,164 | 1,737 | 1,654 | 1,517 | 2,081 | 1,812 |
| | 9 and 9A | 650 | 467 | 554 | 14 | 2,480 | 1,443 |
| | 11 | 316 | 408 | 354 | 123 | 501 | 553 |
| | 12A | 134 | 0 | 0 | 614 | 575 | 477 |
| | 13 | 886 | 0 | 0 | 0 | 231 | 699 |
| | 14 | 75 | 310 | 534 | 674 | 645 | 635 |
| | 15 | 761 | 1,150 | 1,633 | 870 | 1,480 | 1,122 |
| | 17A | 1,059 | 1,349 | 959 | 954 | 454 | 1,701 |
| | 19 | _ | _ | 2,123 | 2,184 | 1,497 | 1,696 |
| | 22 | 0 | 0 | 0 | 4,465 | 2,885 | 2,343 |
| | 23 | _ | _ | _ | _ | _ | 0 |
| | 24 | 0 | 0 | 0 | 679 | 200 | 394 |

| Source of Supply | Well # | 1990 | 1995 | 2000 | 2002 | 2004 | 2007 |
|---|---|---|---|---|---|---|---|
| | 25 | 0 | 0 | 0 | 3,686 | 2,386 | 1,334 |
| | 26 | 0 | 0 | 0 | 1,383 | 996 | 934 |
| | 27 | 0 | 0 | 0 | 0 | 253 | 184 |
| | 28 | 0 | 0 | 0 | 0 | 1,369 | 2,324 |
| | *Subtotal* | *6,111* | *6,663* | *9,123* | *17,217* | *19,235* | *18,800* |
| **Metropolitan Raw Water** | WR – 19 | 11,574 | 6,373 | 13,920 | 12,384 | 11,452 | 15,638 |
| | WR – 29 | 451 | 463 | 0 | 0 | 0 | 0 |
| | WR – 33 | 5,471 | 4,661 | 6,258 | 3,924 | 3,039 | 3,919 |
| | WR – 24 | _ | 3,797 | 6,334 | 7,593 | 7,451 | 4,957 |
| **Metropolitan Treated Water** | Lee Lake | _ | _ | _ | _ | 98 | 43 |
| | *Subtotal* | *17,496* | *15,294* | *26,512* | *23,901* | *22,040* | *24,557* |
| **Total** | | **25,693** | **26,224** | **39,634** | **43,697** | **44,055** | **46,874** |

### 4.3.1. Groundwater Basins

The City relies on the underlying groundwater for an increasing percentage of its total water supply. The City currently maintains and operates 21 production wells for its municipal potable water supply: 18 wells in the Temescal Subbasin, 3 wells in the Coldwater Subbasin, and 1 former well in the Bedford Subbasin (recently abandoned).

As previously discussed, most of the City's production is from the Channel Aquifer in the Temescal Subbasin. Typical depths for the City's wells in the Temescal Subbasin range from about 200 to 500 feet deep with screens as shallow as about 100 feet below ground surface. The combined capacity of the 18 Temescal Subbasin wells is approximately 23,405 gpm (about 38,000 AFY). Seven of these wells have been installed in the past five years (Wells 22, 23, 24, 25, 26, 27, and 28) to replace older wells and provide additional supply to the Temescal Basin Desalter for the improvement of water quality in the region.

The City pumps about 3,500 AFY from the Coldwater Subbasin from three active wells. The City also acquired the rights to the surface flows of Coldwater Canyon in 1964 when it purchased the assets of the Corona City Water Company (CCWC). To meet regulatory requirements, runoff from the canyon is recharged through in-stream percolation ponds along Coldwater Wash. The City of Corona and EVMWD pump most of the groundwater extracted from the Coldwater Basin.

The City does not currently produce groundwater from the Bedford Subbasin, but has done so in the past at Well 4 located near WWTP 3. Although this well has been recently abandoned, the City has plans to re-drill in the Bedford Subbasin for future water supply.

The three subbasins from which the City extracts groundwater are not adjudicated. However, under a stipulated judgment entitled *Orange County Water District vs. City of Chino, et al*. (1968), the City, with other purveyors upstream of Prado Dam, have the right to use all surface and groundwater supplies originating above Prado Dam without interference from water purveyors downstream of Prado Dam, provided that the average adjusted base flow at Prado Dam is at least 42,000 AFY. WMWD is one member of a watermaster panel that administers provisions of this judgment. To ensure provisions of the judgment, the City is required to provide a base flow of 1,625 AFY (adjusted for water quality) from the City's WWTP.

The City of Corona has increased the production of local water relative to imported water. In 2000 the groundwater production accounted for 33 percent of the total supply. Last year in 2007 groundwater accounted for 50 percent of total water supply (not including water supplied to the City of Norco or WMWD), which is a 51 percent increase in local production since 2000. Looking forward, Corona would like to maintain an approximate 50 percent groundwater allocation for their water supply by year 2020. Based on the water balance provided in Section 3.6, current groundwater basin conditions in Temescal and Coldwater subbasins cannot support this level of production without significant enhanced recharge.

### 4.3.2. Imported Water

The City's imported water is supplied by Metropolitan and purchased through WMWD, a member agency of Metropolitan. The imported supply is delivered to the City through two separate pipelines. The Lower Feeder Pipeline supplies raw imported water to the City's Lester and Sierra del Oro water treatment plants (WTPs) through metered turnouts (WR-19 and WR-33 respectively). The Mills Pipeline delivers treated imported water directly to the City through a metered turnout (WR -24).

Turnout WR-19 is located in Chase Drive, east of Lester Avenue. The flow from this turnout is typically delivered by gravity to the City's Lester WTP located on Rimpau Avenue. The Lester Raw Water Booster Pump Station provides additional pumping head when the pressure in the Lower Feeder is not sufficient to deliver flow to the plant by gravity. This treatment plant has a firm treatment capacity of 25 million gallons per day (MGD) with a peak capacity of 30 MGD. In addition, current delivery constraints limit the treatment plant's capacity to 30 MGD. The hydraulic grade line at the turnout depends on the operation and flow through the Lower Feeder pipeline. Based on observed pressures at the turnout, the hydraulic grade is around 1,075 feet msl.

Turnout WR-33 is connected to the Lower Feeder near Montana Ranch Road. WR-33 delivers raw water to Sierra del Oro (SDO) WTP located on Wilderness Circle via the SDO Raw Booster Station located on Montana Ranch Road. The SDO WTP has a firm treatment capacity of 6 MGD (9.1 MGD Peak). The estimated operating hydraulic grade elevation at this turnout is 1,070 feet msl, based upon the observed inlet pressure of 56 pounds per square inch (psi) and turnout elevation of 940 feet msl.

Turnout WR-24 is connected to the Mill's Pipeline at Temescal Canyon Road and La Gloria Road. The turnout is at elevation 890 feet msl and provides water to the City at a minimum hydraulic grade elevation of 1,380 feet msl. Corona's maximum allotment for this turnout is approximately 6.5 MGD (10 cfs). WR-24 delivers potable water to Zones 3, 4 and 5. Turnout locations and capabilities are summarized in Table 4-3.

**Table 4-3**
**Imported Water Service Connections**

| Service Connection | Location | Elevation (Ft, msl) | Approx. Hyd. Grade Elev. (Ft, msl) | Max. Capacity (MGD) | Service Zone(s) |
|---|---|---|---|---|---|
| WR-19 (Lester WTP Supply) | Chase Dr East of Lester | 945 | 1,075 | 30 | 3 |
| WR-33 (SDO WTP Supply) | 1670 Montana Ranch Rd West of Green River Rd | 940 | 1,070 | 9.1 | 3 |
| WR-24 (Mills Pipeline) | Temescal Cyn Rd at La Gloria Rd | 890 | 1,380 | 6.5 | 3, 4, 5 |

The City also purchases a small amount of water from LLWD through the Mill's Pipeline at the City's Lee Lake connection. This water serves City customers near Weirick Road west of Temescal Canyon Road in the Bedford Subbasin.

The total combined supply capability of imported water is approximately 45.6 MGD (about 31, 666 gpm), which exceeds the estimated ultimate peak hour demand of 33.8 MGD (23,440 gpm). Assuming total capacity and available water, imported water supply could be as high as about 47,000 AFY.

Recent developments have added some uncertainty regarding the reliability of imported water from the State Water Project (SWP). A U.S. District Court decision in May 2007 ruled that the existing 2005 biological opinion for Delta smelt, issued by the U.S. Fish and Wildlife Service (USFWS), did not comply with the federal Endangered Species Act. The biological opinion guides pumping operations for the SWP to ensure no long-term jeopardy to the health and habitat of Delta smelt. The Court ordered certain interim "remedies" or actions to protect endangered fish species until a revised biological opinion is prepared by the USFWS. These remedies collectively amount to cuts in statewide water supply for about one year (Calendar Year 2008). The long-term effect of the court decision is not known, but with these cuts, the availability of SWP water may be impacted, especially during drought cycles. Even though the City relies less on SWP for its imported water supply, these changes may result in increased competition for other imported water supplies.

### 4.3.3. Recycled Water

The City's recycled water system will ultimately consist of four service zones, four reservoirs, four booster pump stations, four pressure reducing valves and one surge anticipator valve, a portion of which is currently under construction. The existing recycled water distribution system consists of approximately 180,183 feet of pipe ranging from 4-inches to 24-inches in size. Approximately 31,531 feet of pipe is expected to be added to the system in the future.

The City expects recycled water demand to increase in the future and can currently supply up to 4,200 gpm (about 6,780 AFY). In addition, the source is seen as a reliable supply for recharging the groundwater subbasins to increase yield. Future expansions at the City WWTPs will increase recycled water supply by an additional 7,630 gpm (about 12,310 AFY), bringing the total future capacity to 11,830 gpm (about 19,090 AFY). These expansions will allow for increased recycled water for both irrigation and enhanced groundwater recharge (through basins and/or wells).

# 5. Basin Management Objectives

The City recognizes the need for more active groundwater management to maintain and protect the resource for reliable water supply. Establishing basin management objectives (BMOs) can provide a clear direction for the implementation of management activities such as pumping distribution and enhanced groundwater recharge. BMOs outline the water level and water quality conditions that are acceptable in the basin, address conditions that need to be remedied, and identify changes in the groundwater basin that need to be avoided. In consideration of the state of the groundwater basin and the water supply goals of the City, the following BMOs are proposed.

## *5.1. Manage Groundwater Basin in a Sustainable Manner*

The City wishes to use groundwater as a long-term reliable supply and recognizes the importance of sustainability. As such, the City supports the operation of the basin such that natural or enhanced recharge can replenish the groundwater extracted on an average basis over time. This management objective recognizes the current overdraft conditions in the subbasins and proposes to adopt management strategies to move toward more sustainable use.

The perennial yield of a groundwater basin is defined as the amount of water that can be extracted on an average basis over time without adverse impacts (Todd and Mays, 2004). Because the term *adverse impacts* is defined on a site-specific basis and may change over time, the perennial yield of a groundwater basin may also change over time. The term *sustainable yield* suggests that a net decline in groundwater storage over some period of time such as an average hydrologic cycle would be an adverse impact and the goal of sustainability is to eliminate such declines. The sustainable yield of a groundwater basin is difficult to define in the absence of reliable, long-term data on all aspects of the water budget. In addition, the sustainable yield is not a fixed amount and can be altered by changes in inflows or outflows to the basin. This GWMP provides preliminary estimates on sustainable yield, but the actual yield will be better defined in the future as changes in operation and improved monitoring concurrently occur.

## *5.2. Prevent Substantial Water Level Declines in Channel Aquifer*

Given the unconfined nature, shallow occurrence, and relatively limited thickness of the Channel Aquifer, water level declines are especially problematic. As water levels drop, the aquifer is de-watered and well yields are adversely affected. Some water level declines can be tolerated during drought conditions if groundwater is sufficiently replenished when recharge is available. As a preliminary operational guideline, the aquifer should be operated to prevent water level declines below about 50 percent of the total aquifer thickness. Assuming an average thickness of about 200 feet, then water levels should be maintained at least 100 feet above the bottom of the aquifer. The bottom of the aquifer is estimated to occur between about 400 to 450 feet msl, so water levels should be maintained above 500 to 550 feet msl across the aquifer. This lower limit is consistent with the range of historical water levels in the area.

## 5.3. Protect Groundwater Quality in Unconfined Aquifers

The unconfined aquifers on which the City relies are subject to impact from the quality of water infiltrating from the surface. Given the urbanized setting over the Channel Aquifer, this area is especially sensitive to future impact. Once water quality has been compromised, the resource may be subject to loss of use or expensive water treatment processes.

## 5.4. Maintain Required Outflow at Prado Dam

The stipulated judgment in *Orange County Water District vs. City of Chino, et al.* (1968) requires the City to contribute a baseflow of 1,625 AFY (adjusted for water quality) to the Santa Ana River. Depending on water quality the amount may be as high as 2,240 AFY (Boyle, 2001). Current subbasin outflow is significantly more than required, but basin management activities may reduce the total amount. The City wants to ensure that the required outflow continues to be provided in compliance with the judgment.

## 5.5. Monitor Groundwater Levels, Quality, and Storage

In order to continue to analyze current groundwater conditions and track changes in the groundwater basin resulting from active management activities, the City would like to expand and improve their monitoring program. The monitoring program would improve the understanding of groundwater level fluctuations, potential impacts to groundwater quality, and changes in groundwater storage across the three subbasins of interest.

# 6. Basin Management Strategies

## 6.1. Identification of Management Strategies

The following groundwater management strategies have been identified as having potential for improving the management of the groundwater basins. The 24 strategies have been grouped into seven categories involving similar facilities or locations, and are numbered for easy reference. The eight categories of management strategies are listed below:

- New and Replacement Water Supply Wells and Wellhead Treatment
- Groundwater Treatment Process Improvements
- Groundwater Monitoring Program
- Enhanced Groundwater Recharge
- Expanded Use of Recycled Water
- Use of Imported Water
- Wastewater Pond Maintenance
- Coordination with Regulatory Agencies

Specific strategies are listed in Table 6-1 and described in the following text. The strategies are not listed in order of priority. In addition, some strategies overlap those in other categories. For example, injection wells for groundwater recharge are listed as both a strategy for enhanced recharge and a strategy for expanded use of recycled water.

**Table 6-1 List of Management Strategies**

| Management Strategies | |
|---|---|
| 1 | New Water Wells |
| 2 | Replacement Water Wells |
| 3 | Rincon Groundwater Treatment Project |
| 4 | Wellhead Treatment for Wells Impacted with VOCs |
| 5 | El Sobrante Groundwater Treatment Project |
| 6 | Groundwater Treatment Program |
| 7 | Groundwater Blending Program |
| 8 | Improvement of Groundwater Quantity/Quality Monitoring Program |
| 9 | Coldwater Subbasin Enhanced Recharge Project |
| 10 | Recharge Basins within the Oak Avenue Detention Basin |
| 11 | Recharge Basins within the Main Street Detention Basin |
| 12 | Upgradient Injection Wells |
| 13 | Recycled Water Injection Wells |
| 14 | Recycled Water Zone 3 to Zone 2 Interconnect |
| 15 | Recycled Water Zone 4 to Zone 3 Interconnect |
| 16 | WWTP2 Upgrade to Tertiary |
| 17 | WWTP1A Upgrade to Tertiary |
| 18 | Lee Lake Water District Recharge to Bedford Subbasin |
| 19 | Use of Recycled Water as In-Lieu Pumping |
| 20 | Purchase of Metropolitan Water District In-Lieu Water |
| 21 | Pipeline to Convey Metropolitan Water District In-Lieu Water to Border Avenue Recycled Water Reservoir |
| 22 | Lincoln and Cota Street Percolation Ponds Maintenance Program |
| 23 | Coordinate with Riverside County on Water Quality and Well Construction |
| 24 | Coordinate with the Regional Water Quality Control Board on Water Quality |
| 25 | Continue and Expand Water Conservation and Demand Management |

### 6.1.1. New and Replacement Water Supply Wells and Wellhead Treatment

Strategies under this category provide for re-distribution of pumping within the Temescal Subbasin aquifers, use of poorer-quality groundwater, capturing a larger percentage of groundwater discharge from the subbasin, and replacing older less-efficient wells. Facilities associated with these strategies include new wells, wellhead treatment, conveyance to the distribution system, and conveyance to brine disposal lines.

### 1. New Water Wells

In order to more effectively distribute pumping throughout the aquifer, the City is currently planning for the construction of one new water production well every two to three years. These new wells will enhance the City's production of groundwater during drought periods when imported water is limited. Additional wells will also allow for more flexibility in the maintenance of water levels in the Channel Aquifer. Wells will be located to pump within permeable aquifer zones while minimizing well interference. Wells will also be located to capture a portion of groundwater discharge that is currently exiting the groundwater basin, thereby increasing the basin yield.

### 2. Replacement Water Wells

The State Controller's Office lists the service life of water wells at 30 years. The City has eight water wells that have exceeded the 30-year service life. The City plans for one replacement water well about every three years.

### 3. Rincon Groundwater Treatment Project (wells plus treatment)

The Rincon project is in an area of historically high nitrate concentrations and the addition of wellhead treatment facilities will allow for expanded use of this poorer quality water. This project is scheduled for fiscal year of 2015-2016 at a projected cost of $15,000,000, reflecting the added costs of groundwater treatment. The proposed location is in the vicinity of Rincon Street and Alcoa. The project will yield 5,000 AFY to the current potable water system. The specific components of the project are three new wells, a raw water pipeline, a treatment process involving selective resins or best available technology (BAT) to reduce nitrate concentrations, a 6,500 sq. ft. building to house the process, a product pipeline, property acquisition, and brine disposal to the Santa Ana Regional Interceptor (SARI) pipeline.

### 4. Wellhead Treatment for Wells Impacted with Volatile Organic Compounds (VOCs)

Water quality in City Wells 7 and 17 appears to be threatened by groundwater plume(s) containing trichloroethene (TCE) and other VOCs migrating from an industrial area in eastern Temescal Subbasin. The City is evaluating the need to install a granular activated carbon (GAC) system or other groundwater treatment system to mitigate contamination at these production wells. Production here would also provide some containment of the continued migration, but additional data are necessary for a complete evaluation. More complete containment could be accomplished with new, properly-placed production wells in the area. This strategy is proposed as the El Sobrante Groundwater Treatment Project, described below.

#### 5. El Sobrante Groundwater Treatment Project (wells plus treatment)

The El Sobrante project would target an area of impacted groundwater quality and, through proven treatment technologies, improve the quality for beneficial use. The project is currently scheduled for fiscal year of 2020-2021 at a projected cost of $20,000,000, reflecting the high cost of groundwater treatment. The proposed location is in the vicinity of Sixth Street and El Sobrante. The project will yield 5,000 AFY to the current potable water system. The specific components of the project are three new wells, a raw water pipeline, a GAC pre-treatment system to reduce TCE in the extracted groundwater, followed by a treatment process which will be selective resins or BAT to reduce nitrates in the groundwater pumped, a 6,500 sq. ft. building to house the process, a product pipeline, property acquisition, and brine disposal to the SARI pipeline.

### 6.1.2. Groundwater Treatment Process Improvements

Strategies for this category provide for increased treatment capacity to improve the quality of the water supply and the groundwater basin by reducing nitrates and salts in the ambient groundwater. Improving the quality of the water supply reduces the subsequent loading of these constituents in groundwater from wastewater return flows, thereby benefiting the groundwater basin.

#### 6. Groundwater Treatment Program

The City currently operates the Temescal Desalter to reduce salts in the City's water supply. Expansion of the groundwater treatment program is needed to maintain long term water quality and usable supply. The amount of treated groundwater can be increased without additional facility expansion at this time.

#### 7. Groundwater Blending Program

The City has an on-going nitrate blending program that is closely coordinated with the RWQCB and requirements of the City's salt management plan. Groundwater with elevated nitrate is blended with imported water or groundwater with lower nitrate levels. This allows groundwater extraction to occur in areas of high nitrate levels resulting from historical activities including agriculture.

### 6.1.3. Groundwater Monitoring Program

The goal of the monitoring program is to support the long-term sustainability and protection of the groundwater resource. The objectives of the monitoring program are to better understand groundwater conditions, monitor the impacts of groundwater use, identify changes to groundwater quality, and evaluate the performance of management actions. The potential need for improved surface water monitoring and subsidence monitoring will also be evaluated.

#### 8. Improvement of Groundwater Quantity/Quality Monitoring Program

The City desires to improve the current groundwater monitoring program to track water levels, groundwater quality, and groundwater storage throughout the subbasins and over time. Improvements involve the addition of dedicated monitoring wells that are not used for groundwater extraction. These wells provide a better representation of basin water levels and are not as influenced by near-well pumping depressions. The program involves the development of specific monitoring protocols including monitoring locations, frequency, measurements, sampling procedures, data management, and quality assurance/quality control measures. Current monitoring program and protocols are summarized in Appendix B with recommendations for future improvements.

### 6.1.4. Enhanced Groundwater Recharge

In order to increase basin yield and replenish extracted water, an increase in groundwater recharge is needed in all of the subbasins in this GWMP. Strategies for enhancing groundwater recharge involve the use of surface recharge basins, recharge wells, and in-lieu pumping when imported water is available. Sources of recharge water include stormwater, imported water and recycled water. Strategies that are more closely related to recycled water are repeated and expanded in the next section on recycled water.

#### 9. Coldwater Subbasin Enhanced Recharge Project

The City may wish to implement an enhanced recharge project to enhance the quantity and quality of groundwater in the Coldwater Subbasin. Currently the City manages recharge in Coldwater Wash along a reach south of Glen Ivy Road. This enhanced recharge is accomplished through a series of in-stream berms that retain streamflow, allowing for increased percolation. Only high flows during wet years are not captured; these flows have been observed to contribute to local flooding of roads and may represent an opportunity for additional recharge water. The City may wish to work with Riverside County Flood Control District to investigate methods of capturing these additional flows.

In addition to Coldwater Wash, there may be additional drainages where natural recharge could be increased. It is our understanding that runoff from Mayhew Canyon to the south is being diverted and recharged by EVMWD, and additional opportunities for increasing recharge along that drainage may be limited. Some runoff along drainages in the northern subbasin (Anderson, Bixby, and Brown Canyons) may be available for enhanced recharge in the future, but additional analysis is required. These drainages are located in a relatively dense residential area and have been modified for flood control. Enhanced recharge would likely involve diversions to a recharge area rather than in-stream berms.

### 10. Recharge Basins within the Oak Avenue Detention Basin

The Oak Avenue Detention Basin is a large stormwater basin located at the mountain front near Oak Avenue and Chase Drive. The basin is operated for flood control by RCFCWCD. According to a pilot study conducted by the City (PBSJ, 2004), a recharge basin constructed within the larger detention basin is capable of receiving and percolating about 2,500 AFY. If another similar recharge basin were constructed in the detention basin, recharge could be potentially increased to as much as 4,000 or 5,000 AFY. In addition to optimizing the recharge of stormwater, recycled water or imported water could be conveyed to the detention basin for recharge. The City has had discussions with RCFCWCD in the past about cooperating in a groundwater recharge project. This strategy would require stormwater monitoring and continued coordination with RCFCWCD to ensure compatibility in operation of the facility for both flood control and recharge. Facilities to convey recycled water are described in the recycled water strategies below.

### 11. Recharge Basins within the Main Street Detention Basin

Another flood control basin, the Main Street Detention Basin, could also be configured for additional groundwater recharge. The detention basin is located near Main Street and Upper Drive and functions to reduce peak flows into the lined channels of the City's stormwater management system. According to a pilot study conducted by the City (PBSJ, 2004), a recharge basin constructed within the larger detention basin is capable of receiving and percolating about 500 AFY. If two additional basins were constructed at the site, the quantity recharged could be tripled to about 1,500 AFY. Implementation of this strategy will require stormwater monitoring and may also involve potential cleanup work within the basin. Similar to the Oak Avenue basin, any evaluation for implementing a recharge strategy at the Main Street basin will require ongoing coordination with RCFCWCD.

### 12. Upgradient Injection Wells

Enhanced recharge through wells is an option for increasing yield to the groundwater basin. Although exact locations have not yet been determined, recharge would most likely be effective at the upgradient portion of the Channel Aquifer, near the Arlington Gap. Recharge wells would need to be located to minimize interference with inflow from the adjacent Riverside-Arlington Subbasin. Although the inflow has been observed to contain elevated nitrate concentrations, the area represents a major source of recharge water to the Channel Aquifer. Potable water, recycled water, or blended water could be injected into these wells. Specific components at each site would include a well, well head, down-comer pipes, flow metering, supply piping, flow control and pressure reducing valve, and air relief system.

### 6.1.5. Expanded Use of Recycled Water

The management strategies in this GWMP provide for the expanded treatment and use of recycled water. Given the potential restrictions on imported water and highly variable rainfall patterns in the valley, recycled water may be the most reliable source of water available for management strategies. Strategies within this category involve the expansion of recycled water use in the basin. Currently, recycled water is used for urban irrigation, but the demand is relatively small. These strategies would develop the infrastructure to expand recycled water use for irrigation, which would decrease reliance on the groundwater basin. The infrastructure would also allow the movement of recycled water to areas within the Temescal Subbasin for enhanced groundwater recharge, currently planned through injection wells.

In 2001, the City conducted a Recycled Water Master Plan (Boyle, 2001) to evaluate the potential to expand the direct use of recycled water for non-potable applications such as park irrigation. The study concluded that additional opportunities for recycled water use exist, primarily during the summer months. Current irrigation demand of recycled water is about 5,600 AFY. As this supply is expanded, additional recycled water could provide in-lieu pumping in the summer months and groundwater basin recharge in the winter months. The recycled water strategies that follow are built around this concept.

#### 13. Recycled Water Injection Wells

Recycled water injection wells could be constructed in several areas of the City that meet regulatory requirements for residence time underground prior to extraction. The *Title 22, California Code of Regulations (Division 4, Chapter 3, Section 60320.010, California Department of Public Health)* states: "for a subsurface injection project, all the recycled water shall be retained underground for a minimum of twelve (12) months prior to extraction for use as a drinking water supply, and shall not be extracted within 2,000 feet of a recycled water injection well." The required distance from extraction wells is currently under review and may be revised. This strategy would also need to meet other regulatory requirements including water quality objectives as provided in the DPH draft regulations (California DPH, 2007).

Specific components at each site include a well, well head, down-comer pipes, flow metering, piping and valves that are connected to the adjacent recycled water piping, and a flow control and pressure reducing valve.

#### 14. Recycled Water Zone 3 to Zone 2 Interconnect

A pipeline that connects Zone 3 to Zone 2 would allow conveyance of recycled water to different water storage facilities in the City. Currently, Zone 3 is fed by WWTP3 and is not connected to any potential recharge sites such as the Oak Avenue and Main Street detention basins. Therefore, during wet periods the effluent from WWTP3 is currently unavailable for enhanced recharge to the groundwater basin.

### 15. Recycled Water Zone 4 to Zone 3 Interconnect

A pipeline that connects Zone 4 to Zone 3 would allow conveyance of recycled water to customers in Zone 4. This would provide more flexibility in using Zone 3 recycled water in Zone 4 rather than conveying Zone 1 or Zone 2 water to Zone 4.

### 16. WWTP2 Upgrade to Tertiary

The secondary effluent from Wastewater Treatment Plant 2 (WWTP2) is currently conveyed to the Lincoln and Cota percolation ponds. Upgrades could be constructed at WWTP2 that would provide tertiary treatment and disinfection of the secondary effluent and produce Title 22 recycled water. The recycled water from WWTP2 could be connected to the recycled water system distribution at Harrison Street—which is immediately north of WWTP2—or sent to the percolation ponds for recharge.

### 17. WWTP1A Upgrade to Tertiary

The secondary effluent from Wastewater Treatment Plant 1A (WWTP1A) is currently conveyed to the Lincoln and Cota percolation ponds. Upgrades could be constructed at WWTP1A that would route the flows through the WWTP1 tertiary filters and chlorine contact tank to produce Title 22 recycled water. The recycled water could then be stored in the on-site recycled water reservoir or sent to the percolation ponds for recharge.

### 18. Lee Lake Water District’s (LLWD) Recharge to Bedford Subbasin

This recharge project includes discharging recycled water (tertiary treated and disinfected) produced by LLWD into surface recharge basins or injection wells (exact locations to be determined) in the Bedford Subbasin. This recycled water is currently being discharged to Temescal Wash and is not contributing to groundwater basin storage. Since the groundwater basin ultimately discharges to the wash, surface water flow on an average basis is not expected to be substantially decreased. The source of the recycled water is wastewater from local residential communities that are supplied with imported water of generally higher quality than ambient groundwater. The resulting recycled water typically has lower TDS values than the ambient groundwater. Therefore, the recharge of recycled water will likely have a beneficial water quality impact on the ambient TDS in the subbasin. In addition, both the City and LLWD may need to rely on local groundwater to increase water supply. Enhancing recharge is expected to increase the subbasin yield. A feasibility study of this project including impacts to water levels and water quality is included as Appendix D.

### 19. Use of Recycled Water as In-Lieu Pumping

The expanded use of recycled water as a substitute for groundwater under certain non-potable applications (such as park irrigation) would have major benefits for groundwater management. This use of recycled water would decrease pumping from the groundwater basin.

Currently, the City provides approximately 5,600 AFY of recycled water for irrigation. In 2001, the City conducted a survey to examine the potential for expanded recycled water use (Boyle, 2001). In that analysis, the engineers concluded that approximately 1,300 acres of parks, golf courses, and other landscape areas could be irrigated with recycled water. The City has a current capacity of about 6,780 AFY, with a current demand of about 5,600 AFY. As system improvements are made and additional recycled water is available, using recycled water to replace groundwater pumping is a viable management strategy. In addition, the sale of recycled water to customers for additional non-potable applications could provide revenue for continued investment in groundwater management strategies.

### 6.1.6. Use of Imported Water

Imported water has been and continues to be an important source of supply for the City. Water from the Colorado River and State Project Water is available from the Metropolitan Mills filtration plant and delivered to the City through three existing turnouts. These strategies involve the purchase of additional imported water when available for direct use to decrease groundwater basin pumping (in-lieu pumping). Alternatively, imported water may be used for enhanced recharge to the groundwater basin.

#### 20. Purchase of Metropolitan Water District In-Lieu Water

In-lieu purchase water is excess raw water provided to Metropolitan customers at reduced rates. Use of this water will reduce the amount of groundwater pumped from the basin. When Metropolitan offers in-lieu water, the City should purchase it while concurrently reducing groundwater pumping as practicable. The in-lieu purchase water could be: 1) stored in the City's recycled water reservoir(s) for use; 2) stored in the City's recycled water reservoirs(s) and conveyed to spreading basins or injection wells for storage in the groundwater basin; or 3) treated at the City's water treatment plants and used as Title 22 drinking water.

#### 21. Pipeline to Convey Metropolitan Water District (Metropolitan) In-Lieu Water to Border Avenue Recycled Water Reservoir

To convey the in-lieu purchase water to the City's recycled water facilities, a pipeline would need to be constructed from the City's WR-19 turnout (Metropolitan Lower Feeder connection) to the City's Border Avenue recycled water reservoir. In this area, available imported water could also be conveyed to recharge basins at the Oak Avenue Detention Basin. Recharge of imported water would require coordination with regulatory agencies such as the RWQCB and RCFCWCD.

### 6.1.7. Wastewater Pond Maintenance

This strategy provides for improved percolation of permitted amounts of wastewater into the groundwater basin. It is anticipated that amounts may decrease over time as treatment and use of recycled water is expanded.

#### 22. Lincoln and Cota Street Percolation Ponds Maintenance Program

Regularly scheduled maintenance on the percolation ponds is critically important to optimize pond percolation and minimize losses to evaporation. This percolation provides groundwater recharge and contributes positively to the subbasin water balance. Even if most of this water ultimately leaves the subbasin as rising groundwater, it maintains head in the discharge area, decreasing gradients and the potential outflow of additional groundwater. Based on past monitoring of percolation rates in the ponds, they require maintenance approximately every 3 to 5 years. This consists of removing the fine soil particulates (filter cake) from the pond bottom and sides and hauling the filter cake offsite for approved disposal.

### 6.1.8. Coordination with Regulatory Agencies

The City maintains positive working relationships with local agencies, but currently has no centralized effort to coordinate with agencies on water quality issues for the protection and enhancement of the groundwater subbasins. The strategies offered below are a starting point for increased communication and action on specific groundwater issues.

#### 23. Coordinate with Riverside County on Water Quality and Well Construction

The County of Riverside Department of Environmental Health (RDEH) conducts programs and services that are beneficial to the local groundwater subbasins (RDEH, 2008). Through the Water Engineering Program, the County handles well permitting for any well constructed in the County including, but not limited to, driven wells, monitoring wells, cathodic wells, extraction wells, agricultural wells, and community water supply wells. They are also responsible for the permitting, inspection, compliance, monitoring, and enforcement of state standards for small water systems in the County. These programs are consistent with and ensure well construction/destruction standards are implemented as developed by DWR. The City wishes to maintain a positive working relationship with the Water Engineering Program to track wells drilled within the subbasins and ensure proper well construction and destruction for the protection of the groundwater resource. Methods of coordination to access the well information at the County will be further explored through communication with Riverside DEH.

The Riverside DEH also conducts programs related to groundwater contamination. Their ongoing Local Oversight Program provides for oversight of the investigation and cleanup of soil and groundwater contamination from unauthorized releases from leaking underground storage tanks (LUSTs). This program is conducted under contract from the State Water Resources Control Board (SWRCB) and compiles regional information on assessment and cleanup efforts.

Information regarding UST cleanup sites and proposed corrective actions are available online and will be accessed periodically by the City to identify areas of concern. If such areas are identified, the caseworker at the County will be contacted for additional information and coordination.

#### 24. Coordinate with the Regional Water Quality Control Board (RWQCB), Santa Ana Region on Water Quality Issues in the Basin

The City will work with the RWQCB to obtain information on groundwater contamination areas that may adversely impact water quality in the City's drinking water wells. This coordination will involve communication with the RWQCB on sites or areas of known or suspected groundwater impacts. This communication can also involve the periodic access of site cleanup lists on the RWQCB websites.

The City will also continue coordination with the RWQCB on monitoring industrial waste discharges to the sanitary sewer through the City's ongoing Industrial Waste Pre-treatment and Source Control Program. As a requirement of this program, quarterly and annual reports are provided to the RWQCB.

### 6.1.9. Water Conservation and Demand Management

As previously discussed, the City has committed to aggressive steps on water conservation and demand management. A full-time Water Conservation Coordinator has developed and implemented numerous educational programs (including an education center), water wise events and awards, rebate programs, data-based field tests to demonstrate actual water savings, installation of landscape irrigation controllers, and coordinated programs with Metropolitan and WMWD. Although these measures will continue on their established schedules, the City wishes to acknowledge and incorporate these activities into an overall GWMP strategy.

#### 25. Continue and Expand Water Conservation and Demand Management Activities

Numerous programs have been implemented by the City's aggressive water conservation efforts. A rebate program for low-flow toilets and washing machines has been in place for several years. In addition to an extensive education program previously described (Section 4.2), the City is taking aggressive steps to reduce irrigation demand. The City has initiated a program of working directly with homeowners' associations and others on the installation of weather-based irrigation controls (WBIC) on landscape irrigation systems. Two test programs are planned to determine specific water savings for such devices and include a condominium neighborhood in the older part of Corona and a single-family residential neighborhood in an area of newer development. These two tests will provide monitoring data and information on potential water savings and demand reduction for application to other areas.

## 6.2. Evaluation of Management Strategies using AB3030 Checklist

Water Code Section 10753 provides a list of 12 examples of groundwater basin issues that may be considered in an AB3030 GWMP. These examples serve as a checklist to ensure that major groundwater basin issues are addressed. The issues are listed below, followed by an explanation of the relationship between each issue and the management strategies proposed in this GWMP.

### 6.2.1. Control of Saline Water Intrusion

The subbasins of interest are located in upland basins away from the coast and are not subject to the typical threat of coastal seawater intrusion. This issue can also include the potential influx of highly mineralized or brackish water from either natural or anthropogenic (human-influenced) sources. However, no highly mineralized influx has been identified to date. Although water entering the Temescal Subbasin through the Arlington Gap has been observed to have elevated nitrate and other minerals, the inflow contains similar water quality to ambient groundwater in the subbasin and is not a significant threat to water quality. In fact, this area has served as the main source of aquifer recharge to the basin.

### 6.2.2. Identification and Management of Wellhead Protection and Recharge Areas

Wellhead protection and recharge areas have been evaluated in the past and have been further assessed in this GWMP. In 2002, the City conducted an assessment of the vulnerability of their drinking water wells under the California Drinking Water Source Assessment Program (DWSAP). This program, developed by the California Department of Public Health (DPH) (formerly Department of Health Services), delineates the area around drinking water sources, such as wells, through which contaminants might reach the water supply. This assessment identified surface recharge areas in the vicinity of City wells. In addition, the analysis in this GWMP identifies the main areas of subbasin recharge for the aquifers tapped by City wells. These areas include the entire footprint of the unconfined Channel Aquifer, recharge areas along washes and alluvial fans, and areas of subsurface inflow such as Temescal Canyon and Arlington Gap.

Strategies to manage and protect the recharge zones involve coordination with regulatory agencies such as Riverside County DEH and the RWQCB. These agencies are responsible for evaluating impacts to water quality from industrial or commercial activities and leaking underground storage tanks (LUSTs). Strategies 23 and 24 provide for the coordinated management required for protection of water supply. Also, the City's expanded monitoring program (Strategy 8) will allow for better tracking of groundwater conditions in recharge areas.

### 6.2.3. Regulation of the Migration of Contaminated Groundwater

The RWQCB, Riverside DEH, and other regulatory agencies provide data and information on impacts to groundwater and potential offsite migration of contamination plumes. Strategies 23 and 24 allow for better coordination with regulatory agencies and identification of areas of contaminated groundwater. Strategies 4 and 5 (involving wellhead treatment of wells downgradient of contaminant sources) directly address one area where groundwater contaminated with certain VOCs has been migrating toward water supply wells.

### 6.2.4. Administration of a Well Abandonment and Well Destruction Program

Through their Water Engineering Program, Riverside DEH requires that a permit be obtained for the abandonment of any well in the County (Riverside DEH, 2008). Guidance for well abandonment procedures are consistent with the standards developed by DWR for drilling and destroying wells in California (DWR, 1991). In addition, the County provides a registry of approved well drillers who are familiar with County regulations and policies. The publication of such a list increases the likelihood that permits and proper well abandonment procedures will be followed. Strategy 23 involves increased coordination with the Riverside DEH Water Engineering Program and well abandonment procedures.

### 6.2.5. Mitigation of Overdraft Conditions

As indicated by the preliminary water balances for the Temescal and Coldwater subbasins, both areas have experienced overdraft conditions over the Study Period. From 1990 through 2004, Coldwater Subbasin experienced overdraft conditions with an estimated loss of about 20,000 AF of groundwater storage over the 15-year period. However, the water balance indicates that conditions were improving at the end of the Study Period because of decreased pumping rates in the subbasin. The City is working with other subbasin pumpers to control overdraft conditions through pumping limitations. Strategy 9 provides for an evaluation of enhanced recharge in Coldwater Subbasin.

The water balance in Temescal Subbasin indicates that overdraft conditions occurred in the last three years of the Study Period as average pumping increased from about 10,000 AFY to almost 20,000 AFY. Given the uncertainty associated with imported water amounts in the future, the City will need to rely on the groundwater subbasin for a substantial amount of its water supply. This indicates that control of overdraft conditions through pumping limitations alone may be unrealistic. As such, the City is including numerous strategies for managing groundwater while maintaining groundwater production.

Strategies 1 through 3 include new wells that will allow flexibility in pumping distribution and maintenance of water levels. Strategies 10, 11, 12, and 13 provide for enhanced recharge directly into the Temescal Subbasin. Strategies 9 and 18 provide for increased recharge in Coldwater and Bedford subbasins. Strategies 14, 15, and 21 provide the infrastructure necessary for the conveyance of water to recharge facilities. Strategies 19 and 20 provide replacement water sources for a portion of the groundwater demand, potentially decreasing Temescal Subbasin production. Finally, Strategy 8 will allow for increased monitoring of groundwater levels and storage for the tracking of overdraft mitigation.

### 6.2.6. Replenishment of Groundwater Extracted by Water Producers

For this Study Area, the replenishment of groundwater extracted by pumpers in the basin is the same issue as the mitigation of overdraft conditions discussed above with a focus on Temescal Subbasin. As previously discussed, the replenishment of Coldwater Subbasin can likely be obtained with natural recharge over time if pumping reductions are in place. For Temescal Subbasin, enhanced recharge is more critical given the current and planned reliance on the subbasin for water supply. Strategies 10, 11, 12, and 13 are the most important strategies for replenishment with Strategies 14, 15, and 21 to provide the supporting infrastructure.

### 6.2.7. Monitoring of Groundwater Levels and Storage

Strategy 8 provides for the adoption of a monitoring program and protocols and a commitment for improved monitoring components in the future. The current monitoring program and protocols are described in Appendix B. Also included are recommendations for future improvements to the program.

### 6.2.8. Facilitating Conjunctive Use Operations

To provide for the efficient use of all water sources including groundwater, imported water, and recycled water, the City is interested in the construction and operation of several conjunctive use facilities. Strategies 9, 10, and 11 rely on existing detention basins or permeable off-stream sites for conjunctive use of surface water, imported water, and/or recycled water. In particular, Strategies 10 and 11 seem implementable with relatively minimal land acquisition and recharge basin construction costs. Strategies 12 and 13 involve the construction of injection wells that could use imported water or recycled water to replenish groundwater, especially during the winter months when excess water may be available. Collectively, these strategies provide for key conjunctive use facilities to be constructed and operated by the City.

### 6.2.9. Identification of Well Construction Policies

Since 1949, DWR has been given the responsibility for developing well standards for the purpose of water quality protection (DWR, 1991). Standards for the construction and destruction of water wells were first published in 1968 and updated in 1974 (DWR, 1981). Subsequent amendments to the Water Code required the development of minimum standards for monitoring and cathodic wells in addition to water wells. Bulletin 74-91 sets those standards as minimum requirements by local agencies. A permit filed in the form of a Well Completion Report/Driller’s

Log is required by DWR for the drilling or destruction of wells in the State. A permit is also required by Riverside DEH to track wells in the County and ensure adherence to minimum construction standards. The City has not developed their own standards, but requires DWR standards and Riverside DEH standards.

### 6.2.10. Construction and Operation of Groundwater Contamination Cleanup, Recharge, Storage, Conservation, Water Recycling, and Extraction Projects

Strategies for groundwater management involve each of the components listed in this item with the exception of water conservation, which is being addressed separately by the City as summarized in previous sections of this document and described in the City's Urban Water Management Plan (AKM, December 2005). Strategies 4 and 5 provide for migration control of a VOC plume of contaminated groundwater and mitigation of water quality impacts to City wells. Strategies 9 through 13 and 18 describe recharge projects for increasing groundwater storage. Strategies 13 through 19 address the expanded and efficient use of recycled water. Strategies 1, 2, 3, and 5 provide for more flexibility in groundwater extraction through varying pumping distribution within the aquifer to manage levels and quality.

### 6.2.11. Development of Relationships with State and Federal Regulatory Agencies

Strategies 23 and 24 specifically address coordination with key regulatory agencies on groundwater management activities. Coordinated management focuses on water quality issues as regulated by the RWQCB and Riverside DEH and well construction/abandonment policies regulated by Riverside DEH and DWR.

### 6.2.12. Review of Land Use Plans and Coordination with Land Use Planning Agencies to Assess Activities which Create a Reasonable Risk of Groundwater Contamination

The City of Corona is close to build out with little opportunity for major changes to land use planning. Nonetheless, the Department of Water and Power can communicate closely with City planners on the vulnerability of the groundwater resource and protection measures for risk assessment. In the City's General Plan, adopted in March 2004, the City established a goal and related policies to manage urban runoff for protection of groundwater. Policies address the proper handling, storage, application, and disposal of pesticides, insecticides, and similar substances. Policies also address stormwater management and reuse and BMPs from construction.

## *6.3. Evaluation of Management Strategies*

Several of the identified groundwater management strategies were evaluated with the groundwater flow model constructed as part of this GWMP. The evaluation and results are discussed in the following sections. Details on model construction, calibration, and setup for application of the management strategies are provided in Appendix C. Figures C-11 through C-14 summarize changes in water levels in the target wells associated with the baseline evaluation and management strategies as described in the sections below.

### 6.3.1. Baseline Evaluation

To provide a baseline against which to measure groundwater management strategies, a baseline model run was developed that accounts for a total demand at build out of about 51,631 AFY. As previously discussed, the City has a tentative target for obtaining one-half of the demand from the groundwater subbasins, or a total pumping amount of 25,816 AFY. The Coldwater Subbasin appears capable of providing at least 3,500 AFY (equal to the City's 2007 pumping). Pumping in Bedford Subbasin could potentially provide another 600 AFY, leaving a demand of about 21,700 AFY from the Temescal Subbasin. Additional details of the baseline scenario are provided in Appendix C.

Modeling indicates that baseline pumping results in average water level declines of about 30 to 50 feet in the main portions of the Channel Aquifer over the simulation period. These declines would result in dewatering of more than 50 percent of the aquifer thickness in some wells, substantially decreasing well capacity.

The decline also represents a substantial loss of groundwater in storage in the unconfined aquifer. A summary of the average water budget components under baseline conditions is provided in Table 6-2.

**Table 6-2**
**Baseline Evaluation Water Balance (AFY)**

| **INFLOWS** | Ave. |
|---|---|
| Deep Percolation from Precipitation | **1,689** |
| Infiltration of Runoff in Detention Basins | **479** |
| Recharge from Wastewater Discharge | **8,504** |
| Subsurface Inflow Subtotal | **5,163** |
| - Arlington Gap | 4,182 |
| - Temescal Wash (Temescal Canyon) | 113 |
| - Bedrock in Watershed | 816 |
| - Norco | 52 |
| Return Flows Subtotal | **2,542** |
| **TOTAL INFLOWS (AFY)** | **18,377** |
| | |
| **OUTFLOWS** | |
| Groundwater Pumping | **21,722** |
| Subsurface Outflow to Santa Ana River | **5,481** |
| **TOTAL OUTFLOWS (AFY)** | **27,203** |
| **Change in Storage** | **-8,826** |

Values above represent average conditions over a 15-year model simulation period. The complete baseline simulation is summarized in Table C-3 in Appendix C. The groundwater basin water budget shown above indicates that under hydrologic conditions similar to the Study Period, an average decline in groundwater storage of about -8,826 AFY would be expected (subtract outflows of 27,203 AFY from inflows of 18,377 AFY). According to this analysis, pumping under the baseline scenario is unsustainable without additional management strategies to increase basin yield or reduce groundwater production.

### 6.3.2. Scenario 1 - Pumping Redistribution

To evaluate the impact of redistributing pumping within the Channel Aquifer, two new downgradient wells were simulated in this model run. The new wells were positioned to potentially intercept subbasin outflow to the Prado Management Area and were assigned a pumping amount of 2,500 AFY for each well. The baseline pumping total was maintained and pumping amounts were systematically decreased in current production wells to account for the added production in the new wells.

The water budget from this model run is summarized in Table 6-3. As shown in the table, the outflows are similar to the baseline simulation, but inflows have decreased (compare 18,377 AFY in Table 6-2 to 18,122 AFY in Table 6-3). As such, the average storage decline of -9,095 AFY is slightly worse than under baseline conditions due to the slight decrease in inflow from Arlington Gap. This occurred because decreased pumping in upgradient wells resulted in rising water levels and decreasing gradients across the gap. In addition, the new pumping was not sufficient to decrease basin outflow, which resulted in almost the same average outflow total as simulated under baseline conditions (compare outflows in Table 6-3 to Table 6-2). Annual results from the Scenario 1 simulation are provided in Appendix C in Table C-4.

**Table 6-3**
**Scenario 1**
**Pumping Redistribution Water Balance (AFY)**

| | |
|---|---|
| **INFLOWS** | |
| Deep Percolation from Precipitation | **1,689** |
| Infiltration of Runoff in Detention Basins | **479** |
| Recharge from Wastewater Discharge | **8,504** |
| Subsurface Inflow Subtotal | **4,908** |
| - Arlington Gap | 3,901 |
| - Temescal Wash (Temescal Canyon) | 113 |
| - Bedrock in Watershed | 842 |
| - Norco | 52 |
| Return Flows Subtotal | **2,542** |
| **TOTAL INFLOWS (AFY)** | **18,122** |
| | |
| **OUTFLOWS** | |
| Groundwater Pumping | **21,742** |
| Subsurface Outflow to Santa Ana River | **5,475** |
| **TOTAL OUTFLOWS (AFY)** | **27,217** |
| **Change in Storage (AFY)** | **-9,095** |

Although the decline in storage was greater, Scenario 1 was successful at increasing water levels in most target wells from baseline conditions (see Figures C-11 through C-14 in Appendix C). By the end of the 15-year simulation period, water levels had risen an average of about 10 feet in key wells. This is expected, given that most of the calibration targets are active pumping wells and any decrease in pumping will result in a rise in water levels. Nonetheless, this simulation suggests the water levels can be maintained on a short-term basis through redistributions in pumping.

Several additional model simulations were conducted with additional downgradient pumping wells to capture basin outflow to the Prado Management Area. Results of these runs are not included in the GWMP, but indicated that substantial increases in pumping just upgradient of the Prado Management Area were not capable of capturing large percentages of the outflow. It is not clear whether boundary conditions limit the model's ability to simulate the capture of outflow or whether most of the outflow is not occurring near the area of simulated wells. Additional analyses will be required to further evaluate the optimal location and number of wells for decreasing outflow and increasing basin yield.

### 6.3.3. Scenarios 2 and 3 - Enhanced Recharge at Detention Basins

As previously discussed, pilot testing conducted by the City at the Oak Avenue and Main Street detention basins noted high infiltration rates and indicated that up to about 6,500 AFY could be recharged with construction of spreading basins within each larger detention basin (about 5,000 AFY in Oak Avenue Basin and about 1,500 AFY in Main Street Basin). The source of the recharge water would most likely be a combination of recycled water and stormwater. Imported water could also be used if available. Since current draft regulations regarding the recharge of recycled water call for dilution with another source, a combination of source waters will likely be needed. Actual implementation of this strategy would require coordination with regulatory agencies, including RCFCWCD, monitoring, and in-basin cleanup.

For simulation in the groundwater model, it is assumed that one-half of the recharge water is from water available only during the wet season. Recycled water is recharged year-round in the simulation. Recharge at the two basins was simulated separately for evaluation. Baseline pumping was used. Wastewater discharge to percolation ponds was slightly decreased reflecting the use of recycled water. Details of the simulations are provided in Appendix C.

The results of the model water budgets are summarized in Tables 6-4 and 6-5 for the Oak Avenue Detention Basin and Main Street Detention Basin recharge scenarios, respectively. Both scenarios show less groundwater storage declines than baseline scenarios because of the increase in inflows, equivalent to the amount of recharge assigned to each scenario. Because a larger volume of water was recharged at Oak Avenue, that scenario shows the most improvement. Declines in groundwater storage were -4,309 AFY and -6,562 AFY for Oak Avenue and Main Street basin recharge, respectively. This compares to the average decline in groundwater storage of -8,826 AFY under baseline conditions. Annual results for the two simulations are provided in Appendix C on Tables C-5 and C-6.

In general, water levels did not respond significantly to the smaller amount of recharge in the Main Street Detention Basin over a 15-year simulation period. Water levels rose about 16 feet on the alluvial fan in response to the larger recharge amounts in the Oak Avenue Detention Basin. In addition, water levels also rose several feet in the Channel Aquifer under this scenario. Water level hydrographs in target wells are provided in Appendix C.

**Table 6-4**
**Scenario 2**
**Recharge at Oak Avenue Basin Water Balance (AFY)**

| | |
|---|---|
| **INFLOWS** | |
| Deep Percolation from Precipitation | **1,689** |
| Infiltration of Runoff in Detention Basins | **5,246** |
| - Oak Street | 5,006 |
| - Main Street | 240 |
| Recharge from Wastewater Discharge | **8,214** |
| Subsurface Inflow Subtotal | **5,199** |
| - Arlington Gap | 4,192 |
| - Temescal Wash (Temescal Canyon) | 113 |
| - Bedrock in Watershed | 842 |
| - Norco | 52 |
| Return Flows Subtotal | **2,542** |
| **TOTAL INFLOWS (AFY)** | **22,890** |
| | |
| **OUTFLOWS** | |
| Groundwater Pumping | **21,718** |
| Subsurface Outflow to Santa Ana River | **5,481** |
| **TOTAL OUTFLOWS (AFY)** | **27,199** |
| **Change in Storage (AFY)** | **-4,309** |

**Table 6-5**
**Scenario 3**
**Recharge at Main Street Basin Water Balance (AFY)**

| | |
|---|---|
| **INFLOWS** | |
| Deep Percolation from Precipitation | **1,689** |
| Infiltration of Runoff in Detention Basins | **1,743** |
| - Oak Street | 240 |
| - Main Street | 1,502 |
| Recharge from Wastewater Discharge | **9,507** |
| Subsurface Inflow Subtotal | **5,161** |
| - Arlington Gap | 4,154 |
| - Temescal Wash (Temescal Canyon) | 113 |
| - Bedrock in Watershed | 842 |
| - Norco | 52 |
| Return Flows Subtotal | **2,542** |
| **TOTAL INFLOWS (AFY)** | **20,642** |
| | |
| **OUTFLOWS** | |
| Groundwater Pumping | **21,722** |
| Subsurface Outflow to Santa Ana River | **5,481** |
| **TOTAL OUTFLOWS (AFY)** | **27,204** |
| **Change in Storage (AFY)** | **-6,562** |

### 6.3.4. Scenarios 4a and 4b - Upgradient Injection Wells in Channel Aquifer

Currently, 5 MGD to 10 MGD could be dedicated to a recharge well project during the wet season (2,762 AF to 5,524 AF over six months). Assuming an injection well capacity of about 1,000 gpm, approximately four wells to seven wells would be needed for the recharge of recycled water. As such, two scenarios were evaluated in the groundwater model: four wells recharging 2,762 AFY and seven wells recharging 5,524 AFY (with recharge occurring over a six month period). Wastewater discharge is also decreased to reflect the treatment of additional wastewater for recycled water production. To provide benefits to downgradient wells, the preliminary location selected for the injection wells was the most upgradient position in the Channel Aquifer, near Arlington Gap. Additional details on the simulation of the injection wells are provided in Appendix C.

The results of the scenarios are summarized by the model water budgets presented in Tables 6-6 and 6-7. (Annual results are provided in Appendix C on Tables C-7 and C-8). In both cases, the average subbasin inflows are higher than estimated for baseline conditions, reflecting the increased recharge. As shown in the tables, total inflows are estimated at 20,987 AFY and 21,068 AFY for the injection well scenarios compared to average inflows of 18,377 AFY for the baseline scenario. However, the increase in inflows was not equivalent to the amount of recharge added because of decreases in other inflow totals including less subsurface inflow at Arlington Gap. The locations of the injection wells create water level rises near the gap and block a certain portion of the inflow. Additional evaluation is necessary to optimize the location of the injection wells. Nonetheless, the storage decline associated with these two scenarios is less than under baseline conditions. Water level hydrographs showing the change in water levels at the end of the 15-year simulation period for both injection well scenarios (Scenarios 4a and 4b) are provided in Figures C-11 through C-14 in Appendix C.

**Table 6-6**
**Scenario 4a**
**Recharge near Arlington Gap (4 wells) Water Balance (AFY)**

| | |
|---|---|
| **INFLOWS** | |
| Deep Percolation from Precipitation | **1,689** |
| Infiltration of Runoff in Detention Basins | **479** |
| Recharge from Wastewater Discharge | **9,390** |
| Subsurface Inflow Subtotal | **4,125** |
| - Arlington Gap | 3,131 |
| - Temescal Wash (Temescal Canyon) | 113 |
| - Bedrock in Watershed | 833 |
| - Norco | 48 |
| Return Flows Subtotal | **2,542** |
| Recharge Wells at Arlington | **2,762** |
| **TOTAL INFLOWS (AFY)** | **20,987** |
| | |
| **OUTFLOWS** | |
| Groundwater Pumping | **21,717** |
| Subsurface Outflow to Santa Ana River | **5,481** |
| **TOTAL OUTFLOWS (AFY)** | **27,199** |
| **Change in Storage (AFY)** | **-6,212** |

**Table 6-7**
**Scenario 4b**
**Recharge near Arlington Gap (7 wells) Water Balance (AFY)**

| | |
|---|---|
| **INFLOWS** | |
| Deep Percolation from Precipitation | **1,689** |
| Infiltration of Runoff in Detention Basins | **479** |
| Recharge from Wastewater Discharge | **7,988** |
| Subsurface Inflow Subtotal | **2,846** |
| - Arlington Gap | 1,839 |
| - Temescal Wash (Temescal Canyon) | 113 |
| - Bedrock in Watershed | 842 |
| - Norco | 52 |
| Return Flows Subtotal | **2,542** |
| Recharge Wells | **5,524** |
| **TOTAL INFLOWS (AFY)** | **21,068** |
| | |
| **OUTFLOWS** | |
| Groundwater Pumping | **21,715** |
| Subsurface Outflow to Santa Ana River | **5,481** |
| **TOTAL OUTFLOWS (AFY)** | **27,195** |
| **Change in Storage (AFY)** | **-6,127** |

In addition to improving changes in groundwater storage, these two recharge scenarios also benefit water levels throughout the Channel Aquifer. Water levels rose more than 25 feet in some upgradient areas near the injection wells. As expected, water levels rose more in upgradient wells, but even some downgradient wells recorded water level rises of about 8 feet over baseline conditions (Figures C-11 through C-14, Appendix C).

In summary, the management strategy of recharge wells improved water levels and water budgets, but decreased Arlington Gap inflow. Recharge wells offer the best potential for direct and immediate recharge to the Channel Aquifer, but additional evaluation will be necessary to determine optimal locations and number of wells.

### 6.3.5. Recycled Water Recharge

As described in the management strategies above, enhanced recharge will be needed for management of the groundwater subbasins. Given recent uncertainties in the reliability of SWP and other sources of imported water, recycled water may be the City's most reliable supplemental supply for groundwater recharge. To ensure that groundwater quality is not adversely impacted from the recharge of recycled water, a preliminary review of 2007 recycled water quality data was conducted. Prior to implementation, recycled water recharge projects will be further evaluated to ensure compliance with recharge regulations and permit requirements.

Water quality data from the 2007 monitoring program was compared against the primary and secondary MCLs for regulated compounds relevant in draft recycled water recharge regulations (California DPH, 2007). Because the City is not currently recharging recycled water, not all of the regulated constituents have been analyzed to date. In particular, radionuclides and an expanded list of organic chemicals will be analyzed as recycled water recharge is further evaluated. Additional unregulated constituents may also require analysis.

A review of the 2007 monitoring data demonstrates that all but one constituent (TDS) analyzed in the City's recycled water already meet relevant regulatory standards. The recycled water TDS concentration of 650 mg/L does not meet the secondary recommended MCL of 500 mg/L, but is significantly below the maximum permitted of 1,000 mg/L. Because the City's wastewater is a blend of groundwater and imported water (with lower TDS), the concentration of TDS in wastewater is generally lower than in groundwater, resulting in a benefit to the subbasin. DPH regulations allow recharge of TDS concentrations higher than 500 mg/L under certain conditions. Final permitted levels will be determined as the project moves forward.

Only one regulated organic compound, chloroform, has been detected in the City's recycled water. This chemical is typically formed as a disinfection byproduct after chlorination has been used to ensure extinction of microbial pathogens. The compound was detected at only a trace value and is more than two orders of magnitude below the MCL. Given the data reviewed to date, the recharge of recycled water is not anticipated to adversely impact groundwater quality.

## 6.4. Recommended Management Strategies

As indicated in the evaluations above, no single strategy will achieve BMOs. A combination of strategies will be required, especially those supporting enhanced recharge and in-lieu pumping. Without management strategies, the groundwater subbasins will not be sustainable at the pumping rates identified as being needed at build out. Management strategies will be conducted in concert with continued water conservation strategies to manage demand.

