CHINO BASIN
OPTIMUM BASIN MANAGEMENT PROGRAM

State of the Basin Report – 2004

Administrative Draft

Prepared for:

Prepared by:

January 2005

WILDERMUTH™ ENVIRONMENTAL INC.

WILDERMUTH™
ENVIRONMENTAL INC.

January 19, 2005

Chino Basin Watermaster
Attn: Ken Manning, CEO
9641 San Bernardino Road
Rancho Cucamonga, CA 91730-4665

Subject: Transmittal of Administrative Draft of the State of the Basin Report (2004) for the Chino Basin Optimum Basin Management Program

Dear Ken,

Wildermuth Environmental, Inc. is pleased to transmit an *Administrative Draft* of the State of the Basin Report (2004) for the Chino Basin Optimum Basin Management Program. We are delivering four (4) hard copies to your offices for Watermaster review and comments. In addition, we have posted a PDF version of the report for download on our FTP site at:

http://www.wild-environment.com/downloads/cbwm/SOB_2004/

Please contact us if you have any questions.

Best regards,

Mark J. Wildermuth, PE
President/Principal Engineer

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CHINO BASIN
OPTIMUM BASIN MANAGEMENT PROGRAM

State of the Basin Report – 2004

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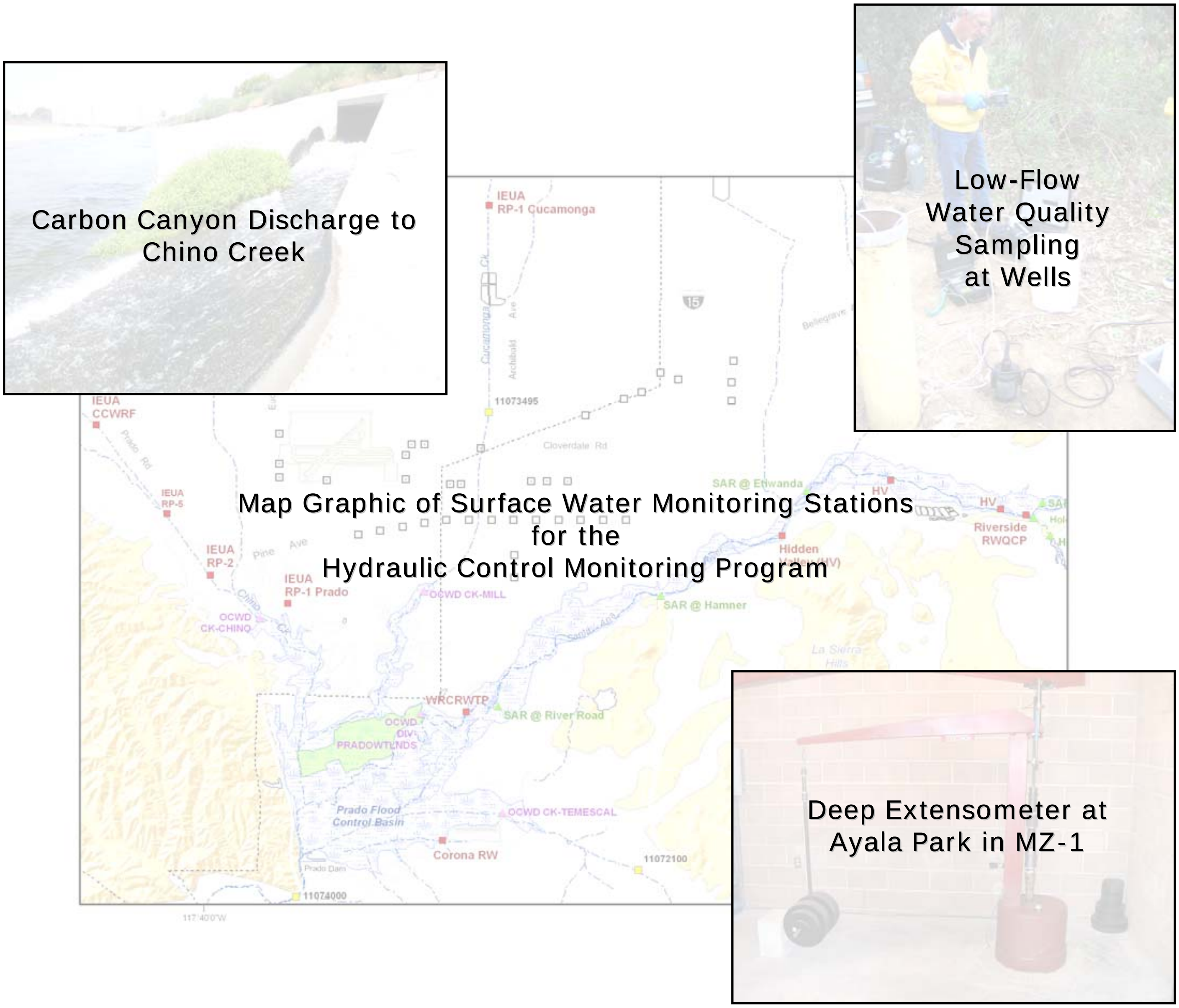

January 2005

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ACRONYM AND ABBREVIATIONS LIST	
µg/L	micrograms per liter
acre-ft/mo	acre feet per month
acre-ft/yr	acre feet per year
ADFM	accumulated departure from the mean
bgs	below ground surface
CALFED	California-Federal Bay-Delta Program
CBDCAMP	Chino Basin Data Collection and Monitoring Program
CBWCD	Chino Basin Water Conservation District
CDA	Chino Desalter Authority
CIM	California Institution for Men
CMP	Comprehensive Monitoring Program
DBCP	1,2-dibromo-3-chloropropane
DHS	California Department of Health Services
DWR	California Department of Water Resources
EDB	1,2-dibromoethane
EPA	US Environmental Protection Agency
ERD	entity relationship diagram
GE	General Electric
GIS	geographic information system
IEUA	Inland Empire Utilities Agency
JCSD	Jurupa Community Services District
JMM	James M. Montgomery, Consulting Engineers, Inc.
MAF	million acre feet
MCL	maximum contaminant level
mg/L	milligrams per liter
MJW	Mark J. Wildermuth, Water Resources Engineers
MOA	Memorandum of Agreement
msl	mean sea level

ACRONYM AND ABBREVIATIONS LIST	
MTBE	methyl-tert-butyl-ether
MWD	Metropolitan Water District of Southern California
MWDSC	Metropolitan Water District of Southern California
ND	not detected
NO_3	nitrate
NO_3-N	nitrate as nitrogen
O&M	operations and maintenance
OBMP	Optimum Basin Management Program
OCWD	Orange County Water District
PDR	preliminary design report
PWMP	Private Well Monitoring Program
QAP	Quality Assurance Plan
RAM	Rapid Assessment Model
RFP	Request for Proposals
RO	reverse osmosis
RP1	IEUA's Regional Plant 1
RWQCB	Regional Water Quality Control Board, Santa Ana Region
SAP	Sampling and Analysis Plan
SAR	Santa Ana River
SEIR	Supplemental Environmental Impact Report
SWQIS	State Water Quality Information System
SWRCB	State Water Resources Control Board
TCE	trichloroethene
TDS	total dissolved solids
TIN	total inorganic nitrogen
TMDL	total maximum daily load
USCGS	US Coast and Geodetic Survey
USGS	US Geological Survey
WEI	Wildermuth Environmental, Inc.

EXECUTIVE SUMMARY

The baseline for the Initial State of the Basin is on or about July 1, 2000 – the point in time that represents the start of Optimum Basin Management Program (OBMP) implementation. This initial state or baseline is one metric that can be used to measure progress from implementation of the OBMP.

Section 2 Geology and Hydrogeology

Since 2002, three investigations to support OBMP-related programs have improved Watermaster's hydrogeologic understanding of Chino Basin. These investigations were related to (1) the Hydraulic Control Monitoring Program (HCMP) in southern Chino Basin, (2) subsidence and fissuring in Management Zone 1, and (3) basin-wide groundwater modeling to predict the effects of various storage-and-recovery program alternatives on groundwater levels and quality. These investigations resulted in a new, three-dimensional, hydrogeologic conceptual model of Chino Basin. Current and future well drilling programs to support monitoring of the HCMP and recycled water recharge projects will provide additional hydrogeologic data, and likely will refine the hydrogeologic conceptual model.