# 7. Implementation Plan

In development of an implementation plan for the management strategies identified, issues such as funding opportunities, budgeting, and need are considered. Several of these programs are ongoing and are required for continued operation of the water supply. In addition, several of the strategies rely on the implementation of other strategies. Information on the prioritization of projects and the implementation are provided below.

## 7.1. Prioritization of Strategies

Given the results of the water balance and the need for increased groundwater development, the highest priority for groundwater management are strategies that provide for enhanced recharge (or in-lieu pumping) in the groundwater basin. The best use for imported water at this time seems to be direct use, especially if the availability allows for an offset in pumping. The most reliable supply for recharge is likely to be recycled water. However, for the expanded use of recycled water, additional conveyance and infrastructure improvements are required, namely, Strategies 14 and 15 (Interconnect Recycled Water Zone 3 to Zone 2 and Interconnect Recycled Water Zone 4 to Zone 3).

## 7.2. Implementation Plan and Schedule

Capital improvement projects and corresponding implementation schedule are summarized in Table 7-1. These projects, designated C-1, C-2, etc., correspond directly to the strategies described in Chapter 6 (C denotes a capital improvement project). The remaining management strategies not listed in Table 7-1 include Strategy 19 (Use of Recycled Water as In-Lieu Pumping), 23 (Coordination with Riverside DEH), and 24 (Coordination with RWQCB). The coordination efforts will begin immediately and build on current relationships with the agencies. Strategy 25 (Water Conservation and Demand Management) is ongoing and will continue as a coordinated effort with the City's Water Conservation Coordinator. The use of recycled water as in-lieu pumping (Strategy 19) is also ongoing and will be expanded as additional markets are identified.

**Table 7-1**
**Implementation Plan and Schedule**

| Project Number | Project Description | Annual Water Yield (AF) | Project Cost | Year |
|---|---|---|---|---|
| C-1 | New Water Wells | 1,935 | $1,500,000/ well | On-going |
| C-2 | Replacement Water Wells | 1,935 | $1,500,000/ well | On-going |
| C-3 | Rincon Groundwater Treatment Project | 5,600 | $15,000,000 | 2015 |
| C-4 | Wellhead Treatment for Wells 6, 7, and 17 | 4,800 | $10,000,000 | 2012 |
| C-5 | El Sobrante Groundwater Treatment Project | 5,600 | $20,000,000 | 2020 |
| C-6 | Groundwater Treatment Program | 3,800 | $3,000,000 | 2011 |
| C-7 | Groundwater Blending Program | 1,800 | $600,000 | 2010 |
| C-8 | Improvement of Groundwater Quantity/Quality Monitoring Program | 0 | $50,000 | 2010 |
| C-9 | Coldwater Subbasin Enhanced Recharge Project | 2,000 | $100,000 | 2011 |
| C-10 | Recharge Basins within Oak Avenue Detention Basin | 5,000 | $2,300,000 | 2010 |
| C-11 | Recharge Basins within Main Street Detention Basin | 1,500 | $690,000 | 2012 |
| C-12 | Upgradient Injection Wells | 4,800 | $5,000,000 | 2009 |
| C-13 | Recycled Water Injection Wells | 4,500 | $4,600,000 | 2011 |
| C-14 | Recycled Water Zone 3 to Zone 2 Interconnect | 1,800 | $4,800,000 | 2009 |
| C-15 | Recycled Water Zone 4 to Zone 3 Interconnect | 3,000 | $2,400,000 | 2009 |
| C-16 | WWTP2 Upgrade to Tertiary | 3,300 | $9,500,000 | 2010 |
| C-17 | WWTP1A Upgrade to Tertiary | 1,100 | $2,100,000 | 2012 |
| C-18 | Lee Lake Water District Recharge to Bedford Subbasin | 80 | $500,000 | 2010 |
| C-20 | Purchase of Metropolitan Water District In-Lieu Water | Unknown | Unknown | As Available |
| C-21 | Pipeline to Convey Metropolitan Water District In-Lieu Water to Border Avenue Recycled Water Reservoir | Unknown | Unknown | As Available |
| C-22 | Lincoln and Cota Street Percolation Ponds Maintenance Program | 1,000 | $100,000/ every 3-5 years | On-going |

## 7.3. Annual Re-evaluation of Management Performance

The implementation of groundwater management strategies and the performance of management activities will be reviewed on an annual basis. A close assessment of the basin response to operational changes and pumping re-distribution among existing wells will provide additional information on management. Ongoing improvements to the monitoring network will also allow for a more detailed evaluation of groundwater levels, quality, and storage.

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# Figures

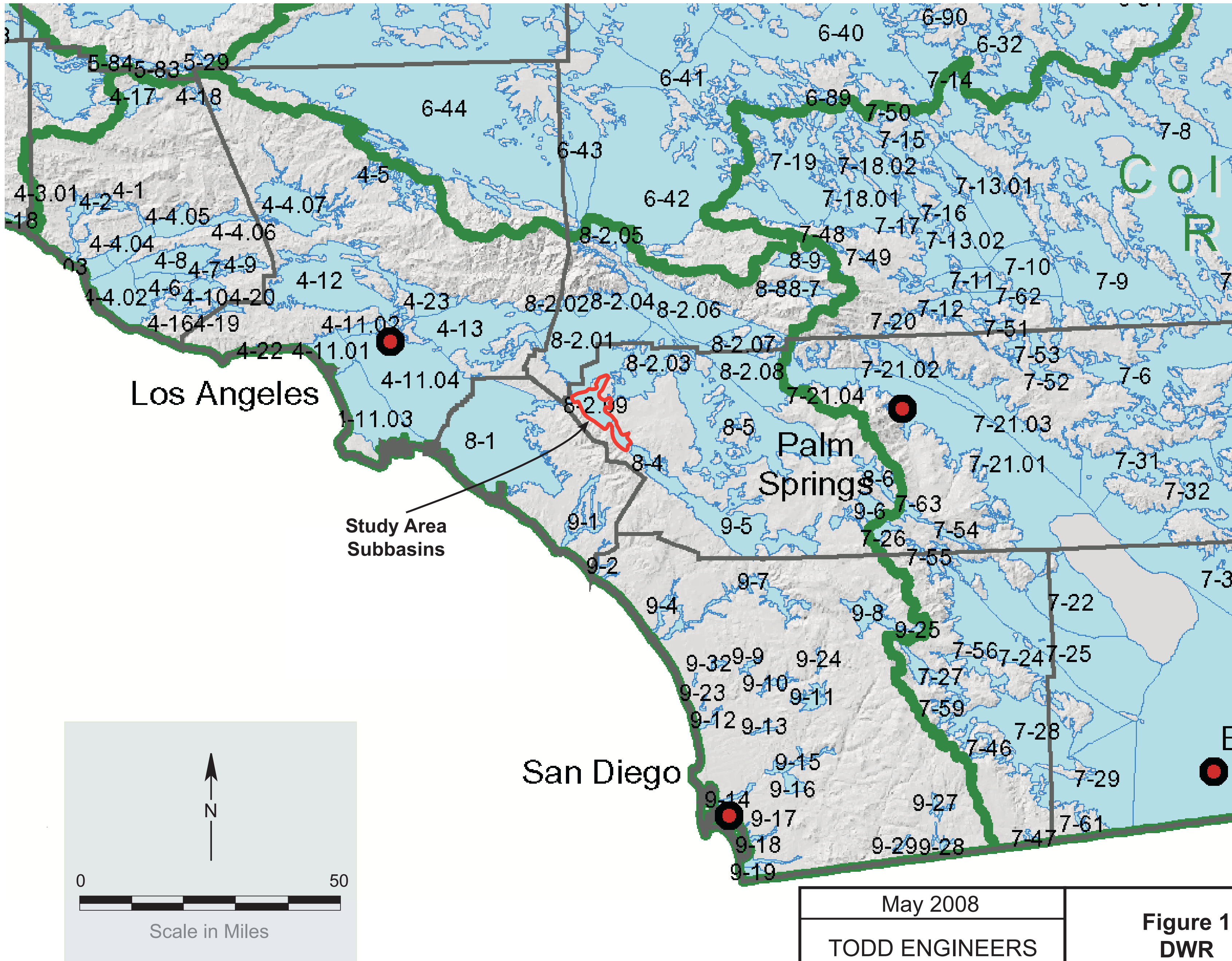


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**Figure 1**
**DWR**
**Groundwater Basins**

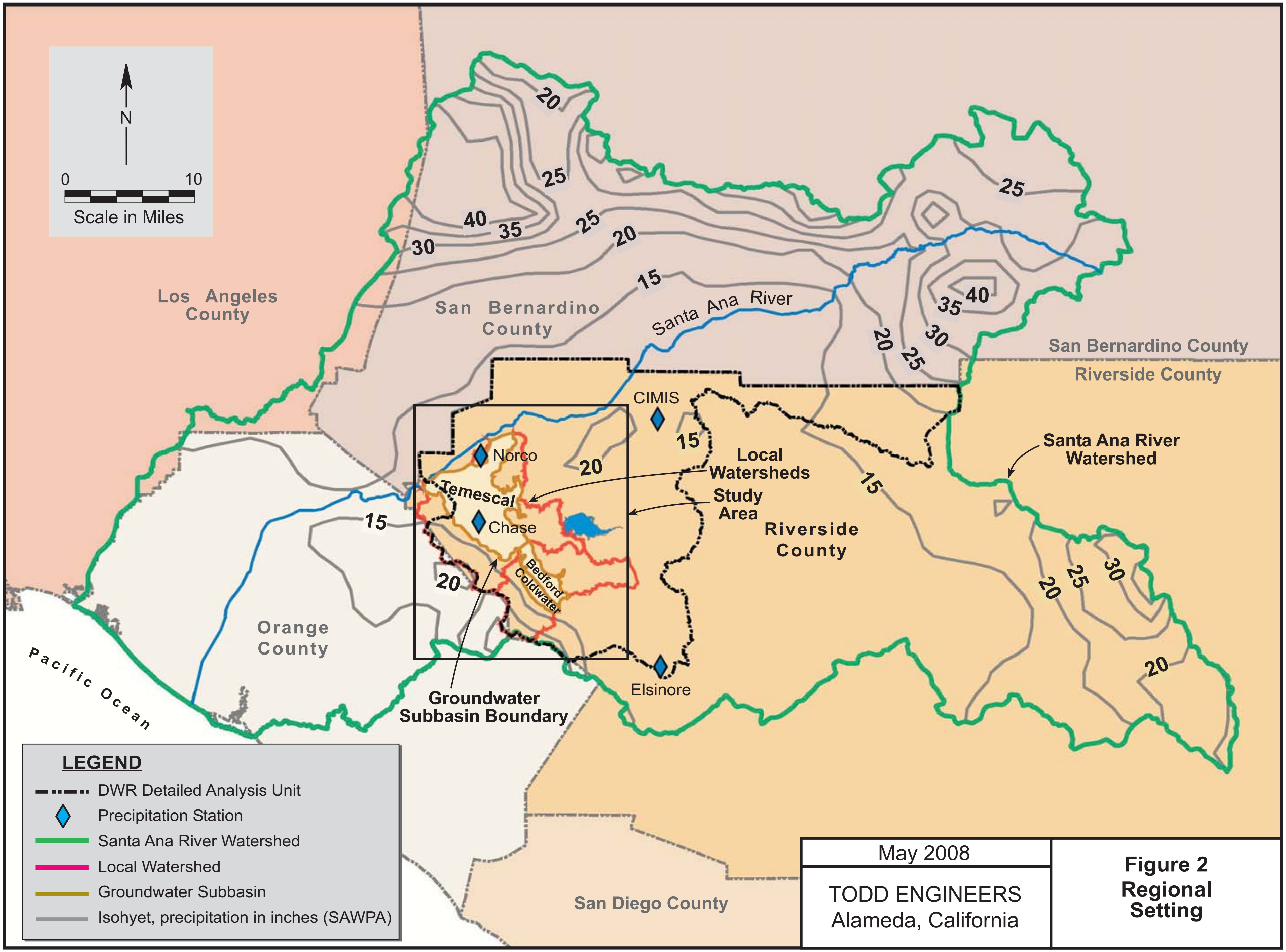
N
0
10
Scale in Miles
Los Angeles County
San Bernardino County
Santa Ana River
San Bernardino County
Riverside County
Santa Ana River Watershed
CIMIS
Norco
Local Watersheds
Temescal
Study Area
Chase
Riverside County
Bedford
Coldwater
Orange County
Pacific Ocean
Elsinore
Groundwater Subbasin Boundary
San Diego County
40
35
30
25
20
15
LEGEND
DWR Detailed Analysis Unit
Precipitation Station
Santa Ana River Watershed
Local Watershed
Groundwater Subbasin
Isohyet, precipitation in inches (SAWPA)
May 2008
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Figure 2
Regional Setting


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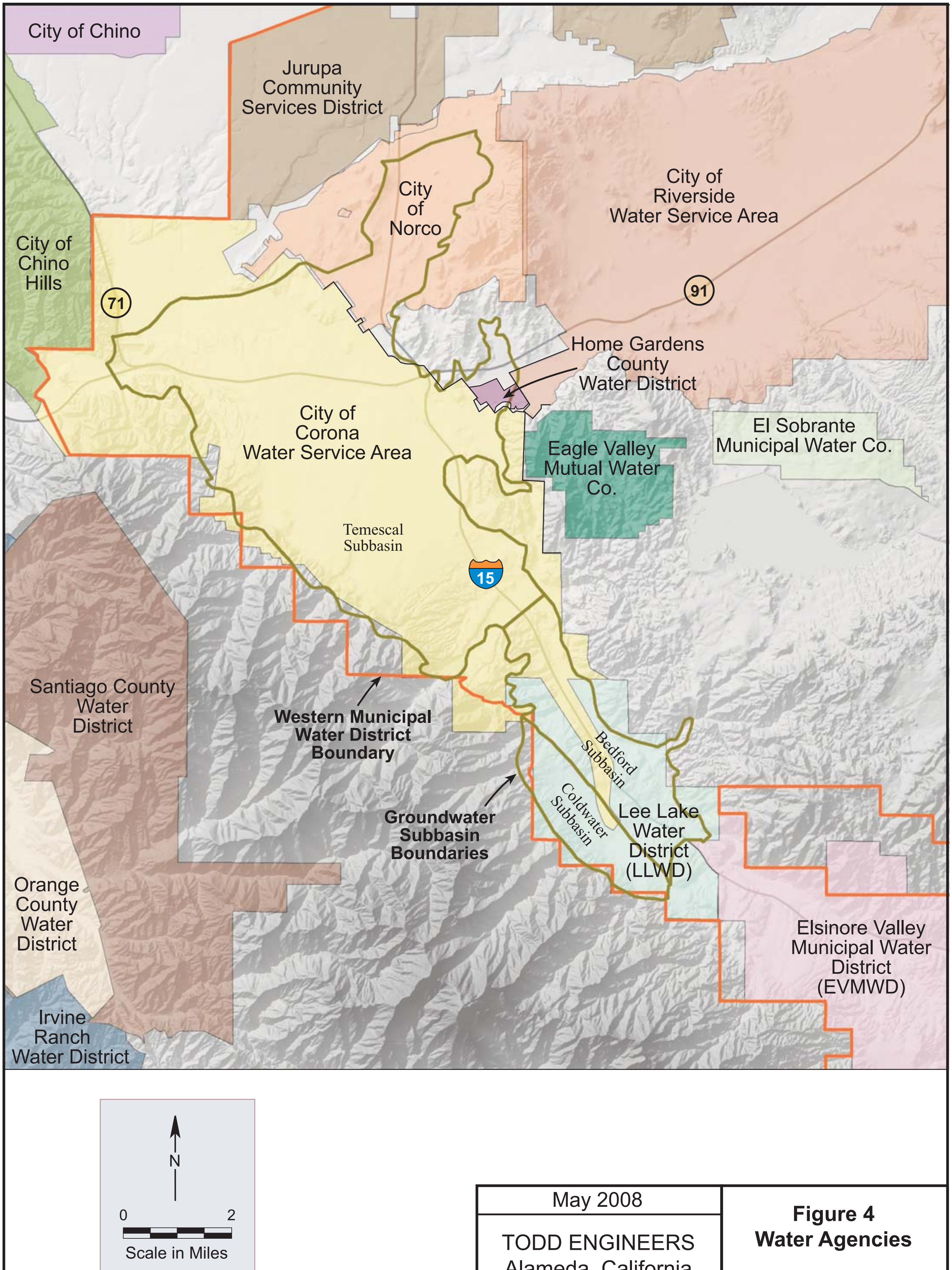
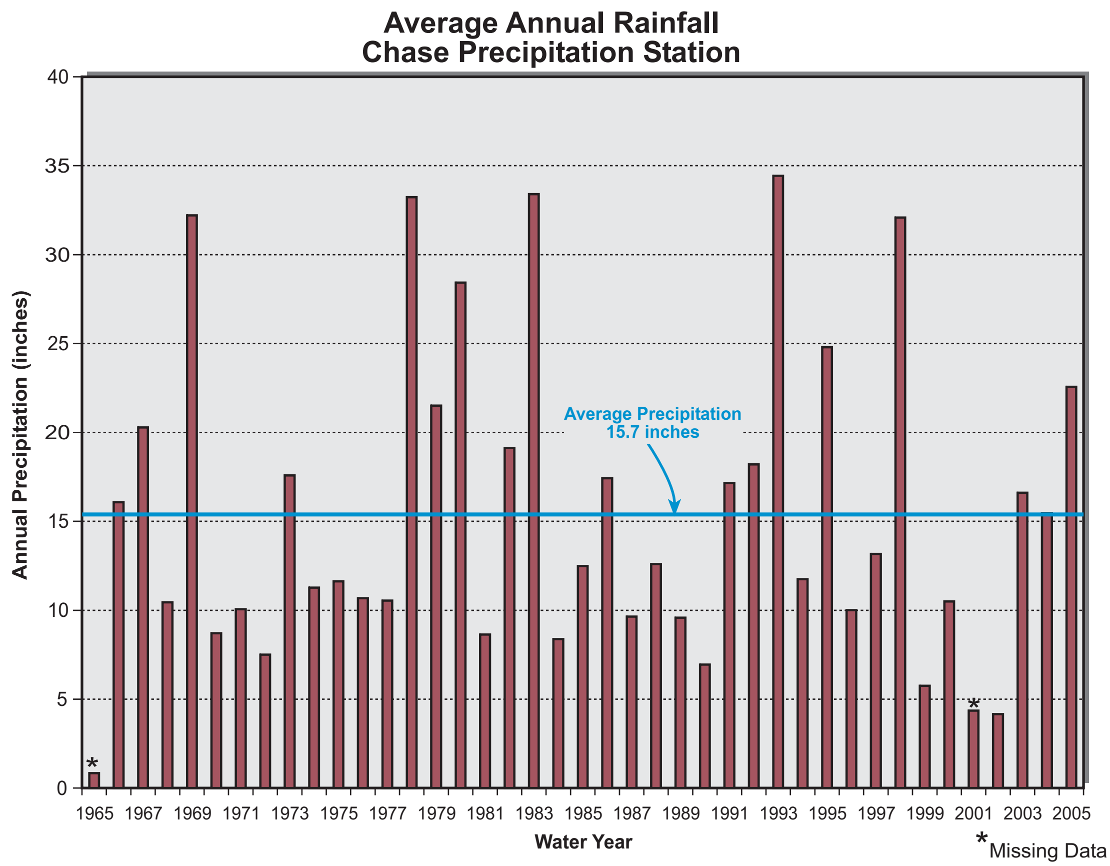
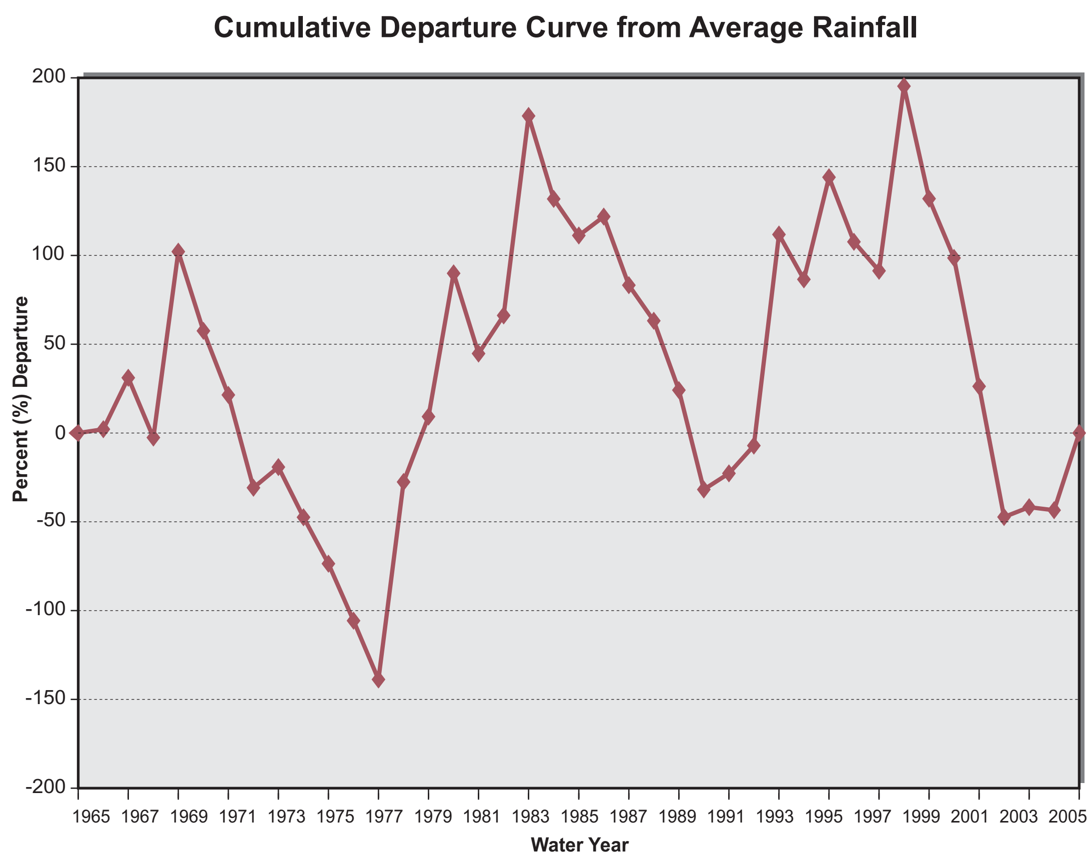
**Figure 3**
**Study Area**




| May 2008 | **Figure 4** **Water Agencies** |
|---|---|
| TODD ENGINEERS Alameda, California | |




| May 2008 | **Figure 5** |
|---|---|
| TODD ENGINEERS<br>Alameda, California | **Precipitation and Cumulative Departure Curve** |

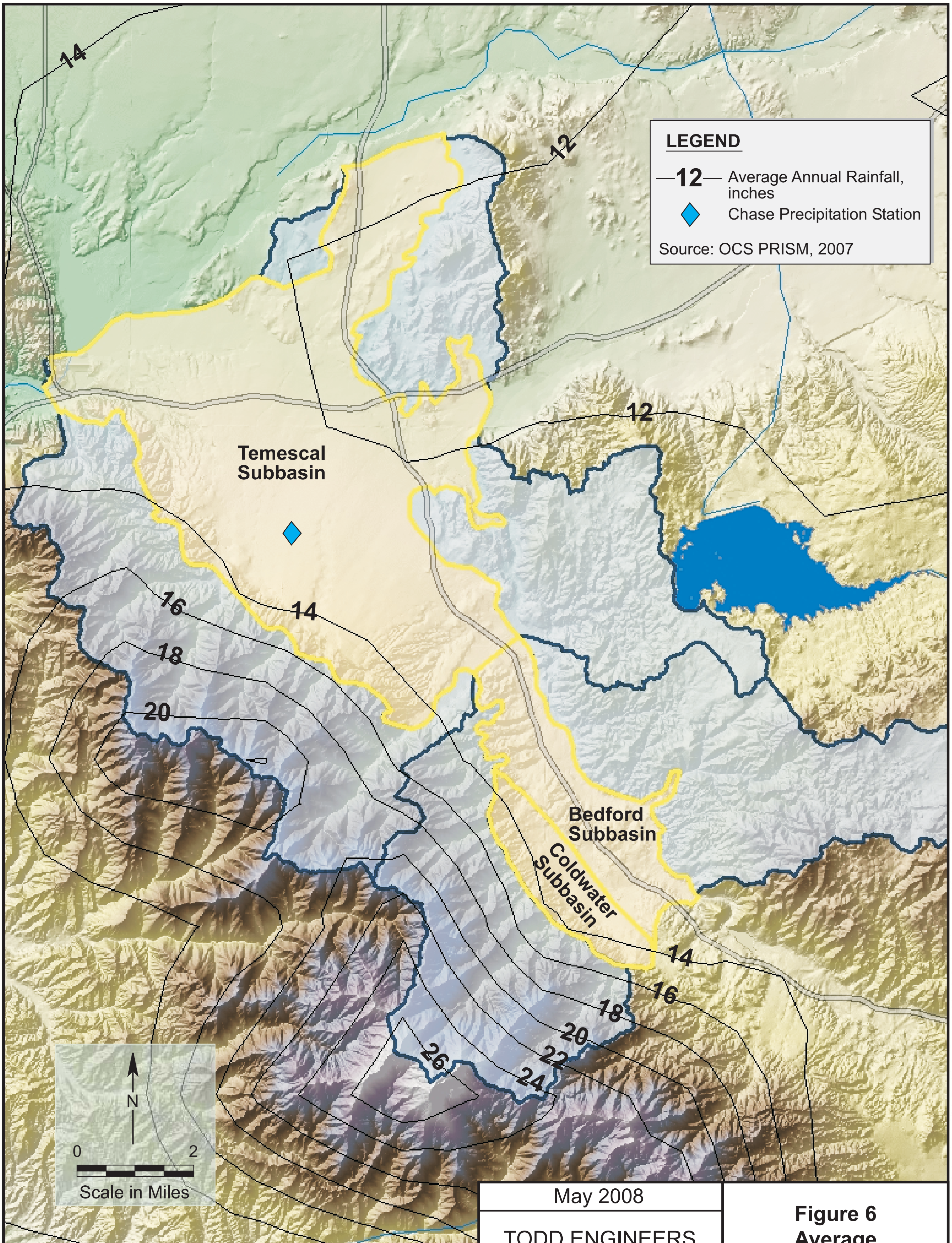



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**Figure 6**
**Average Annual Rainfall**

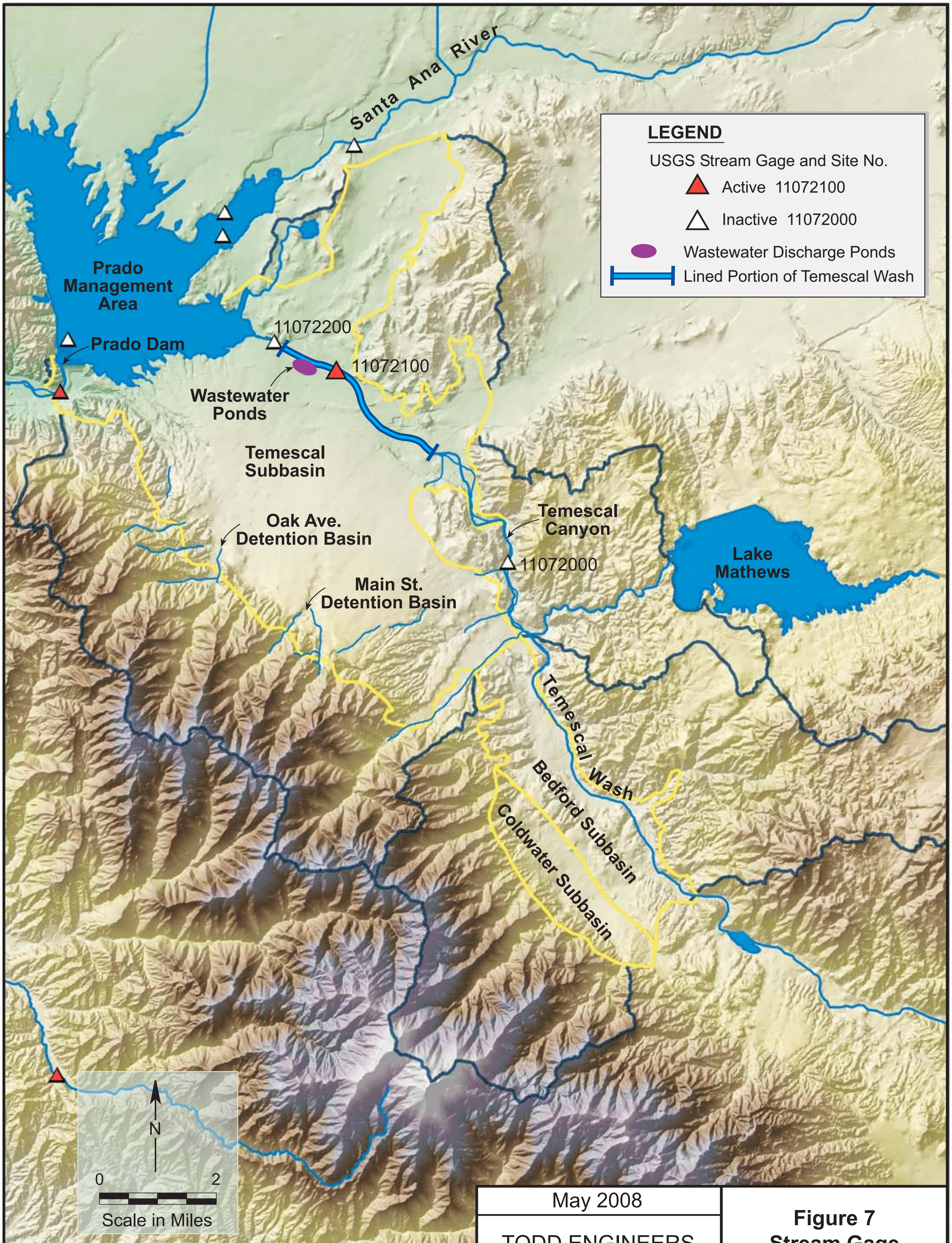


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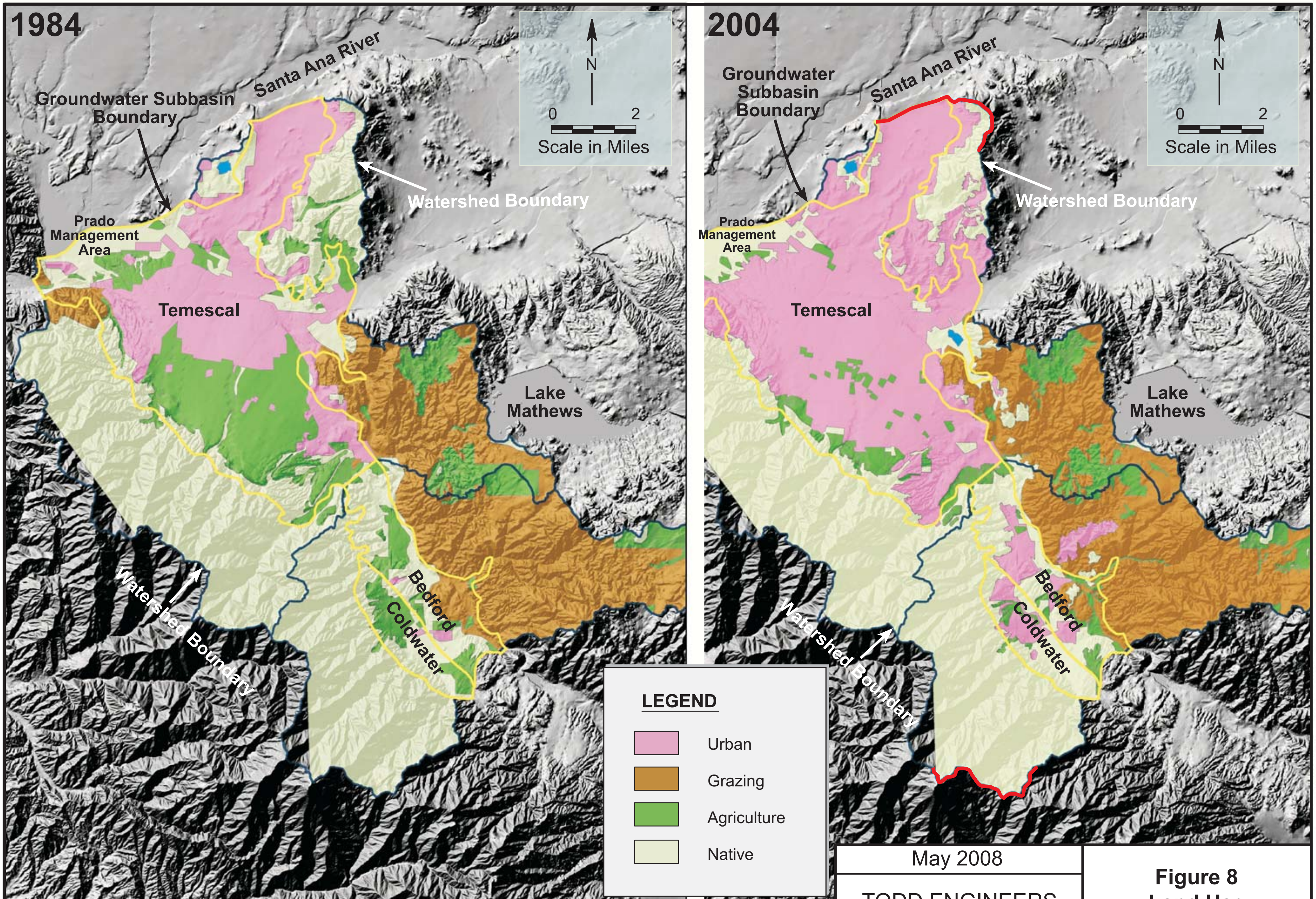
**Figure 7**
**Stream Gage Locations**




Source: DWR, July 2006.

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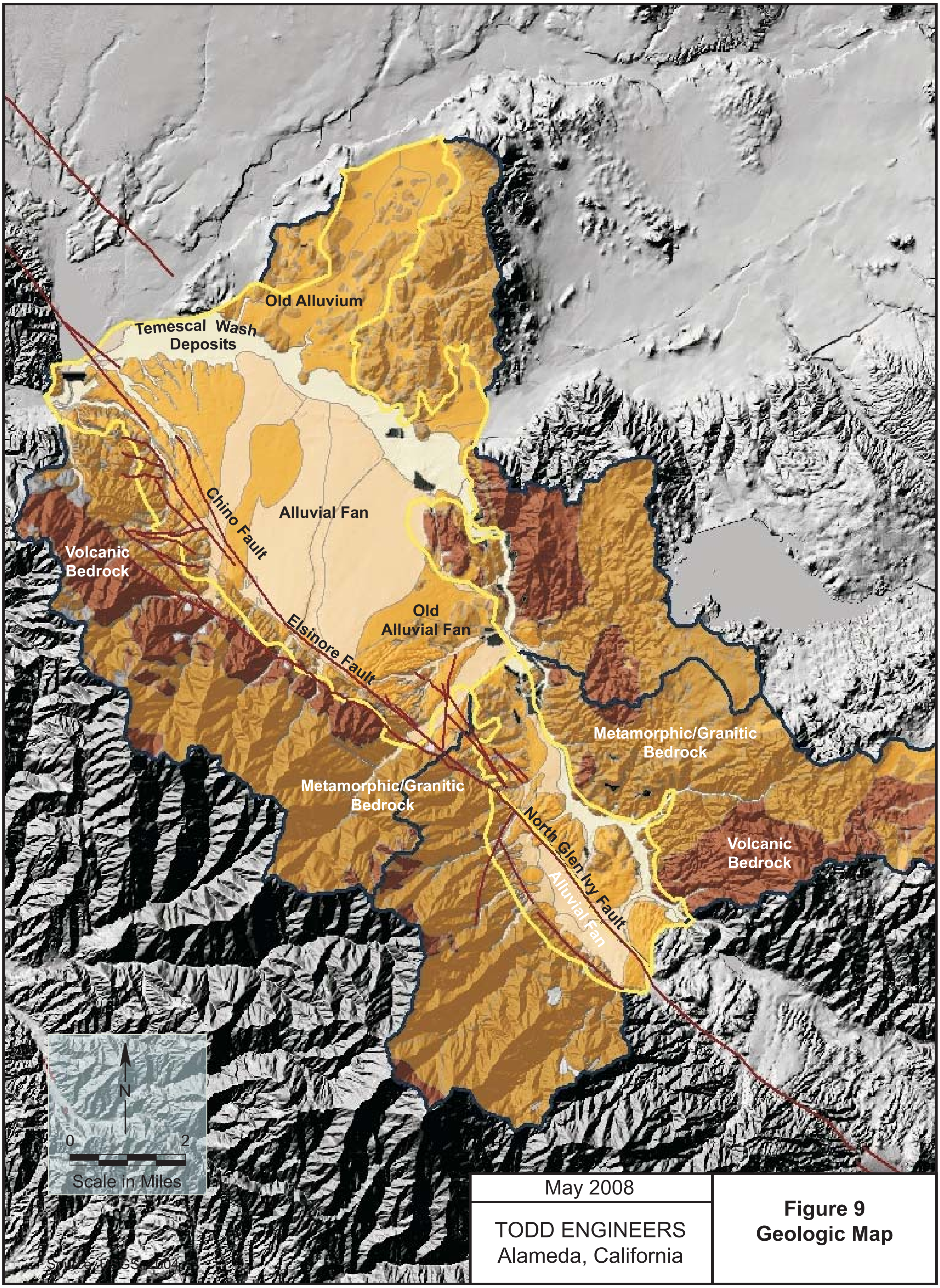
**Figure 8**
**Land Use**
**1984 and 2004**




| May 2008 | **Figure 9** |
|---|---|
| TODD ENGINEERS<br>Alameda, California | **Geologic Map** |

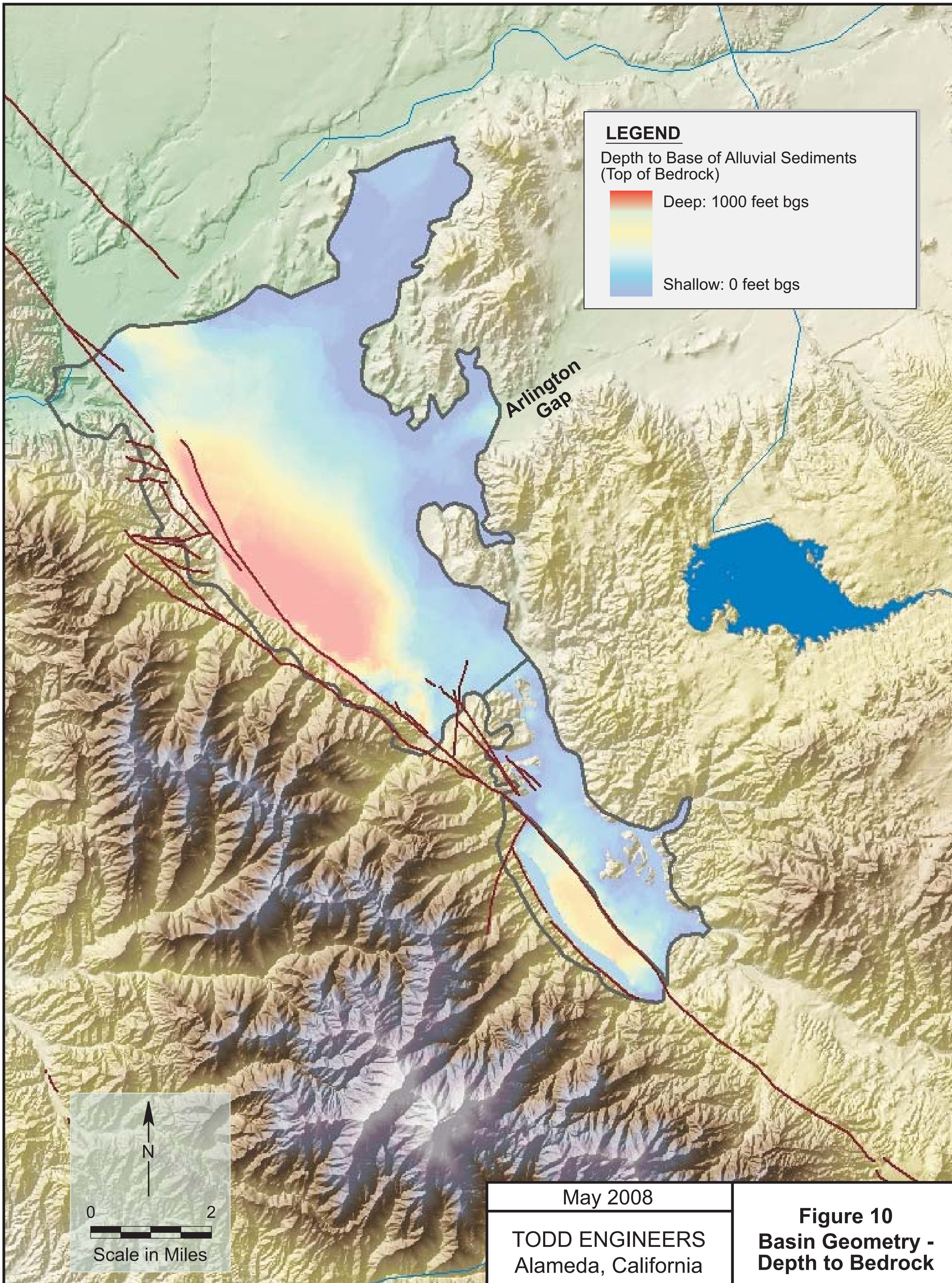



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**Figure 10**
**Basin Geometry - Depth to Bedrock**

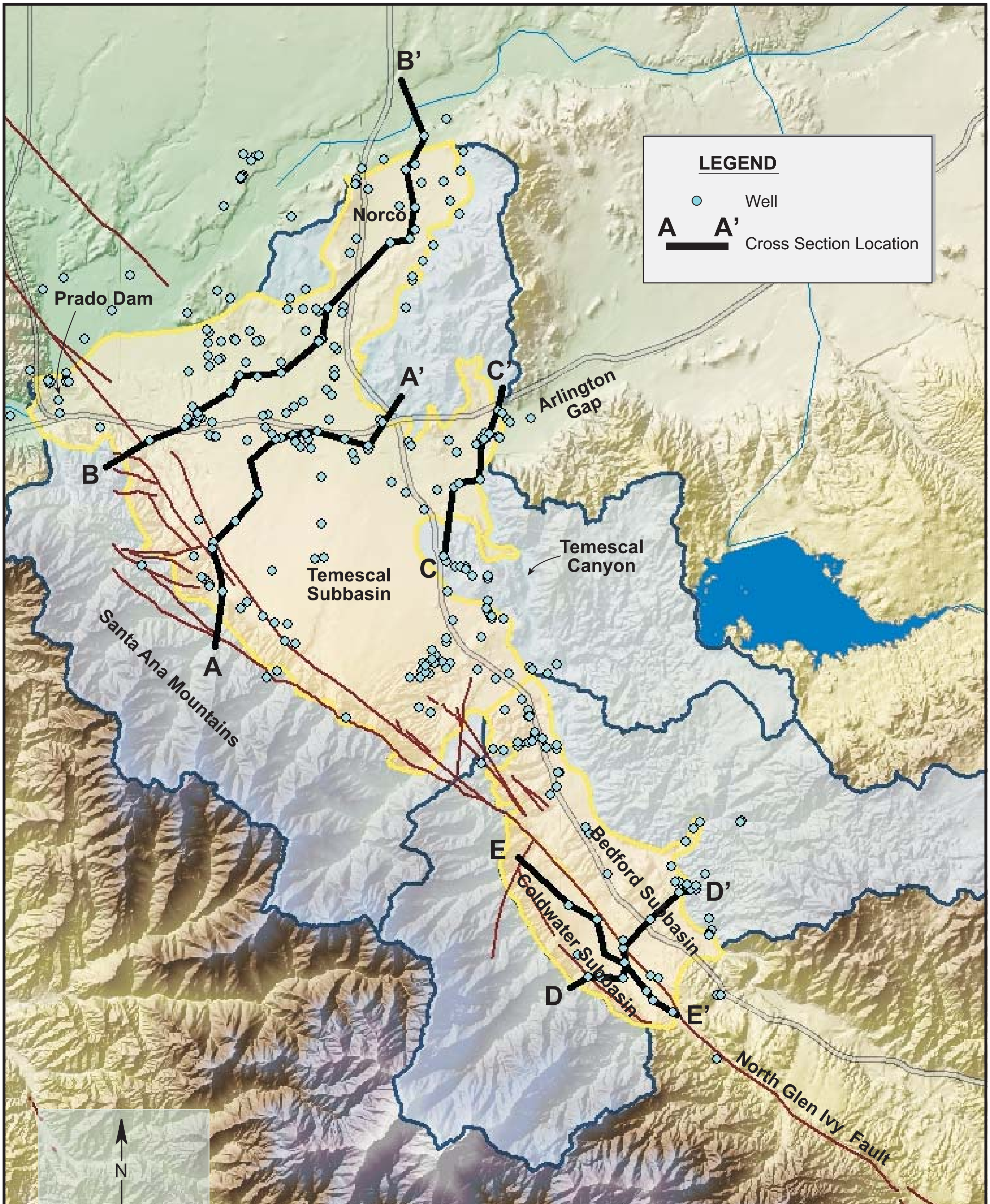


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**Figure 11**
**Cross Section Location Map**

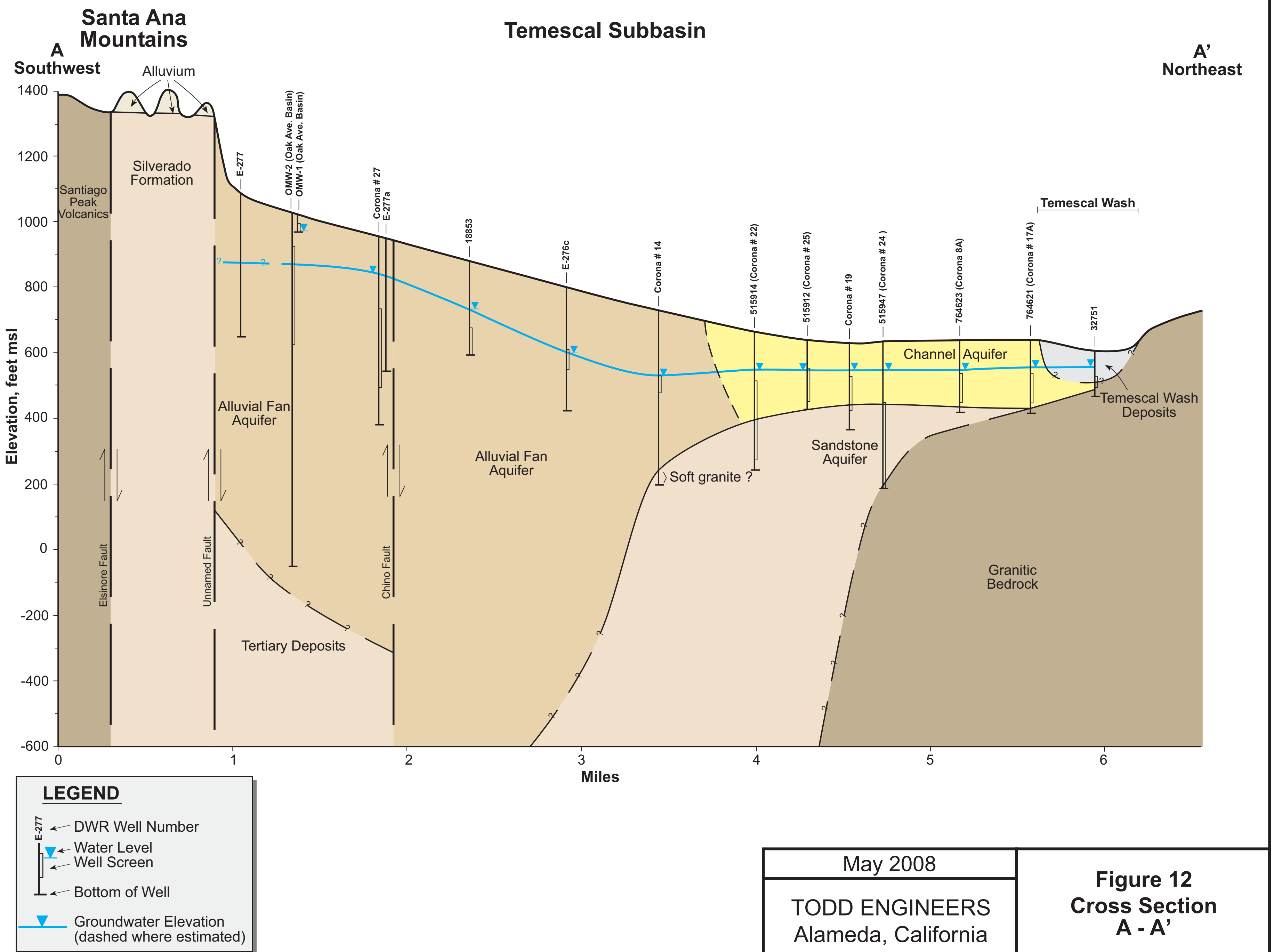


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**Figure 12**
**Cross Section A - A'**

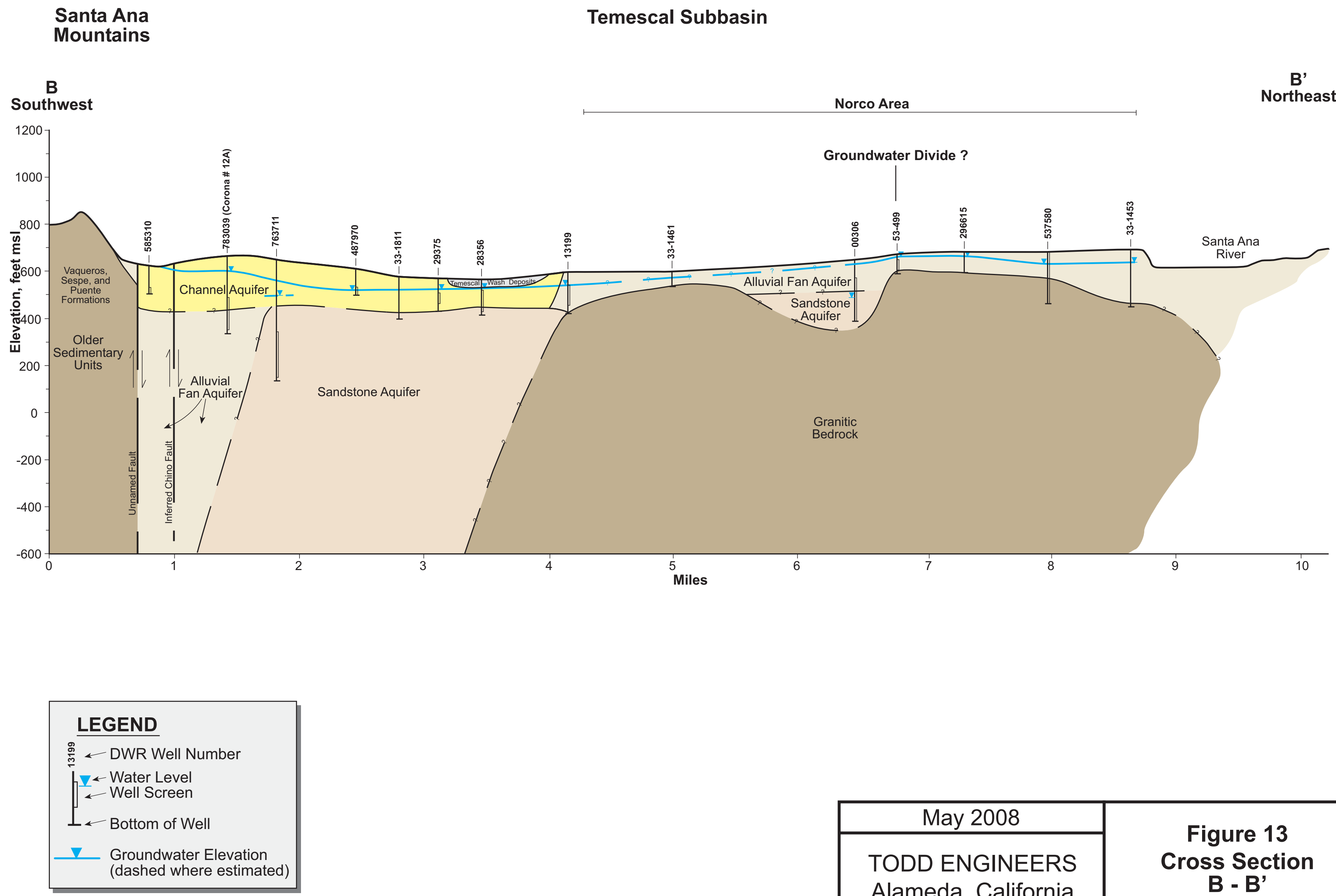


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**Figure 13**
**Cross Section**
**B - B'**

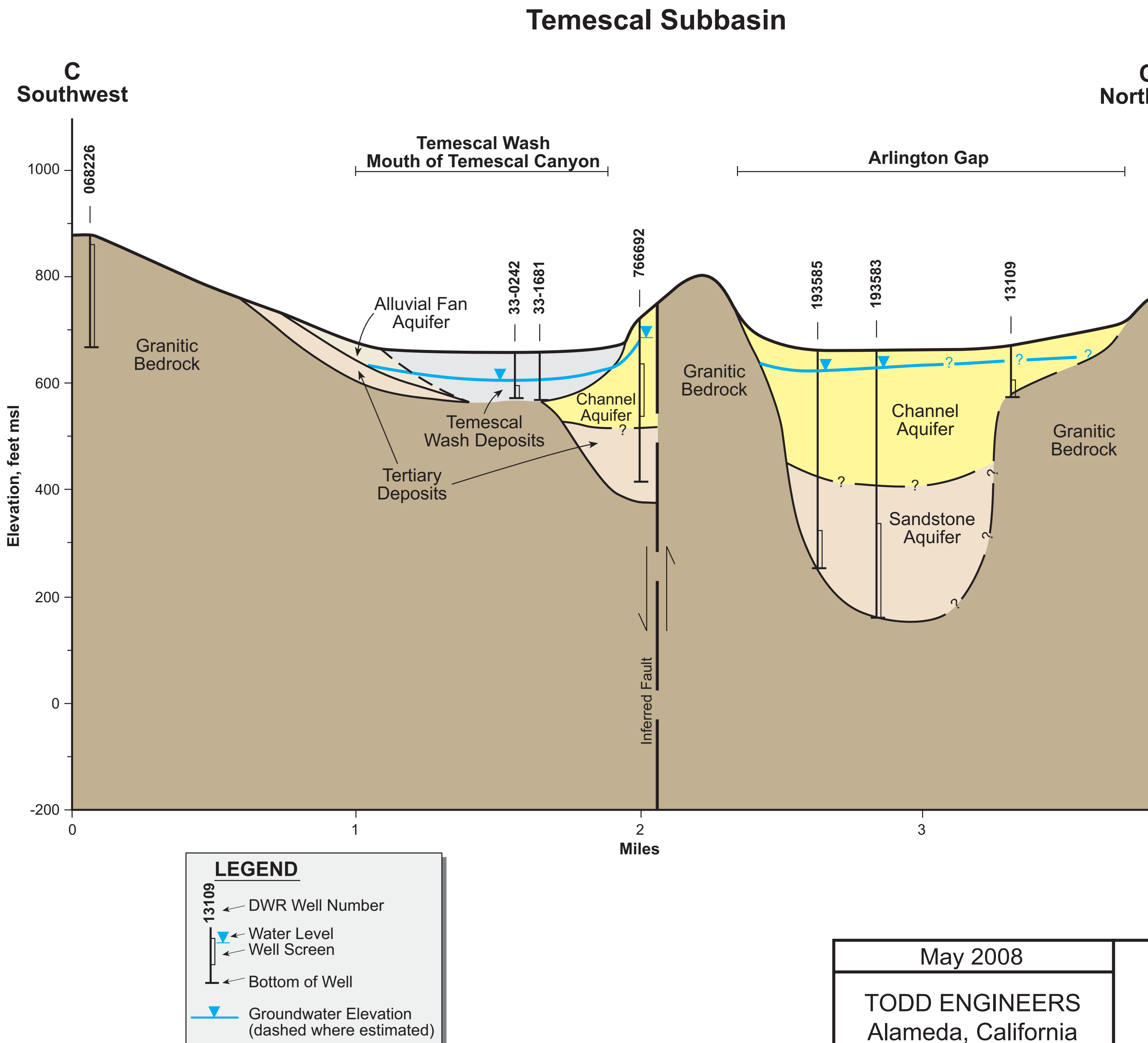


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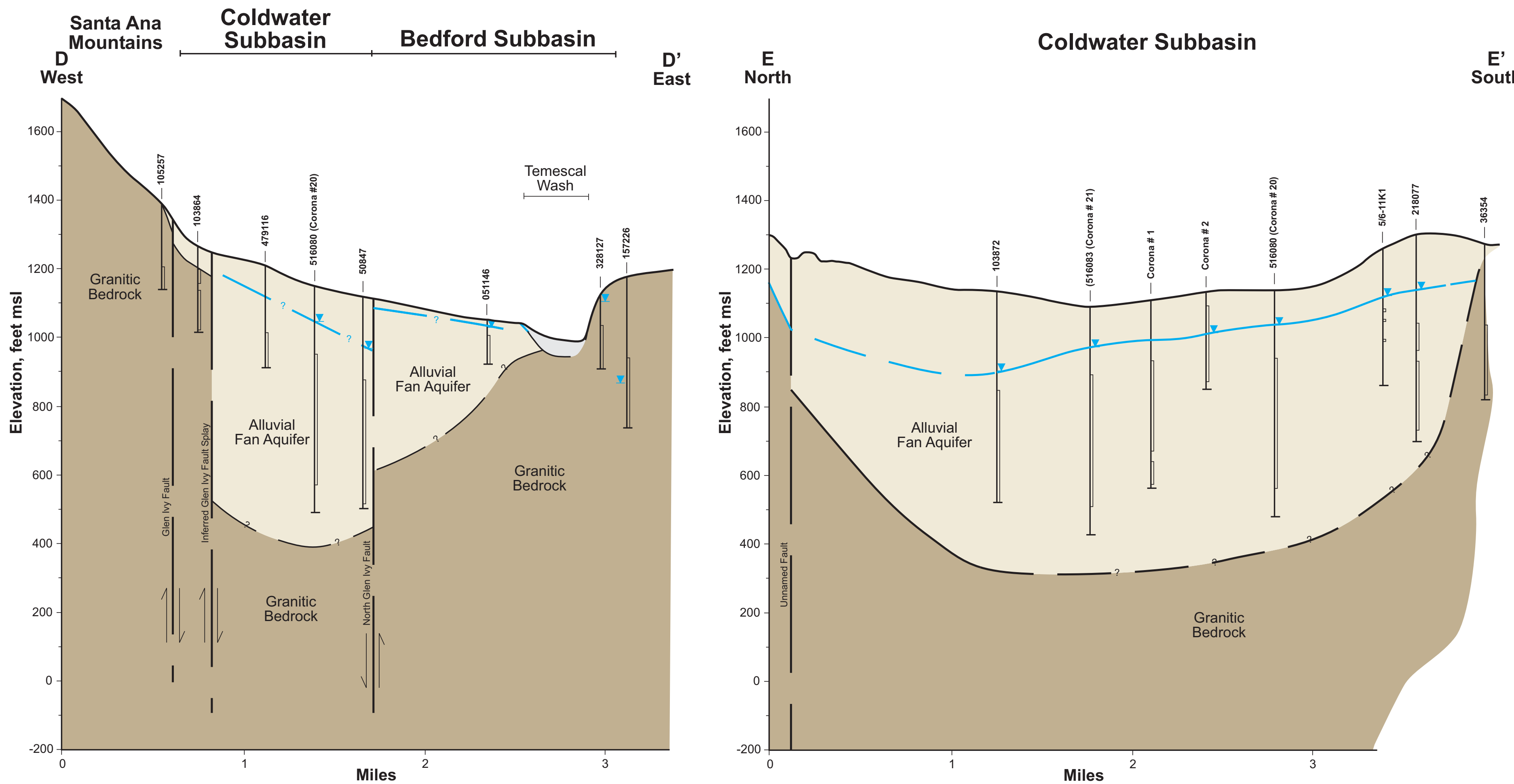
**Figure 14**
**Cross Section**
**C - C'**