Section 3 Groundwater Levels and Storage

Watermaster has established three groundwater-level monitoring programs for the Chino Basin – a semiannual basin-wide program; an intensive key well monitoring program associated with the Chino Desalter well fields and the Hydraulic Control Monitoring Program (HCMP); and an intensive piezometric monitoring program associated with the land subsidence and ground fissuring investigations in Management Zone 1. Since 2003, Watermaster has been installing pressure transducers/data loggers in many of the wells it monitors for water levels. The transducers provide highly-detailed groundwater level data (one data point per 15 minutes) that can reveal aquifer-system details (*e.g.* groundwater barriers, head responses to nearby pumping) that are not typically revealed through analysis of infrequently-collected data. Nine (9) nested sets of monitoring wells are currently being installed in the southern Chino Basin for the HCMP, and will provide highly-detail, depth-specific piezometric (and water quality) data. Additional monitoring wells likely will need to be constructed in southern Chino Basin as private wells (that are currently being used for monitoring by Watermaster) are destroyed as agricultural land uses convert to urban.

A groundwater elevation contour map of the uppermost saturated aquifer system in Chino Basin was created for Fall 2003. A storage model was created (using data obtained and generated in Section 2) to estimate storage change in the basin over the Fall 2000 to Fall 2003 time period. Basin-wide, the groundwater storage decreased by about 93,000 acre-feet over this three-year period. Sub-areas of Chino Basin that experienced a decrease in storage were in the northwest near Pomona and Montclair; in the northeast near Fontana, eastern Ontario, and Rancho Cucamonga; and near the Chino-I Desalter well field which began producing water in 2000. Sub-areas that experienced an increase in storage were in the southwest near Chino; and in the south (just north of the Santa Ana River) where many agricultural wells are being destroyed as urban land uses replace agricultural.

Section 4 Groundwater Quality

Watermaster has completed an initial comprehensive assessment of groundwater quality in the Chino Basin that included every well that could be sampled. Watermaster continues to monitor water quality in the Basin and stores these data in a relational database, which also includes all the historical data that

Watermaster has been able to acquire for wells in the region. Watermaster has instituted a cooperative process whereby water quality data are acquired on a routine basis from the appropriators. This alleviates some of the data quality control issues with downloading data from the state water quality database.

The groundwater quality in Chino Basin is generally very good, with better groundwater quality found in the northern portion of Chino Basin where recharge occurs. Salinity (TDS) and nitrate concentrations increase in the southern portion of Chino Basin. Seventy-two percent of the private wells south of the 60 Freeway (169 wells) had TDS concentrations above the secondary MCL. About 83 percent of the private wells south of the 60 Freeway had nitrate concentrations greater than the MCL. The other constituents that have the potential to impact groundwater quality from a regulatory or Basin Plan standpoint are certain VOCs, arsenic, and perchlorate. There are a number of point source releases of VOCs in Chino Basin. These are in various stages of investigation or cleanup. Likewise, there are known point source releases of perchlorate (MVSL area, Stringfellow, *et cetera*) as well as what appears to be non-point source-related perchlorate contamination from currently undetermined sources. Arsenic at levels above its WQS appears to be limited to the deeper aquifer zone within the City of Chino. Total chromium and hexavalent chromium, while currently not a groundwater issue for Chino Basin, may become so depending on the promulgation of future standards.

Watermaster formed the Water Quality Committee (WQC) in Spring 2003 to reflect that Watermaster is the “go-to” entity because of its role as an arm of the Court. The WQC is reviewing both existing and emerging contaminants. The WQC is developing plans to collect data on the active cleanup of basin contaminants, so that lessons learned concerning mitigation measures and cleanup technologies can be effectively shared.

Section 5 Ground-Level Monitoring

Monitoring of land surface deformation in Chino Basin focuses on land subsidence and ground fissuring that likely is related to fluid withdrawal. Specifically, the area underlying the City of Chino and the California Institution for Men (CIM) has experienced ground fissuring (likely associated with land subsidence) as early as 1973, but an accelerated occurrence of ground fissuring ensued after 1991.

Watermaster has developed and implemented a Management Zone 1 (MZ-1) Interim Monitoring Program (IMP) to investigate the mechanisms that cause land subsidence in MZ-1, and to use the results of the IMP to develop a long-term plan to minimize or abate future subsidence and fissuring. The IMP employs traditional ground level surveying, remote-sensing analysis of satellite radar data, and monitoring of the aquifer-system hydraulics and mechanics. The centerpiece of the IMP is the Ayala Park Extensometer facility, which was constructed in 2002-03 and consists of multi-depth piezometers and a dual-extensometer.