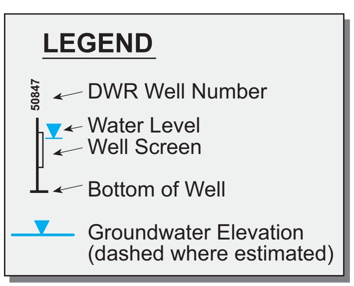



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**Figure 15**
**Cross Sections**
**D - D' and E - E'**

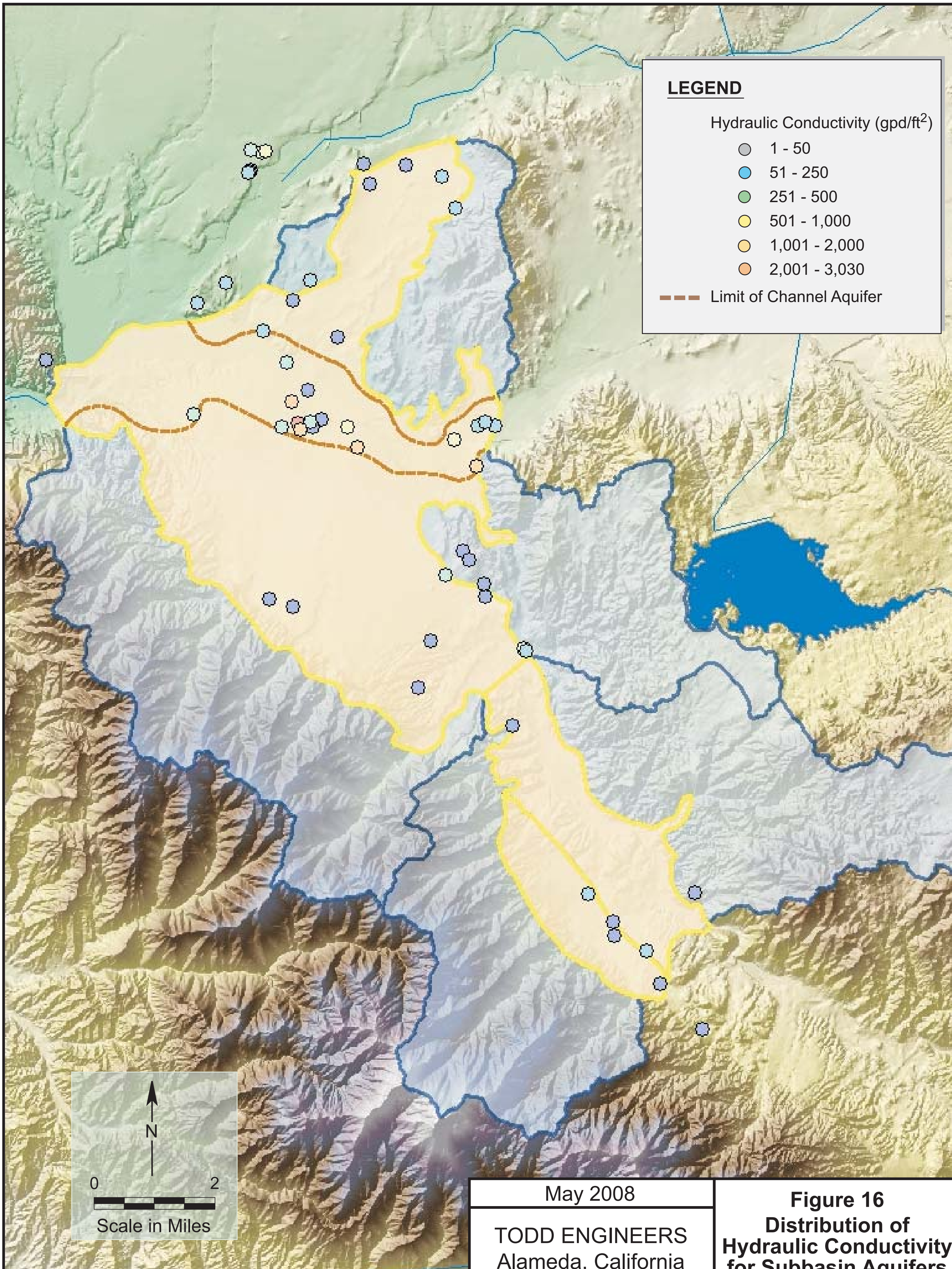


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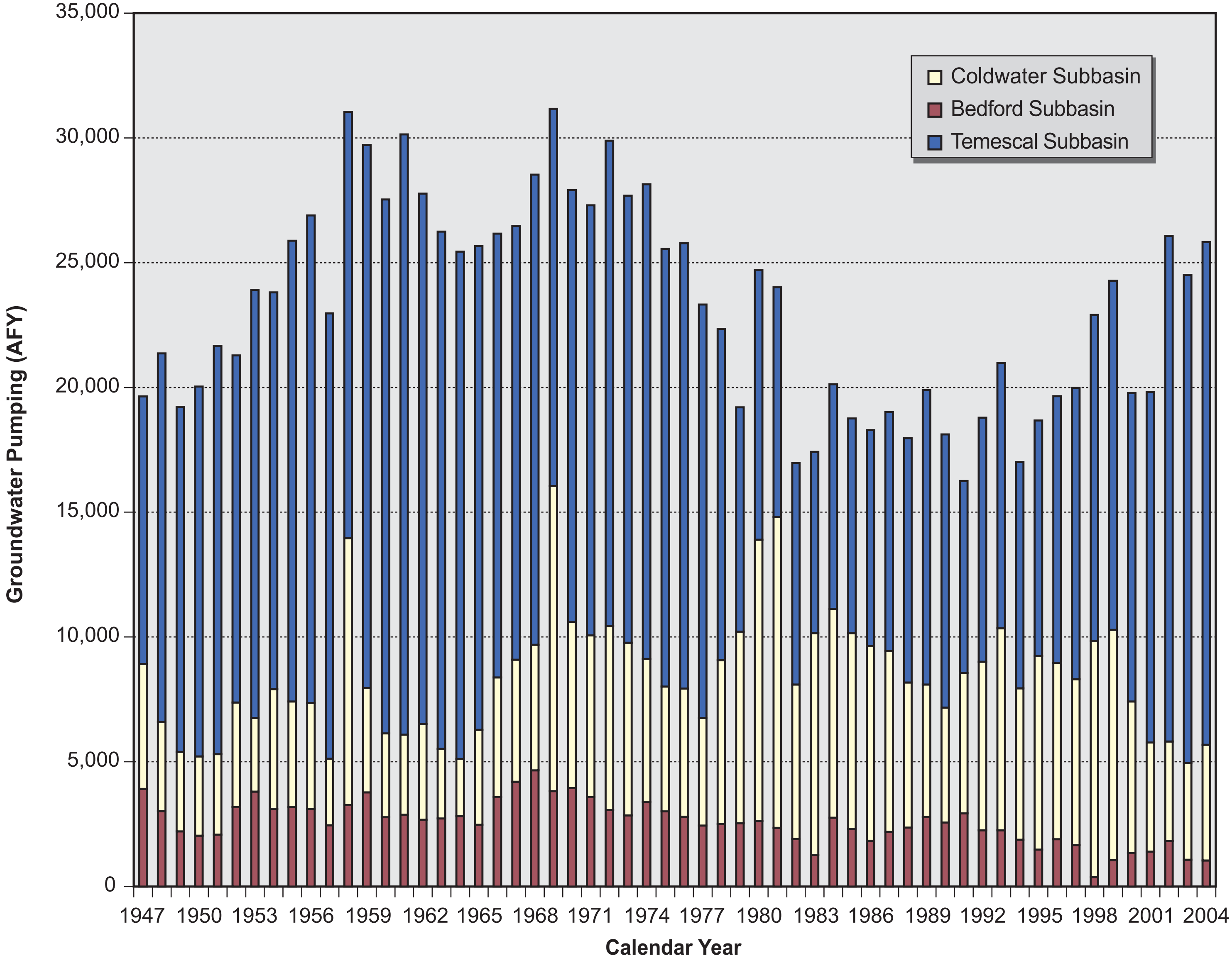
**Figure 16**
**Distribution of Hydraulic Conductivity for Subbasin Aquifers**




| May 2008 | **Figure 17** |
|---|---|
| TODD ENGINEERS<br>Alameda, California | **Study Area Groundwater Pumping** |

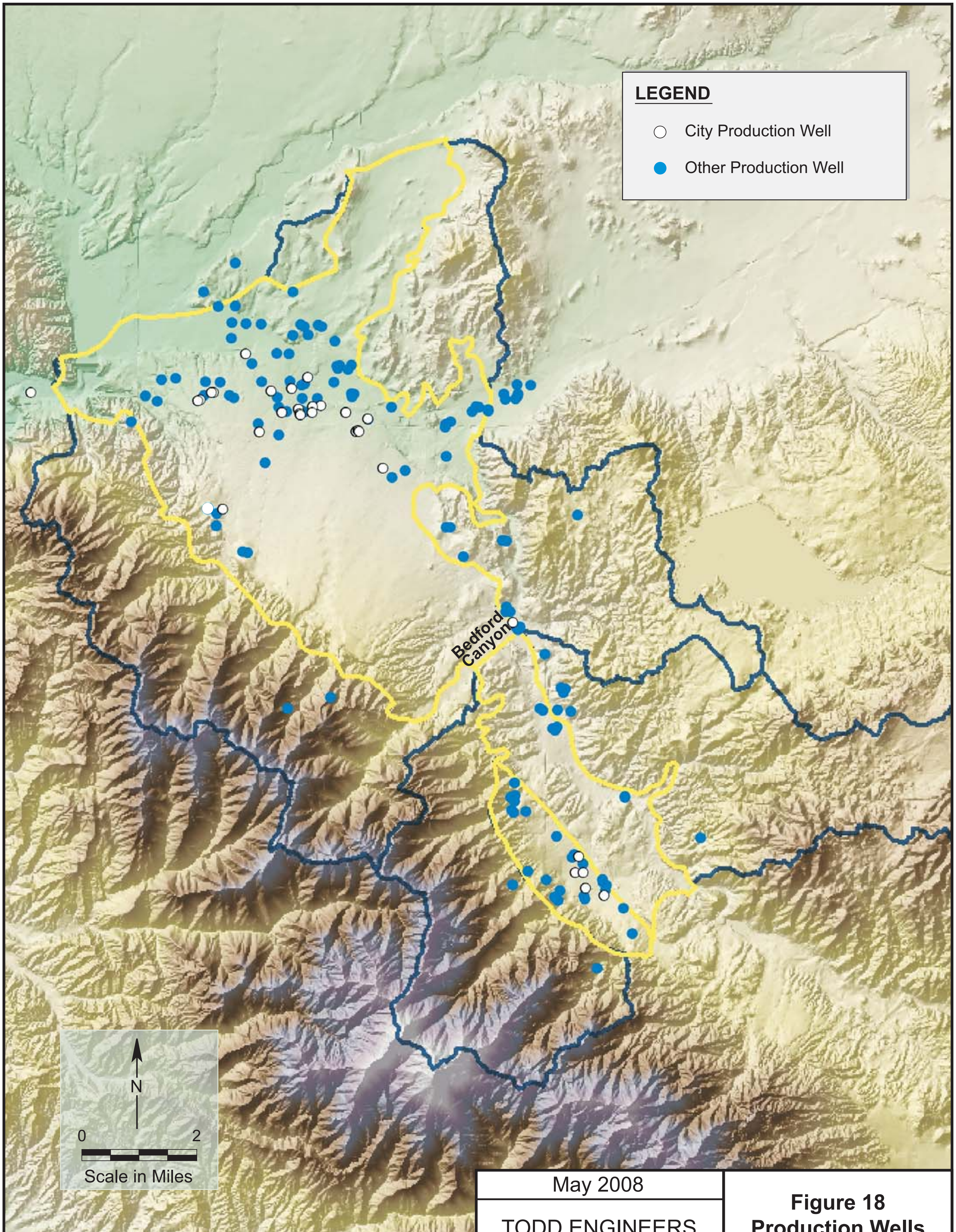



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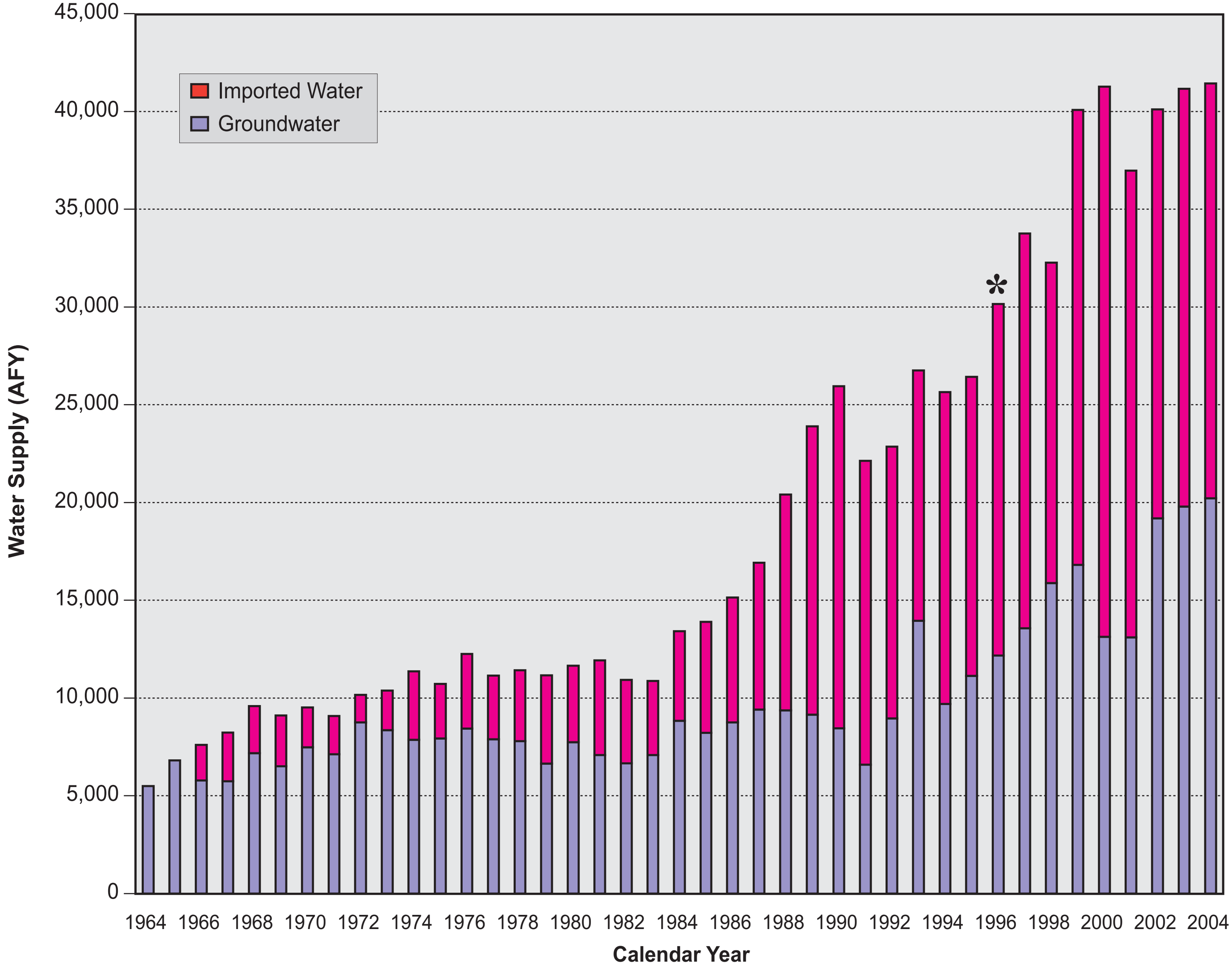
**Figure 18**
**Production Wells**
**1947 - 2004**




* Includes estimates for missing data between July 1996 and December 1996.

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**Figure 19**
**City of Corona**
**Water Supply**

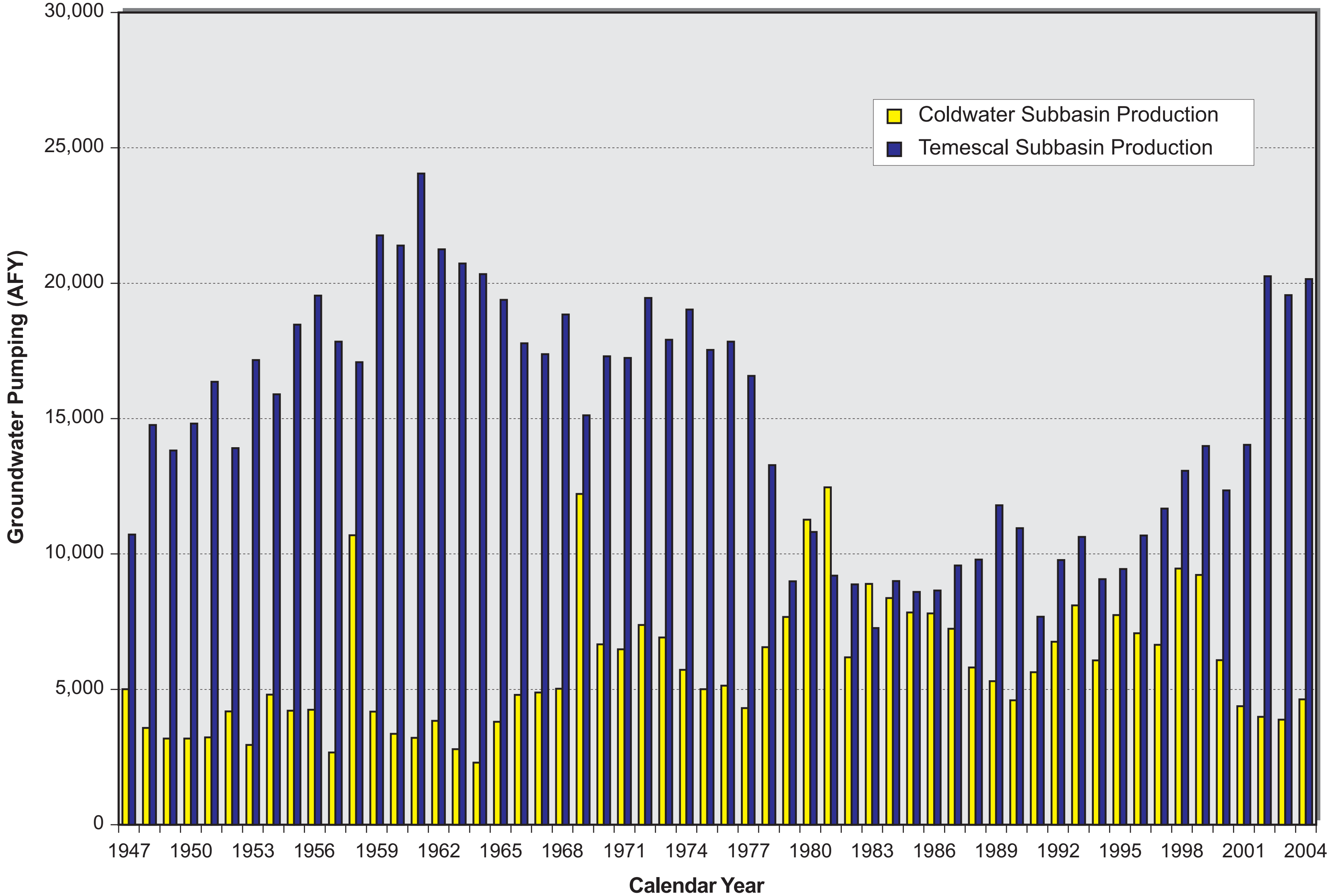


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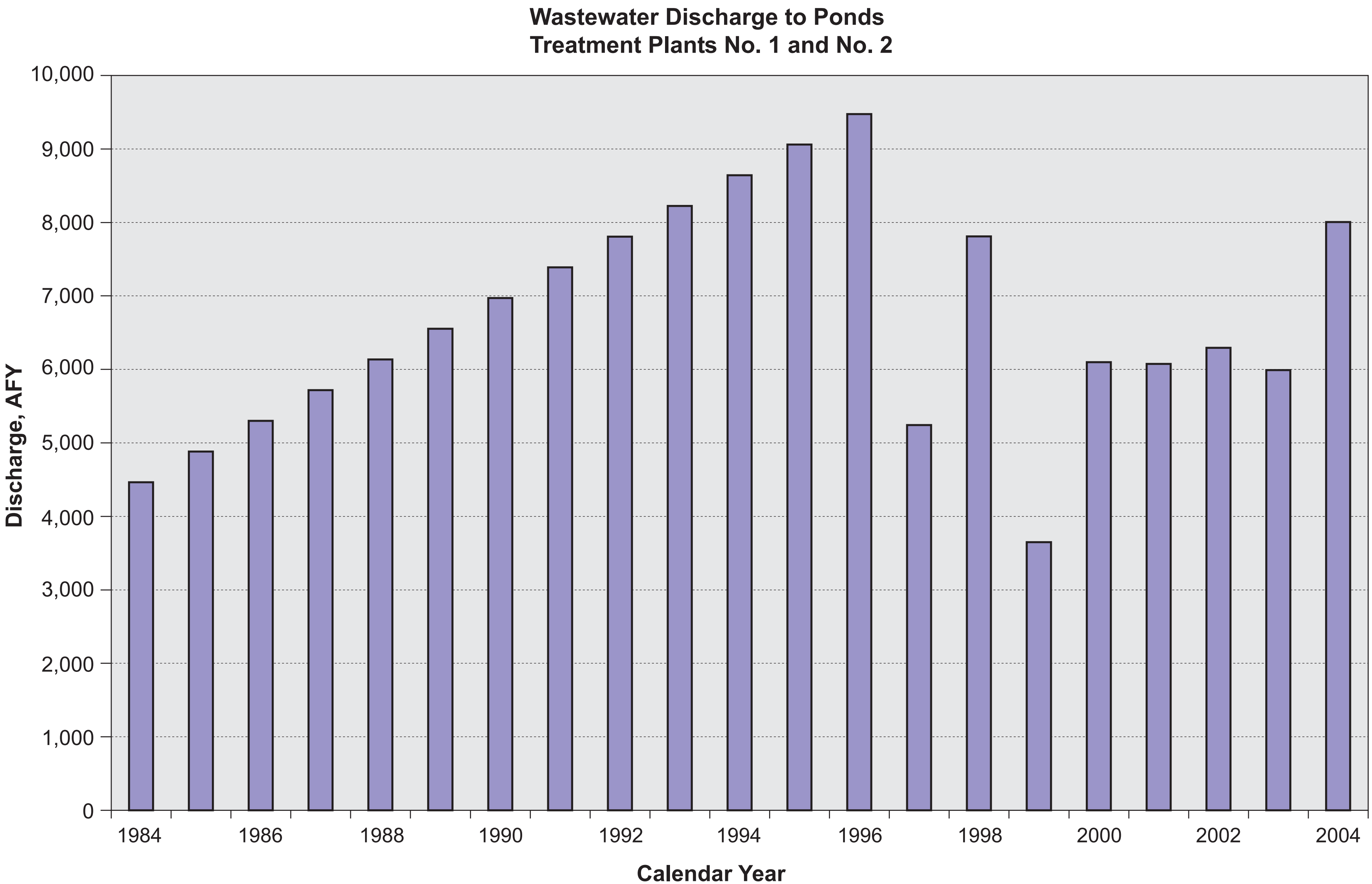
**Figure 20**
**Pumping in Temescal and Coldwater Subbasins**




Note: Prior to 1997, all effluent was discharged to percolation ponds.
After 1997, effluent was discharged to ponds and Temescal Wash.
Effluent discharge 1984 - 1996 estimated based on population.

| May 2008 | **Figure 21** |
|---|---|
| TODD ENGINEERS<br>Alameda, California | **Wastewater Discharge to Ponds** |


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**Figure 22**
**Location of Key Hydrographs**

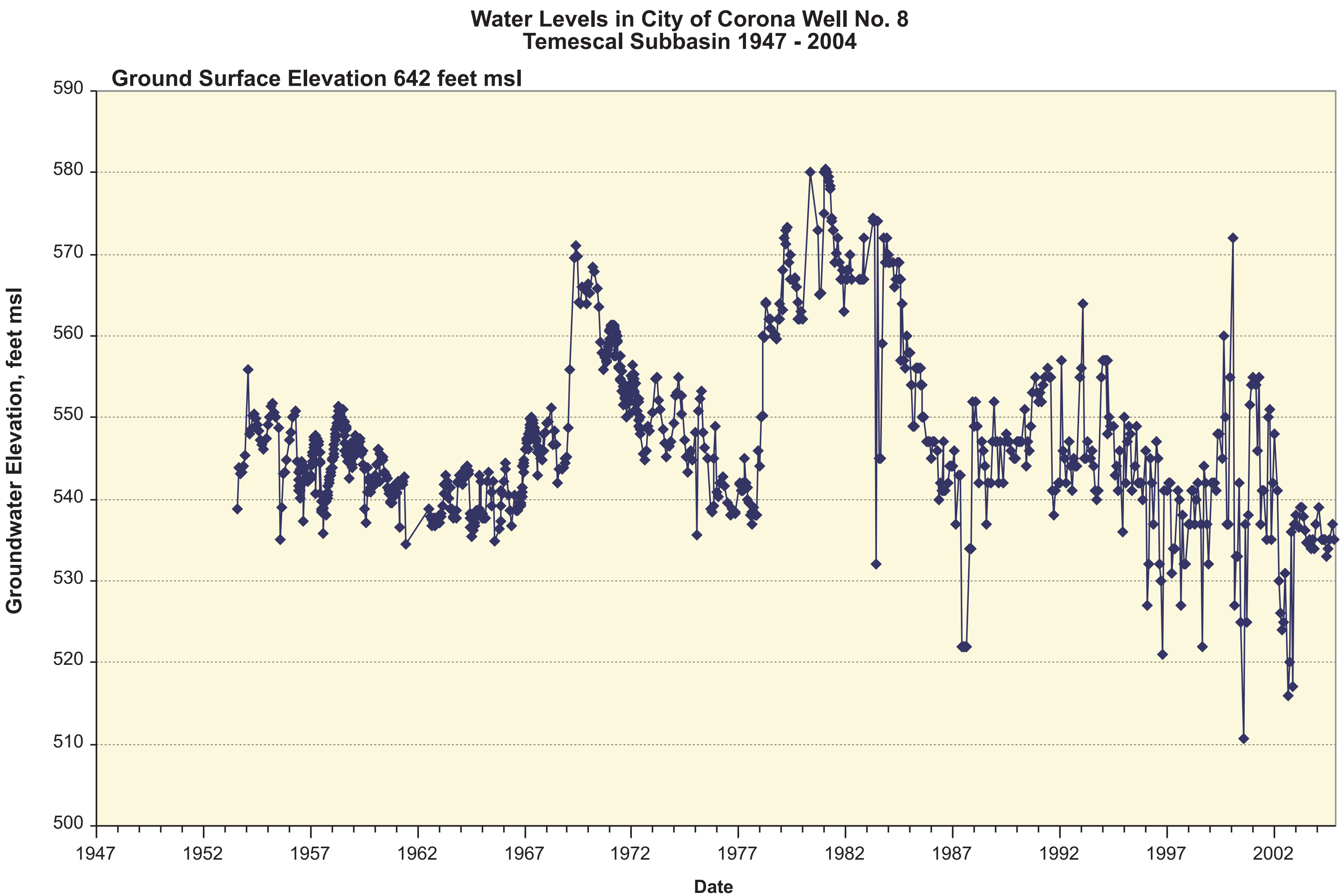


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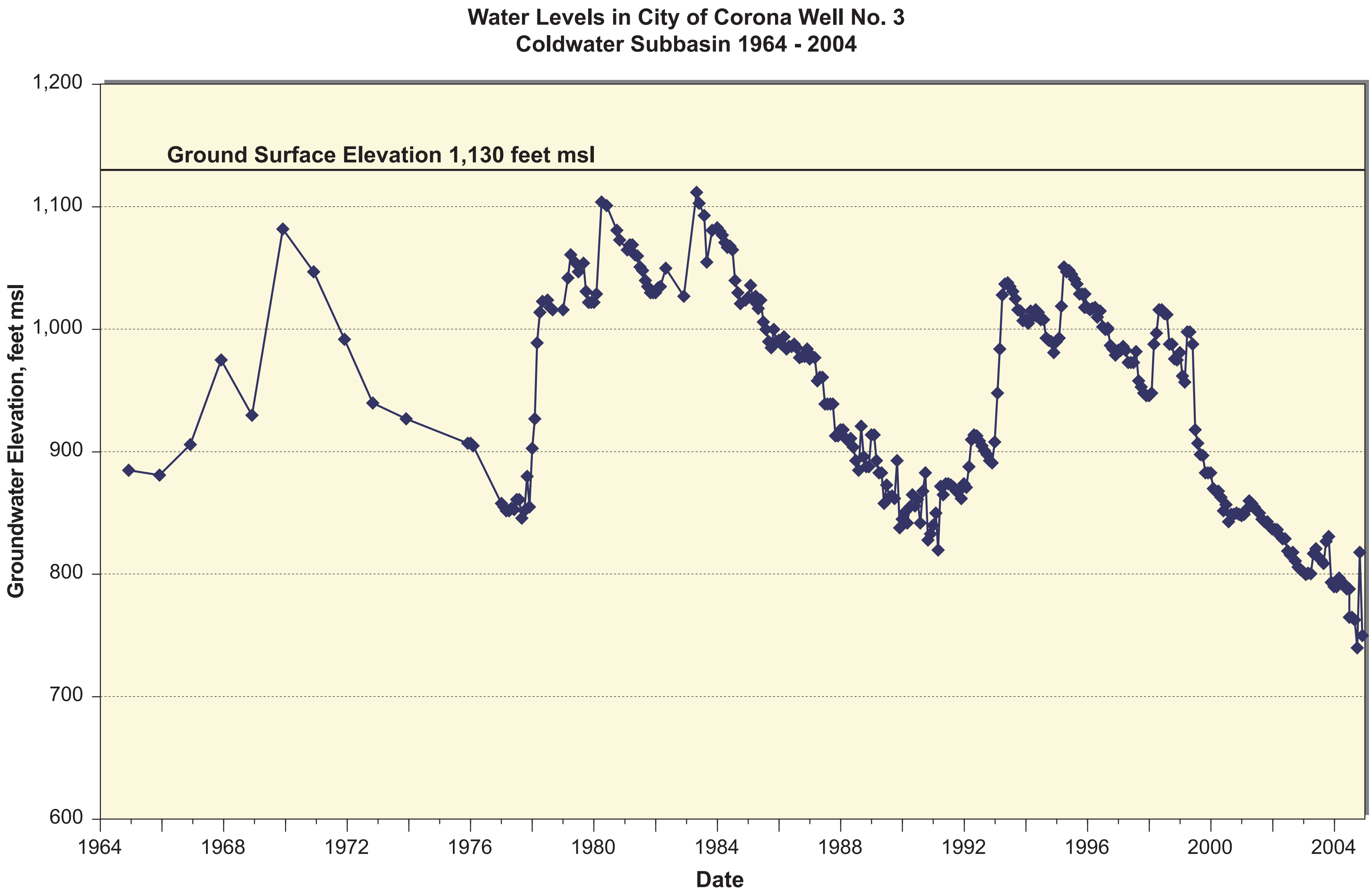
**Figure 23**
**Temescal Subbasin Hydrograph**




| May 2008 | **Figure 24** |
|---|---|
| TODD ENGINEERS<br>Alameda, California | **Coldwater Subbasin Hydrograph** |

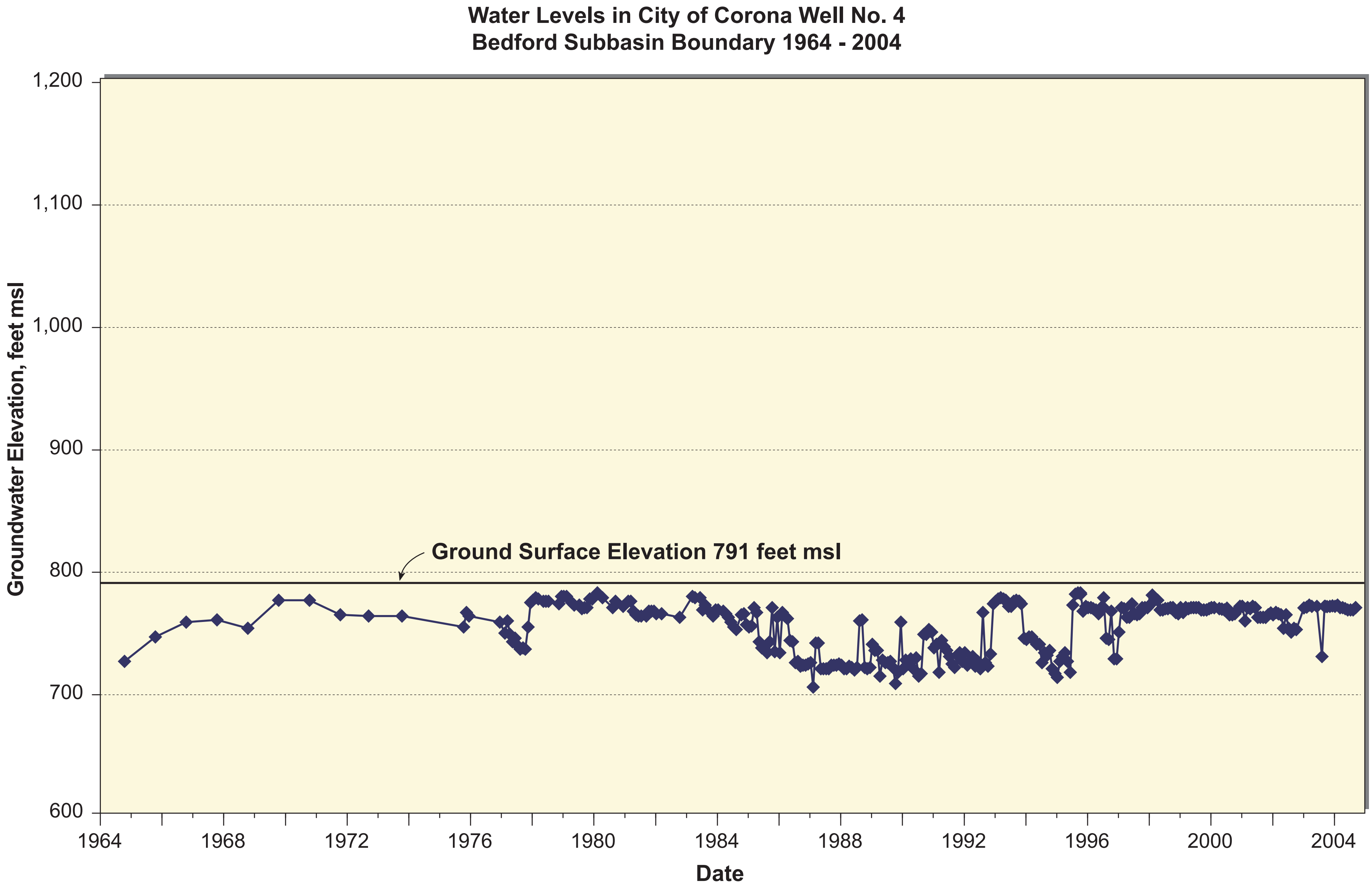



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**Figure 25**
**Bedford Canyon Hydrograph**

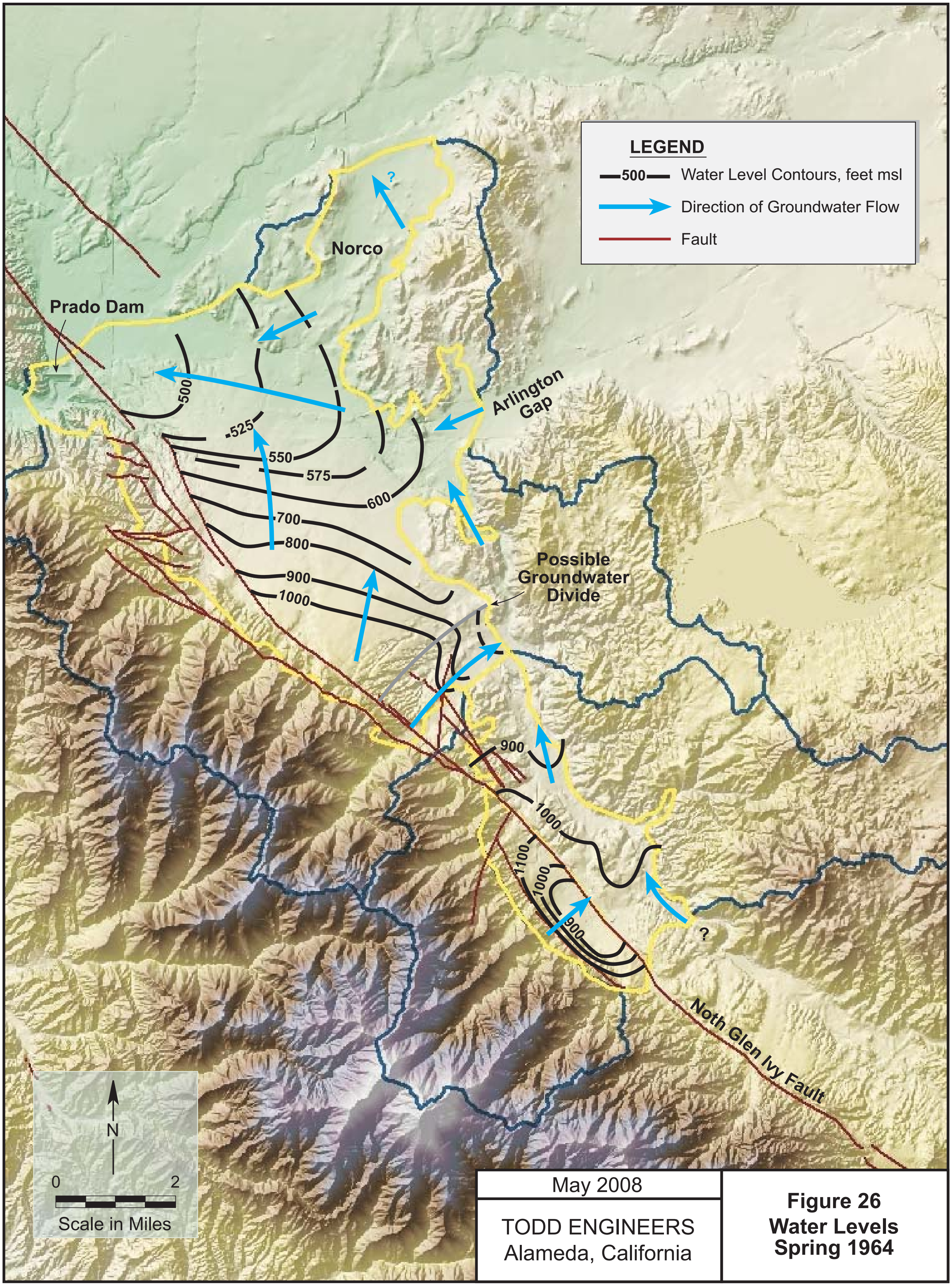


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**Figure 26**
**Water Levels**
**Spring 1964**

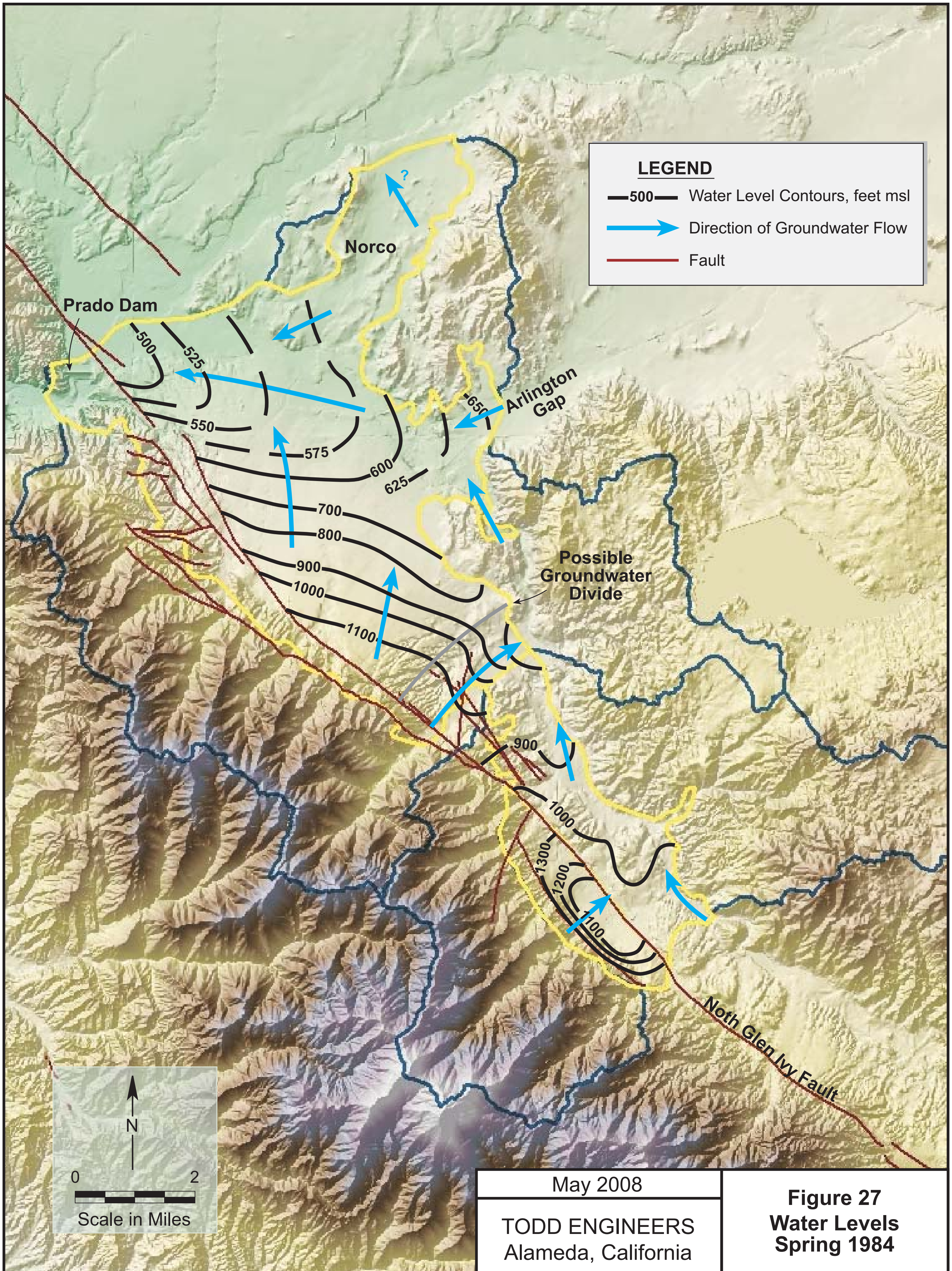


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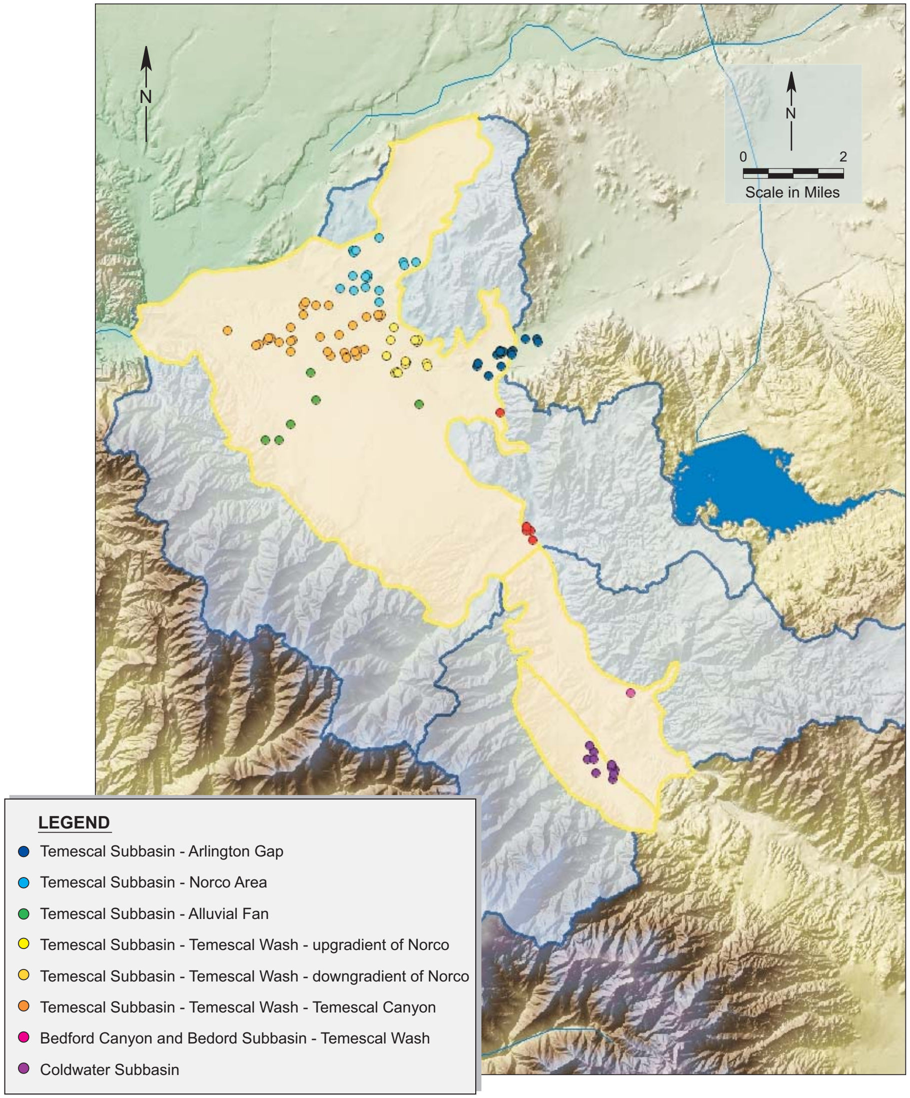
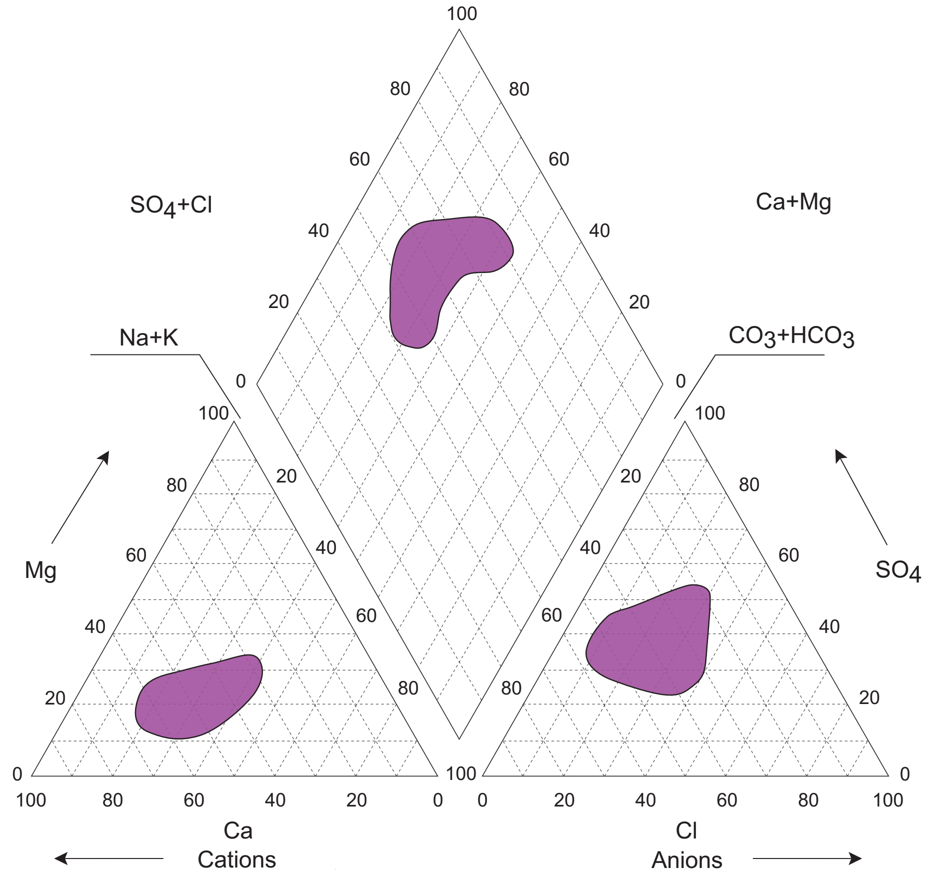
**Figure 27**
**Water Levels**
**Spring 1984**

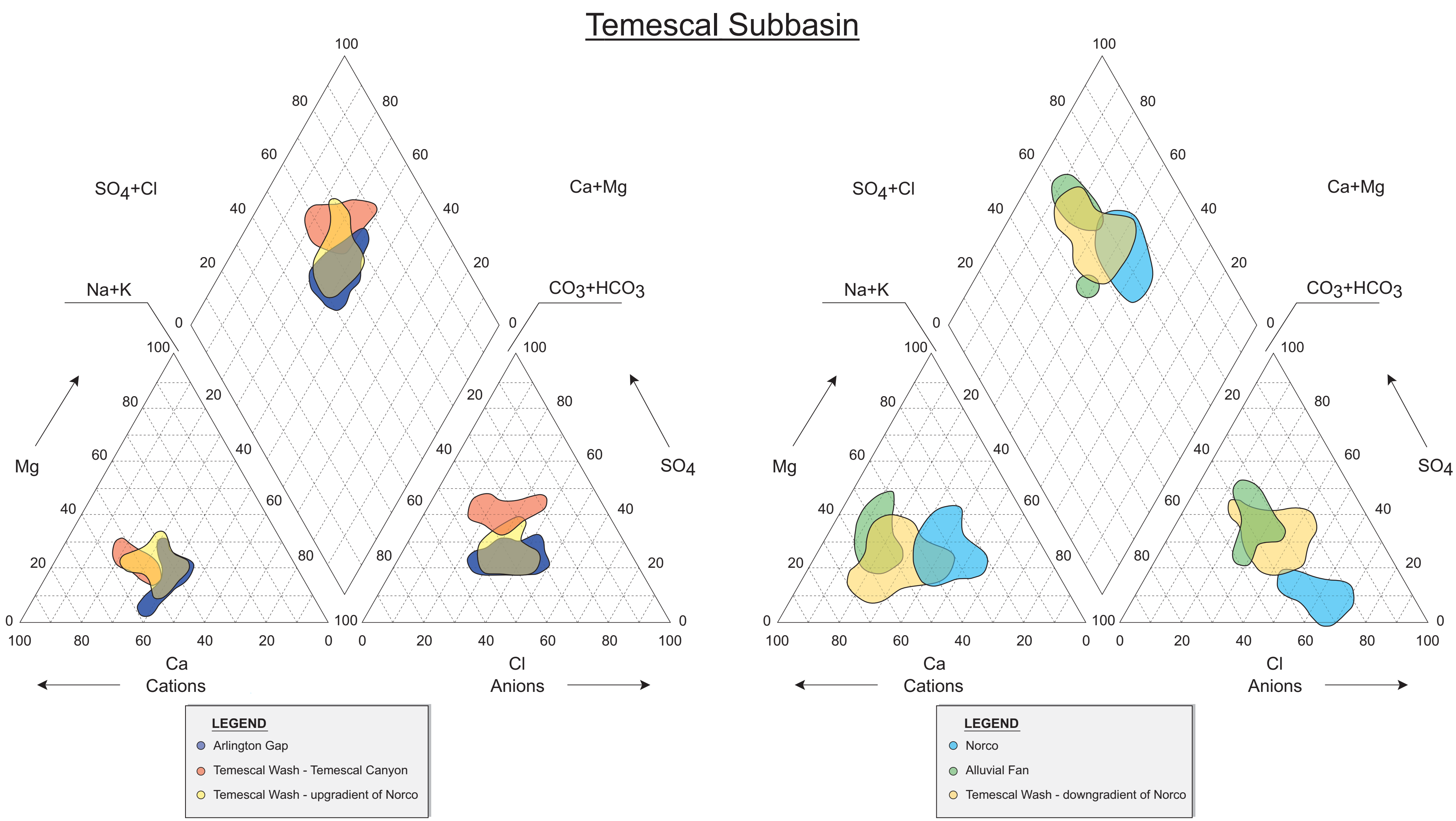
## Water Quality Data Sets by Area




## Coldwater Subbasin




| May 2008 | **Figure 28** |
| --- | --- |
| TODD ENGINEERS<br>Alameda, California | **Water Quality Analysis and Coldwater Subbasin Water Chemistry** |




Colors correspond to map locations on Figure 28.

| May 2008 | **Figure 29** |
|---|---|
| TODD ENGINEERS<br>Alameda, California | **Variability of Water Chemistry Among Aquifers - Temescal Subbasin** |

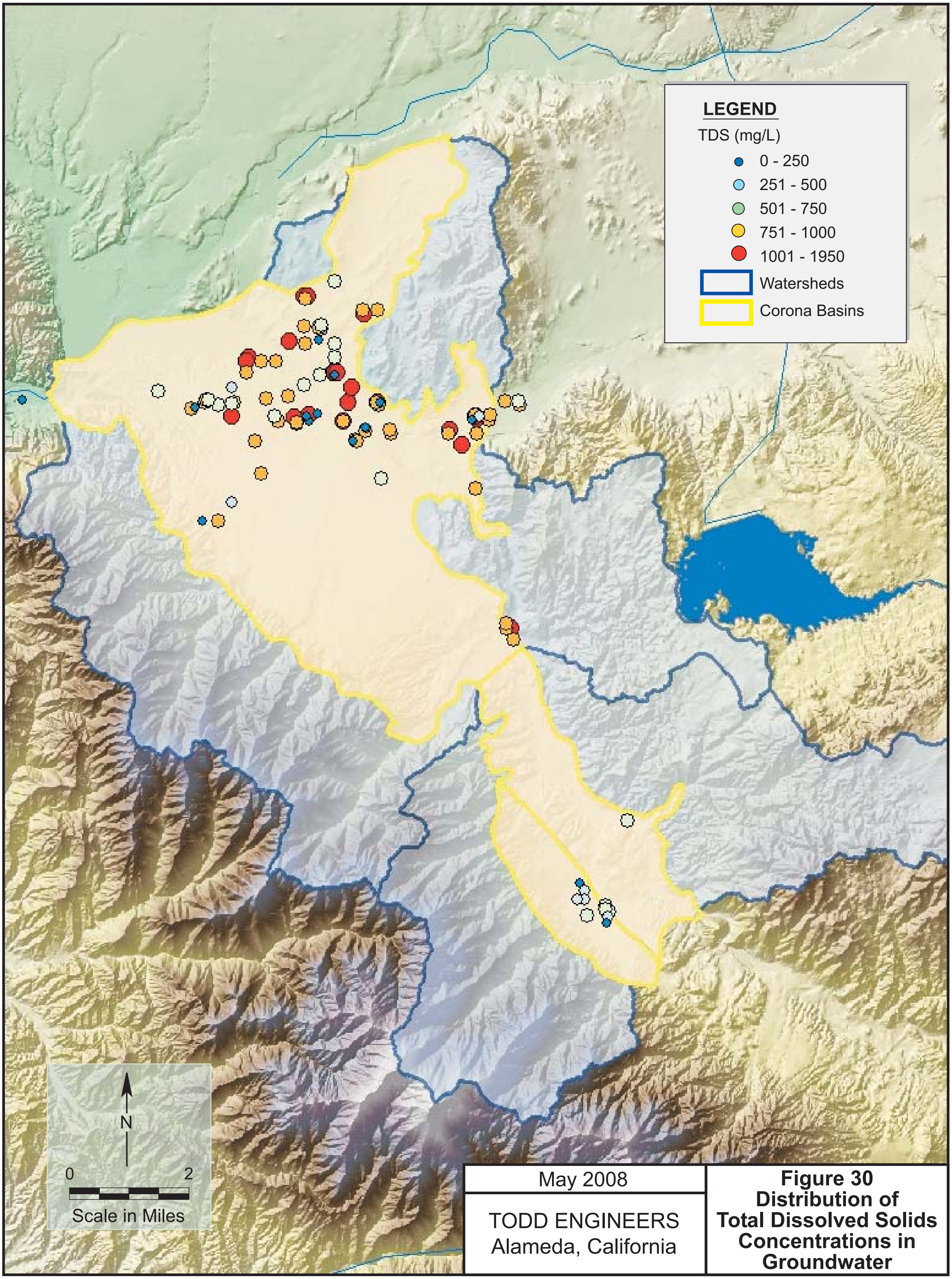



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**Figure 30**
**Distribution of Total Dissolved Solids Concentrations in Groundwater**

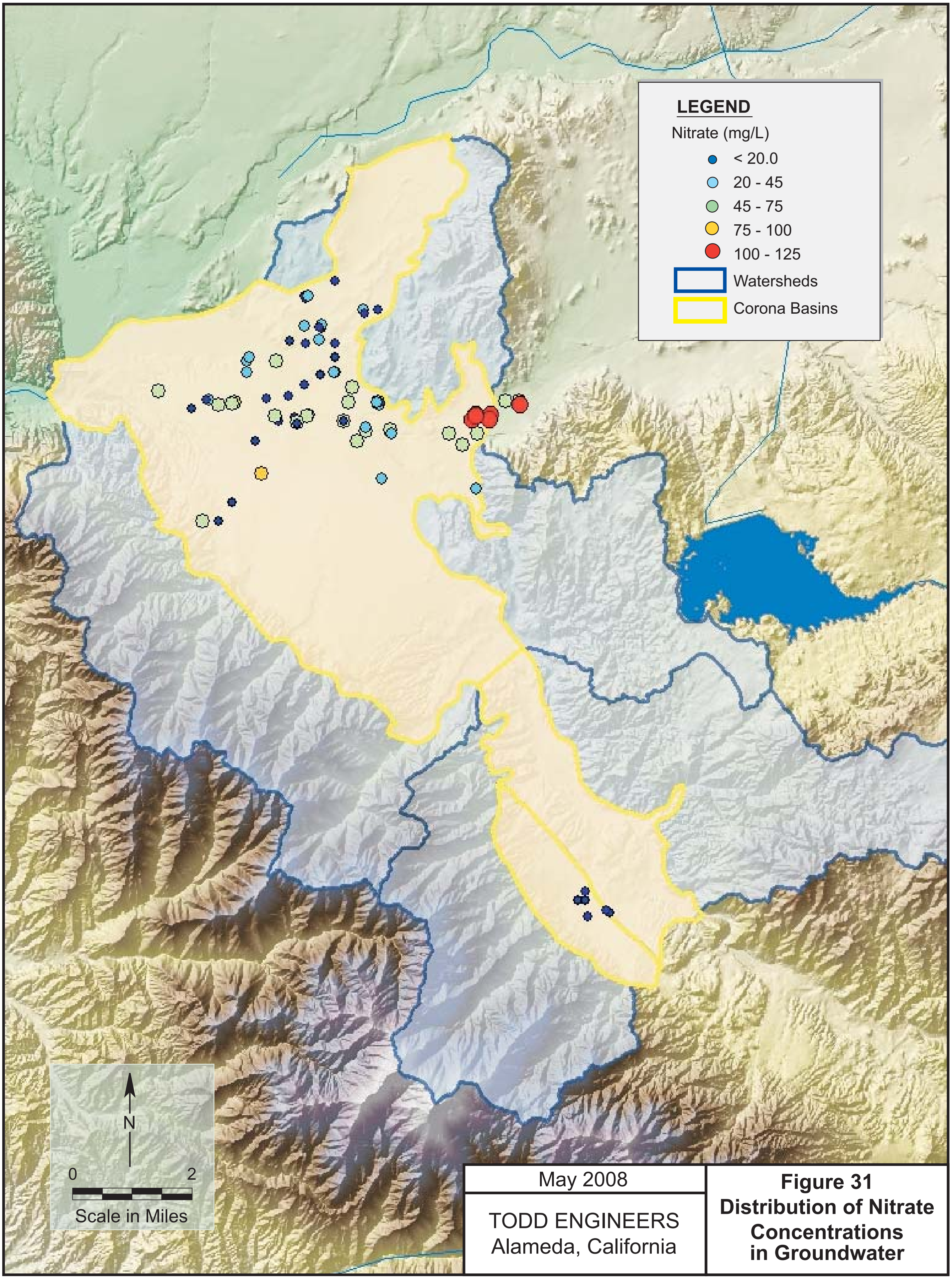


**Figure 31
Distribution of Nitrate Concentrations in Groundwater**

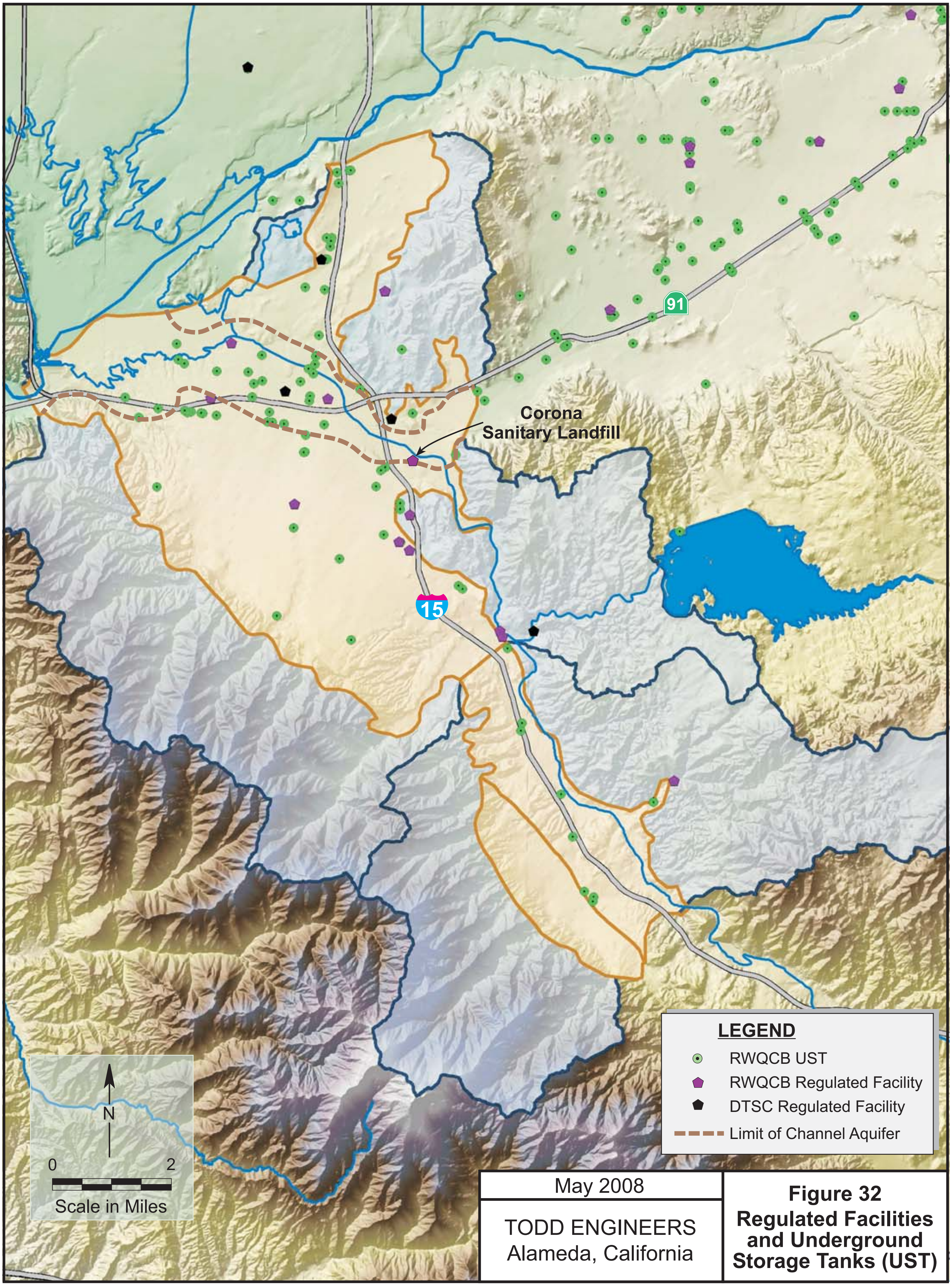


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**Figure 32**
**Regulated Facilities and Underground Storage Tanks (UST)**


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**Figure 33**
**Water Balance Units**

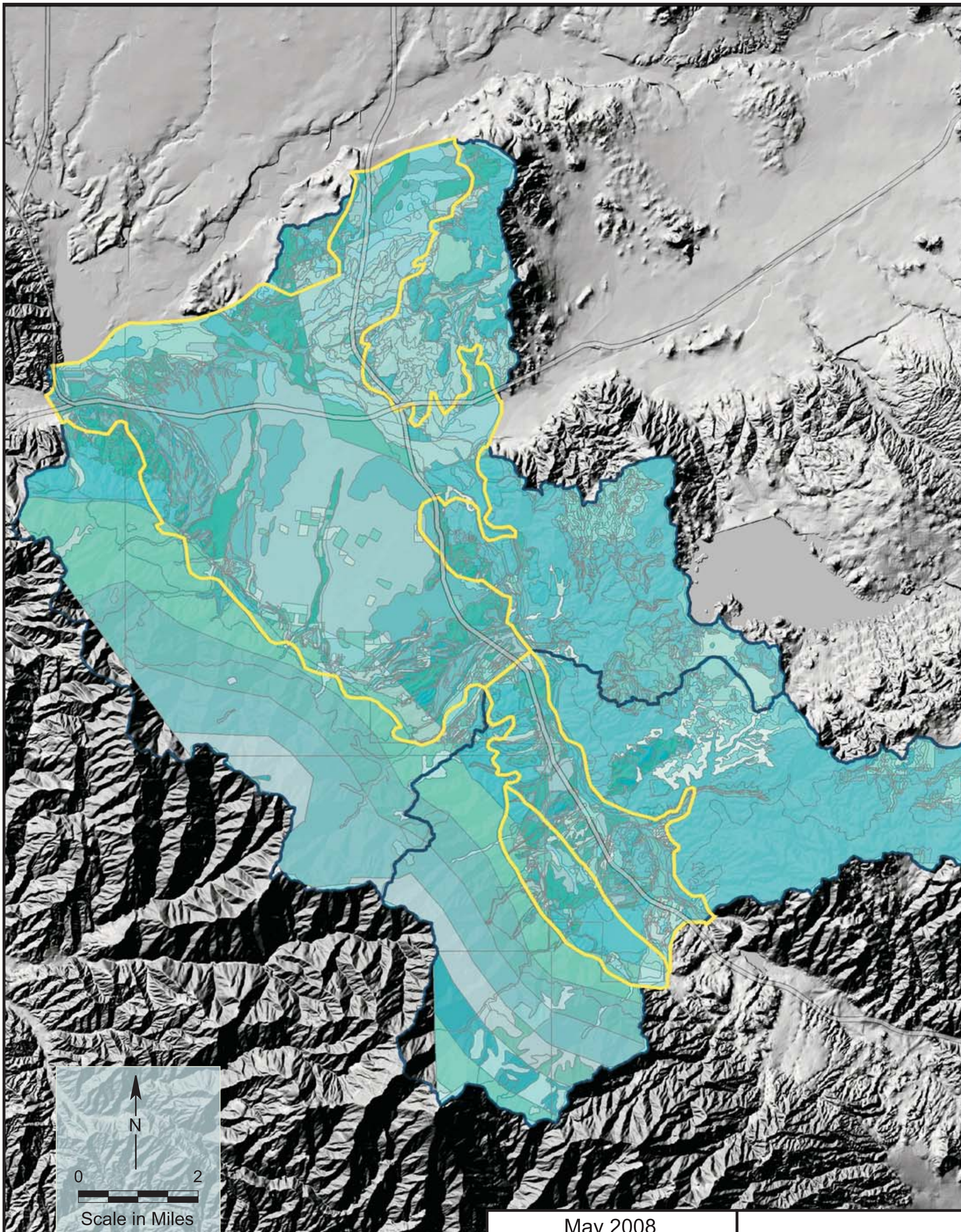


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**Figure 34**
**Water Balance Elements**

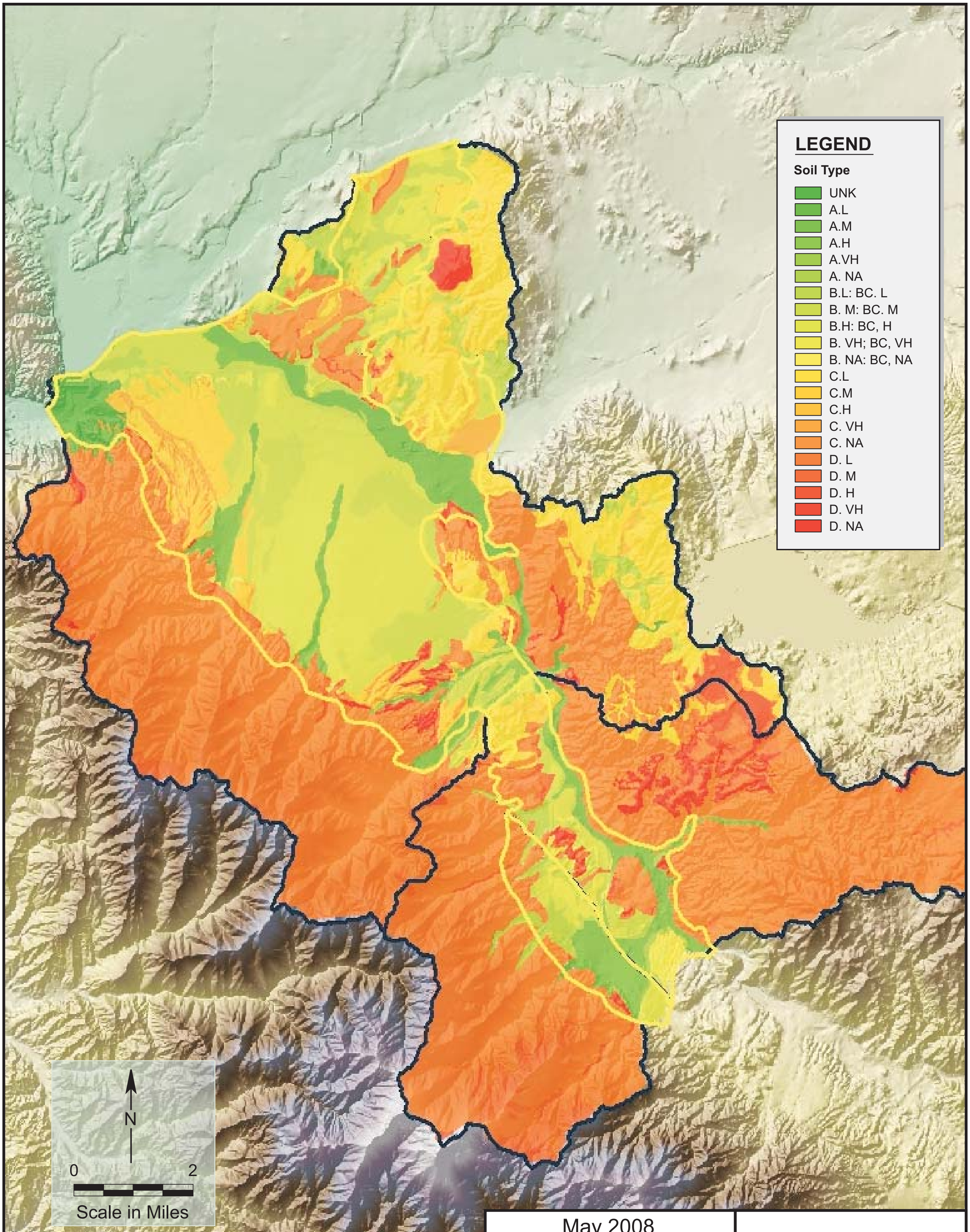


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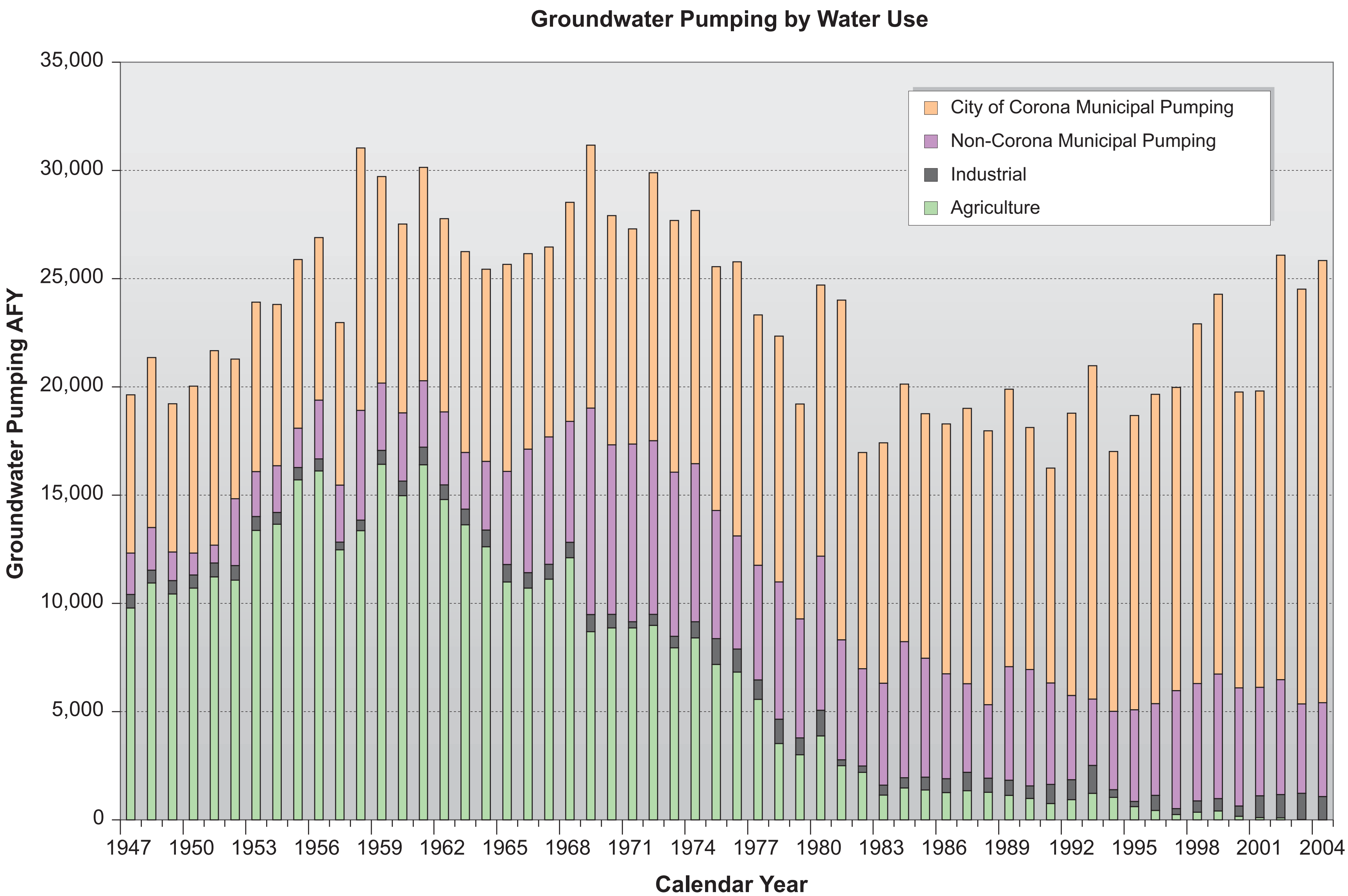
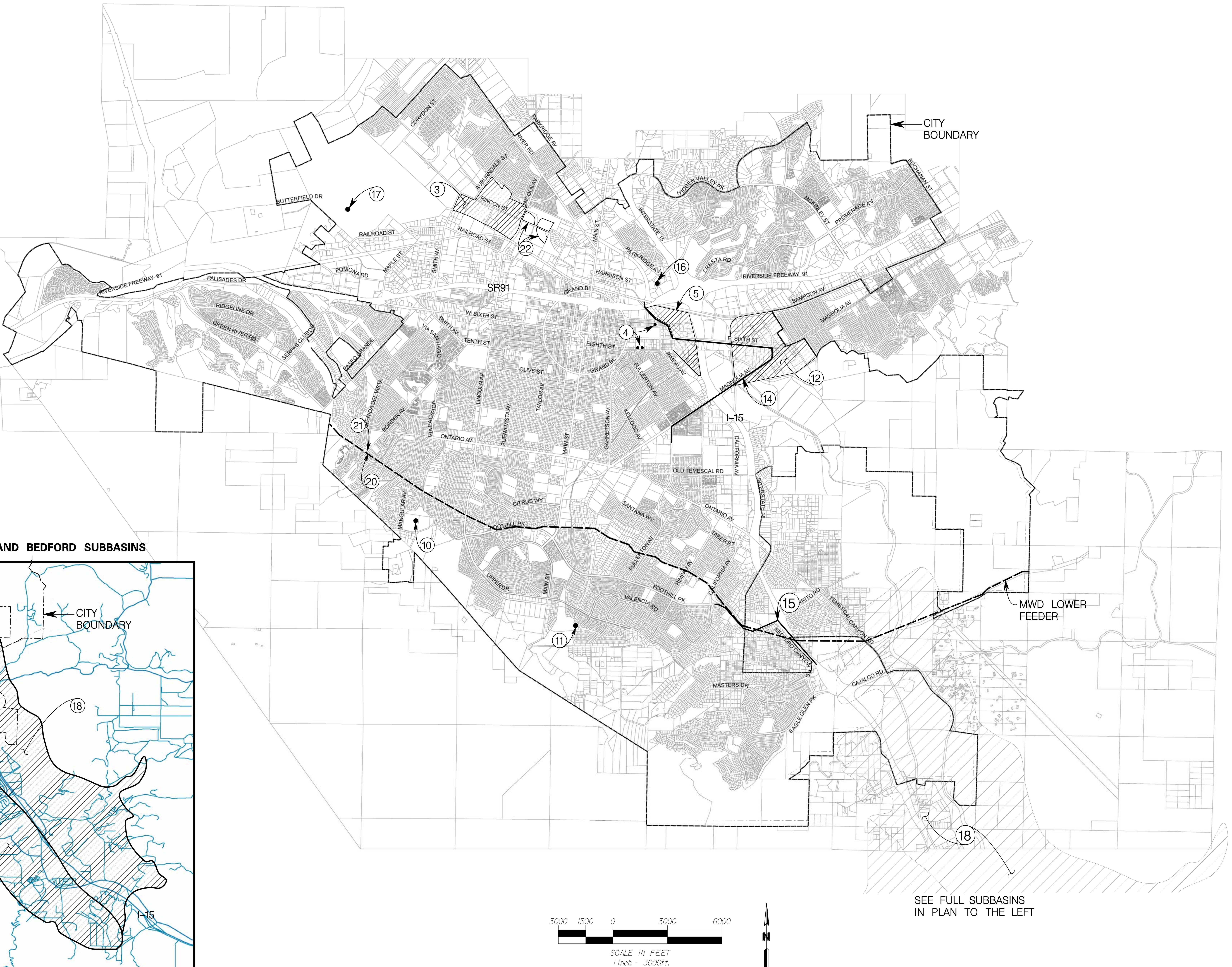
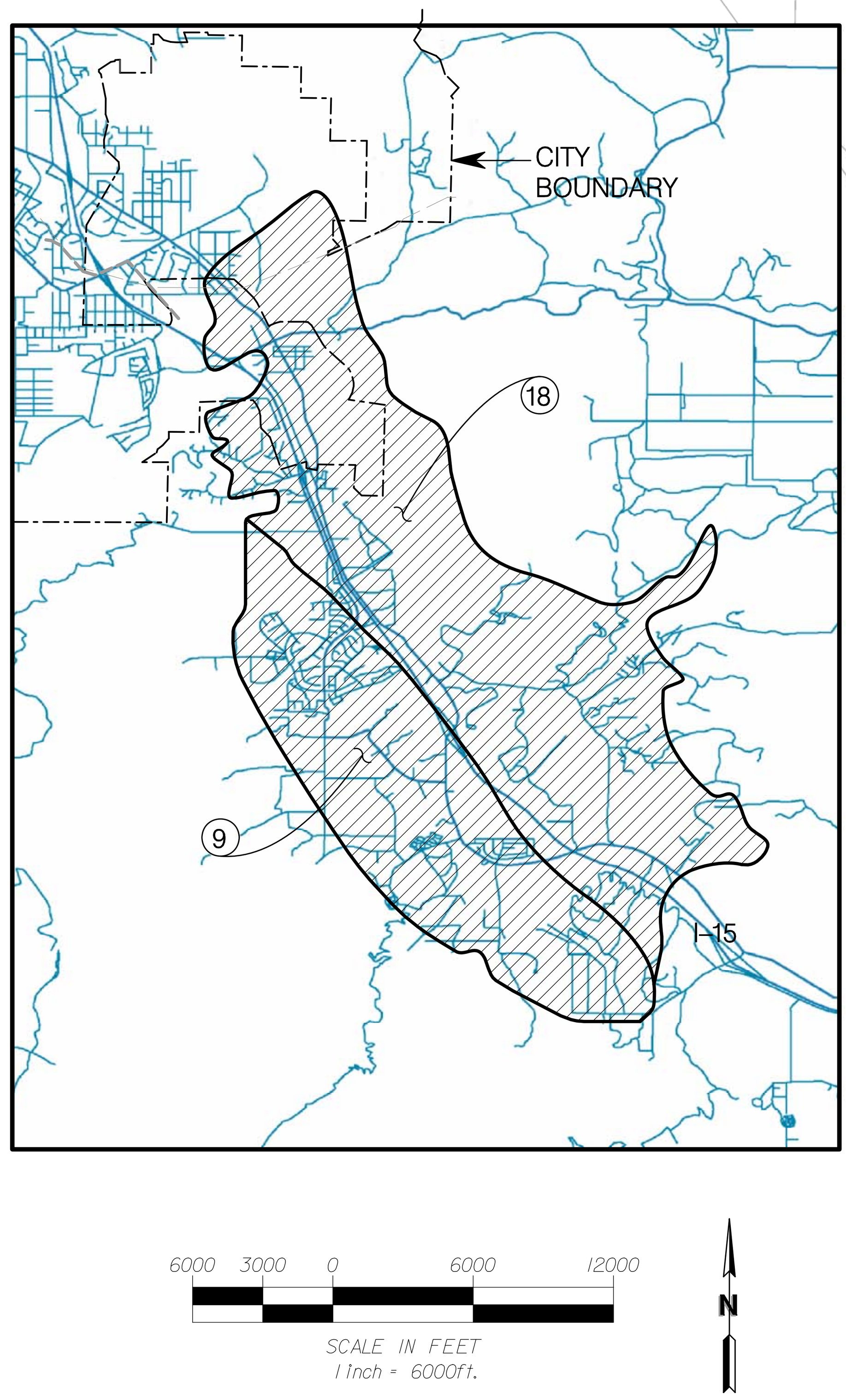
**Figure 35**
**Soil Categories for Water Balance**




| May 2008 | Figure 36 Groundwater Pumping by Water Use |
|---|---|
| TODD ENGINEERS Alameda, California | |




**COLDWATER AND BEDFORD SUBBASINS**




**PROJECT LOCATIONS**

| ITEM | DESCRIPTION |
|---|---|
| 1 | NEW WATER WELLS (CITY WIDE) |
| 2 | REPLACEMENT WATER WELLS (CITY WIDE) |
| 3 | RINCON GROUNDWATER TREATMENT PROJECT |
| 4 | WELLHEAD TREATMENT FOR WELLS 6, 7, AND 17 |
| 5 | EL SOBRANTE GROUNDWATER TREATMENT PROJECT |
| 6 | GROUNDWATER TREATMENT PROGRAM (CITY WIDE) |
| 7 | GROUNDWATER BLENDING PROGRAM (CITY WIDE) |
| 8 | IMPROVEMENT OF GROUNDWATER QUANTITY/QUALITY MONITORING PROGRAM (CITY WIDE) |
| 9 | COLDWATER SUBBASIN ENHANCED RECHARGE PROGRAM |
| 10 | RECHARGE BASINS WITHIN OAK AVENUE DETENTION BASIN |
| 11 | RECHARGE BASINS WITHIN MAIN STREET DETENTION BASIN |
| 12 | UPGRADIENT INJECTION WELLS |
| 13 | RECYCLED WATER INJECTION WELLS (LOCATION TO BE DETERMINED) |
| 14 | RECYCLED WATER ZONE 3 TO ZONE 2 INTERCONNECT |
| 15 | RECYCLED WATER ZONE 4 TO ZONE 3 INTERCONNECT |
| 16 | WWTP2 UPGRADE TO TERTIARY |
| 17 | WWTP1A UPGRADE TO TERTIARY |
| 18 | LEE LAKE WATER DISTRICT RECHARGE TO BEDFORD SUBBASIN |
| 19 | RECYCLED WATER IRRIGATION (PARKS AND URBAN LANDSCAPE AS IN-LIEU PUMPING) |
| 20 | PURCHASE OF METROPOLITAN WATER DISTRICT (MWD) IN-LIEU WATER |
| 21 | PIPLELINE TO CONVEY METROPOLITAN WATER DISTRICT (MWD) IN-LIEU WATER TO BORDER AVENUE RECYCLED WATER RESERVOIR |
| 22 | LINCOLN AND COTA STREET PERCOLATION PONDS MAINTENANCE PROGRAM |

AKM JOB No. 760683.00

AKM Consulting Engineers
553 Wald
Irvine, Ca. 92618
(949) 753-7333

CITY OF CORONA

GROUND WATER MANAGEMENT PLAN

POTENTIAL GROUNDWATER MANAGEMENT STRATEGIES

FIGURE 37

n:\0760 Corona\683 Ground Water Manangement Plan\Groundwtr_Pln.dgn 4/22/2008

# Appendix A
# Public Notice and Outreach

# PUBLIC NOTICES

THE PRESS-ENTERPRISE PE.com

Publication date: June 6, 2006.

## YOU SHOULD KNOW....

The Press-Enterprise public notices serve to notice the entire community that an important government function is being carried out. This includes governmental events, activities, contracting, and other transactions of interest to every citizen. The Press-Enterprise public notices are a permanent record and source of information for the entire community.

**CITATION TO APPEAR**
**Case No. RIJ-109375**
**SUPERIOR COURT OF THE STATE OF CALIFORNIA COUNTY OF RIVERSIDE, JUVENILE DIVISION**

In re the Matter of:
HANNAH MARIE ROPER,
(dob: 09/07/99)
a Minor(s)

THE PEOPLE OF THE STATE OF CALIFORNIA
**TO: THE UNKNOWN FATHER, AND ANYONE CLAIMING TO BE THE FATHER OF THE ABOVE STATED MINOR:**

By order of this Court you are hereby cited and required to appear before a Judge of the Superior Court, located at 9991 County Farm Road, Riverside, California on August 9, 2006, at 8:00 a.m., in Department J-3, to show cause, if any, why the above-named minor(s) should not be declared free from the custody and control of her parents, pursuant to a hearing held in accordance with **Welfare and Institutions Code** Section 366.26. This hearing is for the purpose of terminating your parental rights forever and ordering that the minor be placed for adoption.

You are hereby notified of the following provisions of Welfare and Institutions Code:

Section 366.26(e) (2) provides that: "If you appear without counsel and are unable to afford counsel, the Court shall appoint counsel for you, unless such representation is knowingly and intelligently waived."

Section 366.26 provides: "The Court may continue the proceeding for a period not to exceed 30 days as necessary to appoint you counsel, and to enable counsel to become acquainted with your case."

Section 366.26(b) (1) provides: "At the hearing....the court....shall do one of the following: (1) Permanently sever your parental rights and order that the child be placed for adoption; (2) Without permanently terminating your parental rights, appoint a legal guardian for the minor and issue letters of guardianship; or (3) Order that the minor be placed in long-term foster care, subject to the regular review of the juvenile court."

Given under my hand and seal of the Superior Court of the County of Riverside, State of California, this 24th day of May 2006.
(SEAL)
INGA McELYEA
Executive Officer
Superior Court of the State California, in and for the County of Riverside.
By: , Deputy
**JOE S. RANK**
**County Counsel**
**Lilia Wilkerson**
**Deputy County Counsel**
**9991 County Farm Road, Suite 113**
**Riverside, California, 92503**
**Telephone: 951-358-4125**
**Attorneys for the Petitioner Department of Public Social Services** 6/6,13,20,27

CITY OF CORONA
NOTICE OF PROPOSED RESOLUTION OF INTENTION TO DRAFT A

**GROUNDWATER MANAGEMENT PLAN FOR CITY OF CORONA DEPARTMENT OF WATER & POWER**

NOTICE IS HEREBY GIVEN that at 7:00 p.m. on June 21, 2006, at City Hall, Council Chamber, 400 S. Vicentia Avenue, Corona, CA, a public hearing will be held to discuss whether or not the City of Corona, Department of Water & Power should adopt a resolution of intention to draft a groundwater management plan.

Section 10753 of the Californian Water Code permits the adoption and implementation of groundwater management plans to encourage authorized local agencies to manage groundwater resources within their service areas.

Landowners within the City of Corona and other interested parties are invited to attend the hearing. Copies of the proposed resolution and other relevant written materials will be available for review by the public at the hearing or may be obtained in advanced at the Department of Water & Power, 400 S. Vicentia Avenue, Corona, CA. Opportunity for public questions/input will be provided at the hearing.

In compliance with Water Code §10753.4 (b), landowners and other interested parties who wish to participate in developing the groundwater management plan may do so by attending the hearing, and indicating their interest, or by submitting a written letter to:

Asad Korgan,
Strategic Planning Manager
400 S. Vicentia Avenue,
Corona, CA 92882-2187

In compliance with the Americans with Disabilities Act, if you need special assistance to participate in this meeting, please contact the Building and Safety Director, (951) 736-2250. Notification 48 hours prior to the meeting will enable the City to make reasonable arrangements to ensure accessibility to this meeting.

The public is invited to attend and comment on the applications described above. Due to time constraints and the number of persons wishing to give oral testimony, each speaker will be limited to three minutes. You may make written comments and submit them to the City Clerk for inclusion into the public record. If you challenge any portion of these projects in court, you may be limited to raising only those issues you or someone else raised at the public hearing described in this notice, or in written correspondence delivered at, or prior to the public hearing. Any person unable to attend the public hearing may submit written comments to the City Clerk, 400 S. Vicentia Avenue, Corona, CA 92882. If you have questions regarding this notice or the applications to be heard, please call the City Clerk's Office at (951) 736-2201.

For additional information pertaining to the Groundwater Management Plan, please call Asad Korgan at (951) 736-2230. 6/6,13

**Corona-Norco Unified School District**
**NOTICE OF PUBLIC HEARING**

A public hearing by the Governing Board of the **Corona-Norco Unified** School District will be held prior to the adoption of the 2006-2007 budget. Such hearing will be held at **CNUSD-BOard Room 2820 Clark Avenue, Norco, CA on June 20, 2006, at 6:35 p.m.**. The budget will be available for public inspection between **June 7 and June 20** at the following location(s):

Boulevard, Moreno Valley, California (business address) no later than
**2:00 P.M. on JUNE 14, 2006**

**Proposals shall be in accordance with plans, specifications, other contract documents prepared by the Moreno Valley Unified School District and WLC Architects, Inc.**

PROSPECTIVE BIDDERS WHO DID NOT ATTEND THE MANDATORY JOB WALK ON MAY 31 MUST SCHEDULE A JOB WALK WITH ROGER GAY AT WLC ARCHITECTS, (909) 987-0909, **NO LATER THAN JUNE 7, 2006.**

Prospective general contract bidders may secure up to three sets of said documents from the Office of WLC Architects, Inc., 10470 Foothill Blvd., Virginia Dare Tower, Rancho Cucamonga, CA 91730 (909) 987-0909, upon payment of a deposit of Seventy Five Dollars ($75.00) per set. **Deposits will be refunded upon the return of said documents in good condition within seven (7) days after bids on the project have been opened.** A non-refundable mailing charge of Twenty Dollars ($20.00) will be required for each set mailed to California cities.

Prospective subcontract bidders may secure one set of said documents from the office of WLC Architects, Inc., 10470 Foothill Blvd., Virginia Dare Tower, Rancho Cucamonga, California 91730 (909) 987-0909, upon non-refundable payment of Seventy Five Dollars ($75.00) per set. A non-refundable mailing charge of Twenty Dollars ($20.00) will be required for each set mailed to California cities.

For information regarding this project, prospective bidders are requested to contact Roger P. Gay, Project Manager at WLC Architects, Inc.

The Board of Education reserves the right to reject any or all bids, or any or all items of any bid, and to waive any informality on a bid.

Pursuant to Section 22300 of the Public Contract Code of the State of California, the contract will contain provisions permitting the successful bidder to substitute securities for any moneys withheld by the District to ensure performance under this contract.

Pursuant to the Labor Code, the governing board of the Owner has obtained from the Director of the Department of Industrial Relations, State of California, his determinations of per diem wages applicable to the work, and for holiday and overtime work, including employer payments for health and welfare, pension, vacation and similar purposes, as set forth on schedule which is on file at the principal office of the Owner, and which will be made available to any interested person upon request.

The bid shall be accompanied by the security referred to in the contract documents and the list of proposed subcontractors. **ALL BOND SURETIES MUST BE ADMITTED SURETIES LICENSED TO DO BUSINESS IN THE STATE OF CALIFORNIA AND MUST HAVE A FEDERAL TREASURY LISTING IN THE FEDERAL REGISTER WHICH EQUALS OR EXCEEDS THE BONDING AMOUNT. NO PERSONAL SURETIES WILL BE ACCEPTED.**

This Project is a "public work" as defined within California Labor Code Section 1720 and is subject to the requirement to pay prevailing wages to all workers on the "public work" without

der must maintain the license throughout the duration of this contract.

In accordance with Section 1773.2 of the California Labor Code, the Contractor shall post a copy of the determination of prevailing rate of wages at each job site.

It shall be mandatory upon the Contractor to whom the contract is awarded, and upon any subcontractors under him, to pay not less than the said prevailing rates to all workmen employed by them in the execution of this contract.

No bidder may withdraw his bid for a period of forty-five (45) days after the date set for the opening of bids.

As an equal opportunity employer, the District requires that all of its prospective contractors or bidders comply with the intent of the "equal opportunity clause" as set forth in Form HEA-514 (4-69). Contractor shall not discriminate in its recruiting, hiring, promotion, demotion or termination practices on the basis of race, religious creed, color, national origin, ancestry, physical handicap, medical condition, marital status or sex in the performance of this contract, and, to the extent they shall be found to apply hereto, shall comply with the provisions of the California Fair Employment Practices Acts (commencing with Section 1410 of the Labor Code), and the Federal Civil Rights Act of 1964 (P.O. 88-352).

**The Moreno Valley Unified School District encourages vendors and contractors (subcontractors) representing the demographics of the local and surrounding community to actively pursue business opportunities with the School District. In order to advocate this participation, the District advertises requests/bids in newspapers and publications whose circulation reflects the various demographic groups of the local and surrounding community.**

Assistant Superintendent
Bid packet Legal Counsel approved 11/89
Bid Opening:
2:00 p.m., June 14, 2006 6/6

**MORENO VALLEY UNIFIED SCHOOL DISTRICT**
**25634 Alessandro Blvd.**
**Moreno Valley, California 92553**
(951) 571-7535

**NOTICE INVITING BIDS REVISED NOTICE DUE TO ADVERTISING ERROR**

Moreno Valley Unified School District, herein called OWNER, invites sealed proposals for:

**SUNNYMEADOWS ELEMENTARY SCHOOL REPAIRS (BUILDING A AND B ONLY) LICENSE REQUIRED IS B OR C-5**

Proposals for these bids shall be delivered to the District Office, 25634 Alessandro Boulevard, Moreno Valley, California (business address) no later than
**2:00 P.M. on JUNE 15, 2006**

PROSPECTIVE BIDDERS WHO DID NOT ATTEND THE MANDATORY JOB WALK ON JUNE 1 MUST CALL ROGER GAY AT WLC ARCHITECTS, (909) 987-0909, **NO LATER THEN JUNE 7, 2006,** TO SCHEDULE A JOB WALK.

Proposals shall be in accordance with plans, specifications, other contract documents prepared by the Moreno Valley Unified School District and WLC Architects, Inc.

Prospective general contract bidders may secure up to

be required for each set mailed to California cities.

For information regarding this project, prospective bidders are requested to contact Roger P. Gay, project Manager at WLC Architects, Inc.

The Board of Education reserves the right to reject any or all bids, or any or all items of any bid, and to waive any informality on a bid.

Pursuant to Section 22300 of the Public Contract Code of the State of California, the contract will contain provisions permitting the successful bidder to substitute securities for any moneys withheld by the District to ensure performance under this contract.

Pursuant to the Labor Code, the governing board of the Owner has obtained from the Director of the Department of Industrial Relations, State of California, his determinations of per diem wages applicable to the work, and for holiday and overtime work, including employer payments for health and welfare, pension, vacation and similar purposes, as set forth on schedule which is on file at the principal office of the Owner, and which will be made available to any interested person upon request.

The bid shall be accompanied by the security referred to in the contract documents and the list of proposed subcontractors. **ALL BOND SURETIES MUST BE ADMITTED SURETIES LICENSED TO DO BUSINESS IN THE STATE OF CALIFORNIA AND MUST HAVE A FEDERAL TREASURY LISTING IN THE FEDERAL REGISTER WHICH EQUALS OR EXCEEDS THE BONDING AMOUNT. NO PERSONAL SURETIES WILL BE ACCEPTED.**

This Project is a "public work" as defined within California Labor Code Section 1720 and is subject to the requirement to pay prevailing wages to all workers on the "public work" without exception.

A payment bond and performance bond will be required of the General Contractor prior to the execution of the contract. In addition, a performance bond will be required of all subcontractor providing goods and services in excess of $15,000.00. These bonds shall be in the form and amount set forth in the Contract Documents.

In accordance with provisions of Public Contract Code Section 22300, substitution of eligible and equivalent securities for any monies withheld to ensure performance under this contract will be permitted at the request and expense of the Contractor.

Each bidder will possess at the time of bid, the applicable Contractor's license, pursuant to Public Contract Code Section 3300 and Business and Professions Code Section 7028.15. The successful bidder must maintain the license throughout the duration of this contract.

In accordance with Section 1773.2 of the California Labor Code, the Contractor shall post a copy of the determination of prevailing rate of wages at each job site.

It shall be mandatory upon the Contractor to whom the contract is awarded, and upon any subcontractors under him, to pay not less than the said prevailing rates to all workmen employed by them in the execution of this contract.

No bidder may withdraw his bid for a period of forty-five (45) days after the date set for the opening of bids.

As an equal opportunity employer, the District requires that all of its prospective contractors or bidders comply with

tion, demotion or termin
practices on the basis of
religious creed, color, nat
origin, ancestry, phy
handicap, medical cond
marital status or sex ir
performance of this con
and, to the extent they sh
found to apply hereto,
comply with the provisio
the California Fair Em
ment Practices
(commencing with Se
1410 of the Labor Code)
the Federal Civil Rights /
1964 (P.O. 88-352).
**The Moreno Valley U**
**School District encou**
**vendors and contractors**
**contractors) representin**
**demographics of the loc**
**surrounding community**
**actively pursue busines**
**portunities with the S**
**District. In order to adv**
**this participation, the D**
**advertises requests/bic**
**newspapers and public**
**whose circulation reflec**
**various demographic g**
**of the local and surrou**
**community.**
Assistant Superintenden
Bid packet Legal Couns
approved 11/89
Bid Opening:
2:00 p.m., June 15, 2006

NOTICE INVITING B
**School District:** C
Norco Unified School D
of Riverside County, Cal
(hereinafter, "DISTRICT
**Bid Deadline:** 3:00 c
p.m. of the 20th day Jun
**Bid Opening:** 3:00 c
p.m. of the 20th day of
2006.
**Place of Bid Recei**
**Opening:** Business S
Office, 2820 Clark A
Norco, California 92860
**Bid Identification**
Bid Number 2005/06-G
dustrial Technology
ment and Softwar
Roosevelt High School
NOTICE IS HE
GIVEN that the DIS
acting by and through i
erning Board, will rece
to, but not later than the
stated time, sealed bids
award of a Contract
above referenced bid.
Bids shall be receive
place identified abov
shall be opened and
read aloud at the above
time and place.
All work, equipment
supplies must be de
within **Thirty (30)** cons
calendar days from the
the notice issued by t
TRICT. Time is of the e
Failure to deliver the
ment and/or supplies
the time set forth here
constitute a breach of c
for which the DISTRIC
exercise any equitable
legal remedies availab
Each Bid must conf
be responsive to the C
Documents.
Pursuant to Public C
Code Sections 2011
20652, the Bidder ma
other public entities
State of California to p
equipment and supplie
the same terms
conditions.
The DISTRICT rese
right to reject any and
or to waive any irregul
informalities in any b
the bidding.
No Bidder may w
any bid for a period of
days after the date se
opening of bids.
Governing Board
CORONA-NORCO UN
SCHOOL DISTRICT
Date: June 2, 2006
By: (Rosalie Aio)
Purchasing Manager

NOTICE INVITING
Bids will be opened in
forum at 2:00 P.M. on
2006 for PROJECT
**Tract 31330 Winches**
**Storm Drain Impro**

# RESOLUTION NO. 2006-074

**RESOLUTION OF THE CITY COUNCIL OF THE CITY OF CORONA, CALIFORNIA, APPROVING A NOTICE OF INTENTION FOR THE CITY OF CORONA DEPARTMENT OF WATER & POWER TO DRAFT A GROUNDWATER MANAGEMENT PLAN**

**WHEREAS,** adoption of a Groundwater Management Plan is in furtherance of and consistent with the City's Water Master Plan as adopted by the City Council; and

**WHEREAS,** Section 10753 of the California Water Code permits the adoption and implementation of groundwater management plans to encourage authorized local agencies to manage groundwater resources within their services areas; and

**WHEREAS,** the City of Corona Department of Water & Power (CDWP) is an authorized local agency and may, therefore, adopt and implement such a Groundwater Management Plan; and

**WHEREAS,** a Public Notice of Intention was published in a newspaper of general circulation on June 6, 2006, and on June 13, 2006, announcing the City's intention to consider the adoption of a resolution of intention to draft a Groundwater Management Plan in accordance with the California Water Code Section 10753.2 and California Government Code Section 6066; and

**WHEREAS,** a public hearing was held on June 21, 2006, to discuss the adoption and implementation of a Groundwater Management Plan in accordance with California Water Code Section 10753.2; and

**WHEREAS,** the City Council believes the groundwater can best be managed, as in the past, by CDWP in coordination with owners of properties overlying the groundwater basin; and

**WHEREAS,** the City Council believes the adoption of a Groundwater Management Plan will be in the best interest of the city's property owners and water users and can help meet the projected long-term water needs of the City.

**NOW, THEREFORE, BE IT RESOLVED** by the City Council of the City of Corona, California, as follows:

**<u>Section 1</u>:** It is the intention of CDWP to draft a Groundwater Management Plan in accordance with Section 10753.4 of the California Water Code, and CDWP's consultant is hereby authorized and directed to draft such plan.

**<u>Section 2</u>:** This Resolution shall be deemed a resolution of intention in accordance with California Water Code Section 10753.2.

**<u>Section 3</u>:** The CDWP is authorized and directed to publish this resolution of intention to draft a Groundwater Management Plan in accordance with the provisions of California Water Code Section 10753.3 and to provide interested persons with a copy of this Resolution upon written request.

**<u>Section 4</u>:** The City Council hereby authorizes the CDWP General Manager to execute all documents and take any other action necessary or advisable to carry out the purpose of this Resolution.

**<u>Section 5</u>:** After the Groundwater Management Plan has been prepared, CDWP will conduct a second public hearing in accordance with California Water Code Section 10753.5, <u>et</u> <u>seq.</u> to determine whether to adopt the plan.

**ADOPTED** this 21st day of June 2006.

Karen Spiegel

Mayor of the City of Corona, California

**ATTEST:**

Victoria Wasko

City Clerk of the City of Corona, California

## CERTIFICATION

I, VICTORIA J. WASKO, City Clerk of the City of Corona, California, do hereby certify that the foregoing Resolution was passed and adopted by the City Council of the City of Corona, California, at a regular adjourned meeting held on the 21st day of June 2006, by the following vote of the Council:

| | |
|---|---|
| **AYES:** | **MILLER, MONTANEZ, NOLAN, SPIEGEL, TALBERT** |
| **NOES:** | **NONE** |
| **ABSENT:** | **NONE** |
| **ABSTAINED:** | **NONE** |

**IN WITNESS WHEREOF,** I have hereunto set my hand and affixed the official seal of the City of Corona, California, this 21st day of June 2006.

Victoria J. Wasko

City Clerk of the City of Corona, California

(SEAL)

DEPARTMENT OF WATER & POWER
*"Protecting Public Health"*
General Manager's Office

(951) 279-3692 | 730 Corporation Yard Way | Corona, California 92880

**PRESS RELEASE**

June 5, 2008
For Immediate Release
Contact: Matthew Bates, Utility Engineer, (951) 279-3692

## Corona Groundwater Management Plan

As part of the City's on-going efforts to efficiently manage its finite water resources, the Corona Department of Water and Power contracted with AKM Consulting Engineers and Todd Engineering in January 2006 to prepare an Assembly Bill 3030 compliant Groundwater Management Plan (GWMP). The Plan recommends approaches the City can utilize to increase the efficient usage of its groundwater to ensure its availability in the future.

AKM Consulting Engineers and Todd Engineering recently completed the Plan and the Department of Water and Power will recommend its adoption at the City Council meeting on June 18th, 2008 at 7:00 p.m. in Council Chambers.

If you have any questions or require additional information regarding the Plan, please contact Matthew Bates, Utility Engineer at (951) 279-3692.

#####

**Table A-1**
**List of Potential Stakeholders**
**City of Corona Groundwater Management Plan**

| Stakeholder Organization | Contact | | | Title | Address | City | State | Zip Code |
|---|---|---|---|---|---|---|---|---|
| County of Orange | Ms. | Angela | Burrell | Public Information Officer | PO Box 4048 | Santa Ana | CA | 92702-4048 |
| Riverside County Flood Control District | Mr. | Steve | Stump | Chief of Operations and Maintenance | 1995 Market Street | Riverside | CA | 92501 |
| City of Norco | Mr. | Bill | Thompson | Director of Public Works | 2870 Clark Avenue | Norco | CA | 92860 |
| Dept. of Environmental Health | Mr. | Damien | Meins | Deputy Director | 4080 Lemon Street, 9th Floor | Riverside | CA | 92501 |
| City of Riverside, Planning Division | Ms. | Diane | Jenkins | | 3900 Main St., 4th Floor | Riverside | CA | 92501 |
| Santa Ana Watershed Project Authority | Mr. | Eldon | Horst | | 11615 Sterling Avenue | Riverside | CA | 92503 |
| Santa Ana Region | Mr. | Gerard | Thibeault | Regional Water Quality Control Board | 3737 Main Street, Ste. 500 | Riverside | CA | 92501 |
| Riverside County Waste Management Dept. | Mr. | Hans | Kernkamp | General Manager | 14310 Frederick Street | Moreno Valley | CA | 92553 |
| Lee Lake Water District | Mr. | Jeff | Pape | General Manager | 22646 Temescal Canyon Road | Corona | CA | 92883 |
| Western Municipal Water District | Mr. | John | Rossi | General Manager | PO Box 5286 | Riverside | CA | 92508 |
| Chandler’s Sand & Gravel & Temescal Mining LLC | Mr. | John | Robertson | Vice President & General Manager | PO Box 295 | Lomita | CA | 90717 |
| Municipal Water District of Orange County | Ms. | Karen | Warren | Assistant to the General Manager | PO Box 20895 | Fountain Valley | CA | 92728 |
| Chino Basin Water master | Mr. | Kenneth | Manning | CEO | 9641 San Bernardino Road | Rancho Cucamonga | CA | 91730 |
| Orange County Resources & Development Mgmt Dept. | Mr. | Nadeem H. | Majaj, P.E. | Manager, Flood Control Division | PO Box 4048 | Santa Ana | CA | 92702-4048 |
| Mission Clay Products | Mr. | Owen | Garret | | PO Box 549 | Corona | CA | 92878 |
| Elsinore Valley Municipal Water District | Mr. | Ron | Young | General Manager | 31315 Chaney Street | Lake Elsinore | CA | 92530 |
| City of Riverside, Planning Division | Mr. | Craig | Aaron | | 3900 Main Street | Riverside | CA | 92522 |
| Santa Ana Watershed Project Authority | Mr. | Mark | Norton | | 11615 Sterling Avenue | Riverside | CA | 92503 |
| Western Municipal Water District | Mr. | Jeff | Sims | | PO Box 5286 | Riverside | CA | 92517 |

# Appendix B

# Monitoring Program and Protocols

# Appendix B – Monitoring Program and Protocols

## *B-1 Introduction*

One of the groundwater management strategies (Strategy 8) presented in this GWMP is an improved groundwater monitoring program capable of characterizing groundwater conditions in the subbasins of interest and tracking future changes in water levels, water quality, and groundwater storage. This appendix documents the City's current monitoring program and makes recommendations for improvements going forward.

## *B-2 Background*

The City has monitored water quality in production wells in the Temescal, Coldwater, and Bedford subbasins to ensure a high quality supply and to comply with regulations over time. Since 1998, the City has conducted a more formal monitoring program including water level measurements in about 23 production wells and maintaining these data in a water level database. Data on water levels in City production wells dating back to 1994 have been provided to a consultant for the Santa Ana River Watermaster (Watermaster Support Services). This firm provided these data in a publicly-available database to Todd Engineers in support of this project. Those data have been combined with other water level data and entered into the City's Data Management System (DMS) constructed for this GWMP. Although the City water level data were noted as being measured either during pumping or non-pumping (static) conditions, some static measurements have been overly influenced by well drawdowns and indicate that the well had not completely recovered when levels were recorded. In addition, some of the noted pumping water levels appear to correlate more closely to static water levels in other wells. In addition, surveyed reference elevations are not always recorded for a well.

Over the last two years, the City expanded the water level monitoring program to include wells that are not currently pumping (or pump on a limited basis). These wells are a combination of inactive irrigation wells, inactive or periodically-used production wells, and dedicated monitoring wells installed by the City. These data are less influenced by pumping and are more representative of overall subbasin conditions. In connection with this GWMP, the City wishes to document and formalize the monitoring program and consider additional improvements to the program over time.

## *B-3 Objectives of Monitoring Program*

Objectives of the monitoring program include the following:

- characterize water levels and water quality in various aquifers across the subbasins

- monitor areas of concern to continue to address specific problems
- evaluate the performance of groundwater management activities
- track changes in groundwater levels, quality, and storage over time.

The spatial distribution of the monitoring points should focus on key areas based on specific subbasin hydrogeologic conditions. In addition, the program should maintain an element of random locations to allow for the identification of unanticipated changes within the system. To achieve these objectives, protocols of the monitoring program including the locations, measurements, equipment, frequencies, and constituents to be monitored are reviewed below. This program is evaluated with respect to the hydrogeologic conditions described in Chapter 3 of the GWMP and recommendations are made for program improvements.

## *B-4 Current Groundwater Monitoring Program*

The City maintains a groundwater monitoring program consisting of about 39 wells, 21 of which are active production wells owned and operated by the City for drinking water supply. The remaining 18 wells are a combination of inactive production wells and wells installed specifically for monitoring groundwater conditions. For the purposes of this discussion, the 18 wells are referred to as monitoring wells and the 21 wells in the City's system are referred to as City production wells. The selection of monitoring locations has generally been based on the following criteria:

- Availability of unused wells owned by others
- Easy access to wells
- Ability to physically access the well with a sounder or sampling pump/bailer
- Well screens across aquifer of interest
- Well location monitors specific activity of interest (e.g., installed for a pilot test for enhanced recharge)
- Network spatially distributed throughout the subbasins of interest.

Wells included in the monitoring program are shown on Figure B-1 with the City's active production wells identified separately. For the purposes of this discussion, the wells in the monitoring program that are not wells in the City's active production water system are referred to as monitoring wells. Well data and monitoring components are summarized in Table B-1.

### B-4.1. Water Levels

As shown on Figure B-1, the 18 monitoring wells are located in about eight separate locations with more than one well at four locations. Clusters of four monitoring wells are located near City production Well 11, Oak Avenue Detention Basin, and Main Street Detention Basin. Two wells are located in the eastern arm at Arlington Gap.

The monitoring and production wells in the water level monitoring program are well distributed across Temescal Subbasin and cover most key areas (Figure B-1). Nine of the monitoring wells track water levels in or near the Channel Aquifer along with most of the production wells. Two inactive production wells owned by Home Gardens County Water District allow the City to share water level data. These are key wells located near the Arlington Gap and provide data for the assessment of groundwater storage and the subbasin water balance. In addition, shallow monitoring wells have been drilled in the Oak Avenue and Main Street detention basins in the upland portion of the alluvial fan in Temescal Subbasin.

Water levels at the downgradient extent of Bedford Subbasin are monitored by the irrigation well at Dos Lagos. No dedicated monitoring wells are currently located in the Coldwater Subbasin, but the City is making attempts to locate a former state monitoring well to track water levels there. Currently, water levels in the Coldwater Subbasin are available from City production wells.

Water levels are measured at each of the 18 monitoring wells on a monthly basis. The City uses an electric sounding probe for measuring depth to water in most of the wells. For the Home Gardens Well 5, data are available from a transducer pressure gauge. Depth-to-water measurements are made by City personnel on an established field monitoring form. Also recorded are the status of the well (pumping or not), the date, and the initials of the field person.

### B-4.2. Water Quality

Groundwater quality monitoring has occurred at the City's active production wells, providing extensive water quality data in the Channel Aquifer. To date, no formal water quality monitoring program has been established at the monitoring wells, primarily because of an inability to pump some of the wells. The high concentration of water quality monitoring in the Channel Aquifer is appropriate given the unconfined nature of the aquifer and the City's reliance on the aquifer for its drinking water supply.

More than 7,400 records of water quality analyses from 1948 through 2004 were compiled for 25 City wells (including historical data from now-abandoned wells) and entered into the GWMP DMS. Currently, groundwater sampling occurs in all active production wells (Table B-1).

The laboratory analyses of groundwater samples include constituents set forth in Title 22 of the California Code of Regulations in compliance with federal standards and state regulations. These constituents allow for testing of both inorganic and organic chemicals of concern in the subbasins. These data are summarized in Consumer Confidence Reports provided to City water users.

### B-4.3. Groundwater Storage

Changes in groundwater storage as estimated in this GWMP were based primarily on an assessment of individual water balance inflows and outflows. The resulting change in storage was compared to changes in water levels in production wells for reasonableness. In the future, this assessment can be improved by comparing the water balance results to water level contour maps that depict change in groundwater storage over the entire subbasin based on data from monitoring wells. This assessment removes the near-wellbore effects of pumping from the analysis of changes in water levels over time. The current monitoring program is not sufficient to conduct such a detailed assessment, but the addition of dedicated non-pumping wells to the program is a step in the right direction. Increased monitoring at non-pumping wells, including City wells that have been turned off sufficiently long for water level recovery, will also improve the City's ability to track changes in groundwater storage over time.

## *B-5 Surface Water Monitoring Program*

Releases to Temescal Wash are monitored by various dischargers through NPDES permit requirements. One active stream gage in the City is monitored by local agencies (11072100, Figure 7 in the GWMP figures). Streamflow data are generally unavailable on Temescal Wash as it enters and exits Bedford Subbasin and as it enters Temescal Subbasin. Improved gaging in these areas could assist in developing a water balance for Bedford Subbasin and improving the water balance analysis in Temescal Subbasin.

As Temescal Wash enters the Prado Management Area, a surface water sampling station is maintained by Orange County Water District. Other stream gage data are available from additional flows into the management area to account for surface outflow at Prado Dam. Additional streamflow measurements by the City in this area seems unnecessary at this time.

Pool elevation data from the Prado Management Area allow for the assessment of rising groundwater that is considered subsurface outflow from the Temescal Subbasin water balance. More detailed data likely exist for this area than were compiled for the GWMP. Additional data compiled from this area could allow for a more detailed assessment of basin outflow than estimated from the groundwater flow model in this analysis. The City is in the process of assessing outflow conditions in connection with a hydrogeologic characterization for their wastewater percolation ponds. Data from this study should be incorporated into the DMS for future assessments of subbasin outflow.

## *B-6 Land Subsidence Monitoring*

Excessive groundwater pumping in certain aquifer systems can cause subsurface compaction, resulting in subsidence of the overlying land surface. Land subsidence resulting from overdraft conditions has been documented throughout the state including the Santa Clara Valley and Central Valley of California. The most susceptible systems contain sufficient thickness of semiconsolidated silt and clay layers (aquitards) that can result in a vast one-time release of "water of compaction" (Galloway, et al., 1999). As this water is permanently released from the structure of the fine-grained units, the layers collapse, impacting overlying units and reducing the storage capacity of the aquifer system.

Land subsidence in the form of ground fissuring has been identified in the adjacent Chino Groundwater Basin since the 1970s. The susceptible area is located about 2.5 miles north of the Prado Management Area (WE, 2006). An extensometer and other monitoring techniques have been employed to track land subsidence in this area.

To our knowledge, neither land subsidence nor ground fissuring have been identified as issues in the Temescal, Bedford, or Coldwater subbasins. The absence of thick, fine-grained aquitards in these areas suggest that land subsidence should not be a concern. The Channel Aquifer contains very little fine-grained sediments as confirmed by lithologic logs and the few geophysical logs in the subbasin. Fine-grained units are likely more predominant in the distal portions of the Temescal Subbasin alluvial fan, south and southwest of the City's current production wells. If the City develops groundwater on the Temescal Subbasin alluvial fan, the potential for land subsidence should be considered. In the Coldwater Subbasin, production wells are located in the proximal and mid-fan portions of a large alluvial fan characterized by coarse-grained sediments. Gravel mining down to 300 feet confirms the nature of these aquifers.

In consideration of these conditions, land subsidence monitoring does not appear to be an issue for the City and is not recommended for expansion of the monitoring program at this time. The City will investigate any reports of ground fissures and consider ground surface monitoring if land subsidence is identified as a potential concern in the future.

## *B-7 Recommendations for Monitoring Program Improvements*

The City will continue to make improvements to their monitoring program as groundwater management strategies are implemented over the next two years. Ongoing efforts include the exploration and identification of additional wells for possible inclusion into the program. In particular, certain non-pumping wells are being researched in the Coldwater Subbasin for increased monitoring there.

### B-7.1. Improvements in Spatial Distribution

The monitoring program should be sufficient to characterize water levels and quality throughout the subbasins and focus on key areas where data collection could prove most beneficial. In addition, the program should be scoped to include an element of random spacing to allow for detections of unanticipated changes. One strategy is to target key areas of subbasin inflows and outflows as identified by the subbasin water balance analysis. For the Temescal

Subbasin, inflows are evaluated by the wells in Arlington Gap and in the upland detention basins. Outflow areas are monitored by the wells at Butterfield Park and Corona High School. Additional inflow monitoring would be beneficial in the area where Temescal Wash enters the basin (south of Magnolia Avenue near All American Way) and the area with inflow from Norco (north of City production Well 26). Additional outflow monitoring could be accomplished with an additional well west of the City percolation ponds (in the vicinity of the Rincon Groundwater Treatment Project included in this GWMP as Strategy 3). With regard to the random element of spatial distribution, additional wells are needed on the slope of the alluvial fan to the south of current production wells.