Under current conditions of aquifer utilization in MZ-1, the aquifer-system deformation appears to be mainly elastic, with up to 0.13 feet of land subsidence and 0.13 feet of rebound during the pumping and recovery seasons, respectively. Minor amounts (~0.02 feet) of permanent compaction and associated land subsidence occurred over this same period. However, a recent pumping test in this area demonstrated that permanent compaction can be triggered when the magnitude and duration of drawdown exceeds certain threshold limits. Analytical and numerical computer models are being constructed to predict future drawdown and associated land subsidence that would result from potential basin management practices (*i.e.* the models can evaluate the effectiveness of various long-term plan alternatives). One unforeseen but key finding of the IMP has been the discovery of a previously unknown groundwater barrier that exists within the deep aquifer-system in the same location as the historic fissure zone.

Section 6 Recharge Basin Monitoring

Watermaster, working with the Chino Basin Water Conservation District, is conducting a program to monitor the volumetric recharge at the Montclair, Brooks, and Turner 1, and Grove basins. In addition, the water quality of recharge is being monitored at these and other basins that have some level of storm water conservation. This recharge monitoring program is important to Watermaster because of new yield implications associated with storm water recharge and water quality mitigation requirements associated with recycled water recharge. Implementation of the Chino Basin Facilities Improvement Program resulted in an increased ability to capture and recharge storm water at several basins.

Section 7 Basin Plan Update for the Chino Basin

The TIN/TDS Task Force was formed in the mid 1990s to perform certain investigations that would lead to the establishment of new total dissolved solids (TDS) and nitrate-nitrogen objectives for groundwater basins in the Santa Ana River Watershed. The Regional Water Quality Control Board (RWQCB), Chino Basin Watermaster, water-recycling agencies, and many other entities participated in the Task Force. The RWQCB used the reports and other information developed by the Task Force to amend the Water Quality Control Plan for the Santa Ana River Watershed (Basin Plan) in 2004.

The TIN/TDS Task Force developed estimates of historical ambient water quality (objectives) and current ambient water quality by management zone. A comparison of these values determines whether or not assimilative capacity exists in a given management zone. The Task Force demonstrated that there is no assimilative capacity in any of the management zones in Chino Basin for TDS or nitrate. For much of the Chino Basin, the TDS and nitrate objectives would be below 300 mg/L and 5 mg/L, respectively.

The new water quality objectives would, from a practical standpoint, make the large-scale use of recycled water very difficult and potentially impractical in the Chino Basin. However, the OBMP anticipated the use of about 26,000 acre-ft/yr of recycled water for direct use by 2025, and about 20,000 to 30,000 acre-ft/yr for recharge by 2025. Recycled water is a critical resource that the OBMP stakeholders are counting on to implement the OBMP. If the groundwater objectives were adopted, Watermaster, the parties to the Judgment, and IEUA would have substantial mitigation obligations for the use of recycled water.

In December 2002, Watermaster and IEUA proposed to the RWQCB to develop new TDS and nitrate objectives based on criteria contained in California Water Code Section 13241 and "the need to develop and use recycled water." The Task Force modified the delineation of the Chino Basin management zones, and established the new (elevated) TDS and nitrate-nitrogen objectives of 420 mg/L and 5 mg/L, respectively, that would permit recycled water re-use in Chino Basin. In exchange, Watermaster and IEUA committed to establishing and documenting "hydraulic control" of the groundwater basin (see Section 8). The Basin Plan Amendment, as it pertains to managing the Chino Basin, is now in effect.

Section 8 Hydraulic Control Monitoring Program

Under virgin conditions in Chino Basin (pre- to early-1900s), groundwater flowing in a southerly direction from the northern part of the basin would rise to become surface flow in the southwestern part of the basin, ultimately discharging to the Santa Ana River. Since the onset of pumping and associated regional drawdown of groundwater-levels, this southerly flow of groundwater is thought to be intercepted by agricultural wells, and in the last few years, by desalter wells before rising as surface flow in significant quantities. The condition where groundwater is intercepted before discharging to the Santa Ana River is herein referred to as "hydraulic control." Past data collection and groundwater modeling efforts suggest that hydraulic control could be occurring, but are not sufficient to conclude that hydraulic control is actually occurring.