In the Coldwater Subbasin, only production wells are currently available for monitoring. Since most of the production occurs in the southern half of the subbasin, it would be optimal to secure a monitoring point both in the south near production and in the north away from the wells to evaluate groundwater storage changes in the subbasin. A well just west of the Glen Ivy fault near Coldwater Wash would be most beneficial for also evaluating subsurface outflow across the fault plane. With respect to Bedford Subbasin, no wells currently exist in the southern portion of the subbasin and additional monitoring there would allow for better understanding of the subbasin groundwater system.

It would be helpful to add monitoring wells to the water quality monitoring program as analyses are currently conducted only in production wells. Extraction wells pull in large volumes of groundwater from a large area, which can mix and dilute specific chemicals of concern. Additional understanding of groundwater quality away from pumping wells would add significant value to the data collection efforts.

These improvements can be accomplished by securing access to existing wells or installation of new monitoring wells. If new wells are constructed, the diameter should be sufficiently large to allow for both groundwater level and quality monitoring.

### B-7.2. Expanded List of Constituents for Analysis

For water quality monitoring, the list of constituents should be responsive to how the data are to be applied. For continued characterization of inorganic water chemistry and assistance with determining the source direction for groundwater types, the monitoring program should contain a full suite of cations and anions and a cation/anion balance. This analysis allows for the designation of water types and fingerprinting of groundwater in various parts of the basin. In addition, the analysis is cost effective and adds very little to the cost of monitoring already conducted by the City.

Because of the large number of underground storage tanks over the shallow and unconfined Channel Aquifer, additional constituents should be added to the monitoring program to ensure no impacts from leaking tanks. In particular, total petroleum hydrocarbons, benzene, toluene, ethylbenzene, xylenes, and methyl-tertiary butyl ether (MTBE) should be included. These analyses should be conducted on all wells for several sampling events to ensure no current impacts. After initial sampling, specific wells could be targeted for continued monitoring of these constituents.

### B-7.3. Monitoring Frequency

A review of hydrographs indicates that water levels change seasonally and are most responsive to changes in groundwater pumping. In order to continue to characterize water level changes with monthly pumping patterns, water level monitoring should be conducted on a monthly basis.

Ambient groundwater quality is not expected to vary on a monthly basis and is less susceptible to seasonal changes. As such, annual to semi-annual monitoring seems sufficient for the groundwater quality monitoring program. Exceptions to this include areas where groundwater contamination has been identified as a threat to groundwater quality. These areas should be monitored more frequently to better understand the potential impacts as contaminants migrate downgradient. This increased frequency in monitoring will likely be conducted by the site responsible for the groundwater quality impact and may not result in increased monitoring by the City. However, the City should periodically acquire and review the monitoring data for incorporation into their DMS. Water quality monitoring at the active production wells will continue at the frequencies required for compliance with state regulations for drinking water supply.

### B-7.4. Quality Assurance/Quality Control Measures

To ensure that data are properly collected and analyzed, a quality assurance/quality control (QA/QC) plan should be implemented for the monitoring program. This program would provide details on the equipment and sampling procedures for ensuring reliable data. For example, the City should continue and improve the use of monitoring data collection forms for both water levels and water quality. Key details from these forms such as sampling date, time, location, and conditions should be extracted from the forms and input into the City DMS. All water quality sampling should use clean, new containers specific to the constituent to be analyzed. Specific QA/QC samples should be taken (approximately one QA/QC sample per every ten monitoring samples) and all samples should be properly preserved in the field. Water quality sampling should follow standard QA/QC procedures specific to the constituents analyzed. All sampling events should contain a strict chain of custody procedure with proper chain of custody forms completed in the field. State-certified laboratories should be used for analyses. Data should be requested in both paper and electronic format from the laboratories to facilitate updating the DMS and minimize data-entry errors.

### B-7.5. Summary of Recommendations

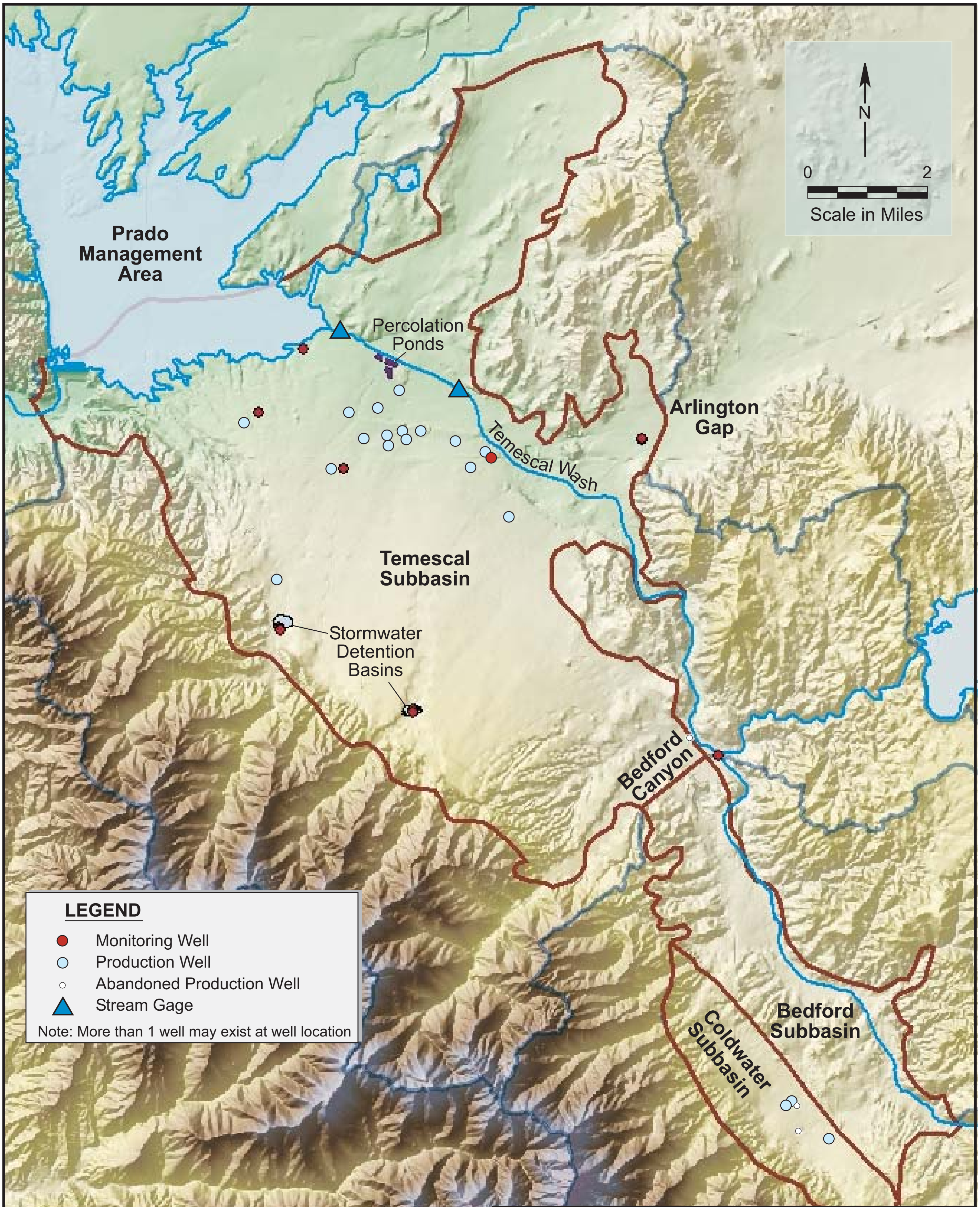
Recommendations for monitoring program improvements are summarized below.

- Continue to locate and add wells to the monitoring program with an emphasis on obtaining detailed construction data for any wells added to the program
- Increase locations in key inflow and outflow areas to improve the ability to depict changes in groundwater storage
- Add wells in any un-monitored areas of the subbasin to include a random component to the monitoring program
- Expand water quality sampling to monitoring wells
- Analyze water quality samples for a full suite of inorganic constituents to allow for fingerprinting of water types throughout the subbasins
- Conduct analyses for a full suite of inorganic chemicals to allow for geochemical plotting techniques for analysis
- Add petroleum hydrocarbon constituent including MTBE to ensure that leaking underground storage tanks have not impacted water quality
- Monitor water levels monthly and water quality annually to semi-annually for improved understanding of changes in groundwater conditions
- Implement a QA/QC program to ensure data reliability
- Re-evaluate the monitoring programs on an annual basis to determine if additional monitoring points are required or if duplicative data collection efforts can be eliminated.

The monitoring program will evolve over time and be modified for performance monitoring of specific management strategies as implemented. The program should be periodically evaluated to optimize the data collection efforts and achieve monitoring objectives.

**Table B-1**
**City of Corona Monitoring Well Program**

| State Well Number | Well Owner | Well Name | Well No. | Date Drilled | Well Use | GSE ft, msl | Ref. Elev. ft, msl | Total Depth | Screen Depth | | Groundwater Monitoring Data | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Top ft | Bottom ft | Water Levels | Water Quality | Groundwater Storage |
| **MONITORING WELLS** | | | | | | | | | | | | | |
| T04S/R07W-10 | City of Corona | Oak Street Channel 1 | OMW-1 | 10/29/2003 | Monitoring | 1023 | 1026 | 65 | 35 | 65 | X | | X |
| T04S/R07W-10 | City of Corona | Oak Street Channel 2 | OMW-2 | 10/14/2003 | Monitoring | 1024 | 1026 | 1070 | 100 | 200 | X | | X |
| T04S/R07W-10 | City of Corona | Oak Street Channel 3 | OMW-3 | 10/30/2003 | Monitoring | 1020 | 1022 | 70 | 40 | 70 | X | | X |
| T04S/R07W-10 | City of Corona | Oak Street Channel 4 | OMW-4 | 10/16/2003 | Monitoring | 1020 | 1022 | 200 | 100 | 200 | X | | X |
| T04S/R07W-13 | City of Corona | Main Street Channel 1 | MMW-1 | 10/247/03 | Monitoring | 1249 | 1252 | 420 | 20 | 400 | X | | X |
| T04S/R07W-13 | City of Corona | Main Street Channel 2 | MMW-2 | 10/22/2003 | Monitoring | 1244 | 1246 | 500 | 20 | 400 | X | | X |
| T04S/R07W-13 | City of Corona | Main Street Channel 3 | MMW-3 | 10/21/2003 | Monitoring | 1248 | 1250 | 260 | 20 | 260 | X | | X |
| T04S/R07W-13 | City of Corona | Main Street Channel 4 | MMW-4 | 10/22/2003 | Monitoring | 1237 | 1240 | 400 | 20 | 400 | X | | X |
| T04S/R06W-16 | Canyon Properties | Dos Lagos Golf Course | IW-1 | | Standby Irrigation | 799 | | | | | X | | X |
| T03S/R06W-28M2 | Home Gardens County Water District | Home Gardens 1 | HG-1 | 1/1/1927 | Production | 666 | 668 | 165 | | | X | | X |
| T03S/R06W-28M | Home Gardens County Water District | Home Gardens 5 | HG-5 | 5/10/1988 | Production | 666 | 669 | 500 | 330 | 495 | X | | X |
| T03S/R07W-35 | Joy Street Water Company | Corona High Parking Lot | CHS-1 | | Inactive Irrigation | 730 | | | | | X | | X |
| T03S/R07W-27 | City of Corona | Well 11 Gate West | 11MW-1 | | Monitoring | 645 | | | | | X | | X |
| T03S/R07W-27 | City of Corona | Well 11 Gate South | 11MW-2 | | Monitoring | 645 | | | | | X | | X |
| T03S/R07W-27 | City of Corona | Well 11 Gate East | 11MW-3 | | Monitoring | 645 | | | | | X | | X |
| T03S/R07W-27 | City of Corona | Well 11 Gate North | 11MW-4 | | Monitoring | 645 | | | | | X | | X |
| T03S/R07W-22 | City of Corona | Butterfield Park | BP-1 | | Standby Irrigation | 597 | | | | | X | | X |
| T03S/R06W-30N | City of Corona | City Park | CP-1 | | Standby Irrigation | 657 | | 140 | | | X | | X |
| **PRODUCTION WELLS** | | | | | | | | | | | | | |
| T05S/R06W-03K01 | City of Corona | Well No. 3 | 3 | 1/26/1935 | Active Production | 1141 | | 543 | 100 | 530 | X | X | X |
| T03S/R06W-30N03S | City of Corona | Well No. 7A | 7A | 6/16/2002 | Active Production | 688 | | 250 | 125 | 230 | X | X | X |
| T03S/R07W-25J02S | City of Corona | Well No. 8A | 8A | 6/6/2002 | Active Production | 641 | | 210 | 100 | 190 | X | X | X |
| T03S/R07W-25M03S | City of Corona | Well No. 9A | 9A | 8/21/2002 | Active Production | 657 | | 250 | 113 | 230 | X | X | X |
| T03S/R07W-27G01 | City of Corona | Well No. 11 | 11 | 11/20/1953 | Active Production | 660 | | | 126 | 234 | X | X | X |
| T03S/R07W-27F02 | City of Corona | Well No. 12A | 12A | 10/19/2000 | Active Production | 665 | | 320 | 180 | 320 | X | X | X |
| T03S/R06W-31K01 | City of Corona | Well No. 13 | 13 | 1952 | Active Production | 728 | | | 152 | 260 | X | X | X |
| T03S/R07W-35C01 | City of Corona | Well No. 14 | 14 | 11/27/1936 | Active Production | 753 | | 515 | 200 | 250 | X | X | X |
| T03S/R07W-26G01 | City of Corona | Well No. 15 | 15 | 4/13/1946 | Active Production | 633 | | 220 | 108 | 204 | X | X | X |
| T03S/R07W-27A01 | City of Corona | Well No. 16 | 16 | 11/12/1980 | Inactive Production | 662 | | 775 | 415 | 755 | X | X | X |
| T03S/R06W-30N03S | City of Corona | Well No. 17A | 17A | 5/24/2002 | Active Production | 653 | | 210 | 100 | 188 | X | X | X |
| T03S/R07W-25L01 | City of Corona | Well No. 19 | 19 | 5/11/1990 | Active Production | 615 | | | 100 | 210 | X | X | X |
| T05S/R06W-11D01S | City of Corona | Well No. 20 | 20 | 10/02/1998 | Active Production | 1140 | | 600 | 200 | 580 | X | X | X |
| T05S/R06W-03J05S | City of Corona | Well No. 21 | 21 | 5/221998 | Active Production | 1120 | | 600 | 200 | 580 | X | X | X |
| T03S/R07W-26J03S | City of Corona | Well No. 22 | 22 | 12/20/1998 | Active Production | 672 | | 410 | 150 | 390 | X | X | X |
| T03S/R07W-25L02S | City of Corona | Well No. 23 | 23 | 10/21/1998 | Active Production | 640 | | 560 | 180 | 540 | X | X | X |
| T03S/R07W-25K02S | City of Corona | Well No. 24 | 24 | 11/18/1998 | Active Production | 633 | | 450 | 200 | 450 | X | X | X |
| T03S/R07W-25E02S | City of Corona | Well No. 25 | 25 | 2/13/1999 | Active Production | 645 | | 210 | 90 | 190 | X | X | X |
| T03S/R07W-25C03S | City of Corona | Well No. 26 | 26 | 3/12/1999 | Active Production | 570 | | 448 | 90 | 446 | X | X | X |
| T04S/R07W-01A01S | City of Corona | Well No. 27 | 27 | 4/28/1980 | Active Production | 954 | | 545 | 288 | 530 | X | X | X |
| T03S/R07W-26K S | City of Corona | Well No. 28 | 28 | 8/20/2003 | Active Production | 610 | | 190 | 105 | 165 | X | X | X |

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Alameda, California

**Figure B-1**
**Current Monitoring Program City of Corona**

# Appendix C
# Model Development

# Appendix C - Model Development

A numerical model was developed to assess and quantify the impacts of the management strategies in the Temescal Subbasin described in the Groundwater Management Plan (GWMP), Chapter 6. The model was constructed using data from 1990 through 2004. This Study Period was selected based on hydrologic conditions and climate, as discussed in Chapter 2. Calibration involved testing and changing model variables to better match observed water levels and estimated water budgets. The calibrated model was then used as a foundation for simulating future conditions. The future conditions included the expected buildout pumping, wastewater recharge, and return flows in the model, while repeating previously observed hydrologic conditions (i.e. recharge). This future baseline model was used to compare management scenarios for the Temescal Subbasin.

The groundwater system of the Temescal Subbasin was simulated using the finite difference numerical model, MODFLOW (McDonald and Harbaugh, 1983). Groundwater Vistas 4 was used as a pre and post processor. The model simulated the conceptual model and the water balance described in detail in GWMP Chapter 3.

## C-1. Model Area

The numerical model area for layers 1 and 2 are shown on Figure C-1. The model differs slightly from the DWR defined basin (shown in yellow) due to several factors including adjustment of the area based on bedrock outcrops and possible groundwater divides. Specifically, the western and northwestern model area was moved slightly eastward to the contact of bedrock and the more permeable alluvial materials. The groundwater divide identified in Chapter 3 was used as the south model boundary. The Norco area was not included in the model area due to lack of available data. The contribution from the Norco area is simulated as a boundary condition. The model gird was rotated 30 degrees to align with the typical groundwater flow direction in the Channel Aquifer. The grid is made up of 4,470 active cells, each 500 feet by 500 feet. The active area and no-flow cells in the model are shown in Figure C-1. The transient part of the model simulates 1990 through 2004 with monthly stress periods.

## C-2. Layers

The numerical model of the Temescal Subbasin is divided into two layers, as shown in Figure C-1. The base of layer 2, the bottom of the model, is defined by the underlying bedrock. The top of layer 1, the top of the model, is defined by the ground surface elevation from the USGS digital elevation model (DEM) files. The depth of layer 1 was set at the approximate base of the Channel Aquifer, estimated at 450 feet above mean sea level (msl).

## C-3. Steady State Condition

The model begins with a steady state stress period. The steady state period assures that the initial heads in the model are internally consistent and mathematically sound. The steady state period is roughly based on 1989, a year characterized by little to no change in storage. The initial heads for the steady state condition are based on actual water level data from the late 1980s and early 1990s (Figure C-2). The contours were transformed into a continuous surface using GIS.

## C-4. Boundary Conditions

A numerical model seeks to simulate a small portion of a larger system. To represent the interaction of Temescal Subbasin with the larger systems, boundaries were simulated using constant head, general head, and specified flux cells. In most cases, only limited data were available to document the inflow or outflow from these boundaries. The locations and types of boundaries selected are shown on Figure C-3. Changes made to these boundaries during calibration are discussed in the calibration section.

### C-4.1. Specified Flux

Subsurface inflow from bedrock was simulated as specified flux along the western (Santa Ana Mountains) and eastern boundaries of the model. Estimates for total flow were derived from recharge calculations used in the water balance, Chapter 3, and adjusted during calibration. As the lag time between precipitation and recharge to the basin is uncertain, a steady state flux, constant over time, was used to simulate inflow. Inflow from the Santa Ana Mountains and the eastern bedrock outcrops was estimated at 721 AFY and 62 AFY respectively.

Inflow from the Norco area of the basin was also simulated as a steady state specified flux. Due to the low permeability in the area, the flow from Norco is expected to be small. However, the lack of recent water level data in the area made calculations uncertain. A simple flux calculation using Darcy's equation was used to estimate flow at 52 AFY, an amount held constant in the model.

Temescal Creek overlies the Temescal Subbasin in some reaches. The creek is in bedrock in the south, enters the subbasin west of Arlington Gap, and then flows in a concrete-lined channel to the Prado Management Area. The creek’s contribution to groundwater recharge is limited to a small area north of Temescal Canyon as described in Chapter 3. Recharge here is estimated at 113 AFY; as such, this amount is simulated in the model as a specified flux. The monthly distribution ranges from 5 AF/month to 15 AF/month, lower in the summer months and higher during the rainy winter months.

### C-4.2. Constant Head

The inflow or outflow from Arlington Gap was simulated using 14 constant head cells located on the eastern boundary of the model. The level of the constant head for each month was selected using water levels from Home Gardens Wells 3, 4 and Todd_0180 Well (data from SAWPA). Water level measurements from these three wells were infrequent and collected at various times over the Study Period. The water levels from these three wells were combined to compile a complete record of water levels for the constant head boundary. The head at the constant head cells were varied monthly based on available data.

The model-simulated flow across this boundary was compared to flow estimates calculated using Darcy's equation as discussed in Chapter 3. Based on Darcy’s equation, the flow into the basin through Arlington Gap was estimated as a steady annual average of 4,800 AFY. Using a range of gradients calculated from water levels in nearby wells over the entire period of record, the inflow was estimated to range between 2,225 AFY and 4,880 AFY over the Study Period.

### C-4.3. General Head Boundary

The inflow or outflow from the basin through Prado Dam was simulated as a general head boundary, located along the northwestern boundary of the model. Interaction between the Santa Ana River and the Temescal Subbasin was assumed to be a no–flow boundary. The conductance of the general head boundary was adjusted during calibration. The water level of the general head boundary was derived from the elevation of the reservoir behind Prado Dam. These elevation data are available from 1999 to the present from the California Data Exchange Center. The average monthly elevation of the reservoir was used for the study period. During calibration the elevation was increased by five feet to better match water level measurements and outflow estimates. The model simulates annual outflow that varied from 3,944 AFY to 4,123 AFY.

## *C-5. Recharge*

Recharge in the model simulated deep percolation from precipitation, irrigation return flows, wastewater, and stormwater. Areal recharge was based on the analysis prepared for the water balance in Chapter 3, simplified to include 15 zones of recharge representing different soils, land use, and percolation rates. The area of the zones varied over time as land use in the basin changed; the zones for the last year of the model are shown in Figure C-4. The return flows associated with each land use type were added to the rate of deep percolation. Recharge from return flows and deep percolation ranged from 902 AFY in 1996 to 14,269 AFY in 1993.

Wastewater was simulated by three cells in the northern part of the basin, shown in purple in Figure C-4. Annual wastewater totals were estimated in Chapter 3 using available data and population estimates from the City. As seasonal or monthly variation information was not available, an annual distribution was derived from the available water use data. It was assumed that months with higher water use (groundwater pumping and imported water) also indicated months with higher wastewater discharge. As such, wastewater percolation is expected to peak in the summer months June through August. The average monthly rate of wastewater recharge was based on the monthly urban water use distribution (Table C-1). The annual wastewater recharge ranged from 3,650 AFY to 9,474 AFY over the Study Period.

Two stormwater detention ponds located along Main Street and Oak Avenue are sources of increased recharge during winter months. The ponds capture excess runoff from the Santa Ana Mountains and detain this water until it can slowly be released to the stormwater system. The ponds are simulated by two recharge cells in the model, shown in light green on Figure C-4. As discussed in Chapter 3, the average annual inflow to the basin from these ponds was approximately 480 AFY. This volume was divided equally between the two ponds during the rainy winter months November through March.

## C-6. Pumping

Twenty eight wells were active in the Temescal Subbasin between 1990 and 2004. Pumping in these wells was simulated in the model using the well package with monthly stress periods. Annual pumping data were available for all wells and monthly pumping amounts were available for some wells. To account for wells or time periods for which monthly pumping data were not available, estimates were derived by using an annual distribution based on use type (Table C-1). The urban monthly pumping distribution was based on the observed annual distribution of pumping wells with monthly data. For agricultural pumping, a monthly distribution was developed using the distribution of evapotranspiration less monthly precipitation over the year. Pumping occurred only in layer 1 in the model. The active wells are shown in Figure C-3 (flux pumping); total pumping ranged from 7,294 AFY to 20,112 AFY.

**Table C-1**

**Monthly Pumping Distribution**

| Month | Urban | Agriculture |
|---|---|---|
| January | 3% | 0% |
| February | 3% | 0% |
| March | 5% | 6% |
| April | 7% | 10% |
| May | 7% | 13% |
| June | 10% | 14% |
| July | 17% | 15% |
| August | 17% | 15% |
| September | 15% | 11% |
| October | 7% | 7% |
| November | 5% | 5% |
| December | 3% | 2% |

## C-7. Aquifer Parameters

Hydraulic conductivity (K) was first estimated in the model and then adjusted through calibration. A total of nine zones of K values were originally defined. After calibration, the zones were simplified to three zones in layer 1 and two zones in layer 2. The layer 1 zones represented the Channel Aquifer, Norco area, and Alluvial Fan with K values of 125 feet/day, 20 feet/day, and 0.5 feet/day respectively. The layer 2 zones included the area directly below the channel and the deeper Alluvial Fan with K values of 60 feet/day and 0.5 feet/day respectively. These zones are shown in Figure C-5. The assumed ratio of horizontal conductivity to vertical conductivity was 10 to 1. A specific yield of 0.2 was selected for Channel Aquifer and 0.1 was used for all other areas.

## C-8. Calibration

The conceptual model and water balance discussed in Chapter 3 was simulated as a numerical model. Variables including the volume of bedrock inflow, conductance and elevation of the Prado Dam boundary, hydraulic conductivity, and location of the channel sediments were adjusted to match water levels observed in target wells and the conceptual understanding of the water budget.

### C-8.1. Targets

Eight wells were selected as calibration targets, based on available water level measurements over the Study Period and spatial distribution. Target wells are listed below and shown on Figure C-6. The City's water level monitoring over the Study Period occurred solely in the City's pumping municipal wells and it is uncertain if these data reflect pumping water levels or static water levels. While pumping wells generally are not included as model targets, a lack of any other consistent or reliable water level data prevented the addition of other targets. No wells with consistent water levels were available in the Alluvial Fan; however limited data were available near the stormwater ponds from Corona Well 27 in 2003. These data indicated water levels near 850 feet msl. Since very little production has occurred during the Study Period in this area, water levels in this area were assumed to be relatively stable. As such, a hypothetical target with constant water levels of 850 feet msl was developed to aid in calibration.

**Table C-2**

**Targets Used in Model Calibration**

| TODD ID | Agency Name | Local Name |
|---|---|---|
| TODD_0347 | City of Corona | 27 |
| TODD_0191 | Home Gardens | 3 |
| TODD_0257 | City of Corona | 13 |
| TODD_0738 | City of Corona | 8 |
| TODD_0743 | City of Corona | 19 |
| TODD_0783 | City of Corona | 15 |
| TODD_0839 | City of Corona | 11 |
| TODD_0923 | City of Corona | 14 |

The simulated and observed water levels for each target are shown on Figures C-7 and C-8. Water level contours at the end of the model simulation, December 2004, are shown on Figure C-9. Generally, simulated water levels showed a reasonable fit to the elevation and trend of observed water levels. Simulated water levels in wells located in the main part of the Channel Aquifer (Corona Wells 8, 11, 15, and 19) match the elevation and trends of the observed water levels. Simulated water levels on average are slightly higher than observed (by less than five feet). The observed water levels may be reflecting pumping water levels and not static water levels in the area. Simulated water levels in the target located on the edge of the northern portion of the channel, Corona Well 14, were similar to observed water levels.

Simulated water levels in the target located on the southern edge of the channel, Corona Well 13, are slightly lower than observed (about 10 feet). However, the simulated water levels match the overall trend of the observed water levels. Corona Well 13 is located near the outflow of Temescal Wash, an area of observed high water levels. This area is likely to be significantly more heterogeneous than modeled. However, detailed geologic information was not available to refine this area of the model.

Home Gardens Well 3 was included as a target, however, its close proximity to the constant head cells simulating Arlington Gap controlled the simulated water levels. The well was left as a target to check on the specified head of the boundary, rather than as an indication of model fit.

The final target was based on limited data from Corona Well 27. Data from this well were available only from March to October 2003. A constant water level of 850 feet msl over the entire time period was used to check the model fit in the area. The target showed a difference of about 13 feet between the simulated and estimated water levels. This difference is due, in part, to the constant water level estimated from limited data. The simulated water levels showed variation over the study period including a decline near the end of the time period.

A comparison of observed to simulated water levels is shown on Figure C-10. Ideally, simulated and observed water levels would fall along the 1:1 trend line on the chart. Overall, the observed water levels show more variability than the simulated water levels. This variability is most likely caused by pumping in or near the target wells. This local effect of pumping on the water levels is not simulated in the model. Simulated water levels tend to be lower than observed in higher elevations and higher than observed in lower elevations. This relationship could be the result of the channel sediments simulated as one hydraulic conductivity zone. Specifically, the model does not simulate the complex geology and the thinning of the channel along the edges. Again, many of the wells used as targets are production wells, so measured water levels may reflect a pumping water level rather than a static water level. The target on the alluvial fan was not included on this chart as the observed targets were estimated and not based on actual measurements.

### C-8.2. Budget

In addition to targets, the overall water budget was evaluated during calibration. The simulated budget, derived from the "reach report" output in Groundwater Vistas, was compared to the conceptual water balance described in Chapter 3. The conductance of the Prado Dam outflow and the hydraulic conductivity of the channel sediments were adjusted to better match the conceptual water balance as well as water levels.

## *C-9. Sensitivity Analysis*

During calibration, the model response to changes of each variable was evaluated seperately to determine its relative sensitivity. As described below, the model results were determined to be sensitive to 1) estimated conductivity and location of the Channel Aquifer, 2) hydraulic conductivity of the Alluvial Fan materials, and 3) the general head boundary at Prado Dam. The location and hydraulic conductivity of the channel sediments (particularly the southern extent of the channel) was found to control local and regional water level elevations. Hydraulic conductivity for the channel sediments were adjusted from 200 feet per day to 100 feet per day. Using a K value of 200 feet/day resulted in water levels that were consistently 10 to 20 feet higher than those simulated with a K value of 125 feet/day. Water levels in the model, specifically at selected targets, were sensitive to the southern extent of the channel sediments. The location of the high K zone was adjusted to better fit the observed data. While the southern extent of the channel differs slightly from the original geologic interpretation, the width and depth of the channel is uncertain. The model-simulated location of the channel is consistent with the overall geologic understanding of its formation.

Water levels in the Alluvial Fan were very sensitive to the hydraulic conductivity of the area. Various K values were simulated in the area ranging from 0.5 feet/day to 50 feet/day. Using high K values resulted in lower water levels at the hypothetical well in the Alluvial Fan area (567 feet msl using 10 feet/day, compared with 837 feet msl using 0.5 feet/day). Higher K in the alluvial fan resulted in slightly lower water levels in the channel area, a decrease of 3 feet when the K value was adjusted from 0.5 feet/day to 10 feet/day.

Because Prado Dam is the primary outflow of groundwater from the basin (aside from pumping), the volume of outflow was sensitive to the conductance of the general head cells representing Prado Dam. A higher boundary conductance increased the outflow and decreased water levels in the channel. The conductance was adjusted during calibration to obtain a good match with water levels and the expected outflow from Prado, on the order of thousands of AFY. Conductance was adjusted over a range of 1,000 feet/day to 200,000 feet/day.

Less sensitive variables included the seasonal variation of water levels at Arlington Gap, hydraulic conductivity of the area north of the channel, inflow from bedrock on the eastern edge of the model, and inflow from Temescal Wash.

## C-10. Model Limitations

The limited availability and accuracy of data in the Temescal Subbasin constrains the ability to develop detailed conceptual and numerical models. Overall, the numerical model is a good simulation of the conceptual model, but both the conceptual and numerical model can be improved with additional data and understanding of the basin. Possible improvements include consistent static water level monitoring across the entire subbasin, more information on geology and faulting along the western edge of the model, frequent monitoring at the boundaries

(Arlington Gap, Prado Dam, Chino, Norco), and detailed information on the inflow from the stormwater basins.

The model was designed to simulate the basin on a regional scale and should not be used to examine local issues such as well drawdown or solute transport. The model can be used to compare and relatively quantify management alternatives on a regional scale.

## C-11. Management Scenario Application

### C-11.1. Baseline

The numerical model calibrated to the 15-year Study Period, 1990-2004 was used as the foundation for a baseline model that simulates future conditions at build out. The 15-year future simulation repeats the hydraulic conditions observed over the Study Period, including the rate of recharge. Land use from 2004 was used to develop recharge zones in the baseline model to better simulate a developed urban area and the amount of return flows and deep percolation from precipitation.

Boundary conditions were also adjusted to simulate expected future conditions. The water levels from Home Gardens Well 3 from 1990 to 2004 were repeated over the 15-year simulation to represent the range of observed conditions at that Arlington Gap boundary. The future water levels at this boundary are uncertain as groundwater management on the Arlington side of the boundary has a large influence on the water levels and therefore flow into the basin. The height of the Prado Reservoir was also repeated over the 15-year period, and the boundary conductance was held constant.

Expected pumping at buildout, 21,726 AFY, was used for each year of the baseline model. (Rounding of model output resulted in numbers of 21,722 AFY to 21, 725 AFY being displayed in report tables). The increase in pumping over 2004 amounts was distributed among wells based on the 2004 pumping distribution (with small changes to prevent simulated dry cells in the model). Pumping from Wells 25 and 9 were decreased slightly and pumping in Well 17 was increased slightly. Estimated wastewater recharge at buildout is expected to be about 16,350 AFY, based on population projections in the City's General Plan (2003) and the Water Master Plan (AKM, April 2005). Current irrigation demand for recycled water is approximately 5,600 AFY. In addition, an outflow to Prado Dam of approximately 2,240 AFY (adjusted for water quality) is required. Subtracting these two demands from total wastewater leaves a total of about 8,510 AFY, an amount repeated over the baseline model to represent levels of recharge at the percolation ponds. (Again, rounding of model output numbers resulted in the small variation of numbers included in report tables). Other recharge components such as bedrock inflow and Temescal Wash inflow remained constant.

The baseline model was used to simulate management scenarios. Changes made to the model for each scenario are discussed below.

### C-11.2. Scenario 1: Pumping Redistribution

This scenario redistributed pumping in the aquifer. Two new wells were added in the northwestern part of the channel, near Prado Management Area. These wells were simulated as pumping 2,500 AFY each and the remaining 16,742 AFY of buildout pumping was distributed among the existing wells based on the same proportion as used in the baseline model. Aside from the well package, no other changes were made to the baseline numerical model for Scenario 1.

### C-11.3. Scenario 2: Additional Recharge at Oak Detention Basin

This scenario examined additional recharge in the Oak Avenue Detention Basin and a slight reduction in wastewater recharge. The Oak Avenue Detention Basin recharge (simulated in the recharge package) was increased to 5,000 AFY. Wastewater flows, also simulated in the recharge package, were decreased to 8,250 AFY to reflect the use of recycled water for one-half of the enhanced recharge water. The distribution of monthly wastewater recharge was maintained. No changes were made to the well package (including bedrock inflows or pumping).

### C-11.4. Scenario 3: Additional Recharge at Main Street Detention Basin

This scenario, similar to scenario 2, examined additional recharge in the Main Street Detention Basin and an increase in wastewater recharge. The Main Street Detention Basin recharge was increased to 1,500 AFY. Since recharge with recycled water was not as high in this scenario, wastewater flows were increased from Scenario 2. In addition, it was assumed that the outflow to Prado Management Area could be maintained through subsurface outflow and wastewater recharge was increased to the current permit amount of 9,520 AFY recharge at the percolation ponds, using the same monthly distribution (rounding results in an average of 9,507 AFY). No changes were made to the well package (including bedrock inflows or pumping).

### C-11.5. Scenario 4a: Recharge wells near Arlington Gap (4 wells)

This scenario examined the addition of recharge wells near Arlington Gap. It was determined that approximately 5 mgd of recycled water could be dedicated to recharge wells during the non-irrigation season. Four wells, recharging a total of 2,762 AFY (5 mgd over six months of recharge), were simulated near the eastern boundary of the model. Wastewater recharge at the percolation ponds were increased from baseline to 9,369 AFY, while maintaining the same monthly distribution. Extraction pumping remained the same as baseline.

### C-11.6. Scenario 4b: Recharge wells near Arlington Gap (7 wells)

This scenario is similar to scenario 4a; however a total of seven recharge wells were used to recharge near the Arlington Gap. The amount of recharge was 5,524 AFY (10 mgd over six months). In this scenario wastewater recharge at the ponds were decreased to an average of 7,988 AFY, assuming that a portion of that water would be dedicated to recharge. Extraction pumping remained the same as baseline.

### C-11.7. Results

Chapter 6 includes discussion of these management scenarios that were simulated using the numerical model. The water levels and budgets of each scenario were compared to the baseline model and the effectiveness of each management scenario is discussed. Tables with water budgets on an average basis for each management scenario are provided in Chapter 6. The complete water budgets for the baseline model and the five scenarios are provided here in Tables C-3 through C-8. Water levels for the baseline evaluation and the five scenarios at the eight targets are shown in Figures C-11 through C-14.

**Table C-3**
**Baseline Simulation**

| Water Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INFLOWS** | | | | | | | | | | | | | | | | |
| Deep Percolation from Precipitation | 0 | 0 | 384 | 13,937 | 0 | 1,343 | 0 | 0 | 3,500 | 15 | 13 | 1,460 | 3,151 | 617 | 909 | **1,689** |
| Infiltration of Runoff in Detention Basins | 482 | 478 | 478 | 478 | 482 | 478 | 478 | 478 | 482 | 478 | 478 | 478 | 482 | 478 | 478 | **479** |
| Recharge from Wastewater Discharge | 8,511 | 8,502 | 8,502 | 8,502 | 8,511 | 8,502 | 8,502 | 8,502 | 8,511 | 8,502 | 8,502 | 8,502 | 8,511 | 8,502 | 8,502 | **8,504** |
| Subsurface Inflow Subtotal | 6,601 | 6,356 | 5,191 | 4,212 | 4,603 | 5,407 | 5,948 | 5,417 | 5,492 | 5,662 | 5,219 | 4,635 | 3,756 | 4,302 | 4,648 | **5,163** |
| - Arlington Gap | 5,618 | 5,375 | 4,211 | 3,232 | 3,620 | 4,427 | 4,968 | 4,437 | 4,509 | 4,681 | 4,239 | 3,655 | 2,773 | 3,322 | 3,668 | 4,182 |
| - Temescal Wash (Temescal Canyon) | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 |
| - Bedrock in Watershed | 817 | 815 | 815 | 815 | 817 | 815 | 815 | 815 | 817 | 815 | 815 | 815 | 817 | 815 | 815 | 816 |
| - Norco | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 |
| Return Flows Subtotal | 2,404 | 2,760 | 2,760 | 2,760 | 2,040 | 2,760 | 933 | 2,389 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | **2,542** |
| **TOTAL INFLOWS (AFY)** | **17,997** | **18,096** | **17,316** | **29,889** | **15,636** | **18,491** | **15,862** | **16,786** | **20,744** | **17,417** | **16,973** | **17,835** | **18,659** | **16,659** | **17,297** | **18,377** |
| | | | | | | | | | | | | | | | | |
| **OUTFLOWS** | | | | | | | | | | | | | | | | |
| Groundwater Pumping | 21,725 | 21,722 | 21,722 | 21,722 | 21,725 | 21,722 | 21,722 | 21,722 | 21,725 | 21,722 | 21,722 | 21,722 | 21,725 | 21,722 | 21,722 | **21,722** |
| Subsurface Outflow to Santa Ana River | 6,472 | 6,011 | 5,732 | 5,604 | 5,512 | 5,436 | 5,382 | 5,337 | 5,313 | 5,284 | 5,255 | 5,231 | 5,231 | 5,215 | 5,195 | **5,481** |
| **TOTAL OUTFLOWS (AFY)** | **28,196** | **27,733** | **27,454** | **27,325** | **27,236** | **27,157** | **27,104** | **27,059** | **27,037** | **27,005** | **26,976** | **26,953** | **26,956** | **26,936** | **26,917** | **27,203** |
| | | | | | | | | | | | | | | | | |
| **CHANGE IN STORAGE (AF)** | | | | | | | | | | | | | | | | **-8,826** |

**Table C-4**
**Scenario 1: Pumping Redistribution**

| Water Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INFLOWS** | | | | | | | | | | | | | | | | |
| Deep Percolation from Precipitation | 0 | 0 | 384 | 13,937 | 0 | 1,343 | 0 | 0 | 3,500 | 15 | 13 | 1,460 | 3,151 | 617 | 909 | **1,689** |
| Infiltration of Runoff in Detention Basins | 482 | 478 | 478 | 478 | 482 | 478 | 478 | 478 | 482 | 478 | 478 | 478 | 482 | 478 | 478 | **479** |
| Recharge from Wastewater Discharge | 8,511 | 8,502 | 8,502 | 8,502 | 8,511 | 8,502 | 8,502 | 8,502 | 8,511 | 8,502 | 8,502 | 8,502 | 8,511 | 8,502 | 8,502 | **8,504** |
| Subsurface Inflow Subtotal | 6,586 | 6,276 | 5,051 | 4,018 | 4,379 | 5,159 | 5,676 | 5,128 | 5,182 | 5,341 | 4,890 | 4,292 | 3,407 | 3,950 | 4,287 | **4,908** |
| - Arlington Gap | 5,576 | 5,269 | 4,044 | 3,012 | 3,369 | 4,152 | 4,670 | 4,121 | 4,172 | 4,334 | 3,884 | 3,286 | 2,397 | 2,943 | 3,281 | 3,901 |
| - Temescal Wash (Temescal Canyon) | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 |
| - Bedrock in Watershed | 844 | 841 | 841 | 841 | 844 | 841 | 841 | 841 | 844 | 841 | 841 | 841 | 844 | 841 | 841 | 842 |
| - Norco | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 |
| Return Flows Subtotal | 2,404 | 2,760 | 2,760 | 2,760 | 2,040 | 2,760 | 933 | 2,389 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | **2,542** |
| **TOTAL INFLOWS (AFY)** | **17,982** | **18,016** | **17,175** | **29,695** | **15,411** | **18,242** | **15,590** | **16,497** | **20,434** | **17,096** | **16,643** | **17,493** | **18,310** | **16,307** | **16,937** | **18,122** |
| | | | | | | | | | | | | | | | | |
| **OUTFLOWS** | | | | | | | | | | | | | | | | |
| Groundwater Pumping | 21,749 | 21,740 | 21,740 | 21,740 | 21,749 | 21,740 | 21,740 | 21,740 | 21,749 | 21,740 | 21,740 | 21,740 | 21,749 | 21,740 | 21,740 | **21,742** |
| Subsurface Outflow to Santa Ana River | 6,472 | 6,011 | 5,732 | 5,604 | 5,512 | 5,436 | 5,381 | 5,336 | 5,310 | 5,282 | 5,249 | 5,225 | 5,222 | 5,196 | 5,158 | **5,475** |
| **TOTAL OUTFLOWS (AFY)** | **28,221** | **27,751** | **27,472** | **27,343** | **27,261** | **27,175** | **27,120** | **27,076** | **27,059** | **27,021** | **26,989** | **26,965** | **26,971** | **26,935** | **26,898** | **27,217** |
| | | | | | | | | | | | | | | | | |
| **CHANGE IN STORAGE (AF)** | | | | | | | | | | | | | | | | **-9,095** |

**Table C-5**
**Scenario 2: Enhanced Recharge at Oak Avenue Basin**

| Water Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INFLOWS** | | | | | | | | | | | | | | | | |
| Deep Percolation from Precipitation | 0 | 0 | 384 | 13,937 | 0 | 1,343 | 0 | 0 | 3,500 | 15 | 13 | 1,460 | 3,151 | 617 | 909 | **1,689** |
| Infiltration of Runoff in Detention Basins | 5,265 | 5,240 | 5,240 | 5,240 | 5,265 | 5,240 | 5,240 | 5,240 | 5,265 | 5,240 | 5,240 | 5,240 | 5,265 | 5,240 | 5,240 | **5,246** |
| - Oak Street | 5,023 | 5,000 | 5,000 | 5,000 | 5,023 | 5,000 | 5,000 | 5,000 | 5,023 | 5,000 | 5,000 | 5,000 | 5,023 | 5,000 | 5,000 | 5,006 |
| - Main Street | 241 | 240 | 240 | 240 | 241 | 240 | 240 | 240 | 241 | 240 | 240 | 240 | 241 | 240 | 240 | 240 |
| Recharge from Wastewater Discharge | 8,252 | 7,768 | 8,244 | 8,244 | 8,252 | 8,244 | 8,244 | 8,244 | 8,252 | 8,244 | 8,244 | 8,244 | 8,252 | 8,244 | 8,244 | **8,214** |
| Subsurface Inflow Subtotal | 6,627 | 6,385 | 5,223 | 4,246 | 4,639 | 5,444 | 5,983 | 5,454 | 5,531 | 5,702 | 5,257 | 4,674 | 3,794 | 4,340 | 4,687 | **5,199** |
| - Arlington Gap | 5,618 | 5,378 | 4,216 | 3,239 | 3,629 | 4,437 | 4,976 | 4,448 | 4,521 | 4,696 | 4,251 | 3,668 | 2,784 | 3,334 | 3,680 | 4,192 |
| - Temescal Wash (Temescal Canyon) | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 |
| - Bedrock in Watershed | 844 | 841 | 841 | 841 | 844 | 841 | 841 | 841 | 844 | 841 | 841 | 841 | 844 | 841 | 841 | 842 |
| - Norco | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 |
| Return Flows Subtotal | 2,404 | 2,760 | 2,760 | 2,760 | 2,040 | 2,760 | 933 | 2,389 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | **2,542** |
| **TOTAL INFLOWS (AFY)** | **22,548** | **22,153** | **21,850** | **34,425** | **20,196** | **23,030** | **20,399** | **21,327** | **25,307** | **21,960** | **21,513** | **22,378** | **23,222** | **21,200** | **21,839** | **22,890** |
| | | | | | | | | | | | | | | | | |
| **OUTFLOWS** | | | | | | | | | | | | | | | | |
| Groundwater Pumping | 21,725 | 21,722 | 21,722 | 21,722 | 21,725 | 21,722 | 21,722 | 21,722 | 21,725 | 21,722 | 21,722 | 21,722 | 21,725 | 21,722 | 21,658 | **21,718** |
| Subsurface Outflow to Santa Ana River | 6,472 | 6,011 | 5,732 | 5,604 | 5,512 | 5,436 | 5,382 | 5,337 | 5,313 | 5,284 | 5,255 | 5,231 | 5,231 | 5,215 | 5,195 | **5,481** |
| **TOTAL OUTFLOWS (AFY)** | **28,196** | **27,733** | **27,454** | **27,325** | **27,236** | **27,157** | **27,104** | **27,059** | **27,037** | **27,005** | **26,976** | **26,953** | **26,956** | **26,936** | **26,853** | **27,199** |
| | | | | | | | | | | | | | | | | |
| **CHANGE IN STORAGE (AF)** | | | | | | | | | | | | | | | | **-4,309** |

**Table C-6**
**Scenario 3: Enhanced Recharge at Main St Basin**

| Water Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INFLOWS** | | | | | | | | | | | | | | | | |
| Deep Percolation from Precipitation | 0 | 0 | 384 | 13,937 | 0 | 1,343 | 0 | 0 | 3,500 | 15 | 13 | 1,460 | 3,151 | 617 | 909 | **1,689** |
| Infiltration of Runoff in Detention Basins | 1,749 | 1,740 | 1,740 | 1,740 | 1,749 | 1,740 | 1,740 | 1,740 | 1,749 | 1,740 | 1,740 | 1,740 | 1,749 | 1,740 | 1,740 | **1,743** |
| - Oak Street | 241 | 240 | 240 | 240 | 241 | 240 | 240 | 240 | 241 | 240 | 240 | 240 | 241 | 240 | 240 | 240 |
| - Main Street | 1,507 | 1,500 | 1,500 | 1,500 | 1,507 | 1,500 | 1,500 | 1,500 | 1,507 | 1,500 | 1,500 | 1,500 | 1,507 | 1,500 | 1,500 | 1,502 |
| Recharge from Wastewater Discharge | 9,515 | 9,505 | 9,505 | 9,505 | 9,515 | 9,505 | 9,505 | 9,505 | 9,515 | 9,505 | 9,505 | 9,505 | 9,515 | 9,505 | 9,505 | **9,507** |
| Subsurface Inflow Subtotal | 6,627 | 6,379 | 5,208 | 4,222 | 4,607 | 5,407 | 5,939 | 5,410 | 5,481 | 5,651 | 5,210 | 4,619 | 3,740 | 4,284 | 4,629 | **5,161** |
| - Arlington Gap | 5,618 | 5,373 | 4,201 | 3,216 | 3,597 | 4,401 | 4,932 | 4,404 | 4,471 | 4,645 | 4,204 | 3,613 | 2,731 | 3,278 | 3,622 | 4,154 |
| - Temescal Wash (Temescal Canyon) | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 |
| - Bedrock in Watershed | 844 | 841 | 841 | 841 | 844 | 841 | 841 | 841 | 844 | 841 | 841 | 841 | 844 | 841 | 841 | 842 |
| - Norco | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 |
| Return Flows Subtotal | 2,404 | 2,760 | 2,760 | 2,760 | 2,040 | 2,760 | 933 | 2,389 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | **2,542** |
| **TOTAL INFLOWS (AFY)** | **20,295** | **20,384** | **19,597** | **32,164** | **17,910** | **20,756** | **18,117** | **19,044** | **23,004** | **19,671** | **19,228** | **20,085** | **20,915** | **18,906** | **19,543** | **20,642** |
| | | | | | | | | | | | | | | | | |
| **OUTFLOWS** | | | | | | | | | | | | | | | | |
| Groundwater Pumping | 21,725 | 21,722 | 21,722 | 21,722 | 21,725 | 21,722 | 21,722 | 21,722 | 21,725 | 21,722 | 21,722 | 21,722 | 21,725 | 21,722 | 21,722 | **21,722** |
| Subsurface Outflow to Santa Ana River | 6,472 | 6,011 | 5,732 | 5,604 | 5,512 | 5,436 | 5,382 | 5,337 | 5,313 | 5,292 | 5,255 | 5,231 | 5,232 | 5,215 | 5,196 | **5,481** |
| **TOTAL OUTFLOWS (AFY)** | **28,196** | **27,733** | **27,454** | **27,325** | **27,236** | **27,157** | **27,104** | **27,059** | **27,037** | **27,013** | **26,976** | **26,953** | **26,957** | **26,937** | **26,917** | **27,204** |
| | | | | | | | | | | | | | | | | |
| **CHANGE IN STORAGE (AF)** | | | | | | | | | | | | | | | | **-6,562** |

**Table C-7**
**Scenario 4a: Arlington Gap Recharge (4 Wells)**

| Water Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INFLOWS** | | | | | | | | | | | | | | | | |
| Deep Percolation from Precipitation | 0 | 0 | 384 | 13,937 | 0 | 1,343 | 0 | 0 | 3,500 | 15 | 13 | 1,460 | 3,151 | 617 | 909 | **1,689** |
| Infiltration of Runoff in Detention Basins | 482 | 478 | 478 | 478 | 482 | 478 | 478 | 478 | 482 | 478 | 478 | 478 | 482 | 478 | 478 | **479** |
| Recharge from Wastewater Discharge | 9,397 | 9,388 | 9,388 | 9,388 | 9,397 | 9,388 | 9,388 | 9,388 | 9,397 | 9,388 | 9,388 | 9,388 | 9,397 | 9,388 | 9,388 | **9,390** |
| Subsurface Inflow Subtotal | 6,136 | 5,547 | 4,252 | 3,190 | 3,561 | 4,338 | 4,853 | 4,302 | 4,352 | 4,519 | 4,074 | 3,486 | 2,608 | 3,157 | 3,497 | **4,125** |
| - Arlington Gap | 5,140 | 4,554 | 3,259 | 2,197 | 2,564 | 3,345 | 3,860 | 3,309 | 3,355 | 3,526 | 3,081 | 2,492 | 1,611 | 2,163 | 2,504 | 3,131 |
| - Temescal Wash (Temescal Canyon) | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 |
| - Bedrock in Watershed | 835 | 832 | 832 | 832 | 835 | 832 | 832 | 832 | 835 | 832 | 832 | 832 | 835 | 832 | 832 | 833 |
| - Norco | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| Return Flows Subtotal | 2,404 | 2,760 | 2,760 | 2,760 | 2,040 | 2,760 | 933 | 2,389 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | **2,542** |
| Recharge Wells at Arlington | 2,762 | 2,762 | 2,762 | 2,762 | 2,762 | 2,762 | 2,762 | 2,762 | 2,762 | 2,762 | 2,762 | 2,762 | 2,762 | 2,762 | 2,762 | **2,762** |
| **TOTAL INFLOWS (AFY)** | **21,181** | **20,935** | **20,024** | **32,515** | **18,241** | **21,069** | **18,415** | **19,319** | **23,252** | **19,922** | **19,475** | **20,334** | **21,160** | **19,162** | **19,795** | **20,987** |
| | | | | | | | | | | | | | | | | |
| **OUTFLOWS** | | | | | | | | | | | | | | | | |
| Groundwater Pumping | 21,705 | 21,722 | 21,722 | 21,722 | 21,705 | 21,722 | 21,722 | 21,722 | 21,705 | 21,722 | 21,722 | 21,722 | 21,705 | 21,722 | 21,722 | **21,717** |
| Subsurface Outflow to Santa Ana River | 6,472 | 6,011 | 5,732 | 5,604 | 5,512 | 5,436 | 5,382 | 5,337 | 5,313 | 5,292 | 5,255 | 5,231 | 5,232 | 5,215 | 5,196 | **5,481** |
| **TOTAL OUTFLOWS (AFY)** | **28,177** | **27,733** | **27,454** | **27,325** | **27,217** | **27,157** | **27,104** | **27,059** | **27,018** | **27,013** | **26,977** | **26,953** | **26,937** | **26,937** | **26,917** | **27,199** |
| | | | | | | | | | | | | | | | | |
| **CHANGE IN STORAGE (AF)** | | | | | | | | | | | | | | | | **-6,212** |

## Table C-8
## Scenario 4b: Recharge Wells at Arlington Gap (7 Wells)

| Water Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INFLOWS** | | | | | | | | | | | | | | | | |
| Deep Percolation from Precipitation | 0 | 0 | 384 | 13,937 | 0 | 1,343 | 0 | 0 | 3,500 | 15 | 13 | 1,460 | 3,151 | 617 | 909 | **1,689** |
| Infiltration of Runoff in Detention Basins | 482 | 478 | 478 | 478 | 482 | 478 | 478 | 478 | 482 | 478 | 478 | 478 | 482 | 478 | 478 | **479** |
| Recharge from Wastewater Discharge | 7,994 | 7,986 | 7,986 | 7,986 | 7,994 | 7,986 | 7,986 | 7,986 | 7,994 | 7,986 | 7,986 | 7,986 | 7,994 | 7,986 | 7,986 | **7,988** |
| Subsurface Inflow Subtotal | 5,381 | 4,407 | 3,010 | 1,904 | 2,253 | 3,016 | 3,521 | 2,960 | 2,990 | 3,167 | 2,721 | 2,132 | 1,264 | 1,816 | 2,148 | **2,846** |
| - Arlington Gap | 4,371 | 3,400 | 2,004 | 897 | 1,244 | 2,009 | 2,514 | 1,954 | 1,981 | 2,160 | 1,714 | 1,126 | 254 | 809 | 1,142 | 1,839 |
| - Temescal Wash (Temescal Canyon) | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 |
| - Bedrock in Watershed | 844 | 841 | 841 | 841 | 844 | 841 | 841 | 841 | 844 | 841 | 841 | 841 | 844 | 841 | 841 | 842 |
| - Norco | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 |
| Return Flows Subtotal | 2,404 | 2,760 | 2,760 | 2,760 | 2,040 | 2,760 | 933 | 2,389 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | 2,760 | **2,542** |
| Recharge Wells | 5,524 | 5,524 | 5,524 | 5,524 | 5,524 | 5,524 | 5,524 | 5,524 | 5,524 | 5,524 | 5,524 | 5,524 | 5,524 | 5,524 | 5,524 | **5,524** |
| **TOTAL INFLOWS (AFY)** | **21,785** | **21,155** | **20,143** | **32,589** | **18,293** | **21,107** | **18,443** | **19,338** | **23,250** | **19,930** | **19,482** | **20,341** | **21,175** | **19,181** | **19,806** | **21,068** |
| | | | | | | | | | | | | | | | | |
| **OUTFLOWS** | | | | | | | | | | | | | | | | |
| Groundwater Pumping | 21,690 | 21,723 | 21,723 | 21,723 | 21,690 | 21,723 | 21,723 | 21,723 | 21,690 | 21,723 | 21,723 | 21,723 | 21,690 | 21,723 | 21,723 | **21,715** |
| Subsurface Outflow to Santa Ana River | 6,472 | 6,011 | 5,732 | 5,604 | 5,512 | 5,436 | 5,382 | 5,337 | 5,313 | 5,284 | 5,255 | 5,231 | 5,231 | 5,215 | 5,195 | **5,481** |
| **TOTAL OUTFLOWS (AFY)** | **28,162** | **27,735** | **27,456** | **27,327** | **27,202** | **27,159** | **27,106** | **27,061** | **27,003** | **27,007** | **26,978** | **26,955** | **26,922** | **26,938** | **26,919** | **27,195** |
| | | | | | | | | | | | | | | | | |
| **CHANGE IN STORAGE (AF)** | | | | | | | | | | | | | | | | **-6,127** |

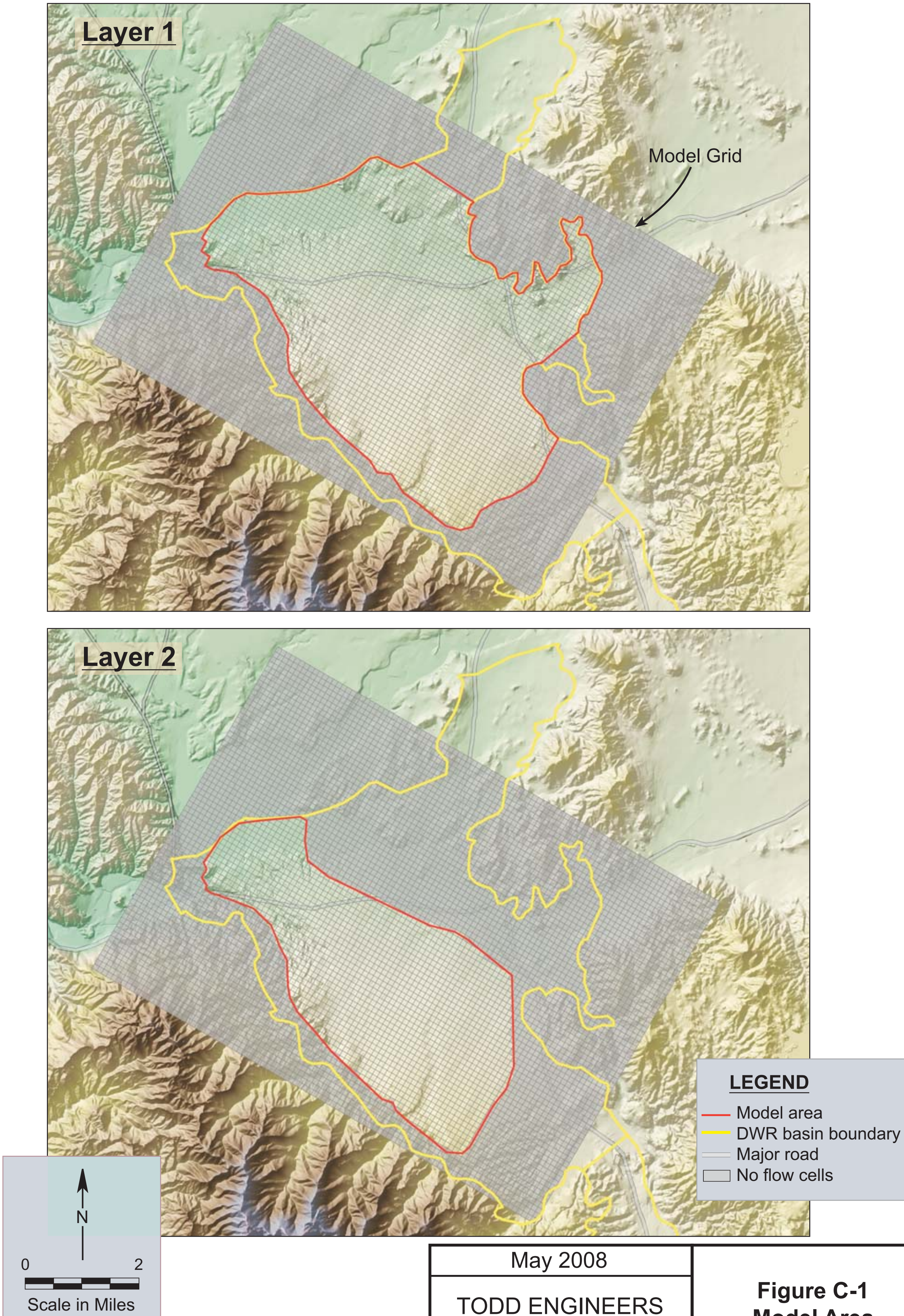


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**Figure C-1**
**Model Area**

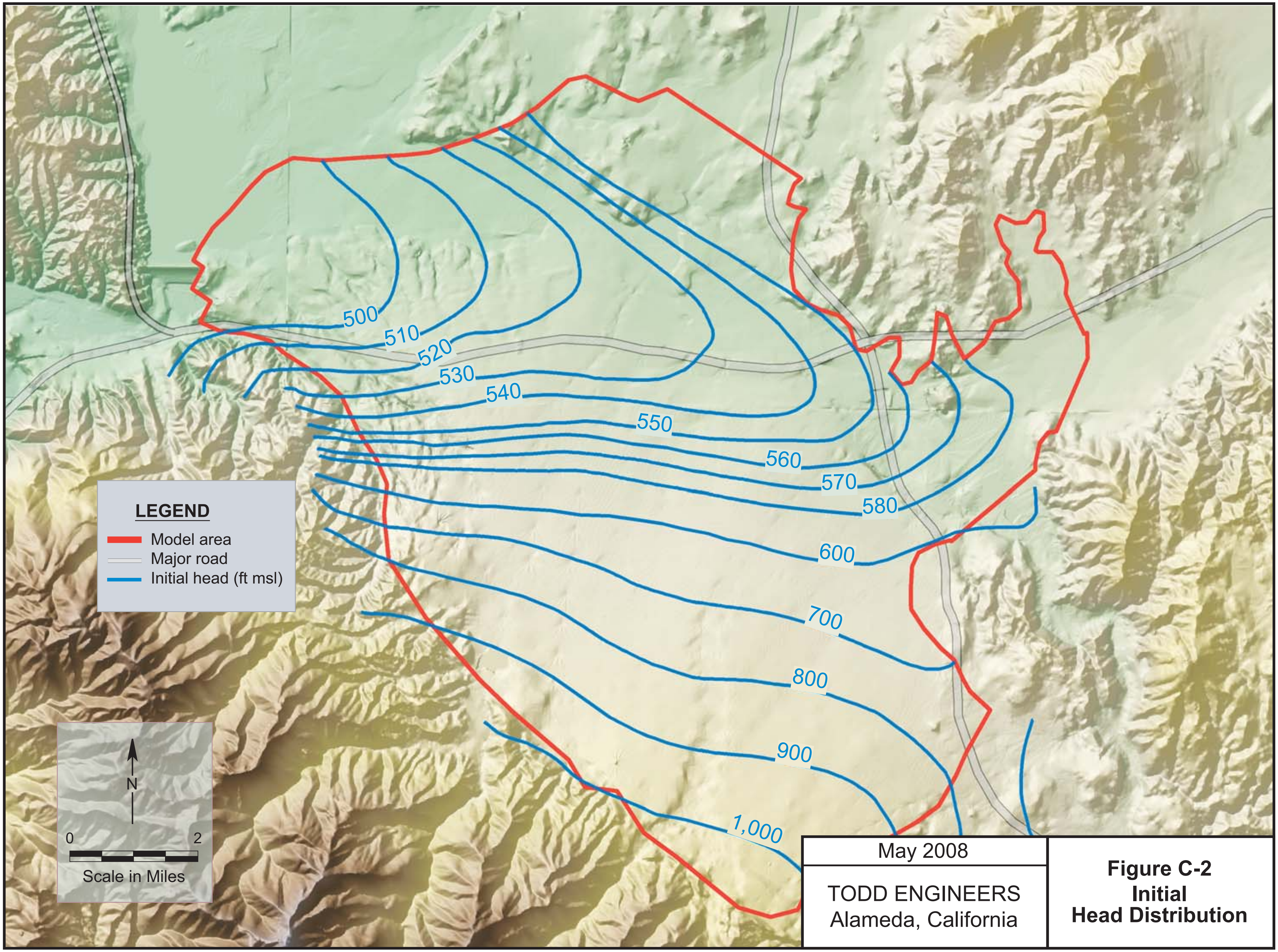


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**Figure C-2**
**Initial**
**Head Distribution**

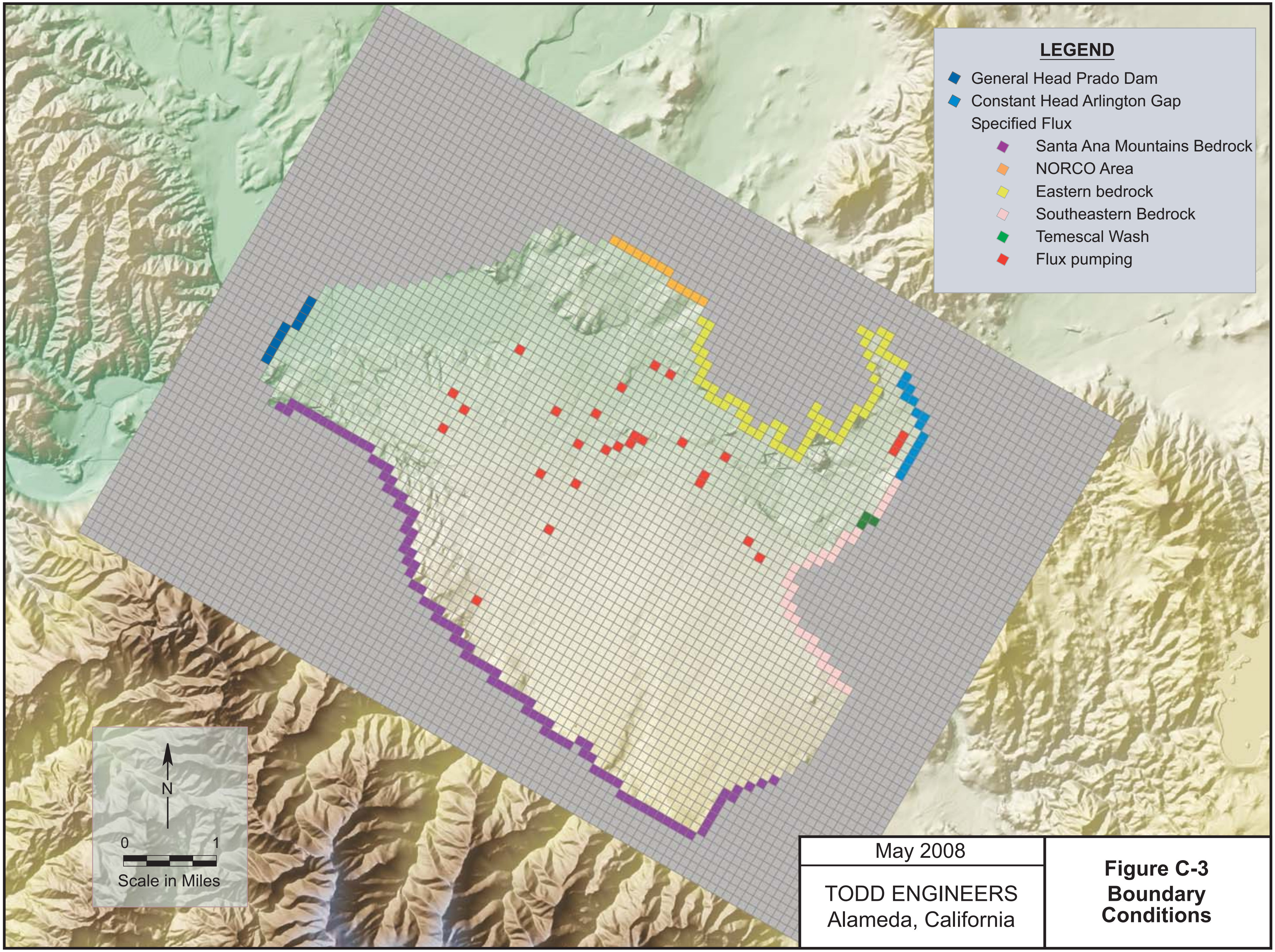


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**Figure C-3**
**Boundary Conditions**

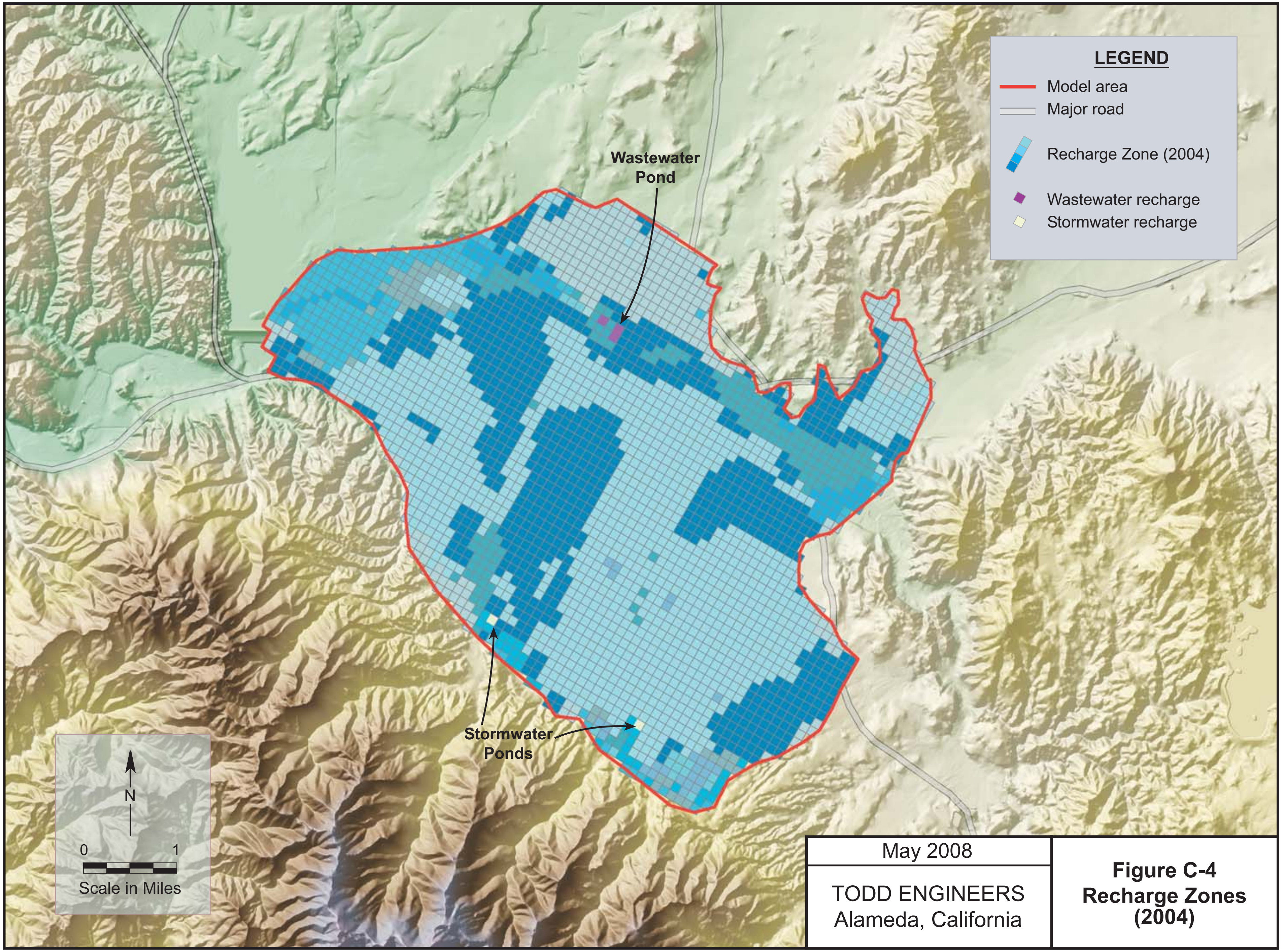


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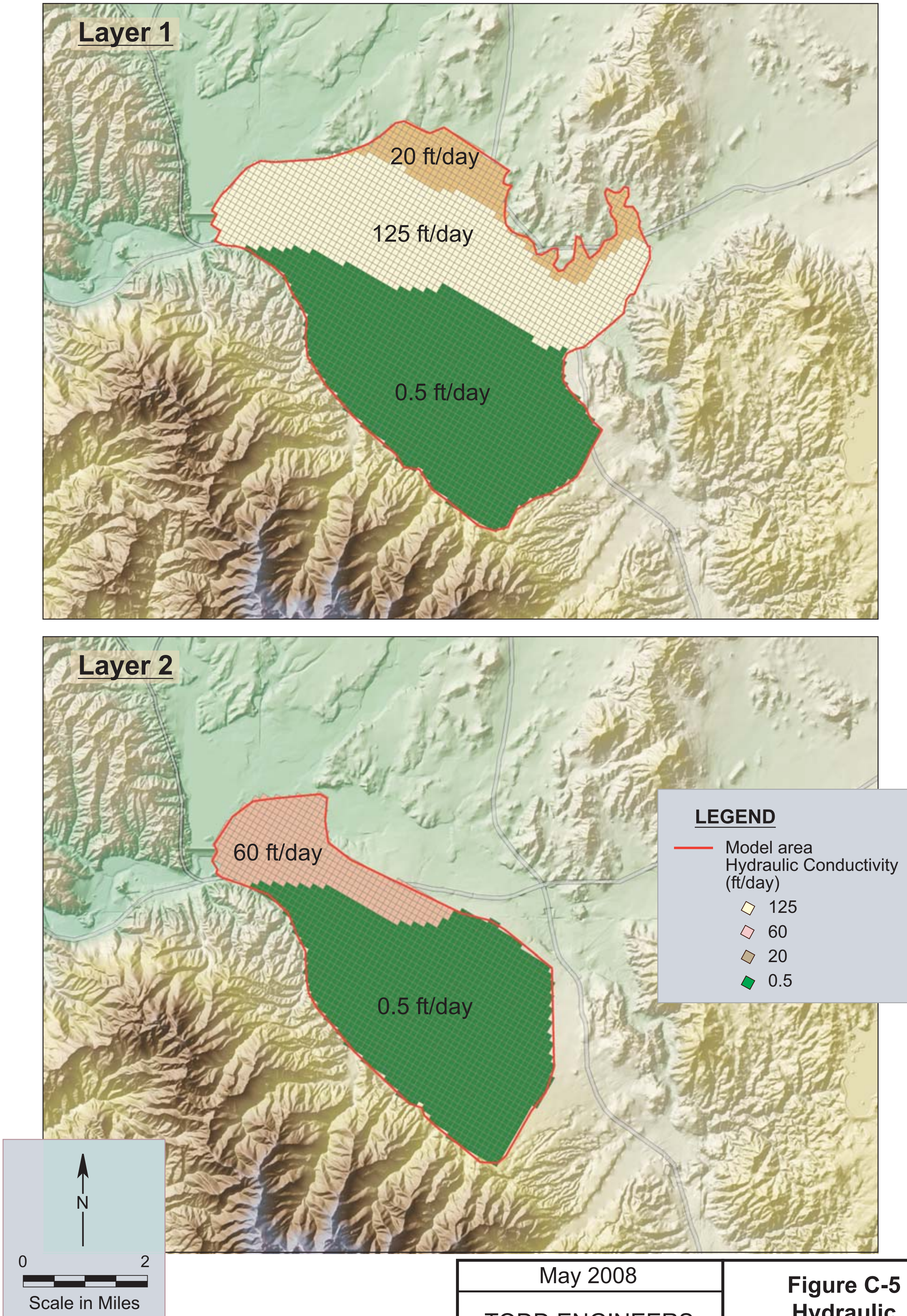
**Figure C-4**
**Recharge Zones (2004)**




| May 2008 | Figure C-5 Hydraulic Conductivity Distribution |
|---|---|
| TODD ENGINEERS Alameda, California | |

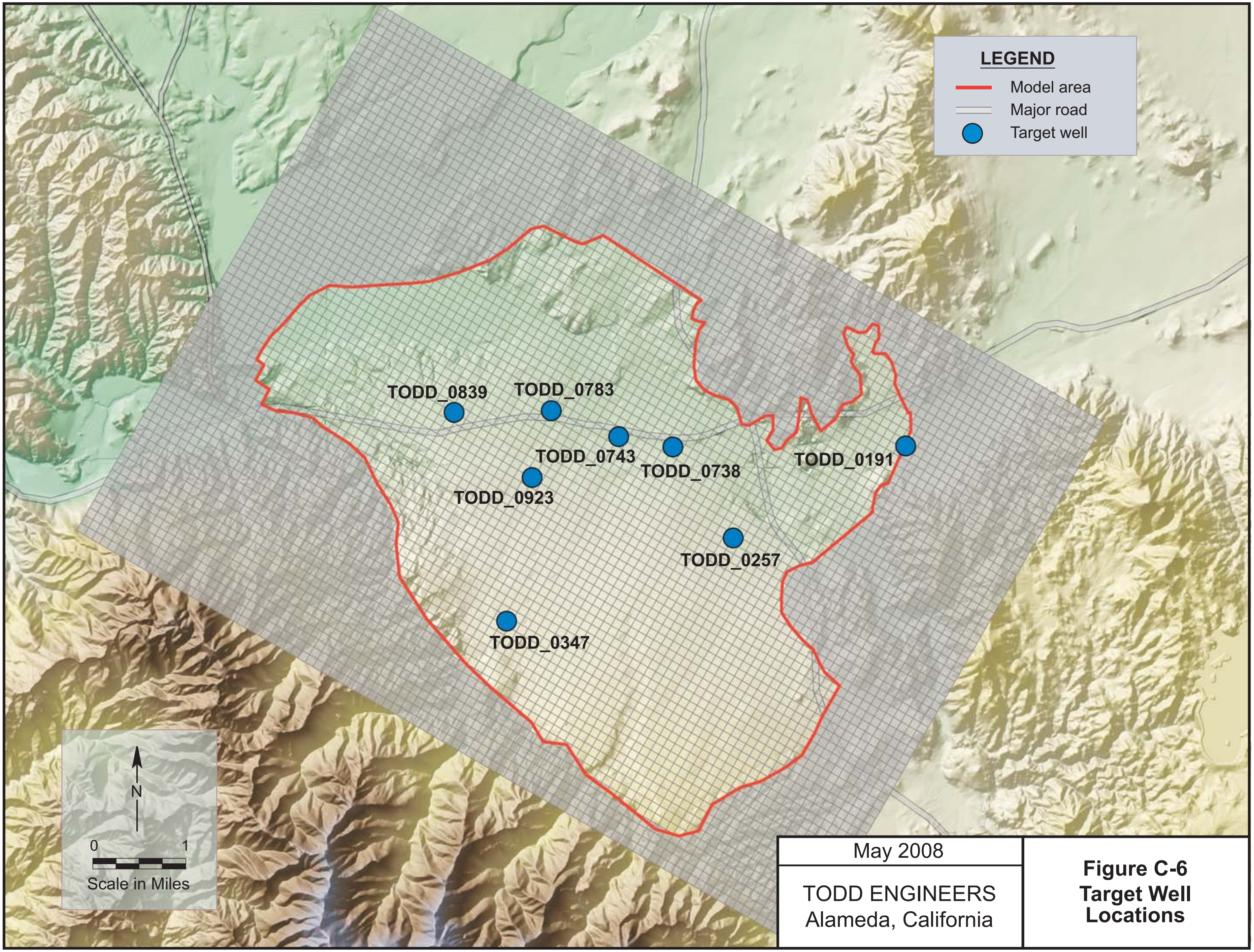



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**Figure C-6**
**Target Well Locations**

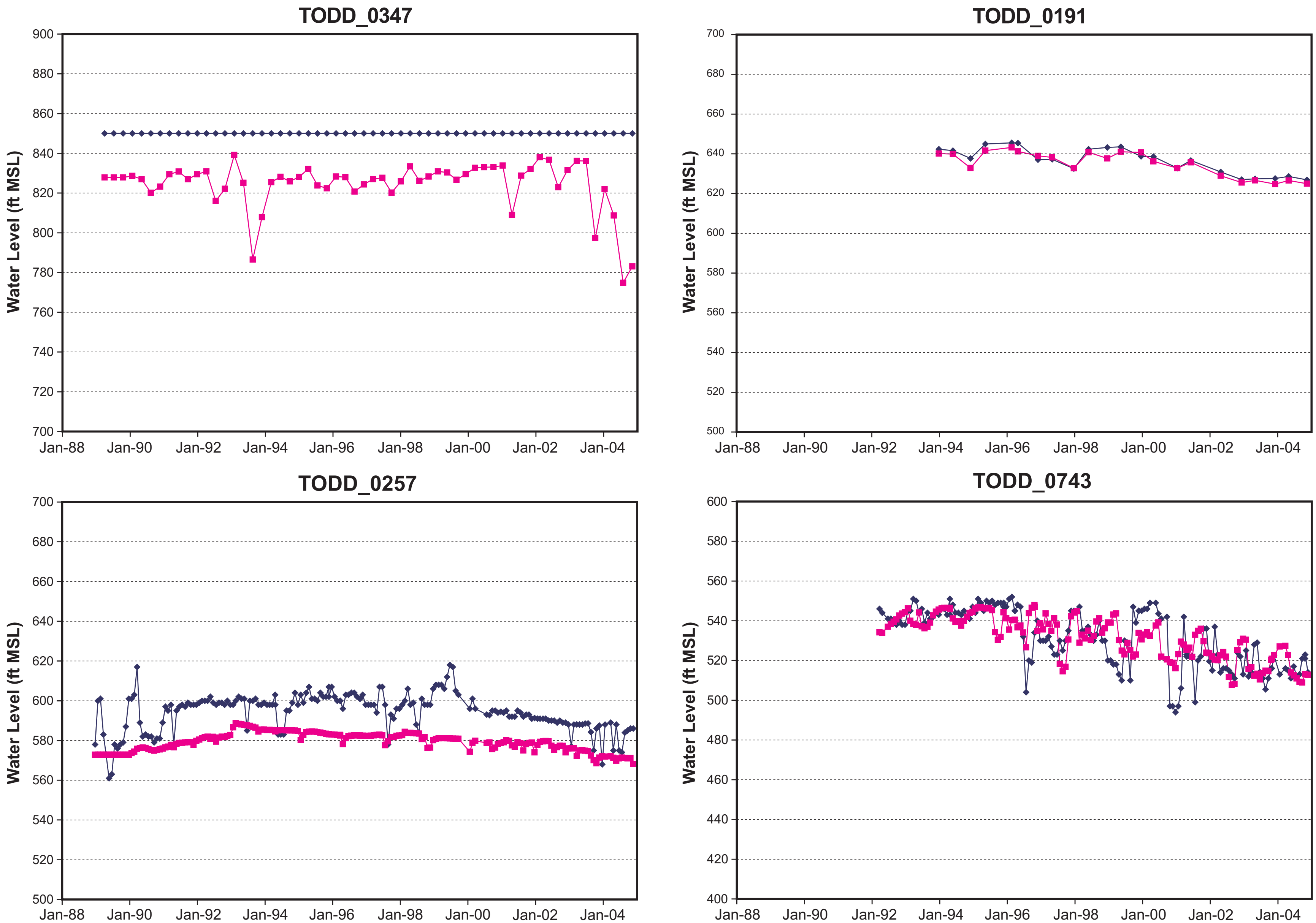


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**Figure C-7**
**Calibration Hydrographs**

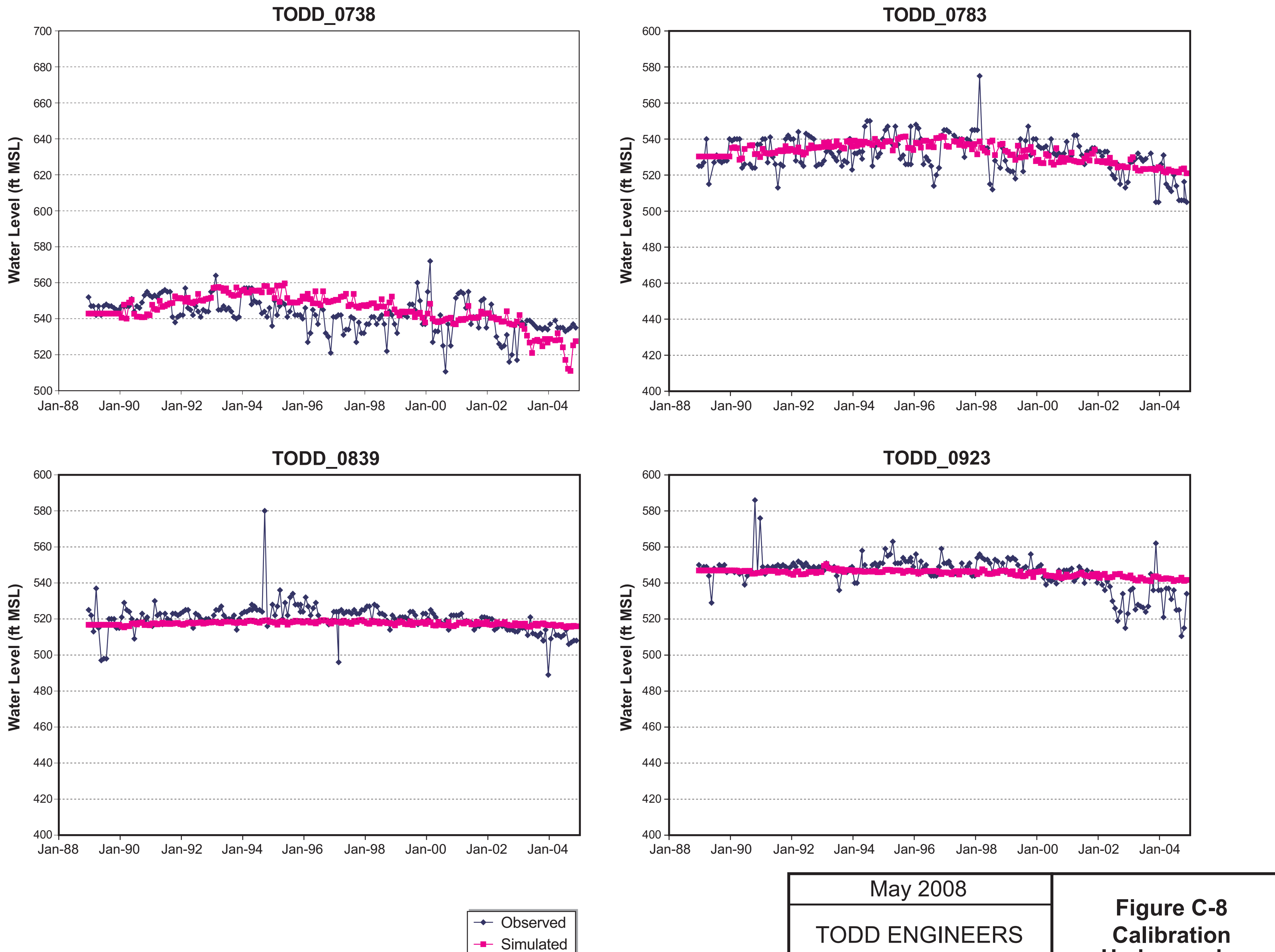


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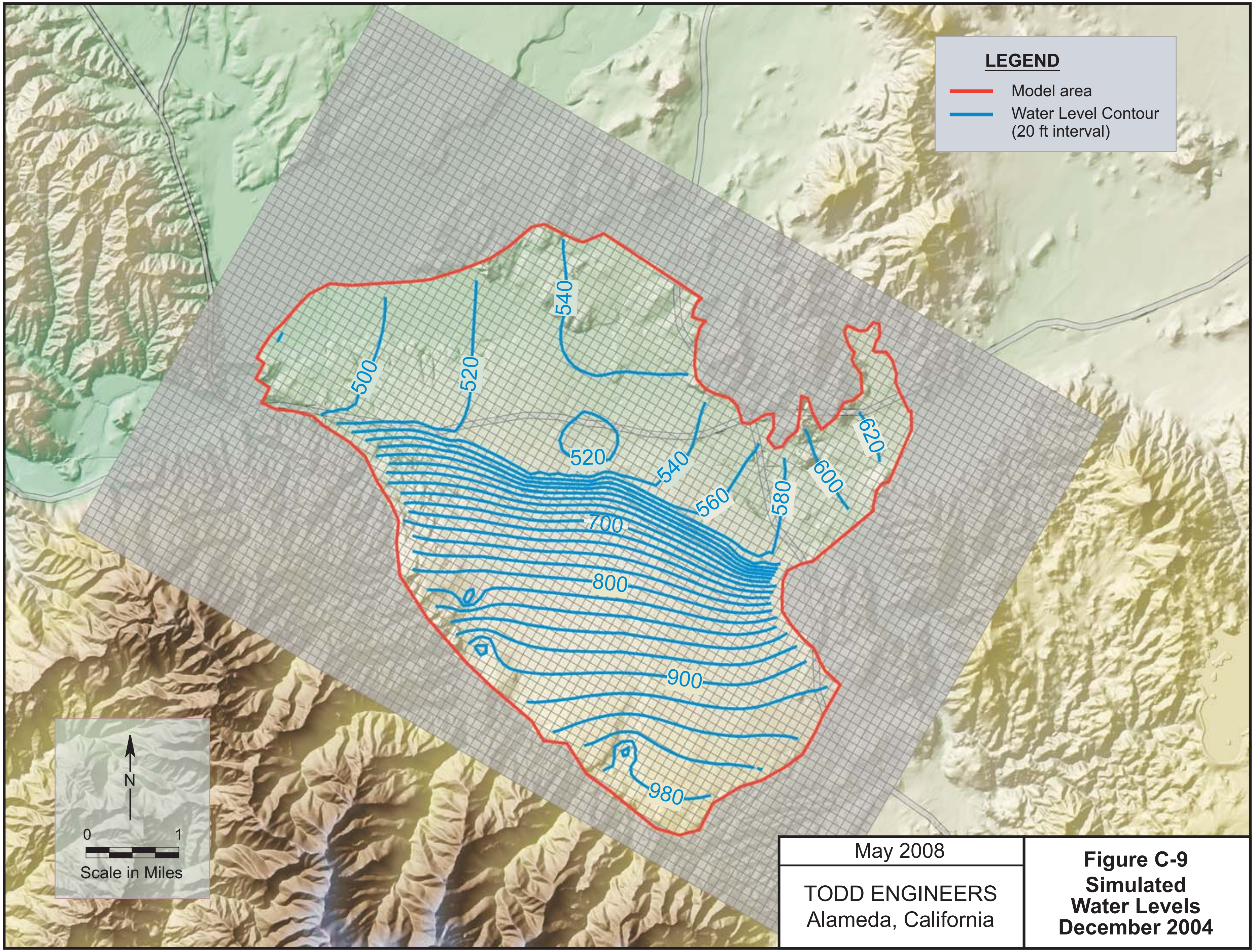
**Figure C-8**
**Calibration Hydrographs**




May 2008

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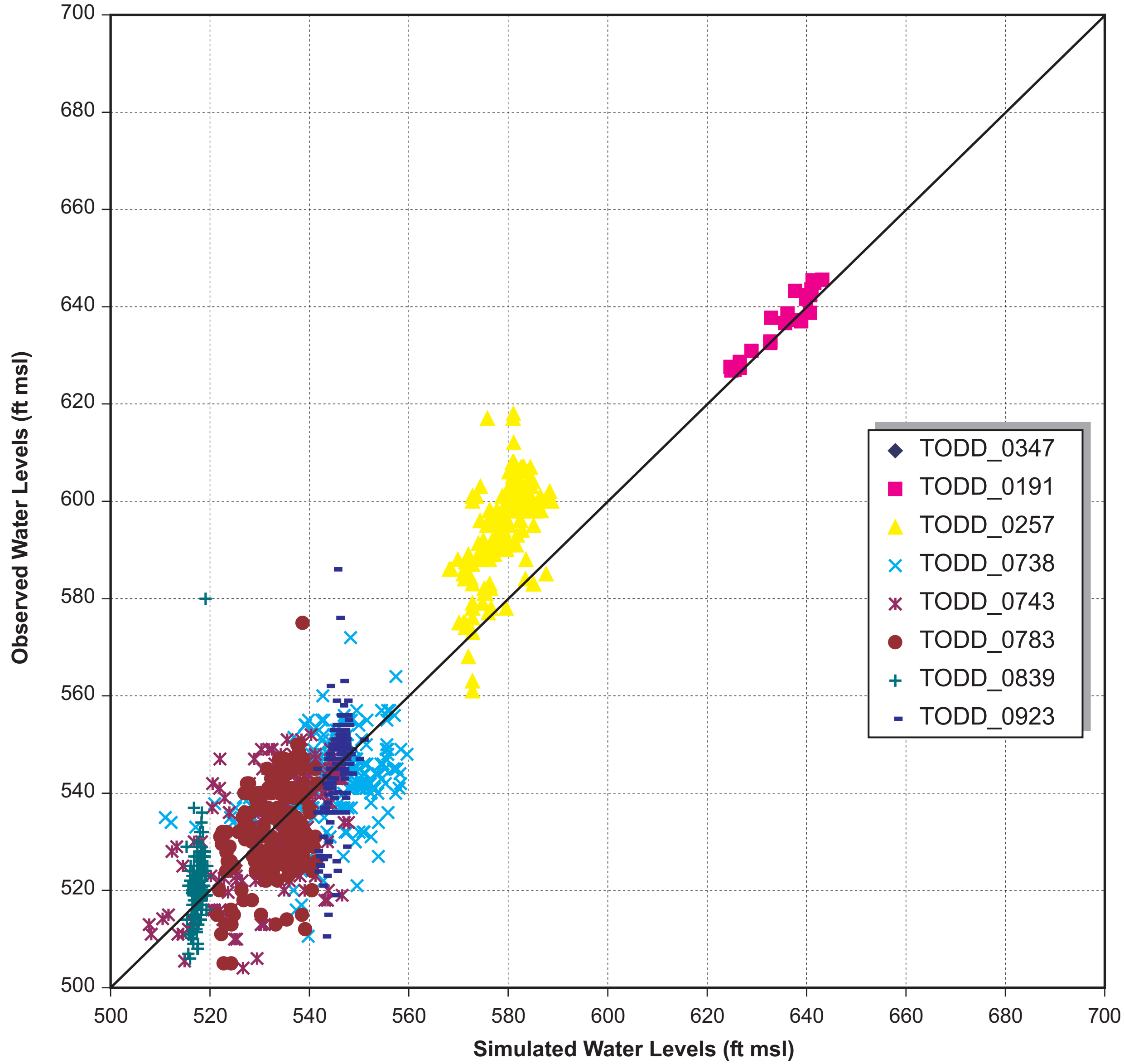
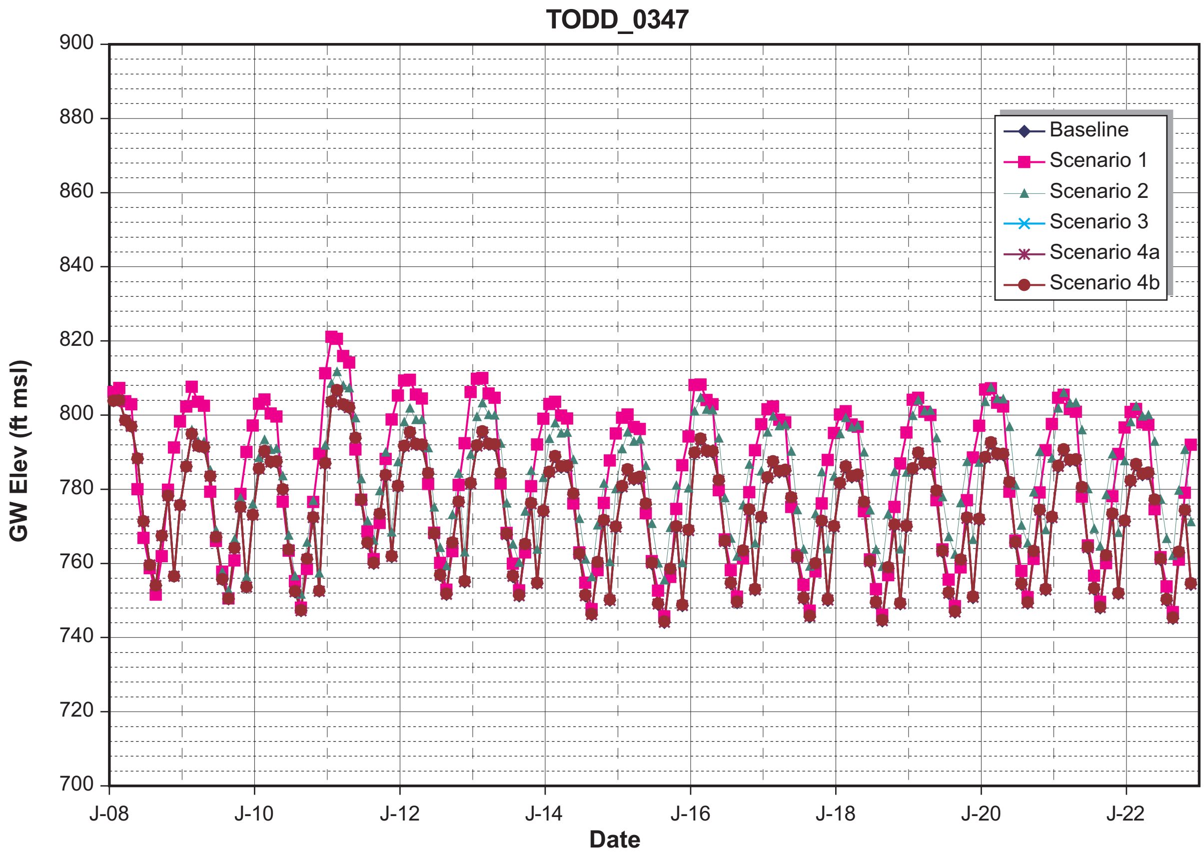
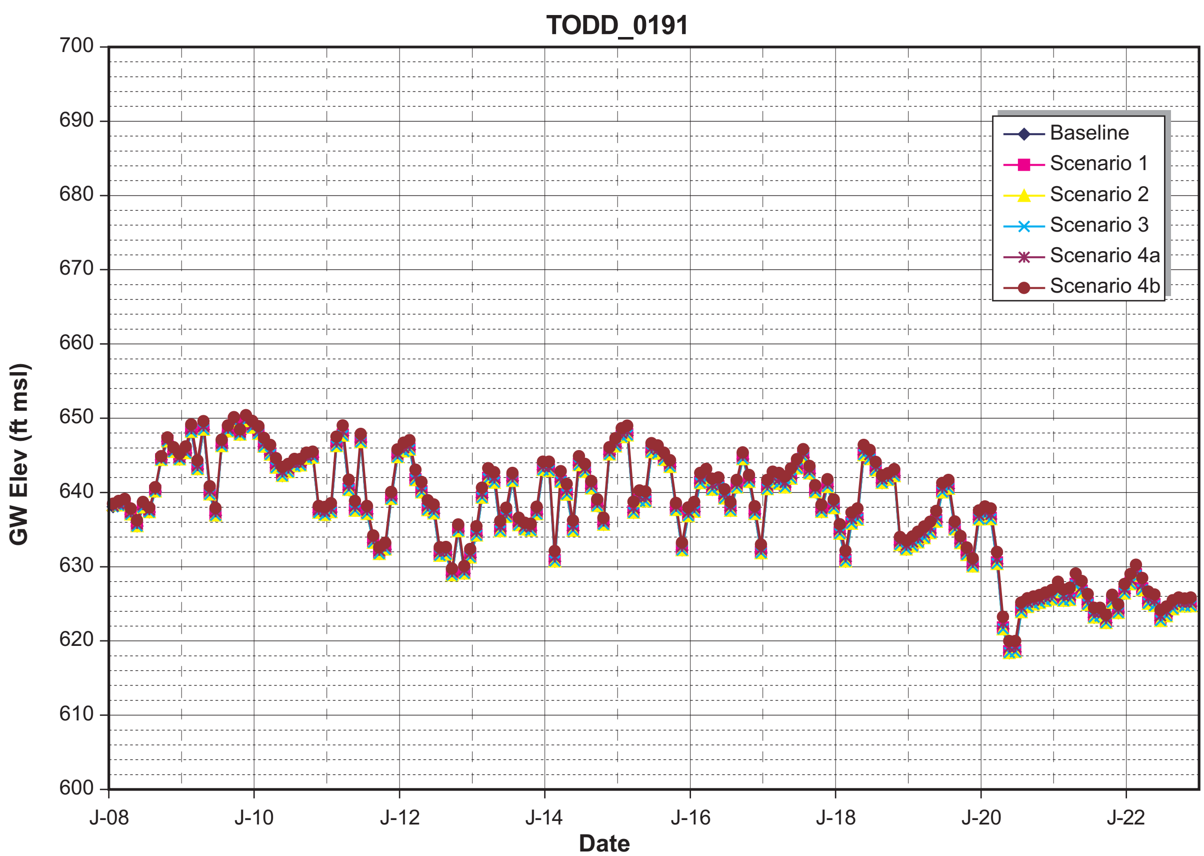
**Figure C-9**
**Simulated Water Levels December 2004**

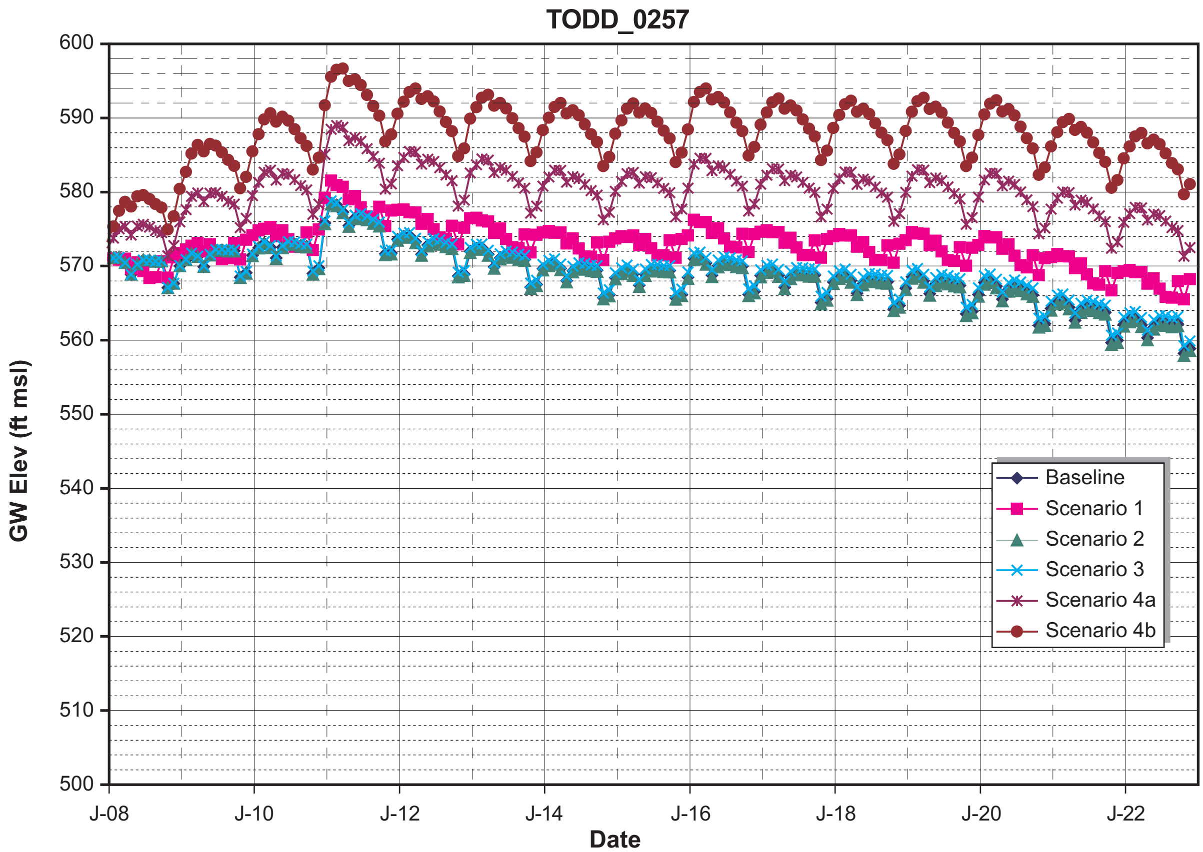


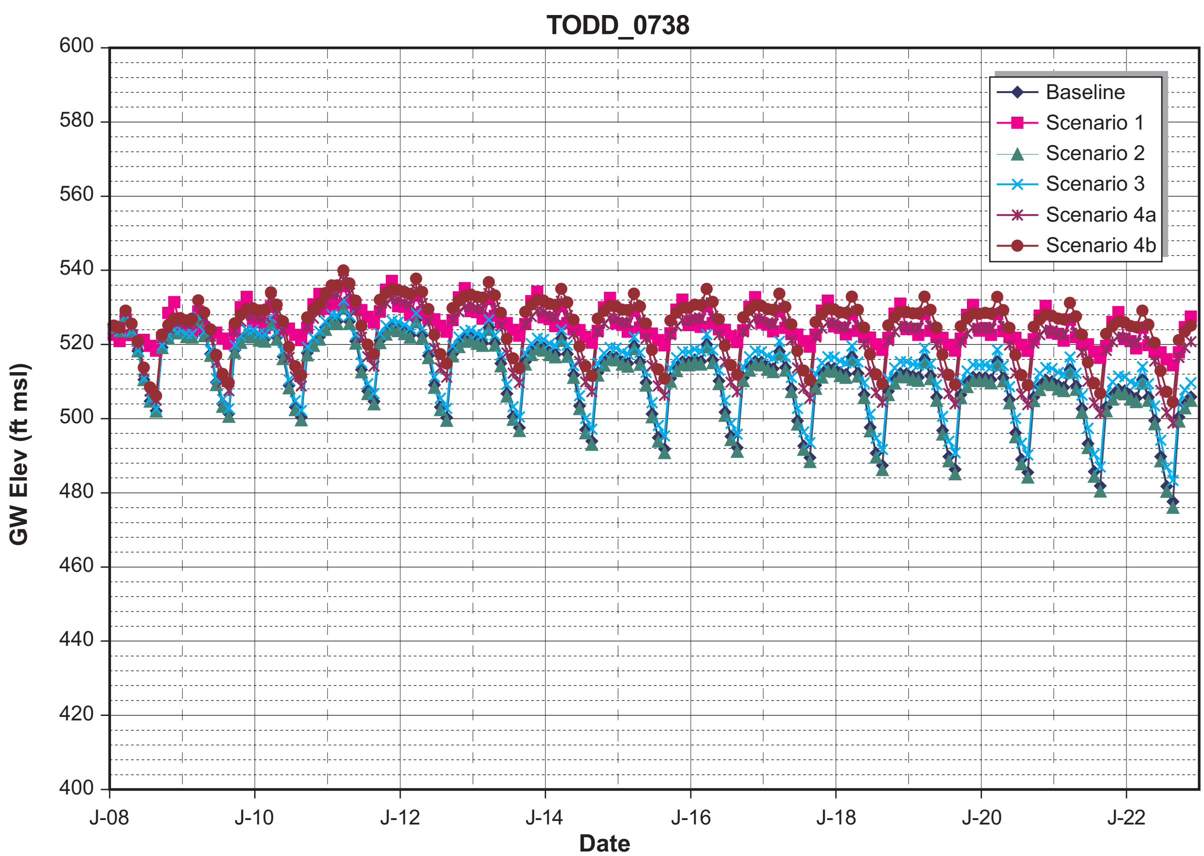

| May 2008 | **Figure C-10 Observed vs. Simulated Water Levels** |
|---|---|
| TODD ENGINEERS<br>Alameda, California | |



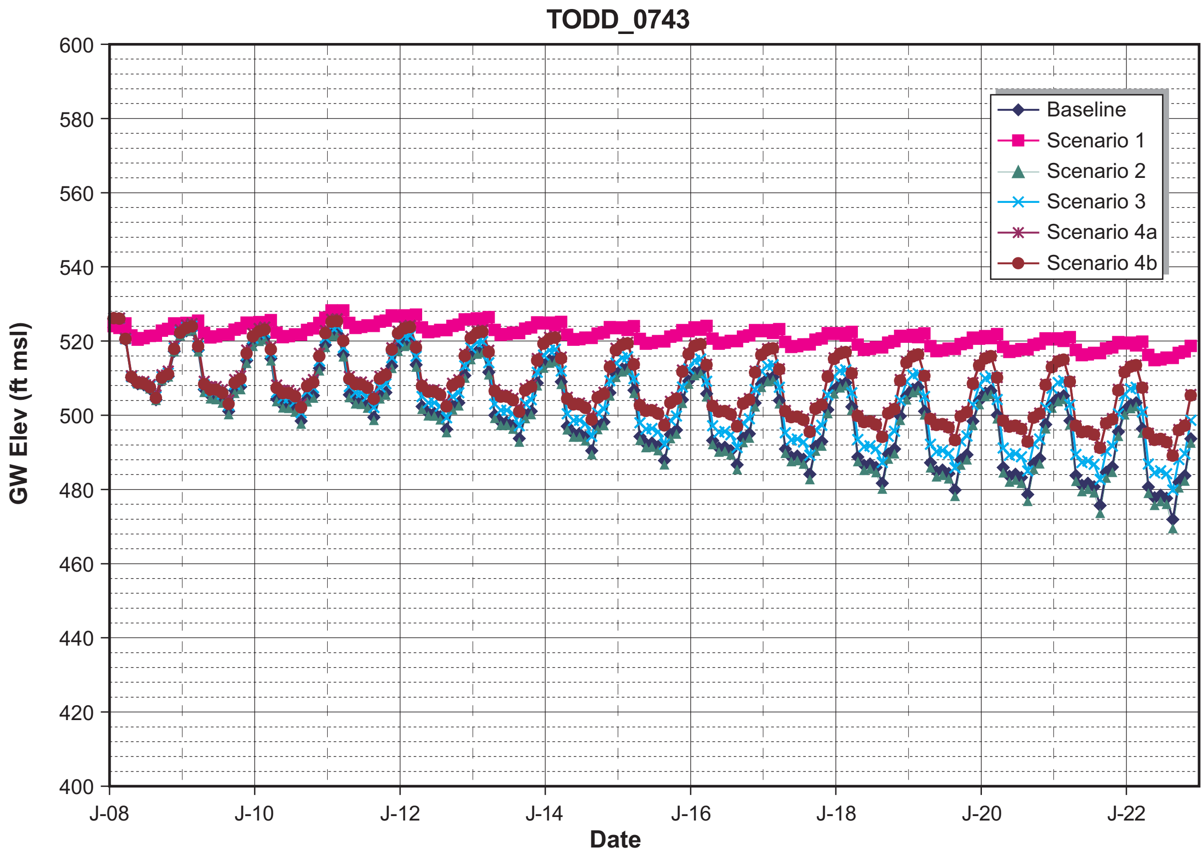



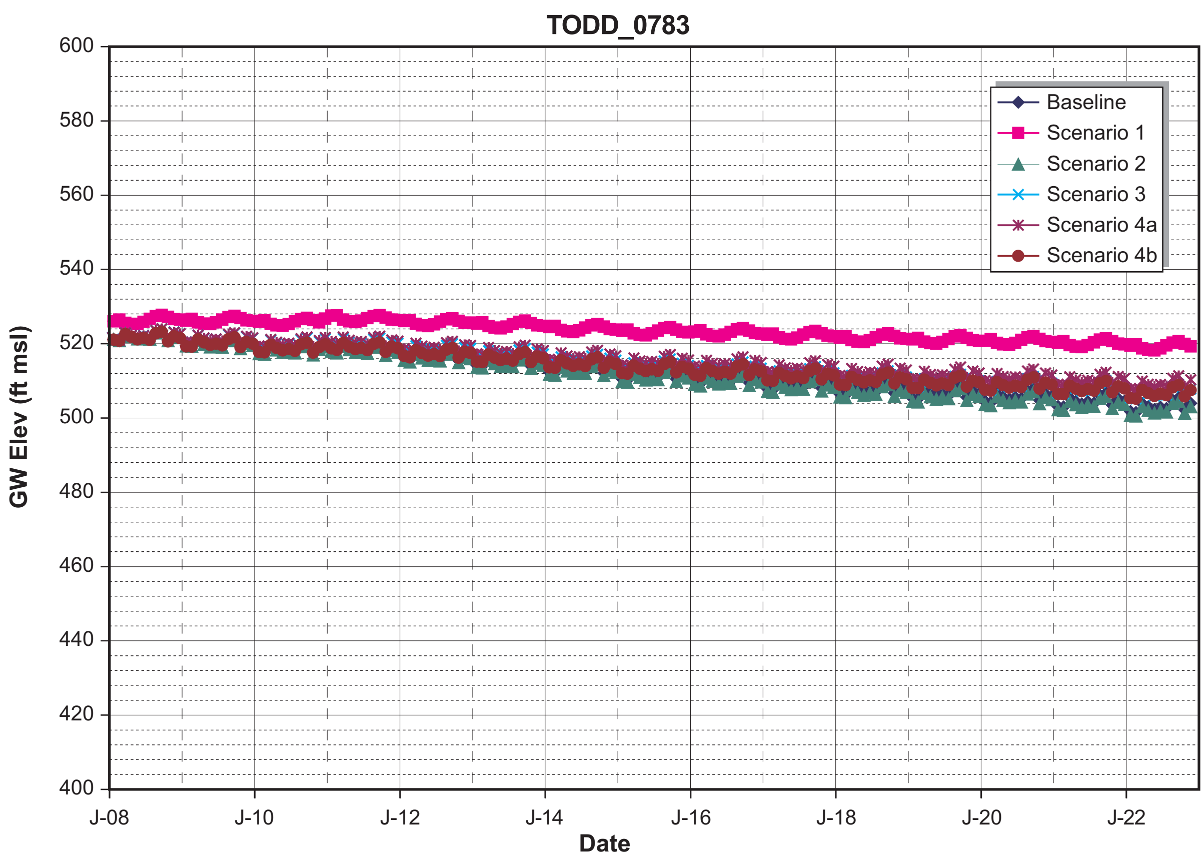

| | |
|---|---|
| May 2008 | **Figure C-11 Baseline and Scenario - Hydrographs** |
| TODD ENGINEERS<br>Alameda, California | |




| May 2008 | **Figure C-12 Baseline and Scenario - Hydrographs** |
|---|---|
| TODD ENGINEERS<br>Alameda, California | |




May 2008

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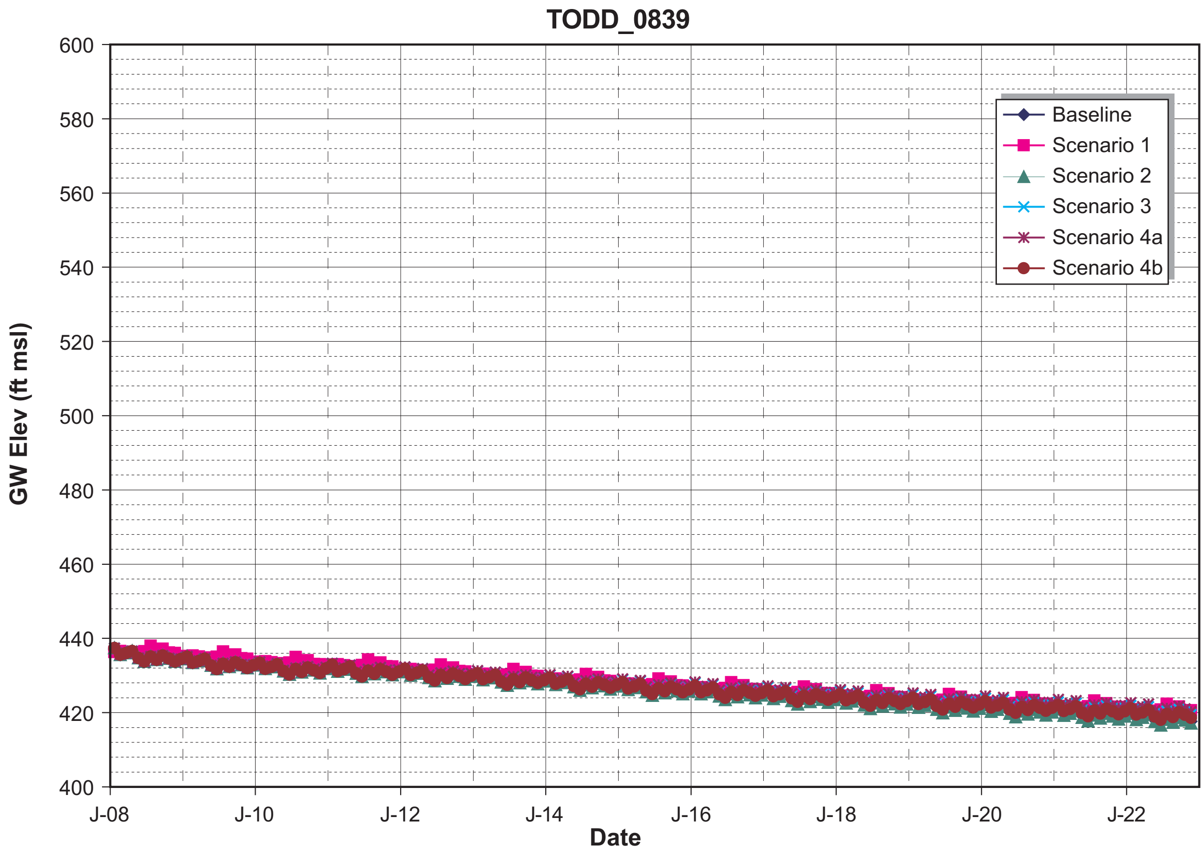
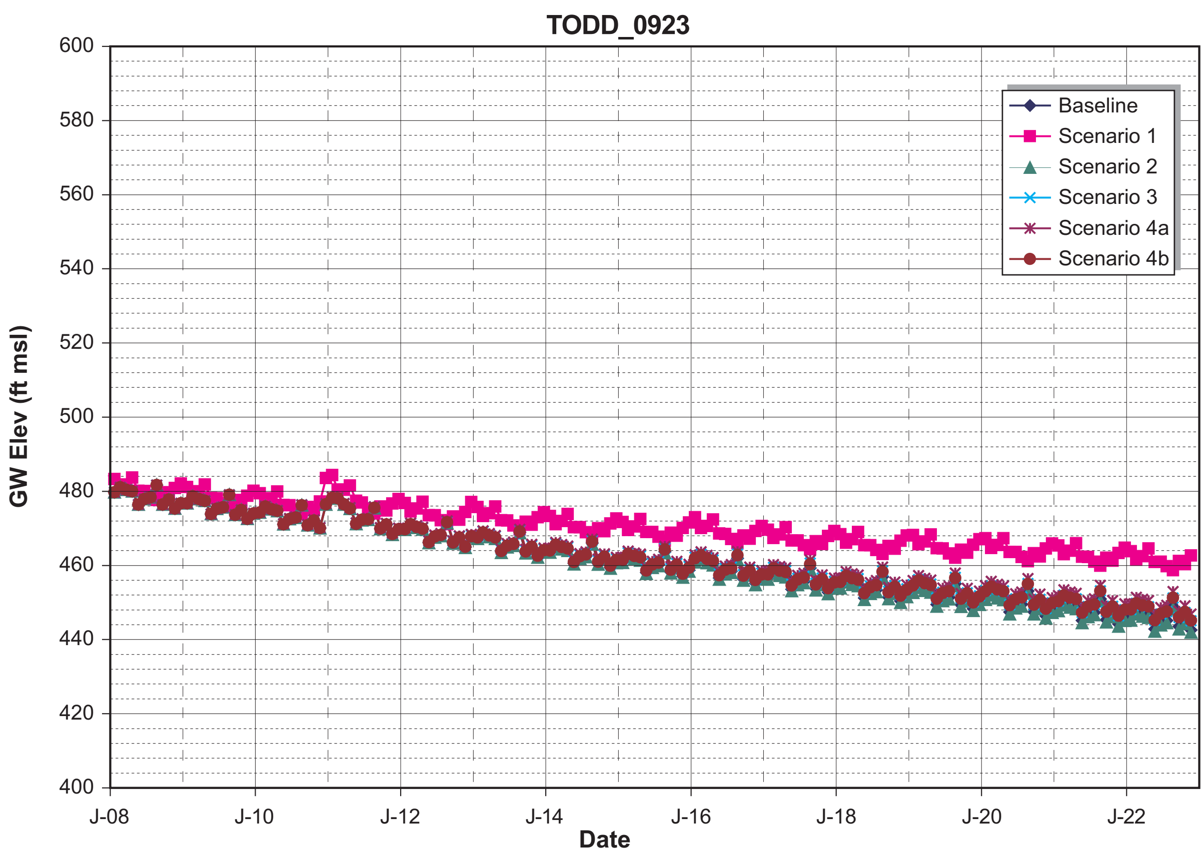
**Figure C-13**
**Baseline and Scenario Hydrographs**




| May 2008 | **Figure C-14** |
| --- | --- |
| TODD ENGINEERS<br>Alameda, California | **Baseline and Scenario Hydrographs** |

# Appendix D
# Feasibility Study
# Recycled Water Recharge
# Bedford Subbasin
# Prepared for Lee Lake Water District

LEE LAKE WATER DISTRICT

# Feasibility Study

# Recycled Water Recharge
# Bedford Subbasin

## Prepared for
## Lee Lake Water District

May 2008

**Todd Engineers**

# Feasibility Study
# Recycled Water Recharge
# in Bedford Subbasin

**Prepared for:**

**Lee Lake Water District**

**22646 Temescal Canyon Road**

**Corona, CA 92883**

**Prepared by:**

**Todd Engineers**

**2490 Mariner Square Loop, Suite 215**

**Alameda, CA 94501-1080**

**May 2008**

# Table of Contents

## List of Tables

**Page No.**



## List of Figures

# 1. Introduction

Lee Lake Water District (District) provides water and wastewater services to residents in the Temescal Valley south of the City of Corona. Tertiary treated wastewater from the Lee Lake Water Reclamation Facility (WRF) is currently being recycled for landscape irrigation and other non-potable uses. Excess recycled water is discharged to nearby Temescal Wash in compliance with regulatory requirements.  The District is considering recharging the recycled water into the underlying groundwater basin, locally referred to as the Bedford Subbasin.