As part of the 2004 Basin Plan update, Watermaster and IEUA committed to establishing and documenting "hydraulic control" of the groundwater basin in exchange for elevated groundwater quality objectives that would permit and encourage recycled water re-use in Chino Basin (see Section 7). Subsequently, Watermaster and IEUA developed and began implementation of the Hydraulic Control Monitoring Program (HCMP). The HCMP employs four engineering or scientific showings can be used to corroboratively demonstrate the state of hydraulic control in the southern portion of Chino Basin:

- analysis of surface water and groundwater chemistry
- estimation of hydrologic balance
- analysis of piezometric levels
- groundwater modeling

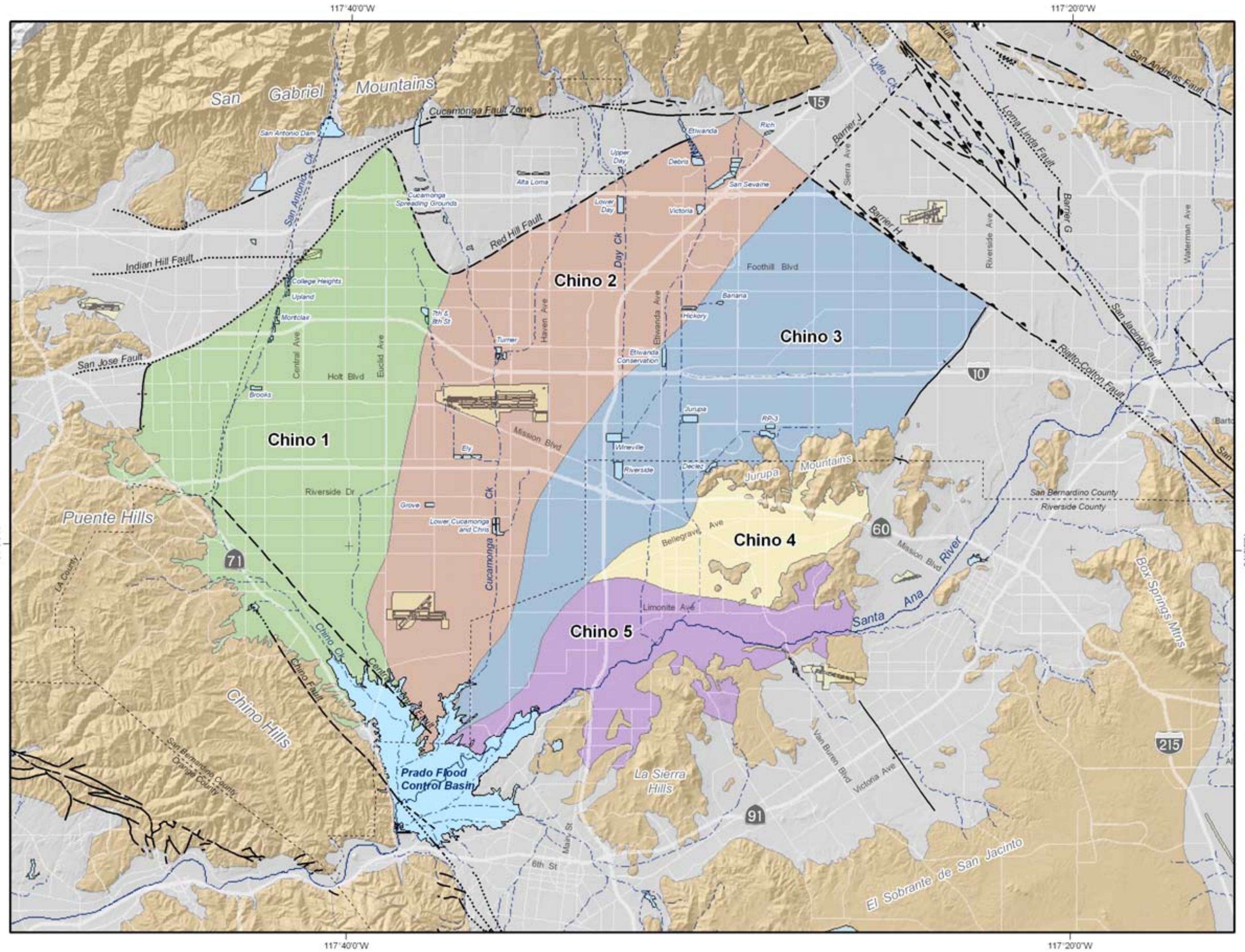
While any individual demonstration may not be adequate to demonstrate complete containment, all four elements can be combined to assess the state of hydraulic control and to optimize the management of the basin to maximize yield and minimize discharge of poor quality groundwater to the Santa Ana River and Prado Basin (*i.e.* protect downstream beneficial uses).