To evaluate the feasibility of the project, the District retained Todd Engineers to conduct a study of the Bedford Subbasin hydrogeology and evaluate potential recharge options. The location of the Bedford Subbasin and adjacent groundwater basins and subbasins are shown on Figure 1.

In a parallel effort, the District is coordinating with the City of Corona in the preparation of a Groundwater Management Plan (GWMP). The GWMP evaluates three groundwater subbasins within the City's water service area and recommends strategies for active groundwater basin management.  The District's recharge project has been included in the GWMP as a potential management strategy. Three groundwater subbasins – Temescal, Coldwater, and Bedford subbasins – are included in the GWMP (Figure 1). Plan adoption is scheduled for June 2008.

The City and the District are also cooperating on the environmental review of the GWMP in compliance with the California Environmental Quality Act (CEQA). This process involves the preparation of a Programmatic Environmental Impact Report (PEIR). The District's recharge project for Bedford Subbasin is included in this review.

This technical memorandum summarizes the analyses and results of the hydrogeologic study and provides support for the GWMP, the PEIR, and the implementation of the District project.

## 1.1. Background

Lee Lake Water District was formed in 1965 to provide water and wastewater services to a growing population in the Temescal Valley area between Corona and Lake Elsinore (LLWD, 2008). The District currently serves about 4,400 residential and commercial customers within an approximate 10 square mile service area as shown on Figure 2. The City of Corona water service area is located primarily to the northwest, but overlaps a small portion of the District in the Bedford and Coldwater subbasins (Figure 2). Elsinore Valley Municipal Water District (EVMWD) is located south of the District, but also provides some water supply to portions of the Bedford Subbasin (Figure 2). Lee Lake Water District imports their water supply from Western Municipal Water District (WMWD) through the Metropolitan Water District State Water Project (SWP) system. The water is treated at the Mills Filtration Plan in Riverside and conveyed to the District through the Mills Pipeline.

The District also operates several groundwater wells in the subbasin and has historically used groundwater to supplement water supply. Although the wells have only produced a few acre feet per year (AFY) over the last several years, the District maintains these wells for anticipated future production. The District's project evaluated herein will enhance recharge in the subbasin to support increased future demand.

The District's wastewater services consist of three wastewater treatment plants: Butterfield Estates, California Meadows, and the District's Water Reclamation Facility (WRF). The WRF is located in the northern portion of the subbasin and provides tertiary treatment to reclaim the wastewater for reuse including landscape and golf course irrigation. Most of the demand for the recycled water occurs during the summer months. Recycled water that exceeds demand is discharged to nearby Temescal Wash. Currently, approximately 700,000 gallons per day (gpd) are discharged in compliance with NPDES Permit No. 8000100, administered by the California Regional Water Quality Control Board, Santa Ana Region (Water Board). The District's permits allow the expansion of their WRF to a full build-out capacity of 1,570,000 gpd.

## 1.2. Goals and Objectives

The goal of this evaluation is to identify feasible alternatives for recharge of tertiary treated wastewater into the Bedford Subbasin. The evaluation considered project feasibility on a technical and regulatory basis. Project objectives include the identification of recharge options involving various locations within the subbasin and various recharge methods (e.g., recharge basins or injection wells).

To meet these goals and objectives, Todd Engineers evaluated the hydrogeology of the Bedford Subbasin, assessed the technical feasibility of subbasin recharge, selected areas judged favorable for a recharge project, and identified potential regulatory constraints. Analyses and results of the study are summarized in this technical memorandum.

# 2. Hydrogeologic Setting

The hydrogeologic setting provides the framework for evaluation of the recharge project. This section summarizes groundwater conditions in the subbasin and presents specific analyses conducted for the project.

## *2.1. Study Area*

The Study Area includes the Bedford Subbasin, covering approximately 6.5 square miles (4,133 acres) of the central Temescal Valley in western Riverside County. The Bedford Subbasin is a relatively small subdivision of the larger Elsinore Groundwater Basin (Figure 1). The Bedford and Coldwater subbasins form the northern portion of the Elsinore Groundwater Basin northwest of a bedrock constriction along Temescal Wash (Figure 1). According to current basin nomenclature used by the California Department of Water Resources (DWR), the Elsinore Groundwater Basin is not formally divided into subbasins (DWR, 2003). The Bedford and Coldwater subbasin nomenclature originates from former DWR basin boundaries in historical documents (DWR, 1959). Since the hydrogeologic conditions, including the bedrock constriction, clearly allow the subbasins to be evaluated separately from the remaining Elsinore Groundwater Basin to the southeast, the nomenclature is preserved in this analysis. Subbasins and contributing watershed areas, as digitized using Geographic Information System (GIS) software, are shown on Figure 1 and summarized on the table below.

**Table 2-1**
**Groundwater Basins and Watersheds**

| DWR Groundwater Basin* (Basin No.) | Subbasin** | Area (acres) | Contributing Watershed (acres) |
|---|---|---|---|
| Elsinore (8-4) | Bedford | 4,133 | 11,858 |
| | Coldwater | 2,176 | 9,525 |
| | Elsinore | 19,391 | Not evaluated |

*DWR, 2004.
**Bedford and Coldwater Subbasins defined and digitized for this project

### 2.1.1. Subbasin Boundaries

The Bedford Subbasin is defined by hydrologic and hydrogeologic boundaries. The eastern and southern boundaries are the approximate intersection of alluvial deposits with bedrock outcrops of the El Sobrante de San Jacinto hills (Figure 1). The Coldwater Subbasin lies to the west, separated from the Bedford Subbasin by the North Glen Ivy fault. The fault trace and the subbasin boundary shown on Figure 1 were recently modified from previous historical documents for the City of Corona's GWMP project. Revisions were based on recent geologic maps from the U.S. Geological Survey (USGS, 2004). On the northwest, the subbasin boundary is defined by the contact between alluvial sediments and the outcropping bedrock of the Santa Ana Mountains. The northern boundary of the Bedford Subbasin is generally defined by the southern edge of Bedford Canyon where the subbasin connects with the Temescal Subbasin of the larger Upper Santa Ana Valley Groundwater Basin (Figure 1).

The subbasin floor is characterized by a narrow sloping valley interrupted by bedrock outcrops and surrounded by uplands. Ground surface elevations range from above 1,300 feet above mean sea level (msl) in the southwest to about 800 feet msl at the northern subbasin boundary near the base of Bedford Canyon. Average ground surface elevations are about 1,000 feet over most of the subbasin. The nature of the land surface can be seen on the aerial photograph on Figure 3. The main drainageway is Temescal Wash (also locally referred to as Temescal Creek), which flows from south to north across the subbasin. Average annual rainfall on the basin is about 13 inches per year (OCS, 2007).

#### 2.1.2. Land Use

The Bedford Subbasin has a rich history as an agricultural area supporting numerous crops including citrus. Through the 1950s and 1960s, almost all of the water use in the subbasin was for agriculture (DWR, 1965). At that time, water supply was a mix of local groundwater, local surface water and imported surface water. In 1954, Western Municipal Water District was annexed to Metropolitan Water District and began providing imported water from the Colorado River (stored at Lake Mathews) to the Temescal Valley (DWR, 1959). In recent years, the I-15 corridor of the Temescal Valley has experienced significant growth. Residential development can be seen on Figure 3 and is especially prevalent west of I-15. Residential communities such as the Retreat, Wildrose Ranch, California Meadows and others have been developed in the area, bringing additional landscaping and golf courses to the subbasin. The community of Dos Lagos has been developed east of I-15 in the northern portion of the subbasin. Commercial and light industrial development occurs along the east side of I-15 in the northern half of the subbasin. Large portions of the southern subbasin east of I-15 remain relatively undeveloped (Figure 3).

In the adjacent Coldwater Subbasin, residential development has occurred primarily in the northern half of the subbasin. The southern half of the Coldwater Subbasin is dominated by active and inactive sand and gravel mining operations (Figure 3). Both the District and EVMWD provide potable and non-potable water supply for Bedford and Coldwater subbasins.

#### 2.1.3. Subbasin Hydrology

As shown on Figure 3, Temescal Wash is the main surface water drainage for both Coldwater and Bedford subbasins. The Santa Ana Region Water Board Basin Plan lists beneficial uses for the creek as groundwater recharge, water contact recreation, non-contact water recreation, warm water fish habitat, industrial service supply, and agricultural supply. Notwithstanding these designated uses, the creek is typically dry throughout most of the subbasin during the summer. The creek is tributary to the Santa Ana River and joins the main river channel at the Prado Management Area near Prado Dam (Figure 1).

Temescal Creek receives surface water runoff from contributing watersheds to the east and west (Figure 1). Although the eastern watersheds are slightly larger in area (approximately 11,858 acres) than the western watersheds (9,525 acres), runoff is generally lower. This is due to the lower elevations and lower average annual rainfall of about 13 to 16 inches per year (OCS, 2007; Environmental Solutions, 1994). This amount compares to an average annual rainfall of about 18 to more than 25 inches per year in the higher elevations west of Coldwater Subbasin. North of the Bedford Subbasin, the creek is fed by surface runoff from Bedford Canyon and rising groundwater in Temescal Canyon (Figure 1). North of Temescal Canyon, the creek flows into lined channels of the City of Corona's stormwater system and receives stormwater runoff from most of the Temescal Subbasin.

Surface water inflows into Bedford Subbasin along Temescal Wash are the result of runoff from surrounding areas. South of Bedford Subbasin, flows along the creek are diverted and bermed to create a small area of impounded surface water, locally known as Corona Lake (Figure 1). Historically, releases from this lake supplemented other agricultural water supplies. Currently, EVMWD provides non-potable supply to Coldwater and Bedford subbasins through releases from this impoundment, contributing to surface water inflows during summer months. Historically, overflow from Lake Elsinore (located about six miles south of Bedford Subbasin) provided surface water to the creek. However, increased water use in the vicinity halted surface water outflow from the lake in the early 1900s (DWR, 1959; MWH, 2003). With the exception of some upstream releases of recycled water to Temescal Creek there are no significant surface or subsurface inflows to the Bedford Subbasin from the Elsinore Subbasin to the south (MWH, 2003) (Figure 1).

## 2.2. Geology and Faulting

The Study Area is located within one of the structural blocks of the Peninsular Ranges of Southern California. The groundwater basins in this area occur in a linear low-lying block, referred to as the Elsinore-Temecula trough, between the Santa Ana Mountains on the west and the Perris Plain on the east (Norris and Webb, 1990). The trough extends from Corona to the southeast some 30 miles and was formed along an extensive northwest-southeast trending fault zone including the Elsinore, Chino, and related faults. The Elsinore and Chino fault zones bound the subbasins on the west and trend along the mountain front.

### 2.2.1. Geologic Units

Figure 4 presents a detailed geologic map illustrating the large number of units in the subbasin as mapped by USGS (2004). The oldest rocks in the Study Area crop out along the eastern edge or the Bedford subbasin. These uplands are composed principally of Mesozoic-age metasedimentary and volcanic rocks including the Estelle Mountain Volcanics (Mzu and Kvem, respectively, on Figure 4). There are also outcrops of Mesozoic metamorphic rocks including the Bedford Canyon Formation to the west of the subbasins in the Santa Ana Mountains (Jbc on Figure 4). Younger sedimentary units of Tertiary age crop out along the mountain front and in the subbasins. In northern Bedford Subbasin, a variety of Tertiary sedimentary units crop out including the Paleocene Silverado (Tsi), Miocene Vaqueros (Tvs), and Miocene Topanga (Tt) formations (Figure 4). Erosion of these units has filled in the trough over time resulting in quaternary-age alluvial fan, channel, and other alluvial deposits, making up the permeable portions of the Bedford and Coldwater groundwater subbasins.

The main surficial deposits on the floor of Bedford Subbasin include younger and older alluvial fans (Qvofg, Qofg, and Qy on Figure 4) deposited from the erosion of Bedford Canyon Formation and granitic rocks to the west. These units prograde across the basin to the northeast and are truncated by channel deposits along Temescal Wash (Qyag).

For analysis of the District's recharge project, similar alluvial and bedrock geologic units have been combined on Figure 5 to show the areal extent of relative high and low permeability units. The bedrock units, shown by the gray color, group together all of the consolidated units in the subbasin for a better understanding of low permeability areas to avoid for the recharge project. Alluvial deposits shown in the various shades of green illustrate the surface area of alluvial fans, valley fill, and channel deposits where more permeable sediments occur.

### 2.2.2. Depth to Bedrock

Although the geologic map shows alluvial sediments covering most of the surface of the Bedford Subbasin, the frequency of bedrock outcrops and shallow depth of many wells are good indications that sediments are likely very thin in some areas. For this reason a bedrock surface was interpolated for the subbasin. Depths to bedrock were noted from water well driller's logs obtained from the Department of Water Resources. The locations of these wells were approximately plotted using GIS software. The locations of these wells are shown on Figure 6. These data were combined with locations of known bedrock outcrops from the 2004 USGS geology map to create an approximate depth to bedrock surface. Figure 7 shows a colored raster and contours of the depth to bedrock surface. The bedrock surface map shows that sediments throughout most of the Bedford Subbasin are between 100 and 200 feet thick. Bedrock outcrops in the northern and south-central potion of the subbasin result in relatively thin and discontinuous pockets of alluvial sediments. However, there is an area in the western central portion of the subbasin where alluvial thickness is between 300 and 400 feet.

## 2.3. Subbasin Aquifers

The primary aquifer within the Bedford Subbasin is unconfined consisting of alluvial fan gravels prograding across valley fill sediments and interfingering with channel deposits associated with Temescal Wash. Although the alluvial aquifer is composed of material from multiple depositional environments, it is considered to be one continuous aquifer due to its high permeability and the prograding / interfingering nature of the deposits.

The bedrock in the subbasin does have some limited aquifer capacity, and there are some domestic wells that are completed in these bedrock aquifers. Bedrock aquifers in the area are primarily recharged from the alluvial aquifers. For the purpose of this study, the bedrock aquifers were not considered to be targets for recycled water recharge due to their limited capacity to store and transmit water.

### 2.3.1. Aquifer Geometry

The Bedford Subbasin alluvial aquifer is controlled by surface topography and the underlying erosional bedrock surface. The resulting aquifer is an elongated northwest southeast structure that is deepest in the middle, shallows to the north and east, is bounded by faults on the west, and is dotted by areas of no thickness where bedrock crops out. The aquifer generally slopes down to the northwest where it thins dramatically and is virtually nonexistent at the northern end of the subbasin.

The approximate latitudinal geometry of the alluvial fan deposits in the Coldwater and Bedford subbasins are shown on Figure 8. The cross section shows generalized subbasin geometry from west to east across the Coldwater/Bedford subbasin boundary at the North Glen Ivy fault. Rather than representative of a specific location, the cross section is a schematic profile illustrating the nature and maximum thickness of the alluvial fan aquifers and the relationship with the Temescal Wash deposits. Alluvial sediments are more than 800 feet thick in the Coldwater Subbasin and up to 500 feet thick in the Bedford Subbasin, with the thickest section occurring near the subbasin boundary and fault zone (Figure 8).

Water levels are lower in the western Coldwater Subbasin as a result of pumping by the City of Corona and others in the subbasin (Figure 8). The discontinuity indicated by water levels across the Glen Ivy fault reflects the commonly held view that groundwater is impeded by low permeability clay along the fault zone. This discontinuity has been observed in water levels on opposite sides of the fault by others (MWH, 2004)These and other data indicate that outflow from the Coldwater Subbasin into the Bedford Subbasin only occurs during times of high water levels (MWH, 2004).

### 2.3.2. Aquifer Parameters

Aquifer parameters for the alluvial aquifer in the Bedford Subbasin are not available throughout most of the subbasin. However, a 72-hour constant rate pumping test was performed on a District well, Well 1A, in February 2003 by Foothill Engine & Pump Company. Groundwater levels in Well 1A, and nearby Wells 3 and 4, were monitored during the test and recorded on field forms by the pumping contractor. The locations of the District wells are shown on Figure 6. No aquifer parameter analysis appears to have been conducted for these data. Therefore, data from this test were made available for analysis by the District as part of this project. Test data from the three wells were plotted on a semi-log graph of drawdown versus time. The graph of these data and the resulting straight line portions are shown on Figure 9. Straight line portions of the data were identified on this graph in order to apply the Cooper-Jacobs straight line approximation for the calculation of transmissivity (T) and storage coefficient (S) as shown by the following equations:

$$T = \frac{264Q}{\Delta s} \quad \text{and} \quad S = \frac{0.3Tt_0}{r^2}$$

Where T = transmissivity
S = storage coefficient
Q = pumping rate
$\Delta s$ = drawdown for one log cycle
$t_0$ = time when drawdown equals zero
r = radius of observation point from pumping well

Data from Well 3 appeared to be the most representative of stabilized aquifer conditions and were less affected by the sporadic breaks in drawdown that were present in the data from Well 1A. Using these data, the calculated aquifer transmissivity is 144,000 gallons per day per foot (gpd/ft), equivalent to 19,250 square feet per day ($ft^2$/day). Storage coefficients were calculated for the straight lines from Wells 3 and 4 at 0.10 and 0.15, respectively. These values represent an effective porosity of the alluvial aquifer of 10 percent from Well 3 and 15 percent from Well 4. Well logs for District Wells 1A, 3, and 4 were not available for this analysis. However, nearby domestic well logs indicate a total saturated aquifer thickness of about 77 feet. Using this value for the saturated aquifer thickness (b), a hydraulic conductivity (K) of 250 feet per day (ft/day) was calculated for the aquifer using $K = T/b$. Because this represents the only K value available in the basin, it is unknown whether the data are representative. As such, a slightly lower K value of 200 ft/day is used for further analysis of the alluvial aquifer.

## 2.4. Groundwater Use and Wells

Groundwater has been used as an irrigation water supply in the Bedford Subbasin for at least 80 years. Published data on wells in the Temescal Valley indicate that at least eleven wells had been drilled for irrigation supply in the Bedford Subbasin (or just downgradient of the boundary) by 1957 (DWR, 1959). One shallow well was reported to have been in place since

1912. Driller reports obtained from DWR indicate that more than 100 wells have been drilled in the subbasin.

### 2.4.1. Subbasin Production

Groundwater pumping data are available from a private firm, Watermaster Support Services (WMSS), which compiles well and pumping data for the Temescal Valley subbasins and other basins in the Santa Ana River watershed. Data from 1947 through 2006 were obtained from WMSS and reviewed for this project. During this period, approximately 22 wells have extracted groundwater in the subbasin. These data include three irrigation wells that pump just outside of the subbasin at the mouth of Bedford Canyon (referred to as the EVWMD Flagler wells). Production from the Flagler wells is included in this analysis because they pump immediately downgradient of the subbasin and extract groundwater, in part, migrating out of the subbasin.

Annual groundwater production is shown on the top graph on Figure 10. As shown on the graph, Bedford Subbasin production has generally decreased over the last 60 years. From 1947 through 1965, annual production averaged 2,900 AFY. Groundwater pumping increased from 1966 through 1971, averaging about 4,000 AFY with a peak in 1966 of 4,658 AFY. Through the 1970s and into the early 1990s, average production declined to about 2,500 AFY. Since 2000, production has declined to about 1,000 AFY and averaged only 245 AFY in 2005-2006.

Several water companies were formed in the subbasin before 1950 to provide irrigation water for subbasin agriculture (DWR, 1959). These companies secured surface and groundwater supplies and operated several groundwater wells in the subbasin. When the District was formed in 1965, two existing production wells were acquired to supplement the District's imported water supply. Production from these two wells by the District and previous well owners are summarized on the graph on the bottom of Figure 10. As shown on the graph, production from the District wells has also declined over time. From 1947 through 1970, production averaged about 676 AFY, accounting for about 20 percent of the documented subbasin pumping. From 1972 through 1995, average production declined by more than one half to 274 AFY (about 10 percent of subbasin production). Over the last 10 years, production has declined to less than 20 AFY and the wells are not currently used for potable water supply.

### 2.4.2. Domestic Wells

Although there is very little documented domestic groundwater extraction from the subbasin, private wells used for domestic water supply likely exist in the basin. DWR driller's logs indicate that some wells were previously permitted for domestic supply as well as irrigation. The number of active wells is not known. The drilling of domestic wells (and other wells) requires a permit to be filed with Riverside County Division of Environmental Health (DEH). The County maintains these well permits in their records and compiles information into a database as internal resources allow. Communication with the County revealed that their databases does not currently allow for geographic filtering of well information and therefore accessing the data for Bedford Subbasin wells would require considerable effort on the part of County staff. Unfortunately, due to current staffing levels, the County cannot accommodate this type of search in a timely manner. As such, permit data were not reviewed for this project.

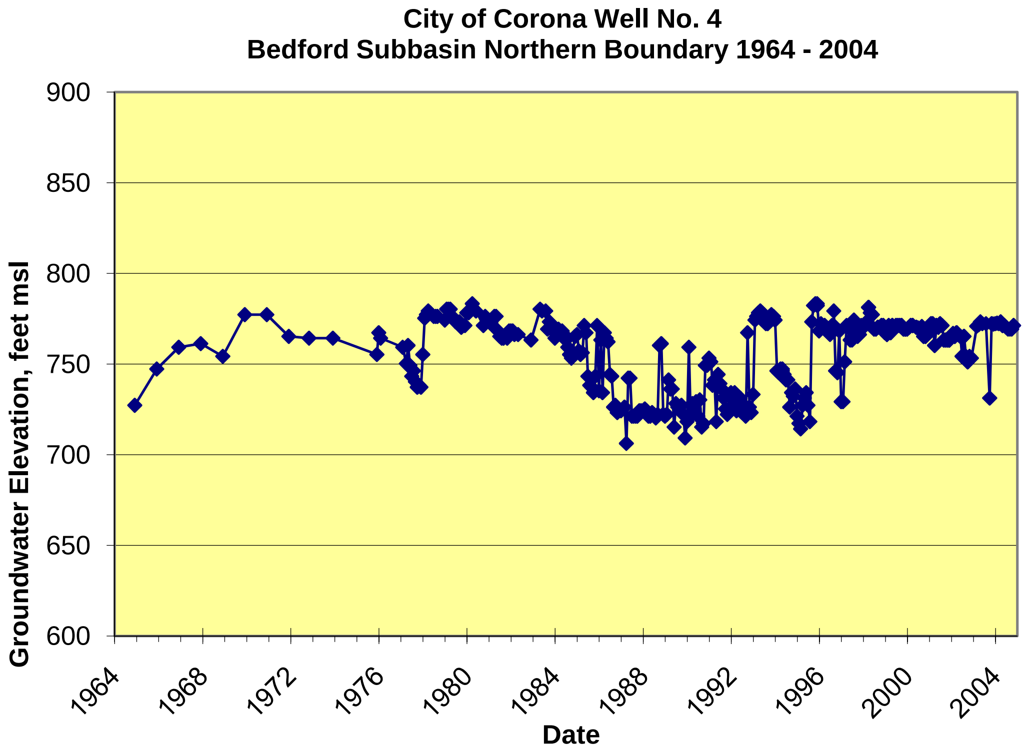
## 2.5. Groundwater Occurrence and Flow

Groundwater occurrence in the unconfined aquifer of the Bedford Subbasin is controlled by recharge and outflow. The primary source of recharge to the alluvial aquifer is runoff from the watershed to the east and percolation of precipitation. Additional runoff enters the basin and the aquifer from the west, but this must first travel through the Coldwater Subbasin, where most of the water infiltrates. Some additional recharge also occurs as a result of subsurface inflow from the alluvial aquifer in the Coldwater Subbasin. However, this recharge source is limited by groundwater pumping in Coldwater Subbasin and impedance across the Glen Ivy fault. Very little, if any, groundwater enters the subbasin from Lake Elsinore due to its limited releases. Groundwater flow in the subbasin is generally easterly toward Temescal Wash and then northwesterly following surface water drainage.

### 2.5.1. Water Levels and Depth to Water

Very few wells in the Bedford Subbasin provide a sufficient water level record to analyze long term trends. However, there are scattered wells throughout the subbasin with original static water levels from water well driller's logs. These water levels were recorded at the time of installation of the wells shown on Figure 6. Since these wells have been constructed over a period of approximately 50 years spanning various hydrologic conditions, it can be reasonably assumed that they collectively approximate average static water levels. Contours of the depth to groundwater, as shown on Figure 11, were created using these data. In addition, there are a number of wells near the northeast outflow of the subbasin that allow for an analysis of water levels at that location (Figure 6). As shown on Figure 11, groundwater is deepest in the western portion of the subbasin (up to about 100 feet deep). Shallower groundwater occurs in the eastern subbasin near Temescal Wash. The exact groundwater-surface water interaction along the wash has not been documented, but groundwater likely provides baseflow to the creek in shallow bedrock areas and the creek likely recharges groundwater where water levels are deeper. As Temescal Wash exits the subbasin in the northeast, groundwater discharge likely occurs.

One former well, operated by the City of Corona (Well 4), is located about 950 feet north of the northeast corner of Bedford Subbasin at the mouth of Bedford Canyon. Wells pumping in this area receive recharge from runoff in adjacent Bedford Canyon (Temescal Subbasin) as well as surface and subsurface outflow from Bedford Subbasin (Figure 1). As such, water levels in this area are indicative of the total groundwater and surface water discharge where Temescal Wash temporarily leaves the subbasins. A hydrograph from this Bedford Canyon well is shown below.




The ground surface elevation at this well is reported to be about 791 feet msl indicating that water levels are within 10 feet of the ground surface during times of high water levels. This is to be expected given the downgradient location of the well and its position near rising groundwater that enters Temescal Canyon as surface water in the wash. Downstream ground surface elevations are around 780 feet, similar to water levels in the well. It appears that this elevation is acting similar to a drain, and likely indicates the level at which the groundwater basin is discharging to Temescal Wash. Given the shallow groundwater, this location would not be applicable to a District recharge project; nonetheless the hydrograph provides a record for long-term water levels at the downgradient extent of the subbasin.

As shown on the hydrograph, water levels have fluctuated only about 60 feet over the last 40 years. Water levels have been recorded as high as 782 feet, but have remained above about 770 feet for most of the period of record. Water levels dropped to around 720 feet during the relatively dry cycle from 1987 to 1995. According to a DWR study (1980), groundwater levels in the Bedford Subbasin fluctuate considerably during the year as a result of seasonal pumping and considerable recovery of water levels during the rainy season. This observation indicates that infiltration of recycled water at the surface can readily recharge the alluvial aquifers.

### 2.5.2. Groundwater Flow

Most of the subsurface flow in the Bedford Subbasin parallels surface water flow to the northwest along Temescal Wash. However, flow is easterly in the western portion of the subbasin, generally following surface topography. In the northern portion of the subbasin, groundwater flow becomes more complex as a result of refraction around low permeability bedrock. Throughout the subbasin, groundwater flow is generally controlled by surface topography.

### 2.5.3. Groundwater Quality

Groundwater quality data for the Bedford Subbasin alluvial aquifer at this time are limited to samples collected from District Well 1A in February 2003 and in Well 4 in August 2007. A complete list of analytical parameters and the concentrations at which they were detected is presented in the following table.

**Table 2-2**
**Groundwater Quality Data**
**District Wells 1A & 4**

| **Well** | | Well 1A | Well 4 |
|---|---|---|---|
| **Sample Date** | | 2/5/2003 | 8/20/2007 |
| **pH** | mg/L | -- | 7.1 |
| **Calcium** | mg/L | -- | 110 |
| **Magnesium** | mg/L | -- | 23 |
| **Nitrate as N** | mg/L | -- | 1.2 |
| **Nitrite as N** | mg/L | -- | < 0.1 |
| **Ammonia** | mg/L | -- | 0.43 |
| **Sulfide** | mg/L | < 0.10 | -- |
| **Total Hardness** | mg/L | -- | 370 |
| **Total Dissolved Solids** | mg/L | -- | 690 |
| **Total Suspended Solids** | mg/L | < 5 | -- |
| **Chlorine Residual** | mg/L | < 0.10 | -- |
| **Oil & Grease** | mg/L | < 5 | -- |

As shown by the values for total dissolved solids (TDS), groundwater contains a relatively high mineral content in the subbasin. The TDS value of 690 mg/L exceeds the secondary maximum contaminant level (MCL) of 500 mg/L. This MCL is not based on health risk, but rather aesthetic values such as odor or taste. The value of total hardness of 370 mg/L indicates a water classified as *very hard* (Todd and Mays, 2005), which can result in scale deposition in pipes and other inconveniences. Preliminary review of these data indicates that recycled water may be of higher quality for some constituents than ambient groundwater. Recycled water quality data are reviewed in the following section.

# 3. Considerations for Groundwater Recharge

The District's recharge project was evaluated in the context of the hydrogeologic setting of the subbasin and District objectives. Based on this analysis, potential recharge locations and methods were selected. This section describes the evaluation and provides project parameters, methods of analysis, assumptions, regulatory considerations, and results.

## 3.1. Recharge Water Parameters

Based on communication with the District and a review of current permit requirements and data, the following parameters and data have been incorporated into the analysis.

### 3.1.1. Quantity Available for Recharge

In compliance with the current NPDES permit, the District can discharge up to 1,570,000 gpd of recycled water to Temescal Creek. The District is currently discharging about 700,000 gpd during non-irrigation months. The recycled water demand is much larger in summer months and discharge to the creek is significantly reduced during that time. The WRF is capable of reclaiming up to about 1,570,000 gpd, but demand for recycled water is also expected to rise (LLWD, 2008). For the purposes of this preliminary analysis, we assume that a current continuous flow of 700,000 gpd is available for recharge on a six-month basis. This amount is equivalent to a continuous recharge rate of 486 gpm. The recharge method and location selected for the District's project needs to accommodate this rate and amount. Additional recycled water will likely be available in the future although the exact amount is unknown. Even though the analysis is based on 700,000 gpd, the potential for increasing this amount is also considered.

### 3.1.2. Recycled Water Quality

The WRF produces tertiary-treated wastewater derived from imported SWP water. This water source is considered to be higher quality than local groundwater for many parameters. According to a 2006 report to consumers, the imported water contains an average TDS of 200 mg/L (LLWD, 2006) compared to a groundwater supply of about 690 mg/L. Although mineral content is concentrated in the wastewater, elevating the TDS, the recycled water is expected to be equal to or better than ambient groundwater quality.

Water quality data from the WRF are available in connection with the District's monitoring program. These data were provided by the District and reviewed for application to the recharge project. Table 3-1 presents a summary of recycled water data with a focus on the parameters relevant to recycled water recharge regulations (Section 60320.030 in DPH, 2007). The table is presented on the following pages and described in the text following the table.

# Table 3-1
## Recycled Water Analytical Results Average Concentrations 2002 - 2007

| ANALYTE (*Italics* - required for recharge project by DPH) | Average Result (**bold underline** - exceeds MCL or Secondary MCL) | Number of Detections | Number of Non-Detect Results (ND) | Maximum Contaminant Level (MCL) | Secondary MCL | Units |
|---|---|---|---|---|---|---|
| ***Aluminum*** | Not Analyzed | -- | -- | 1 | 0.2 | mg/L |
| ***Antimony*** | ND | 0 | 1 | 0.006 | | mg/L |
| ***Arsenic*** | 0.011 | 1 | 6 | 0.05 | | mg/L |
| ***Asbestos*** | Not Analyzed | -- | -- | 7 | | MFL |
| ***Barium*** | ND | 0 | 7 | 1 | | mg/L |
| ***Beryllium*** | ND | 0 | 1 | 0.004 | | mg/L |
| ***Cadmium*** | ND | 0 | 7 | 0.005 | | mg/L |
| Calcium | 29 | 62 | 1 | -- | | mg/L |
| ***Chloride*** | 149 | 63 | 1 | -- | 250 | mg/L |
| ***Chromium (Total)*** | ND | 0 | 7 | 0.05 | | mg/L |
| ***Chromium (Hexavalent)*** | ND | 0 | 13 | 0.05 | | mg/L |
| ***Copper*** | 0.0305 | 4 | 62 | 1.3 | 1 | mg/L |
| ***Cyanide*** | ND | 0 | 7 | 0.15 | | mg/L |
| ***Fluoride*** | Not Analyzed | -- | -- | 2 | | mg/L |
| ***Iron*** | 0.09 | 2 | 5 | -- | 0.3 | mg/L |
| ***Lead*** | ND | 0 | 7 | 0.015 | | mg/L |
| ***Magnesium*** | 12 | 62 | 1 | -- | | mg/L |
| ***Manganese*** | 0.019 | 6 | 1 | -- | 0.05 | mg/L |
| ***Mercury*** | ND | 0 | 18 | 0.002 | | mg/L |
| ***Nickel*** | ND | 0 | 1 | 0.1 | | mg/L |
| ***Nitrate as N*** | 3.5 | 249 | 10 | 10 | | mg/L |
| ***Nitrite as N*** | 0.96 | 84 | 176 | 1 | | mg/L |
| ***Nitrogen (as Ammonia)*** | 4.5 | 148 | 114 | -- | 1.5 | mg/L |
| ***Total Nitrogen (ammonia, nitrate, & nitrite)*** | 9.0 | Calculation | Calculation | * | | mg/L |
| Inorganic Nitrogen | 6.4 | 252 | 8 | -- | | mg/L |
| Biochemical Oxygen Demand | 10 | 49 | 213 | -- | | mg/L |
| ***Perchlorate*** | Not Analyzed | -- | -- | 0.006 | | mg/L |
| ***Selenium*** | 0.0043 | 46 | 21 | 0.05 | | mg/L |
| ***Silver*** | ND | 0 | 17 | -- | 0.1 | mg/L |
| ***Sodium*** | 128 | 63 | 1 | -- | | mg/L |
| ***Sulfate*** | 96 | 62 | 2 | -- | 250 | mg/L |
| ***Thallium*** | ND | 0 | 1 | 0.002 | | mg/L |
| ***Bicarbonate*** | Not Analyzed | -- | -- | -- | | mg/L |
| ***Carbonate*** | Not Analyzed | -- | -- | -- | | mg/L |
| ***Alkalinity*** | Not Analyzed | -- | -- | -- | | mg/L |
| ***Total Hardness*** | 122 | 63 | 1 | -- | | mg/L |
| ***Zinc*** | 0.054 | 7 | 0 | -- | 5.0 | mg/L |
| ***pH*** | 7.3 | 59 | 0 | -- | | Standard Units |
| ***Foaming Agents (MBAS)*** | Not Analyzed | -- | -- | -- | 0.5 | mg/L |
| ***Turbidity*** | Not Analyzed | -- | -- | -- | 5.0 | NTU |
| ***Total Dissolved Solids*** | **<u>554</u>** | 66 | 0 | -- | 500** | mg/L |
| Total Suspended Solids | 14 | 14 | 248 | -- | | mg/L |
| Total Coliform | 2.8 | 5 | 20 | -- | | MPN/100mL |
| **Total Organic Carbon** | Not Analyzed | | | 16*** | | mg/L |

## Table 3-1
## Recycled Water Analytical Results Average Concentrations 2002 - 2007

| **ANALYTE** (***Italics* - required for recharge project by DPH**) | **Average Result** (**bold underline** - exceeds MCL or Secondary MCL) | **Number of Detections** | **Number of Non-Detect Results (ND)** | **Maximum Contaminant Level (MCL)** | **Secondary MCL** | **Units** |
|---|---|---|---|---|---|---|
| ***Radium-226*** | Not Analyzed | -- | -- | 5 (combined) | | pCi/L |
| ***Radium-228*** | Not Analyzed | -- | -- | | | pCi/L |
| ***Gross Alpha*** | Not Analyzed | -- | -- | 15 | | pCi/L |
| ***Uranium*** | Not Analyzed | -- | -- | 20 | | pCi/L |
| ***Beta / photon emitters*** | Not Analyzed | -- | -- | 4 | | millirem/year |
| ***Strontium-90*** | Not Analyzed | -- | -- | 8 | | pCi/L |
| ***Tritium*** | Not Analyzed | -- | -- | 20,000 | | pCi/L |
| ***1,1,1-Trichloroethane*** | ND | 0 | 3 | 0.200 | | mg/L |
| ***1,1,2,2-Tetrachloroethane*** | ND | 0 | 3 | 0.001 | | mg/L |
| ***1,1,2-Trichloro-1,2,2-Trifluoroethane*** | Not Analyzed | -- | -- | 1.2 | | mg/L |
| ***1,1,2-Trichloroethane*** | ND | 0 | 3 | 0.005 | | mg/L |
| ***1,1-Dichloroethane*** | ND | 0 | 3 | 0.005 | | mg/L |
| ***1,1-Dichloroethylene*** | ND | 0 | 3 | 0.006 | | mg/L |
| ***1,2,4-Trichlorobenzene*** | ND | 0 | 3 | 0.005 | | mg/L |
| ***1,2-Dichlorobenzene*** | ND | 0 | 6 | 0.6 | | mg/L |
| ***1,2-Dichloroethane*** | ND | 0 | 3 | 0.0005 | | mg/L |
| ***1,2-Dichloropropane*** | ND | 0 | 3 | 0.005 | | mg/L |
| ***1,3-Dichloropropene*** | Not Analyzed | -- | -- | 0.0005 | | mg/L |
| ***cis-1,3-Dichloropropene*** | ND | 0 | 3 | -- | | mg/L |
| ***trans-1,3-Dichloropropene*** | ND | 0 | 3 | -- | | mg/L |
| ***1,4-Dichlorobenzene*** | ND | 0 | 6 | 0.005 | | mg/L |
| ***2,3,7,8-TCDD*** | Not Analyzed | -- | -- | 0.00000003 | | mg/L |
| ***2,4,5-TP*** | Not Analyzed | -- | -- | 0.05 | | mg/L |
| ***2,4-D*** | Not Analyzed | -- | -- | 0.07 | | mg/L |
| ***Alachlor*** | Not Analyzed | -- | -- | 0.002 | | mg/L |
| ***Atrazine*** | Not Analyzed | -- | -- | 0.001 | | mg/L |
| ***Bentazon*** | Not Analyzed | -- | -- | 0.018 | | mg/L |
| ***Benzene*** | ND | 0 | 3 | 0.001 | | mg/L |
| ***Benzo(a)pyrene*** | ND | 0 | 3 | 0.0002 | | mg/L |
| ***Bromodichloromethane*** | 0.03 | 0 | 3 | 0.08 | | mg/L |
| ***Carbofuran*** | Not Analyzed | -- | -- | 0.018 | | mg/L |
| ***Carbon Tetrachloride*** | ND | 0 | 3 | 0.0005 | | mg/L |
| ***Chlordane*** | ND | 0 | 3 | 0.0001 | | mg/L |
| ***Chloroform*** | 0.009 | 0 | 3 | 0.08 | | mg/L |
| ***cis-1,2-Dichloroethylene*** | Not Analyzed | -- | -- | 0.006 | | mg/L |
| ***Dalapon*** | Not Analyzed | -- | -- | 0.2 | | mg/L |
| ***Di(2-ethylhexyl)adipate*** | Not Analyzed | -- | -- | 0.4 | | mg/L |
| ***Di(2-ethylhexyl)phthalate*** | ND | 0 | 3 | 0.004 | | mg/L |
| ***Dibromochloropropane*** | Not Analyzed | -- | -- | 0.0002 | | mg/L |
| ***Dichloromethane*** | ND | 0 | 3 | 0.005 | | mg/L |
| ***Dinoseb*** | Not Analyzed | -- | -- | 0.007 | | mg/L |
| ***Diquat*** | Not Analyzed | -- | -- | 0.02 | | mg/L |
| ***Endothal*** | Not Analyzed | -- | -- | 0.1 | | mg/L |
| ***Endrin*** | ND | 0 | 6 | 0.002 | | mg/L |
| ***Ethylbenzene*** | ND | 0 | 3 | 0.3 | | mg/L |
| ***Ethylene Dibromide*** | Not Analyzed | -- | -- | 0.00005 | | mg/L |
| ***Glyphosate*** | Not Analyzed | -- | -- | 0.7 | | mg/L |
| ***Heptachlor*** | ND | 0 | 6 | 0.00001 | | mg/L |
| ***Heptachlor Epoxide*** | ND | 0 | 6 | 0.00001 | | mg/L |
| ***Hexachlorobenzene*** | ND | 0 | 3 | 0.001 | | mg/L |
| ***Hexachlorocylopentadiene*** | ND | 0 | 3 | 0.05 | | mg/L |

## Table 3-1
## Recycled Water Analytical Results Average Concentrations 2002 - 2007

| ANALYTE (*Italics* - required for recharge project by DPH) | Average Result (**bold underline** - exceeds MCL or Secondary MCL) | Number of Detections | Number of Non-Detect Results (ND) | Maximum Contaminant Level (MCL) | Secondary MCL | Units |
|---|---|---|---|---|---|---|
| ***Lindane*** | ND | 0 | 6 | 0.0002 | | mg/L |
| ***Methoxychlor*** | ND | 0 | 3 | 0.03 | | mg/L |
| ***Methyl-tert-butyl ether (MTBE)*** | ND | 0 | 3 | 0.013 | 0.005 | mg/L |
| ***Molinate*** | Not Analyzed | -- | -- | 0.02 | | mg/L |
| ***Monochlorobenzene*** | ND | 0 | 3 | 0.07 | | mg/L |
| ***Oxamyl*** | Not Analyzed | -- | -- | 0.05 | | mg/L |
| ***Pentachlorophenol*** | ND | 0 | 3 | 0.001 | | mg/L |
| ***Picloram*** | Not Analyzed | -- | -- | 0.5 | | mg/L |
| ***Polychlorinated Biphenyls*** | Not Analyzed | -- | -- | 0.0005 | | mg/L |
| ***Simazine*** | Not Analyzed | -- | -- | 0.004 | | mg/L |
| ***Styrene*** | Not Analyzed | -- | -- | 0.1 | | mg/L |
| ***Tetrachloroethylene*** | ND | 0 | 3 | 0.005 | | mg/L |
| ***Thiobencarb*** | Not Analyzed | -- | -- | 0.07 | 0.001 | mg/L |
| ***Toluene*** | 0.007 | 1 | 2 | 0.15 | | mg/L |
| ***Toxaphene*** | ND | 0 | 6 | 0.003 | | mg/L |
| ***trans-1,2-Dichloroethylene*** | ND | 0 | 3 | 0.01 | | mg/L |
| ***Trichloroethene*** | ND | 0 | 3 | 0.005 | | mg/L |
| ***Trichlorofluoromethane*** | ND | 0 | 3 | 0.5 | | mg/L |
| ***Vinyl Chloride*** | ND | 0 | 3 | 0.0005 | | mg/L |
| ***Xylenes*** | ND | 0 | 3 | 1.750 | | mg/L |

*See recycled water regulations for limits on total nitrogen and disinfection byproducts
**For TDS, regulations allow upper exceedances of 1,000 mg/L and short-term exceedances of 1,500 mg/L
*** Regulatory requirements for TOC may be lower than MCL

Table 3-1 presents concentrations of metals and other inorganic constituents and physical parameters in the first grouping of analytes. These data are followed by radionuclides that are required for monitoring of recycled water recharge. The last group of analytes contains organic chemicals. Also included on the table are primary and secondary maximum contaminant levels (MCLs) pertinent to regulations for recharge of recycled water (DPH, 2007). Concentrations listed in the column of *Average Result* are average concentrations of detections from 2002 through 2007 and do not consider samples when the concentration was not detected above reporting detection limits (Table 3-1).

As shown on Table 3-1, the District's recycled water appears to meet regulatory requirements for constituents analyzed to date. The average TDS is about 555 mg/L, slightly larger than the secondary MCL of 500 mg/L. However, this is lower than the TDS concentration detected in the limited groundwater data presented above. As noted at the bottom of the table, TDS concentrations above 500 mg/L may be recharged and short-term concentrations of up to 1,500 mg/L may be allowed.

Regulations require control of total nitrogen compounds in recharge water. Total nitrogen as defined by the regulations is the sum of nitrogen in ammonia, nitrite, nitrate and other organic nitrogen-containing compounds. Total nitrogen is calculated on Table 3-1 and averages 8.8 mg/L. Total nitrogen may be limited to as low as 5 mg/L for a recharge project. If the 5 mg/L objective is exceeded, additional groundwater monitoring and/ or blending will likely be required to demonstrate that groundwater quality has not been adversely impacted. Regulations allow for alternative concentration limits to be proposed for a recycled water recharge permit (DPH, 2007). Nitrate, one of the nitrogen compounds of particular concern, meets primary standards as shown on Table 3-1. Concentrations of nitrate (as N) in recycled water average 3.4 mg/L from more than 261 samples analyzed. This value is well below the MCL of 10 mg/L.

Radionuclide data are currently unavailable for the WRF water. The seven parameters listed on Table 3-1 summarize the regulated analytes.

Organic chemicals regulated for recycled water recharge are listed on Table 3-1 beginning on the second page of the table. Almost all of these chemical have been analyzed in recycled water in at least one sampling event since 2002. Most of the data were developed during two sampling events in 2005 (winter and summer) and one event in January 2007. For those sampling events, there have been no detections of any organic chemical that did not meet water quality standards for regulated compounds. Two organic chemicals detected are classified as trihalomethanes (THMs), a group of chemicals formed when chlorine is used to control microbial contaminants in water (referred to collectively as disinfection byproducts). Analyses of THMs include chloroform, bromodichloromethane, dibromochloromethane, and bromoform. Of these chemicals, chloroform and bromodichloromethane have been detected in recycled water samples. Chloroform has been detected in three samples at 0.0026 mg/L, 0.008 mg/L, and 0.015 mg/L. All detections meet water quality standards and were significantly lower than the MCL of 0.080

mg/L. Bromodichloromethane has also been detected in three samples at concentrations of 0.009 mg/L, 0.002 mg/L, and 0.0063 mg/L, all at least one order of magnitude below the MCL of 0.080 mg/L. Only one other organic contaminant, toluene, has been detected in effluent samples. The concentration of that detection (0.007 mg/L) was about two orders of magnitude lower than the MCL of 0.15 mg/L.

As shown on the table, radionuclides and several inorganic and organic constituents have not yet been analyzed in District recycled water because they are not required for current monitoring. The table contains a more complete list of constituents to allow the District to review additional constituents to be analyzed for the recharge project if implemented. In addition to the constituents and parameters provided on Table 3-1, total organic carbon must meet stringent regulatory requirements. DPH will also require initial testing and monitoring for specific non-regulated compounds.

## 3.2. Hydrogeologic Considerations

Hydrogeologic conditions within the groundwater subbasin are important to the performance of a successful recharge project. The vadose zone above the water table must be sufficiently permeable to percolate the recharge water and there must be sufficient storage to accommodate the water during the recharge period. Aquifers must be sufficiently permeable to transmit the recharge water downgradient toward the basin discharge point or extraction wells. During an evaluation of recharge sites in the Lucerne Valley, USGS developed a general list of criteria for site selection. Although the list is specific to large spreading basins, the criteria are applicable to many recharge sites and methods. These criteria are listed below:

1. The infiltration rate of the spreading grounds must be high enough to accept the anticipated rate of recharge.
2. The storage capacity of the groundwater basin must be adequate to accommodate the anticipated volume of recharge.
3. The transmissivity of the water-bearing material must be sufficient to transmit the water at an acceptable rate away from the recharge site toward the area of extraction.
4. An adequate supply of water must be available for recharge, and it must be close enough to the area of need to meet economic criteria.
5. The spreading grounds should be upgradient of the withdrawal areas or be so situated with respect to withdrawal areas that water moves as directly as possible from one area to the other.
6. Faults and other hydrogeologic barriers should not impede the movement of recharge water.
7. The recharge water should be compared geochemically with ambient groundwater to minimize mineral precipitation and clogging of the aquifer with consequent reduction in rates of recharge.

For application to the District's recharge project, criteria 1-3 above are considered the most critical for project success. Data relevant to the infiltration potential, storage capacity, and transmissivity were discussed in the hydrogeologic setting. Although site-specific tests have not yet been conducted to determine infiltration rates, surface alluvial sediments are judged generally adequate for sufficient infiltration. Soil mapping conducted by the U.S. Natural Resources Conservation Service (NRCS) indicates permeable soils over the entire subbasin except in areas where bedrock crops out (NRCS, 2006). The transmissivity of the aquifers, as indicated by the aquifer test at District Well 1A, indicates sufficient permeability for downgradient transport of recharge water away from the recharge site and toward extraction wells. The exact storage capacity of the groundwater basin is currently unknown. Most of the storage is in the alluvial sediments that have infilled the basin around areas of shallow bedrock. The surface area of the subbasin is approximately 4,133 acres, but includes areas of bedrock and negligible groundwater storage. Using reasonable assumptions of two-thirds of the surface area (2,769 acres), an average depth to water of 50 feet, and an S value of 0.15, available subbasin storage is estimated to be about 20,000 AF. Storage estimates are judged adequate for the relatively small volume of recharge considered for this project, approximately 400 AFY of current discharge and 900 AFY at full permitted plant capacity assuming six months of continuous recharge. In addition, both the District and others have indicated an interest in additional extraction in the subbasin, making enhanced recharge a critical component of groundwater management.

Criterion 4 addresses the availability of source water for the project. WRF capacity and water quality data indicate that a reasonable amount of recycled water of sufficient quality is available. In addition, the current and planned conveyance system for recycled water anticipates increased demand throughout most of the subbasin. As such, sites within the central and northern Bedford Subbasin are considered sufficiently close to the recycled water conveyance system for the purposes of this feasibility study. If the project moves forward, final site selection will consider distance to conveyance and costs.

With regard to criterion 5, the upgradient (southern) portion of the subbasin was considered to be higher priority and was targeted for site selection. This criterion was balanced with the need for more favorable aquifer conditions than exist in the most upgradient portion of the subbasin where bedrock crops out, aquifers are thin, and the water table is shallow.

Criterion 6 notes the need to understand subbasin hydrogeology and potential barriers to groundwater flow. Geologic faults, such as the Glen Ivy fault on the western subbasin boundary, have been observed to impede groundwater flow in the area. Additional faults impacting groundwater flow have not been identified within the central and northeastern portions of the Bedford Subbasin. As such, specific faults are not considered to limit project site selection. Bedrock outcrops of the Bedford Subbasin are also considered to be hydrogeologic barriers, where low permeability rock impedes and diverts groundwater flow. Recent mapping in the area by USGS provided guidance on more favorable areas based on surface geology. For this project, Todd Engineers also constructed a detailed map on the depth to bedrock across the subbasin based on existing data (Figure 7). This map was used to identify more favorable areas away from shallow bedrock.

The final criterion in the previous list, criterion 7, addresses the compatibility of the recharge water and ambient groundwater to ensure long-term infiltration can be sustained without well or aquifer damage. This compatibility issue is typically evaluated using geochemical models, such as the USGS-developed model PHREEQC (Parkhurst and Appelo, 1999). Data are currently insufficient to conduct geochemical modeling. Site-specific data will need to be collected for this evaluation after a project site is selected.

### 3.2.1. Potential Recharge Methods

To replenish the unconfined alluvial aquifer, recycled water can be applied in one of several ways: at the surface using infiltration basins, directly into the aquifer using injection wells, or into the subsurface above the water table using vadose zone wells. Each of these recharge methods are illustrated by the schematic diagram on Figure 12. For surface basins, water infiltrates the basin floor and percolates through the vadose zone to the underlying water table (Figure 12). If clay layers are present in the vadose zone, or if sufficient land for recharge basins is unavailable, vadose zone wells can provide a space-efficient pathway for project water to reach the water table. If clay layers are prevalent, especially if they represent confining layers in the aquifer system, injection wells can be used to access aquifers more directly for recharge. Either of these methods, or a combination of methods, could potentially be applied to the District's recharge project. The applicability of each method to the District's project is discussed below.

#### 3.2.1.1. Surface Basins

The use of surface recharge basins involves conveyance of recycled water to a shallow excavated basin or series of basins where water would pond and infiltrate to underlying groundwater. Recharge basins have been used for conjunctive use and enhanced recharge projects for almost a century in areas of Riverside and San Bernardino counties. Since the alluvial aquifers of the Bedford Subbasin are considered to be unconfined, surface recharge would likely be capable of replenishment of subbasin aquifers. The size of the basin depends on the amount of water to be recharged and infiltration rates.

The infiltration rate varies with vadose zone permeability, depth to water, water quality, and other factors. Infiltration rates tend to decrease over time due to physical and/or biological clogging of the basin floor. Maintenance often involves drying and re-working the shallow subsurface. Physical clogging is anticipated to be less with recycled water, given the low amount of suspended solids. To maximize infiltration rates, relatively shallow basins are preferred (Bouwer, 2002).

Using a typical infiltration rate of about two feet per day (ft/day), a one-acre area is calculated to be capable of recharging about 450 gpm, a rate similar to that required for the District project. However, to allow for basin edge effects, maintenance, and other project needs, a minimum area of two acres should be considered.

Surface recharge basins provide the following project benefits:

- Relatively simple to construct and maintain
- Ability to spread recharge water over a large area, minimizing water levels impacts
- Water quality benefits by filtration through the vadose zone
- Ability to rehabilitate shallow clogging problems

Several disadvantages are associated with surface recharge basins compared to other recharge methods including:

- Larger land requirements
- Relatively large environmental footprint
- Potential security and liability issues

#### 3.2.1.2. Vadose Zone Wells

If sufficient land is unavailable for the construction of relatively large surface basins, vadose zone wells can be used. These wells, also referred to as dry wells, consist of an engineered casing/screen/gravel pack assembly installed in a shallow boring above the water table. Vadose zone wells can also be used to by-pass shallow clay layers that may impede or divert percolating recharge water (Figure 12). The amount of clay in the vadose zone throughout the Bedford Subbasin is unknown, but is predicted to be relatively low. Thus, this may not be an important advantage for the District's project. Nonetheless, wells are relatively inexpensive to construct and use, especially for the amounts of water to be recharged in this project. Vadose zone wells can be constructed in a developed area and need relatively small areas for installation and operation. In addition, they can be constructed on several separate parcels, if needed, allowing for a series of smaller projects rather than one larger recharge project. If infiltration rates are relatively high, only a few vadose zone wells would likely be needed to accommodate the District's project.

One major disadvantage is the inability to rehabilitate wells should they become clogged or ineffective. The entrainment of air is often cited for problems with decreasing infiltration rates. However, it is relatively easy to abandon and replace wells as needed.

#### 3.2.1.3. Injection Wells

For more direct recharge into the aquifer, injection wells can be used. These wells are constructed similar to production wells, but are configured for injection. Wells are effective in areas of relatively shallow water tables or for confined aquifers. Because well clogging typically decreases injection rates over time, wells need to be pumped periodically for maintenance, a process referred to as backflushing. The frequency of required backflushing varies from project to project, but is assumed to be required on a bi-weekly or monthly basis. Pumping for backflushing is typically conducted at twice the injection rate. As such, a dedicated pump is usually installed in the injection well with a flow control valve that allows for both injection and pumping to occur in the same wellbore.

Injection wells cost more to install than vadose zone wells and are often associated with significant maintenance costs. Land requirements are typically smaller than for surface recharge basins, but larger than for vadose zone wells since pumping and backflushing operations must be accommodated. However, they can serve as an effective method of recharge.

#### 3.2.1.4. Recharge Methods for District Project

As discussed above, any of the three methods could be applicable for recycled water recharge in the Bedford Subbasin. For a conceptual cost comparison, a recharge basin may be the less expensive alternative if land costs are not considered. The process of constructing a shallow basin is relatively straightforward and fewer inaccessible project components are developed. However, because of the larger land requirement, this method could also easily be the most expensive method depending on land costs. Injection wells would be relatively shallow for this project and would not likely be cost prohibitive. However, the clogging issues and backflushing requirements add significantly to project risk. Existing wells would not be good candidates for use as injection wells, given the lack of construction information, well seals, and the desire by the District to pump wells for water supply in the future. Recharge regulations require a minimum distance from drinking water wells. Vadose zone wells are likely the least expensive recharge option when land costs are considered. Since injection capacity is relatively low for vadose zone wells compared to recharge basins, numerous wells are often required to support a recharge project. However, for the small volume of recharge water associated with this project, this alternative seems slightly more favorable. Because all methods appear feasible, none are eliminated for the purposes of this study. Detailed costs can be generated when a specific site and data are available, and a method can be selected at that time.

### 3.2.2. Selection of Favorable Areas

For the purpose of this feasibility study, three favorable areas were chosen as potential recharge sites. A variety of factors were analyzed in order to select these favorable areas including:

- Depth to bedrock / alluvial thickness
- Depth to groundwater
- Land Use
- Soil / vadose zone lithology and permeability
- Distance to aquifer boundaries
- Ease of obtaining land

As a result of this analysis, the basin was subdivided into five priority zones, with Priority 1 being the most favorable and Priority 5 the least. The distribution of the zones is presented on Figure 13. The areas indicated as Priority 1 were chosen as the most suitable locations for potential recharge facilities. Areas at and near outcrops of bedrock are rated the lowest priority as shown by the gray areas of the subbasin on Figure 13. The southern segment of the subbasin is rated relatively low (Priority 4), even though alluvial deposits and depth to groundwater may present favorable conditions. This low rating is due to the concern that recharge water would be discharged to Temescal Wash as the creek crosses an area of very thin sediments to the north, removing the project water from the groundwater basin without adding to subbasin yield. Areas designated Priority 3 were judged too close to the creek and areas of shallow groundwater and land use considerations. Priority areas 2 were so-designated based on land use and, to some extent, less certainty in hydrogeology. Priority areas 1 were carried forward for further evaluation.

The District currently produces up to 700,000 gallons per day (gpd) of recycled water for potential recharge, an amount equivalent to 2.15 AF/day. The District is permitted to produce 1,570,000 gpd (4.82 AF/day) of recycled water at full build-out. Assuming a conservative recharge rate of 2 ft/day (only one percent of the measured hydraulic conductivity of the aquifer), a recharge basin with a minimum of 1.07 acre infiltration area (wetted area within a recharge basin) would be sufficient to recharge the current quantity of WFR water. For full build-out, a recharge basin with a minimum of 2.41 acres of infiltration area would be required. These parameters are used to evaluate project impacts to subbasin water levels as described below.