1. INTRODUCTION

The Chino Basin Watermaster completed the Initial State of the Basin (ISOB) Report in October 2002. The baseline for the ISOB was on or about July 1, 2000 – the point in time that represents the start of Optimum Basin Management Program (OBMP) implementation. The ISOB and subsequent State of the Basin (SOB) reports is one metric that can be used to measure progress for the implementation of the OBMP. This current SOB report contains water level, water quality, ground-level data *et cetera* through 2003/2004 and Watermaster activity through Fall 2004.

An OBMP for the Chino Basin (see Figure 1-1 for location of Chino Basin and its management zones) was developed pursuant to a Judgment entered in the Superior Court of the State of California for the County of San Bernardino and a February 19, 1998 ruling as described below (WEI, 1999). Pursuant to the OBMP Phase 1 Report, Peace Agreement and associated Implementation Plan, and a November 15, 2001 Order of the Court, Watermaster staff has prepared this State of the Basin (SOB) Report. The intent of this report is twofold.

- During Watermaster fiscal year 2000/01 several OBMP-spawned investigations and initiatives were started. Groundwater level and quality, ground level, annual recharge assessment, recharge master planning, hydraulic control, desalter planning and engineering, and meter installation. This report describes the progress made in these activities through Fall 2004.
- This report also describes the general state of the basin with respect to geology, groundwater levels and storage, groundwater quality, ground level, recharge, and hydraulic control.



OBMP Management Zones

- Chino 1
- Chino 2
- Chino 3
- Chino 4
- Chino 5

Geology

Water-Bearing Sediments

- Quaternary Alluvium

Consolidated Bedrock

- Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

- Flood Control and Conservation Basins

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Date: 20041230
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0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004

OBMP Management Zones

Chino Basin

Figure 1-1

2. GEOLOGY AND HYDROGEOLOGY

2.1 Background

The Chino Basin was formed as a result of tectonic activity along major fault zones. It is part of a larger, broad, alluvial-filled valley located between the San Gabriel/San Bernardino Mountains to the north (Transverse Ranges) and the elevated Perris Block/San Jacinto Mountains to the south (Peninsular Ranges). The Santa Ana River is the main tributary draining the valley and, hence, the valley is commonly referred to as the Upper Santa Ana Valley. Chino Basin is located in the western portion of this valley as shown on Figure 2-1.

The major faults in the Chino Basin area – the Cucamonga Fault Zone, the Rialto-Colton Fault, the Red Hill Fault, the San Jose Fault, and the Chino Fault – are at least in part responsible for the uplift of the surrounding mountains and the depression of Chino Basin. The bottom of the basin – the effective base of the freshwater aquifer – consists of impermeable sedimentary and igneous bedrock formations that are exposed at the surface in the surrounding mountains and hills. Sediments eroded from the surrounding mountains have filled Chino Basin to provide the reservoirs for groundwater. In the deepest portions of Chino Basin, these sediments are greater than 1,000 ft thick.

The major faults also are significant in that they are known barriers to groundwater flow within the aquifer sediments and, hence, define some of the external boundaries of the basin by influencing the magnitude and direction of groundwater flow. The location of the major faults and their spatial relation to Chino Basin are shown in Figure 2-1. These faults, their effects on groundwater movement, and the hydrogeology of the general Chino Basin area have been documented by various entities and authors (Eckis, 1934; Gleason, 1947; Burnham, 1953; MacRostie and Dolcini, 1959; Dutcher & Garrett, 1963; Gosling, 1966; DWR, 1970; Woolfenden and Kadhim, 1997).

Clearly, there have been numerous past studies of the geology and hydrogeology of the Chino Basin, but typically these studies have been general in content or of local extent. Very few of these studies addressed the three-dimensional variability of the aquifer-system sediments and the groundwater hydraulics across the entire Chino Basin.

2.2 Activities and Accomplishments to Date

Watermaster is committed to a more thorough characterization and understanding of Chino Basin hydrogeology to support its many scientific investigations and management programs. Since 2002, three investigations to support OBMP-related programs have improved the hydrogeologic understanding of Chino Basin. These investigations and their related programs are:

- Groundwater modeling investigation to predict the effects of various Dry-Year Yield program alternatives on groundwater levels and quality
- Hydrogeologic characterization of southern Chino Basin to locate proposed monitoring wells to support the Hydraulic Control Monitoring Program
- Subsidence investigation to support the Management Zone 1 Interim Monitoring Program

2.3 Results of Hydrogeologic Investigations

The hydrogeologic results of the investigations listed above are:

2.3.1 Stratigraphy

The stratigraphy of Chino Basin is divided into two natural divisions: (1) the pervious formations that comprise the groundwater reservoirs are termed the water-bearing sediments and (2) the less pervious formations that enclose the groundwater reservoirs are termed the consolidated bedrock. The consolidated bedrock is further differentiated as (a) metamorphic and igneous rocks of the basement complex, overlain in places by (b) consolidated sedimentary rocks. The water-bearing sediments overlie the consolidated bedrock, with the bedrock formations coming to the surface in the surrounding hills and highlands. Below, these geologic formations are described in stratigraphic order, the oldest formations first.

{It should be noted that the terms used throughout this section to describe bedrock, such as "consolidated," "non-water-bearing," and "impermeable," are used in a relative sense. The water content and permeability of these bedrock formations, in fact, is not zero. However, the primary point is that the permeability of the geologic formations in the areas flanking the basin is much less than the aquifers in the groundwater basin.}

2.3.1.1 Consolidated Bedrock

The consolidated bedrock formations of the Chino Basin area include the basement complex that is comprised of crystalline igneous and metamorphic rocks of pre-Tertiary age, the marine sedimentary and volcanic strata of late Cretaceous to late Tertiary age, and the continental deposits of late Pliocene to middle-Pleistocene age. Figure 2-2 shows the surface outcrops of the consolidate bedrock formations that surround Chino Basin. Note that the basement complex is the exposed bedrock north and southeast of the Chino Basin. Consolidated sedimentary rocks are the exposed bedrock west of Chino Basin.

The bedrock formations also occur at depth, underlying the water-bearing sediments of Chino Basin. Pervious strata or fracture zones in the bedrock formations may yield water to wells locally; however, the storage capacity is typically inadequate for sustained production. Figure 2-2 shows the contact between the bedrock formations and the water-bearing sediments as equal elevation contour lines – referred to herein as the base of the freshwater aquifer. The contours were originally generated by DWR (1970) and modified based on work performed for this study. Note that the base of the freshwater aquifer forms an irregular bowl-shaped depression, with its deepest areas located in the central portions of Chino Basin.

Eckis (1934) speculated that the contact between the consolidated bedrock and the water-bearing sediments is unconformable, as indicated by an ever-present weathered zone in the consolidated bedrock directly underlying the contact with the water-bearing sediments. This observed relationship suggests that the consolidated bedrock in the Chino Basin area was undergoing erosion prior to deposition of the water-bearing sediments.

Well boreholes have penetrated the various bedrock formations in Chino Basin. Figure 2-2 shows the locations of these boreholes, and the type of bedrock penetrated. Much like the bedrock surface exposures that surround Chino Basin, the basement complex is typically the bedrock formation first penetrated on the east side of Chino Basin, and sedimentary rocks are typically the bedrock formations first penetrated on the west side of Chino Basin. The nature of the buried contact between the basement complex and the sedimentary bedrock is largely unknown, but is likely an angular unconformity or a fault contact, and strikes north-south through the central portions of Chino Basin.

The general character of the consolidated bedrock formations is known from drillers' logs and surface outcrops, and is described below.

Basement Complex. The basement complex consists of deformed and re-crystallized metamorphic rocks that have been invaded and displaced in places by huge masses of granitic and related igneous rocks. The intrusive granitic rocks, which make up most of the basement complex, were emplaced about 110 million years ago in the late Middle Cretaceous (Larsen, 1958). These rocks were subsequently uplifted and exposed by erosion, as presently seen in the San Gabriel Mountains and in the uplands of the Perris block (Jurupa Mountains and La Sierra Hills). They have been the major source of detritus to the younger sedimentary formations, in particular, to the water-bearing sediments of Chino Basin.

Undifferentiated Pre-Pliocene Formations. Outcropping along the western margin of Chino Basin (in the Chino and Puente Hills) are consolidated sedimentary and volcanic rocks that unconformably overlie the basement complex. They consist of well-stratified marine sandstones, conglomerates, shales, and interlayered lava flows that range in age from late Cretaceous to Miocene. According to Durham and Yerkes (1965), this sequence reaches a total stratigraphic thickness of more than 24,000 feet in the Puente Hills and is down-warped more than 8,000 feet below sea level in the Prado Dam area. Wherever mapped, these strata are folded and faulted and in most places dip from 20 to 60 degrees.