### 3.2.3. Groundwater Mounding Estimates

Potential recharge basins were plotted in each of the Priority 1 areas as shown on Figure 14. The depth to bedrock and depth to groundwater were interpolated for each of these three locations from the bedrock and groundwater surfaces on Figures 7 and 11. At Site 1 the interpolated depth to bedrock is 165 feet and the depth to groundwater is 40 feet, giving an approximate aquifer thickness of 120 feet. At Sites 2 and 3 the interpolated depth to bedrock is 370 feet and the depth to groundwater is 75 feet, giving an approximate aquifer thickness of 295 feet. The red area shown on the figure at Sites 1 and 3 covers approximately five acres, which is about the size necessary for the berms and other structures associated with a recharge basin with a one- to two-acre infiltration area. The blue area in the center of each of the three basins is just over one acre and represents the potential minimum size of the necessary infiltration area.

For a surface recharge project, water levels rise beneath the recharge area creating a groundwater mound. The height and extent of this mound varies over time with hydraulic properties of the aquifer and the amount of water being recharged. The development of a groundwater mound beneath the Study Area was evaluated using an analytical equation developed by Hantush (1967). The Hantush equation estimates the height of the groundwater recharge mound as a function of time and distance from the recharge area. The Hantush equation assumes that the underlying aquifer is unconfined, homogeneous, isotropic, and effectively infinite in areal extent. The analysis does not account for travel time and lateral flow of recharge water through the unsaturated zone, a sloping groundwater table, aquifer boundaries such as surface water bodies, bedrock, or faults, or aquifer stresses, such as pumping.

The Hantush equation was solved using the mounding function for a circular recharge area in Aqtesolv Pro 4.0 (Hydrosolve, Inc., 2006), the equation for which follows:

$$Z(r,t) = h_m^2 - h_i^2 = (V/2\pi K)\left(w(u_0) + \left(1 - e^{(-u_0)}\right)/u_0\right)$$

where,

$Z(r,t) =$ Height of the mound above initial height of water table with respect to distance from center of recharge area over time

$h_m =$ Height of mound above aquifer base

$h_i =$ Initial height of water table above aquifer base

$V =$ Volume of recharge water expressed as $w\pi R^2$, where w is the vertical infiltration rate from a circular recharge area of radius, R

$K =$ Horizontal hydraulic conductivity of the aquifer

$w(u) =$ Theis well function for nonleaky aquifers

$u_0 =$ $R^2/4nt$R, where $n = Kb/Sn$ and $b = 0.5(h_i(0) + h(t)$, where $S$ = Storativity, or specific yield of the unsaturated zone, $t$ = time since start of recharge, and $b$ = constant of linearization

The decay of the recharge mound can also be estimated in Aqtesolv Pro using the law of superposition: $h_m^2 - h_i^2 = Z(r,t) - Z(r,t - t_o)$, where $t_o$ is the time elapsed since recharge stops. Recharge mound contours generated by Aqtesolv Pro were exported as shapefiles and projected in the project GIS.

As shown in the Hantush equation, the development of the recharge mound is largely dependent on the vertical infiltration rate ($w$), storativity ($S$) of the unsaturated zone, and the horizontal hydraulic conductivity ($K_H$) and thickness of the saturated zone. Based on pumping test data, a $K_H$ of 200 feet/day, and $S$ of 0.10 and a conservative $K_V$ of 2 feet/day were applied in the Hantush equation and analyzed for a continuous recharge of six months.

Based on these site-specific input data and the current recycled water production rate of 2.15 AF/day, the calculated maximum height of the recharge mound is estimated to be 2.9 feet at Site 1 and 1.7 feet at Sites 2 and 3 after six months of recharge. At Site 1 the mound dissipates to 0.5 feet high within 4,700 feet of the infiltration basin, while at Sites 2 and 3 the mound is 0.5 feet high at 3,200 feet from the respective infiltration basins. Calculated groundwater recharge mound contours are presented for each of the three sites in Figure 14. The recharge mounds shown on Figure 14 were calculated for recharge basins with approximately 1 acre of infiltration area. However, these recharge mounds would also be representative for appropriately designed vadose zone wells.

For the full build-out recycled water production rate of 4.82 AF/day and recharge basins with approximately 2.5 acres of infiltration area, the calculated maximum height of the recharge mound is estimated to be 6.0 feet at Site 1 and 3.3 feet at Sites 2 and 3 after six months of recharge. At Site 1 the mound dissipates to 0.5 feet high within 8,400 feet (1.6 miles) of the basin, while at Sites 2 and 3 the mound is 0.5 feet high at 7,400 feet (1.4 miles) from the infiltration basin.

The Hantush equation method used to estimate groundwater mounding in response to recharge does not account for changes in the geometry of the mound as a result of boundary effects from faults, surface water bodies, or bedrock. However, it appears that the relative size of the mounds at the sites evaluated is small enough that recharge could be accommodated at any of the three locations evaluated above. Further, a larger amount of recycled water could also be accommodated for recharge if additional water is available in the future.

## 3.3. Regulatory Requirements

The California Department of Public Health (DPH), formerly referred to as the Department of Health Services (DHS), has developed draft regulations for the use of recycled water for groundwater recharge (DPH, 2007). Draft regulations are provided in Title 22, California Code of Regulations, Division 4 Environmental Health, Chapter 3, Recycling Criteria, Articles 1-7, Sections 60301-60323, and endnotes. These regulations provide guidance for siting, operating, and monitoring a recharge project using recycled water. Application of key regulations to the District's proposed recharge project is summarized below. This discussion is not a comprehensive review of all regulations, but rather identifies preliminary requirements that could impact how the project is implemented.

### 3.3.1. Distance from Extraction Wells

To ensure the control of potential pathogenic microorganisms, regulations require a specific residence time in the aquifer prior to the extraction of recharged water. Required residence times are six months for a surface recharge project (i.e., spreading basin) and twelve months for a direct injection project (i.e., injection wells). To accomplish this residence time, DPH has considered vadose zone transport and conservative groundwater flow rates to establish a minimum distance between recharge and any drinking water well. Current required distances are 500 feet and 2,000 feet for surface recharge and direct injection, respectively (DPH, 2007). This requirement has been recently reviewed by DPH and will likely be modified to a required distance of 500 feet from a drinking water well for both surface recharge and injection. Although there is no documented current extraction of groundwater for municipal supply in the Bedford Subbasin, there may be active domestic wells with undocumented extractions as indicated by DWR driller's logs and communications with the District. Riverside County requires well permits for domestic wells and maintains records on those wells. However, due to limited resources, data have not been organized and are not accessible at this time. If the project moves forward, a canvas of active domestic wells will be required within 500 feet and possibly up to 2,000 feet of the selected recharge area.

### 3.3.2. Diluent Water

As a redundant safety measure for public protection, DPH requires that recycled water recharge projects secure an alternative water source to mix with recycled water for dilution of any undocumented occurrence of constituents of concern. This additional water source, referred to in the regulations as diluent water, must also meet all water quality requirements stipulated for recycled recharge water and must be capable of being monitored to demonstrate water quality. The mix of diluent water and recycled water varies depending, in part, on the recharge method. For example, recycled water can account for up to 50 percent of the total recharge water for injection wells but only 20 percent of the total recharge water for surface recharge. This difference reflects the assumed higher level of recycled water treatment for an injection project. If recycled water quality meets regulatory objectives, the same proportion of recycled water can be used for either surface recharge or injection.

The diluent water does not have to be mixed with the recycled water prior to recharge and can be accounted for on a three or five-year average, depending on project operation. Diluent water sources can include stormwater (if collected for recharge and monitored), groundwater, or other surface water source. Recharge of diluent water does not have to be accomplished at the same recharge site, but must be shown to mix with recycled water in the aquifer prior to reaching extraction wells. Diluent water requirements can be reduced or eliminated after a period of monitoring has demonstrated the performance of the project. A meeting with DPH regulators will assist with the determination of diluent water requirements for the District's recharge project.

### 3.3.3. Water Quality Requirements

The recharge water must meet numerous numerical and qualitative water quality objectives to be approved for recharge into a groundwater basin that has been designated a source of drinking water supply. At a minimum, the recharge water must be treated to meet the definition of *disinfected tertiary recycled water*, as defined in Sections 60301.23.

In general, recharge water must meet Title 22 drinking water standards and other requirements for unregulated compounds. Most of the required levels are provided in regulatory tables in Title 22, Chapter 15 including Tables 64431-A (inorganic chemicals), Table 64442/64443 (radionuclides) and Table 64444-A (organic chemicals) (DPH, 2008). Action levels (AL) for lead (0.015 mg/L) and copper (1.3 mg/L) and secondary maximum contaminant levels (MCLs) for certain constituents and characteristics must also be met. Specific requirements for nitrogen compounds vary depending on the location of compliance monitoring. If levels in the recharge water average 5 mg/L with a maximum of 10 mg/L, then concentrations are considered sufficiently low to protect water quality without additional mixing with diluent water or sampling in the vadose zone.

Recycled water data were provided by the District for a preliminary review of water quality as described previously and presented on Table 3-1. A preliminary review of available data does not indicate non-compliance with recharge regulations. For several constituents, including TDS and total hardness, recycled water quality is better quality than ambient groundwater. For constituents listed on Table 3-1 that have not yet been analyzed, additional laboratory analyses will be required to ensure sufficient water quality for recharge. In addition, regulatory agencies may identify additional water quality constituents that will be considered in a recharge permit, including unregulated compounds.

### 3.3.4. Monitoring

Compliance monitoring consists of analyses of recharge water, water in the vadose zone or groundwater mound, and/or downgradient groundwater, depending on the constituent being analyzed and the quality of the source water. For example, if certain stringent requirements can be met in the source water prior to recharge, the need to monitor water quality in the vadose zone can be eliminated. In general, upgradient and downgradient monitoring wells will be required to demonstrate the performance of the project.

### 3.3.5. Other Requirements

There are a number of other requirements that the wastewater management agency (i.e., the District) must meet for a groundwater recharge reuse project including a pollutant source control program, identification of alternative water supplies, a public notification program, and compliance with the details in a project-specific permit. The District should involve early communication with regulators to ensure that the application of regulations to the District's project is well understood.

# 4. Benefits for Groundwater Management

In order to manage the shared groundwater resource of the Bedford Subbasin and provide for planned growth associated with build out, management strategies will be required. The District is cooperating with neighboring agencies including the City of Corona and EVMWD in management of the Bedford Subbasin. Recharge of recycled water appears to be a viable strategy to increase subbasin yield without adverse impacts to groundwater quality.

## *4.1. Subbasin Yield*

In the current draft of the City of Corona's GWMP, the City plans to increase production immediately downgradient of the Bedford Subbasin. The District also has the option to use additional groundwater for augmentation of water supplies through existing or new Bedford Subbasin wells. The nearby Coldwater and Temescal subbasins have experienced declining water levels. Enhanced recharge through the District's proposed project could raise groundwater levels and provide additional yield for increased groundwater extraction. As shown on Figure 10, the addition of 400 AFY to basin resources is not insignificant given historical levels of subbasin production. This amount represents about 15 percent of the average groundwater production total in the subbasin over time.  If additional recycled water is available in the future, basin pumping above historical levels may be supported.

## *4.2. Groundwater Quality*

Because the source of the recycled water contains significantly less dissolved minerals than ambient groundwater, the quality of the recycled water has the potential to improve local groundwater quality for certain constituents. As previously mentioned, TDS and total hardness are lower in recycled water. Mixing in the aquifer would dilute recycled water with groundwater and potential long-term benefits would require additional analysis. Also, additional water quality analyses are required for a full evaluation of impacts to groundwater quality. Nonetheless, based on existing data, the District's recharge project is not expected to adversely impact groundwater quality and could improve local quality in some areas.

## *4.3. Surface Water*

Removing the current discharge of recycled water from Temescal Wash will reduce surface water flows in the short term. However, most of the discharge occurs during the wet season when runoff contributes significantly to flows and additional flows are not likely needed to support beneficial uses. By allowing the recycled water to migrate in the subsurface toward surface water discharge at the subbasin boundary, more surface water discharge could potentially be available during dry conditions.

In addition, several of the constituents in recycled water including selenium have been problematic on occasion for creek discharge. Moving the recycled water to groundwater recharge would eliminate this condition. By allowing the recycled water to receive filtration benefits from aquifer materials, water quality of the recharge water would potentially improve in the subsurface and contribute higher quality water when rising to baseflow at the edge of the subbasin.

The analysis suggests that the basin could accommodate additional recharge from recycled water than amounts analyzed in this memorandum. If more recycled water is recharged than is extracted from production wells, surface water flows would be increased as groundwater rises into Temescal Canyon and exits the subbasin.

These benefits will require further analysis and will be reviewed in the environmental analysis for the City's GWMP. However, at a minimum, no adverse impacts to surface water are expected.

# 5. Conclusions and Recommendations

Based on the Feasibility Study presented in this document, the following conclusions can be made about the District's proposed recharge project:

- Bedford Subbasin hydrogeology is complicated by complex geology with relatively thin alluvial aquifers interrupted by bedrock outcrops.
- Alluvial aquifers are sufficiently thick in some areas to support an enhanced recharge project based on bedrock mapping.
- Aquifer testing in one District well indicates that subbasin aquifers have sufficient permeability and storage to support the District's project.
- Groundwater occurs at depths ranging from 100 feet to about 10 feet across the subbasin and is deepest in the west and shallowest near Temescal Wash.
- Groundwater is sufficiently deep in several areas to provide available storage for the District's recharge project.
- Groundwater quality data are limited, but one analysis indicates very hard water (total hardness of 370 mg/L) with a relatively high mineral content (TDS of 690 mg/L).
- Assuming a conservative infiltration rate of 2 ft/day, WRF recharge would require a minimum infiltration area of 1 acre for the current maximum discharge and 2.5 acres for full build-out.
- An analysis of groundwater mounding indicates that the anticipated water level rise in the vicinity of the proposed recharge sites is estimated to be between 1.7 and 2.9 feet (dependant on the location) for the current maximum WRF output of 2.15 AF/day. It appears that there is adequate unsaturated area in the proposed recharge locations to accommodate this quantity of groundwater.
- Further analysis of groundwater mounding for the increased capacity at full build-out (4.82 AF/day) indicates that the water level rise in the vicinity of the proposed recharge sites is estimated to be between 3.3 and 6.0 feet (dependant on the location). It appears that there is adequate unsaturated area in the proposed recharge locations to accommodate this quantity of groundwater.
- A comparison of recycled water quality data with regulatory requirements did not identify any significant water quality issues for the District's project. Additional water quality analyses will be required to demonstrate regulatory compliance if the project is implemented.

- The District’s project provides management benefits to subbasin yield and, potentially, groundwater and surface water quality.
- Based on the results in this study, the District’s proposed recharge project appears feasible and could involve a variety of recharge methods, depending on final project location.
- The analysis was based on limited data and significant data gaps exist. Recommendations to address these data gaps are provided below.

For continued assessment and implementation of the District’s project, the following recommendations are provided:

- Include the recycled recharge project in the City of Corona’s GWMP and support GWMP adoption.
- Participate in the environmental review process planned for the City’s GWMP.
- Explore options for securing land in the areas designated most favorable for recharge and consider additional infrastructure required for conveyance of recycled water.
- Conduct an exploratory meeting with regulatory agencies regarding project objectives and permit requirements.
- Conduct  site-specific evaluations and investigations to determine potential injection rates and aquifer response to recharge.
- Continue and expand recycled water quality testing to include constituents identified on Table 3-1 as well as additional constituents indicated by regulators in preliminary meetings.

# 6. References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# Figures

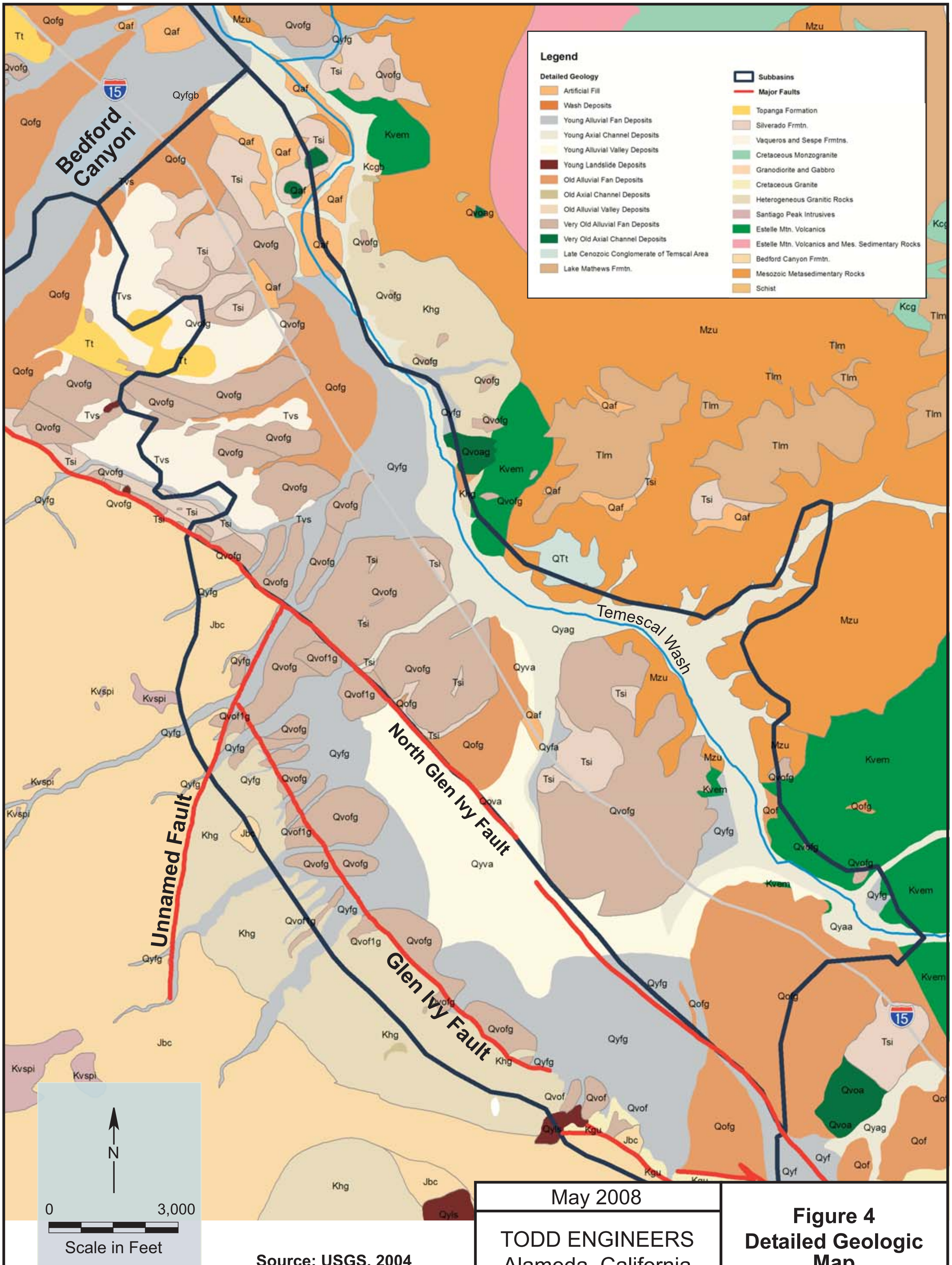

**LEGEND**

- Upper Santa Ana Valley Groundwater Basin
- Elsinore Groundwater Basin

| May 2008 | **Figure 1** |
|---|---|
| TODD ENGINEERS<br>Alameda, California | **Groundwater Basins and Study Area** |


| May 2008 | **Figure 2** |
|---|---|
| TODD ENGINEERS<br>Alameda, California | **Lee Lake Water District and Local Water Agencies** |


| May 2008 | Figure 3 Aerial Photograph Bedford Subbasin |
| --- | --- |
| TODD ENGINEERS Alameda, California | |




Source: USGS, 2004

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**Figure 4**
**Detailed Geologic Map**

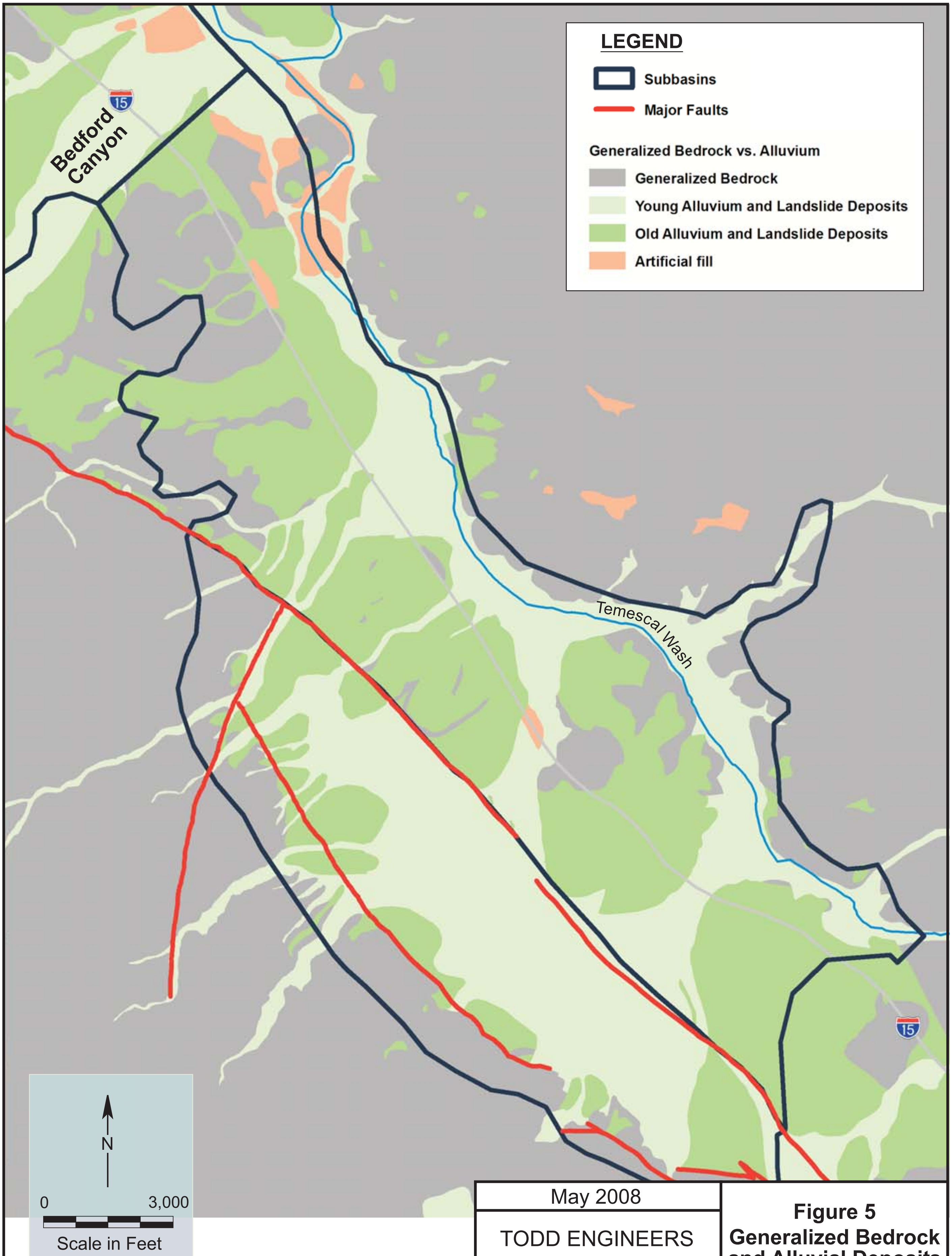


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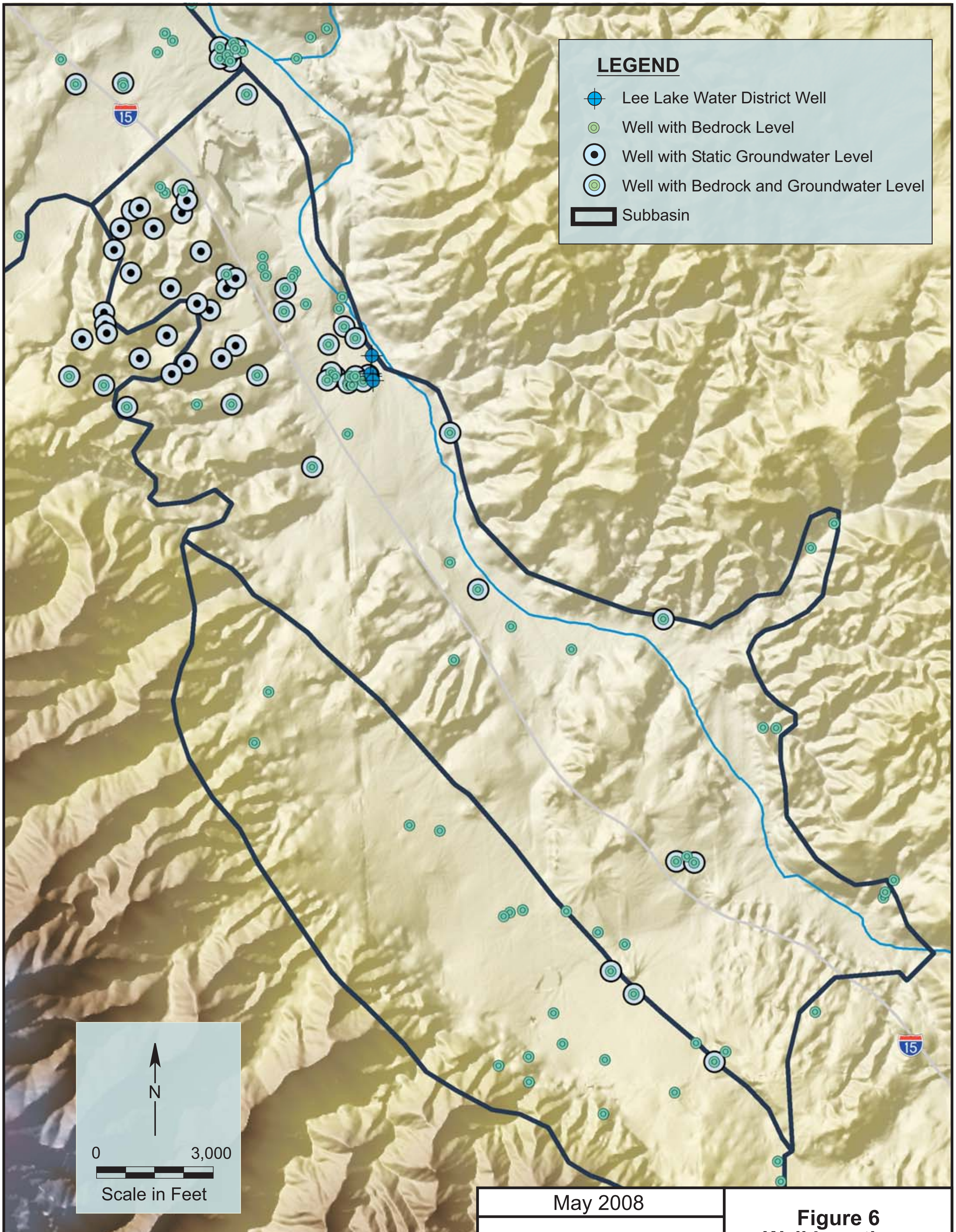
**Figure 5**
**Generalized Bedrock and Alluvial Deposits**




**Well Locations approximated from DWR Driller's logs.**
**Lee Lake Water District well locations provided by District.**

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**Figure 6**
**Well Locations**

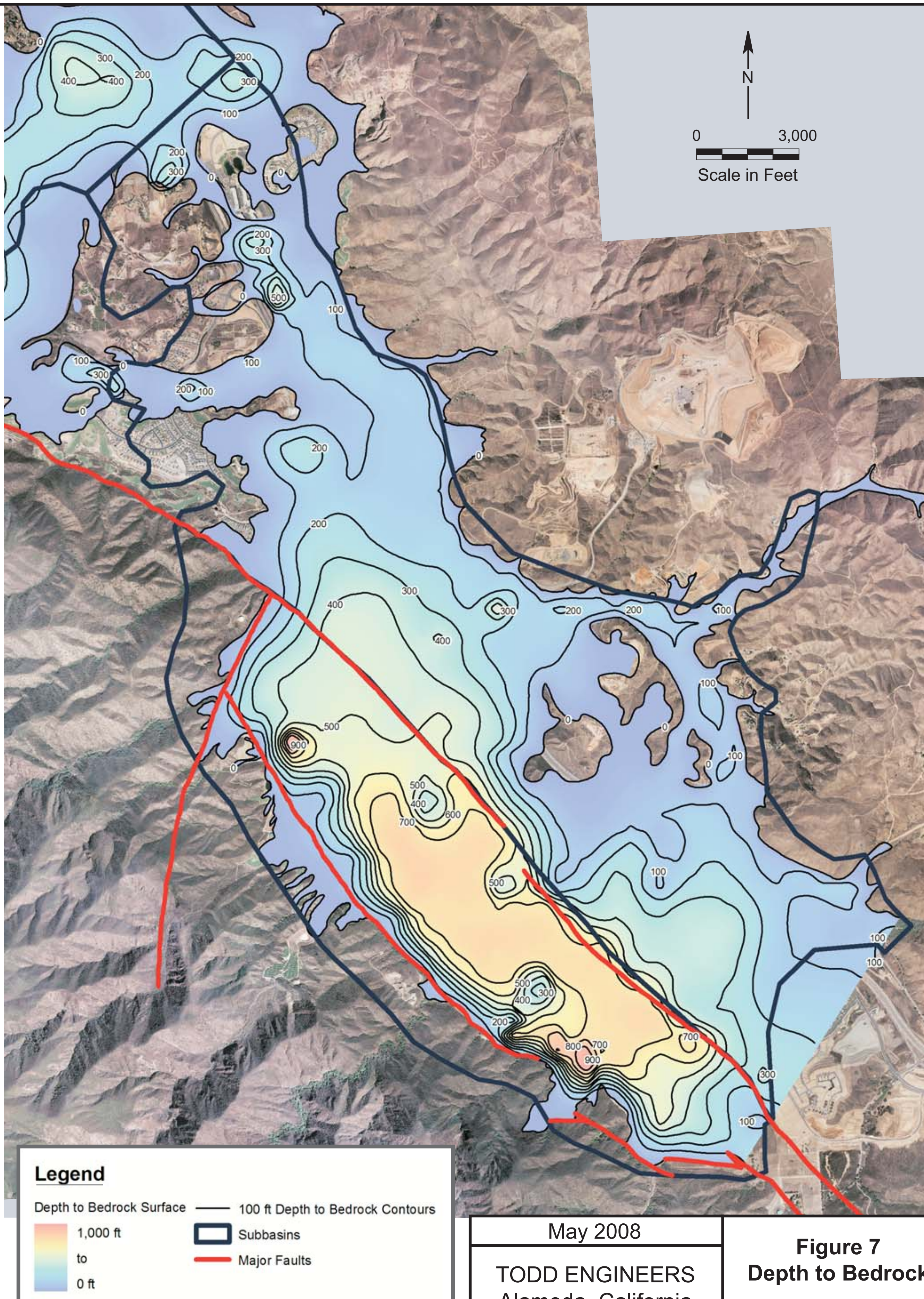


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**Figure 7**
**Depth to Bedrock**

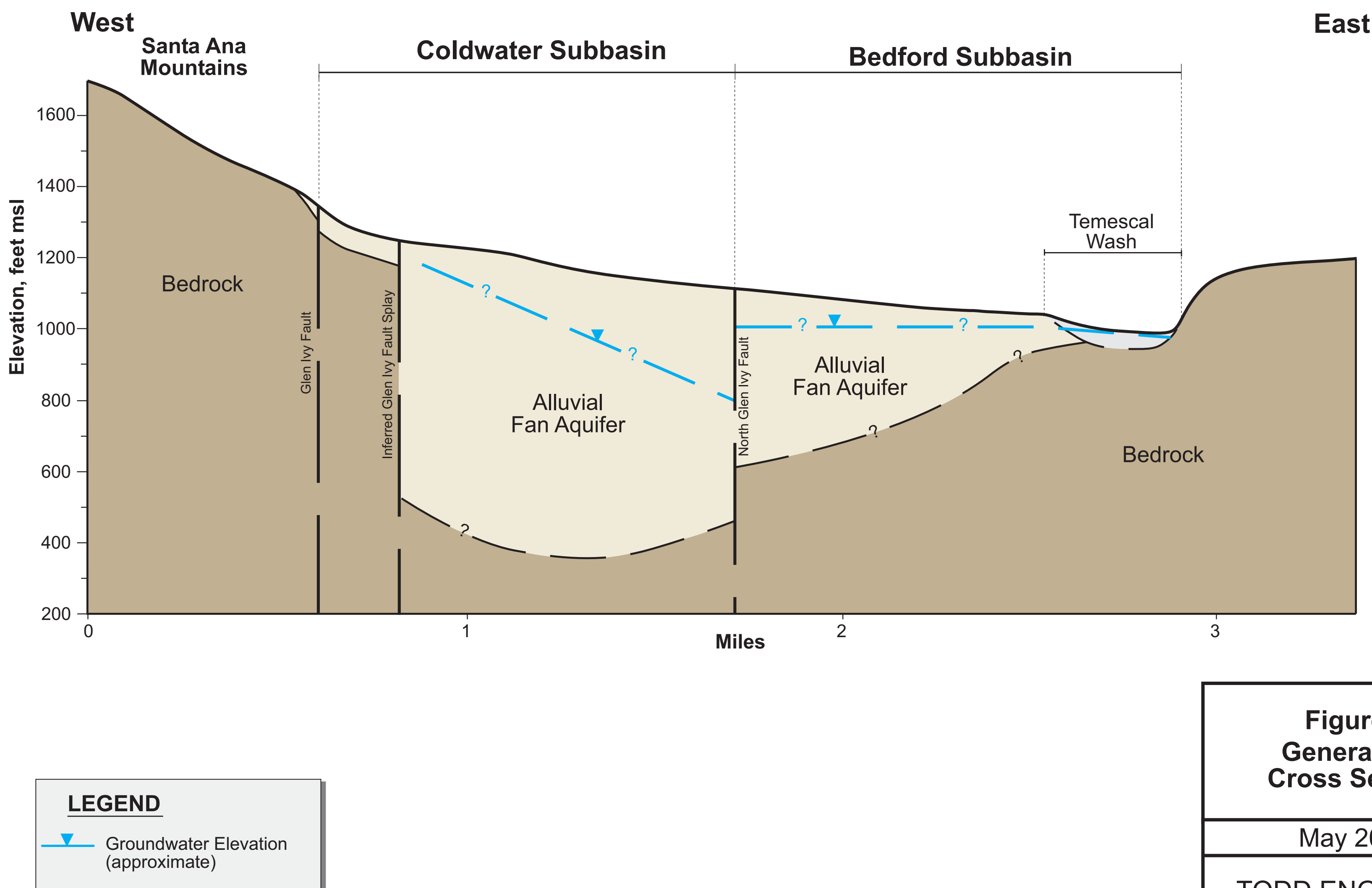


**Figure 8**
**Generalized Cross Section**

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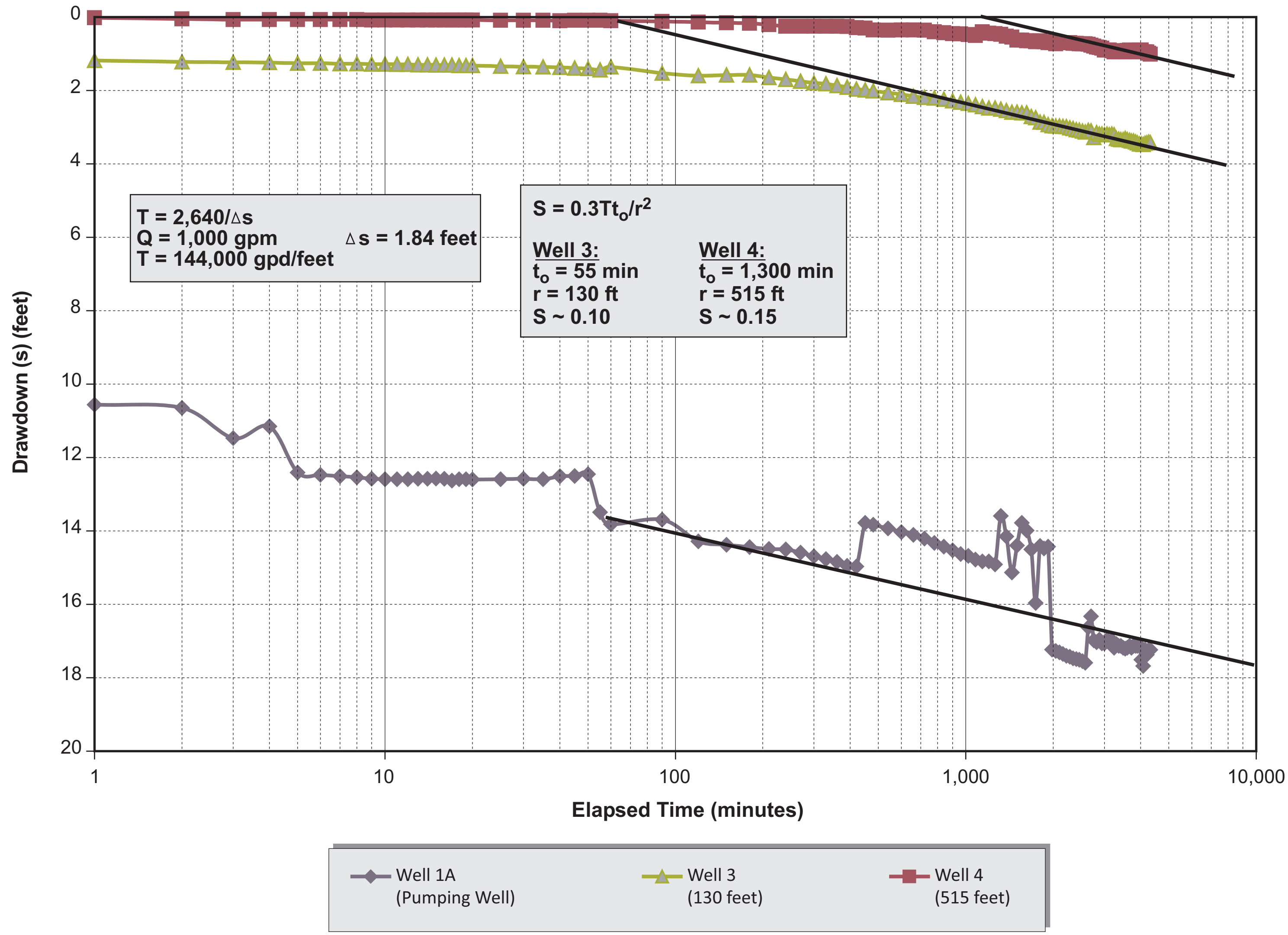


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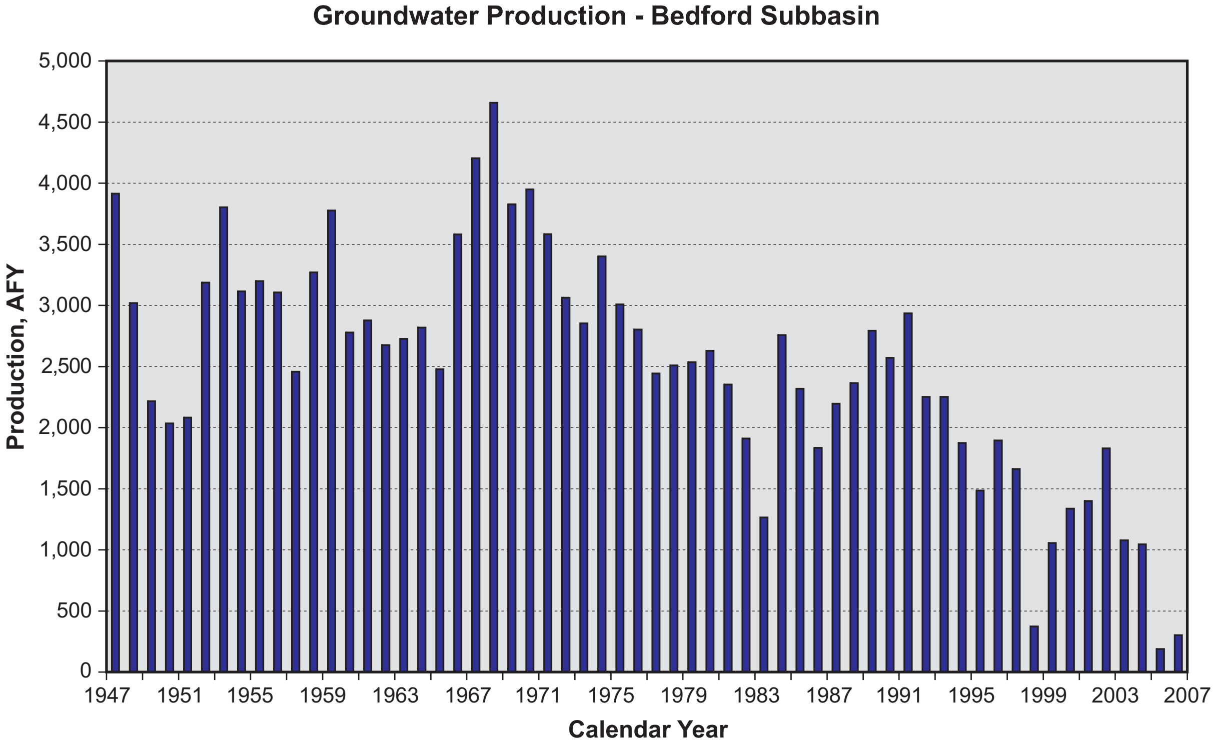
**Figure 9**
**Pumping Test Analysis Well 1A**
**February 2003**



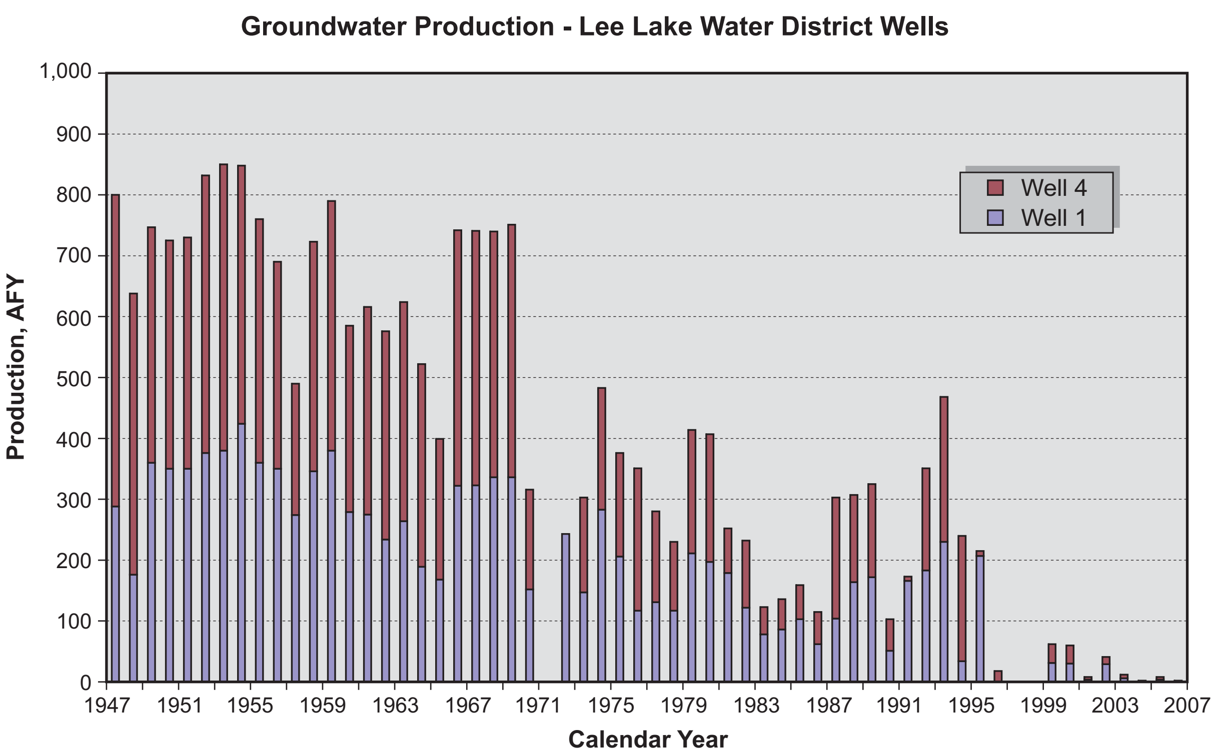




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**Figure 10**
**Bedford Subbasin Groundwater Production**

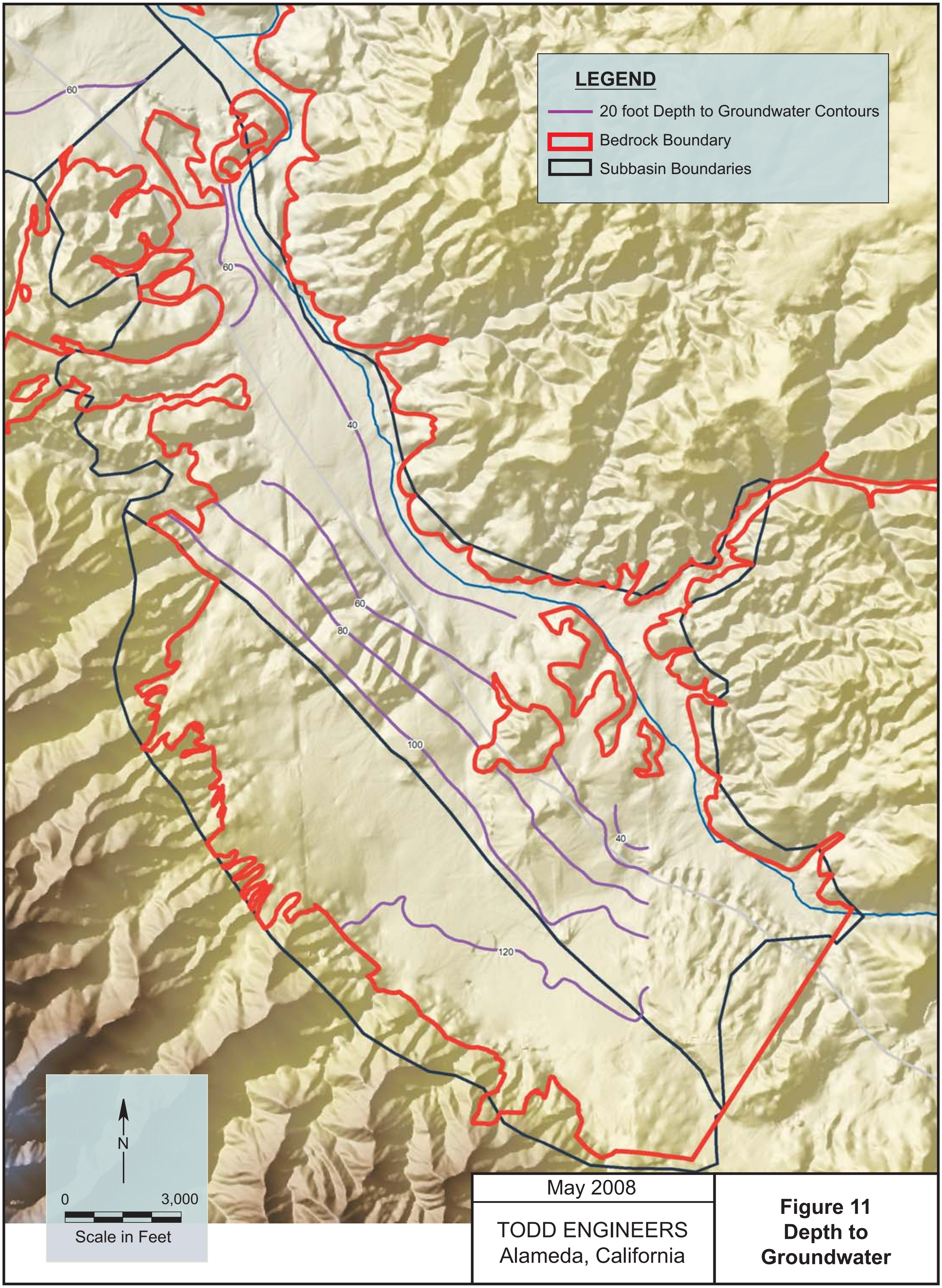


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**Figure 11**
**Depth to Groundwater**

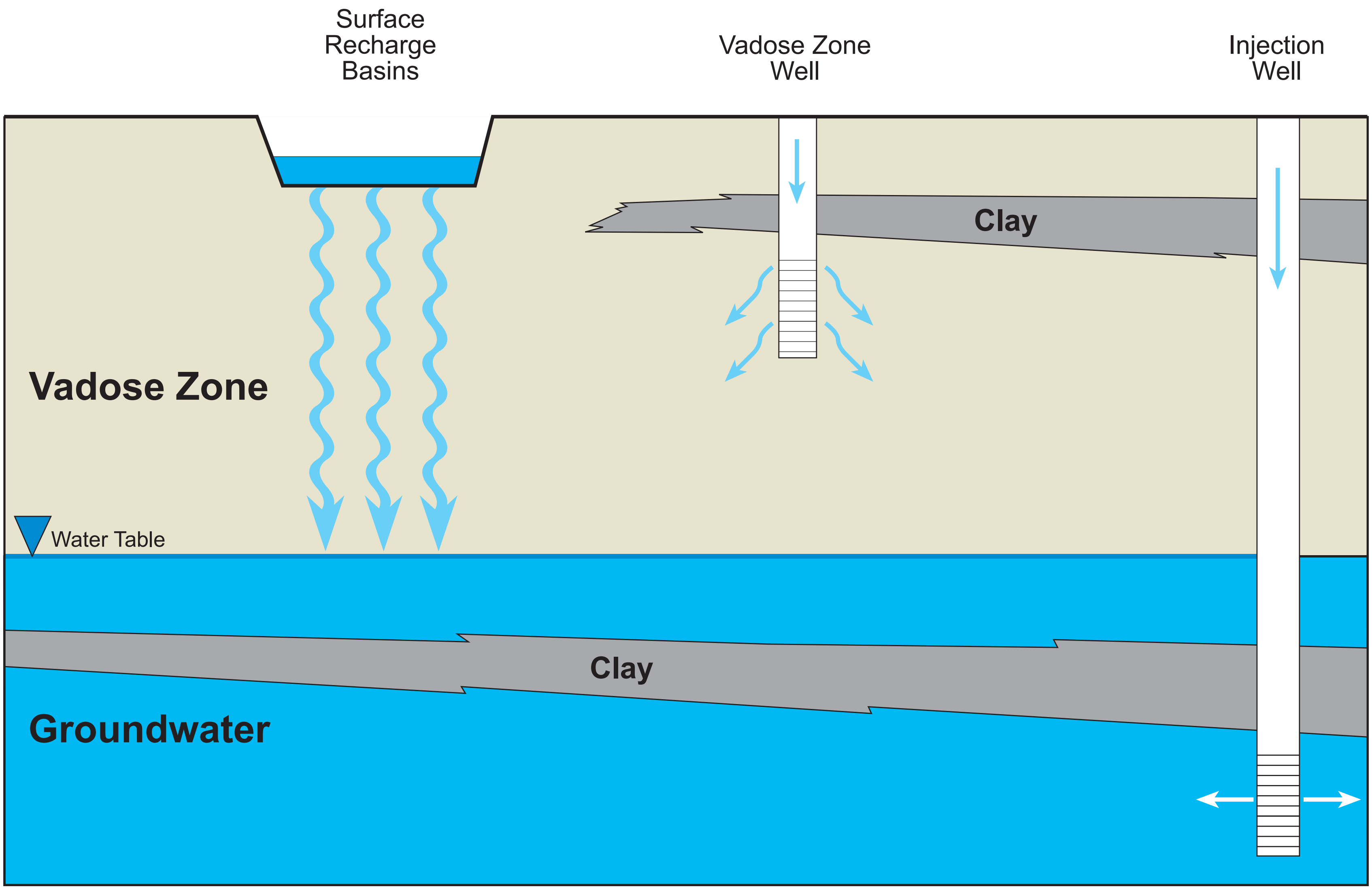


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**Figure 12**
**Recharge Methods Schematic Diagram**

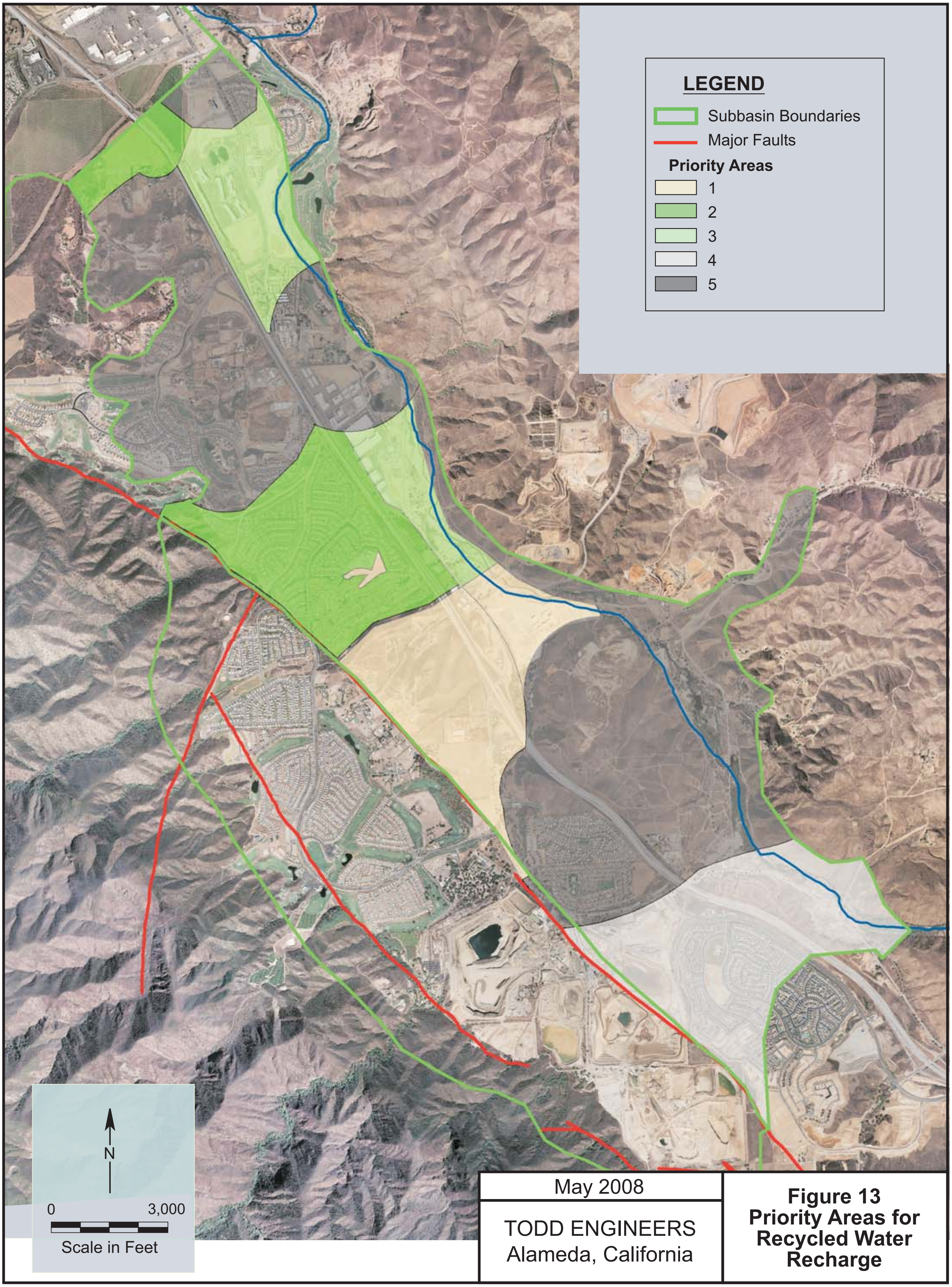


Figure 13
Priority Areas for
Recycled Water
Recharge

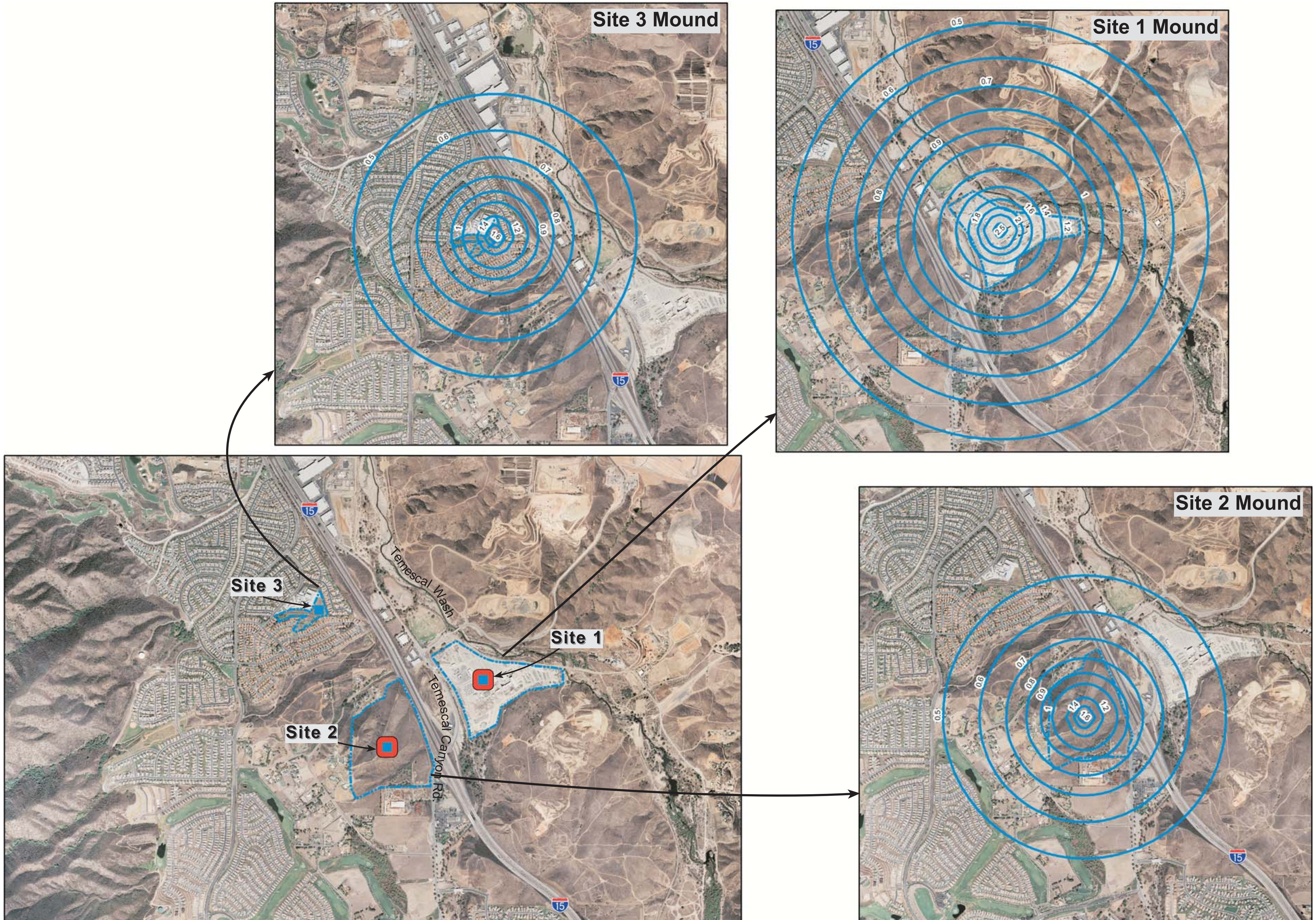


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**Figure 14**
**Potential Recharge Areas and Approximate Recharge Mounds After Six Months**