Plio-Pleistocene Formations. Overlying the older consolidated bedrock formations is a thick series of semi-consolidated clays, sands, and gravels of marine and non-marine origin. These sediments have been named the Fernando Group (Eckis, 1934), and outcrop in two general locations of the study area: the Chino Hills on the western margin of Chino Basin and in the San Timoteo Badlands southeast of Chino Basin. In surface outcrop, the entire Group is mapped as consolidated bedrock for this study, and is likely the first bedrock penetrated in southwest Chino Basin. However, the upper portion of the Fernando Group is more permeable than the lower portion, and thus represents in the subsurface, a gradual transition from the non-water-bearing consolidated rocks to the water-bearing sediments. Furthermore, the upper Fernando sediments are similar in texture and composition to the overlying water-bearing sediments, which complicate the distinction between the formations from borehole data.

2.3.1.2 Water-Bearing Sediments

Beginning in the Pleistocene and continuing to the present, an intense episode of faulting depressed the Chino Basin area and uplifted the surrounding mountains and hills. Detritus eroded from the mountains were transported and deposited in Chino Basin atop the consolidated sedimentary and crystalline bedrock as interbedded, discontinuous layers of gravel, sand, silt, and clay to form the water-bearing sediments.

The water-bearing sediments can be differentiated into the Older Alluvium of Pleistocene age and Younger Alluvium of Holocene age. The general character of these formations is known from driller's logs and surface outcrops, and is described below.

Older Alluvium. The Older Alluvium varies in thickness from about 200 feet thick near the southwestern end of Chino Basin to over 1,100 feet thick southwest of Fontana, and averages about 500 feet throughout the Basin. It is commonly distinguishable in surface outcrop by its red-brown or brick-red color, and is generally more weathered than the overlying Younger Alluvium. Pumping capacities of wells completed in the Older Alluvium range between 500 and 1,500 gallons per minute (gpm). Capacities exceeding 1,000 gpm are common, with some modern production wells test-pumped at over 4,000 gpm (*e.g.*, Ontario Wells 30 and 31 in southeastern Ontario). In the southern part of the Basin where sediments tend to be more clayey, wells generally yield 100 to 1,000 gpm.

Younger Alluvium. The Younger Alluvium occupies streambeds, washes, and other areas of recent sedimentation. Oxidized particles tend to be flushed out of the sediments during transport, and the Younger Alluvium is commonly light yellow, brown, or gray. It consists of rounded fragments derived from erosion of bedrock, from reworked Older Alluvium, and from the mechanical breakdown of larger fragments within the Younger Alluvium itself. The Younger Alluvium varies in thickness from over 100 feet near the mountains to a just few feet south of Interstate 10, and generally covers most of the north half of the Basin in undisturbed areas. The Younger Alluvium is not saturated and thus does not yield water directly to wells. Water percolates readily in the Younger Alluvium and most of the large spreading basins are located in the Younger Alluvium.

2.3.2 Groundwater Occurrence and Movement

The physical nature of the groundwater reservoirs of Chino Basin is described below with regard to basin boundaries, recharge, groundwater flow, discharge, distinct aquifer systems, hydrostratigraphy, aquifer properties, and internal faults.

2.3.2.1 Chino Basin Boundaries

The physical boundaries of the Chino Basin are shown on Figure 2-1 and include:

- **Red Hill Fault to the north.** The Red Hill Fault is a recently active fault evidenced by recognizable fault scarps such as Red Hill at the extreme southern extent of the fault near Foothill Boulevard. The fault is a known barrier to groundwater flow and groundwater elevation differences on the order of several hundred feet on opposite sides of the fault are typical (Eckis, 1934; DWR, 1970). Groundwater seeps across the Red Hill Fault as underflow from the Cucamonga Basin to the Chino Basin, especially during periods of high groundwater elevations within the Cucamonga Basin.
- **San Jose Fault to the northwest.** The San Jose Fault is known as an effective barrier to groundwater flow with groundwater elevation differences on the order of several hundred feet on opposite sides of the fault (Eckis, 1934; DWR, 1970). Groundwater seeps across the San Jose Fault as underflow from the Claremont and Pomona basins to the Chino Basin, especially during periods of high groundwater elevations within the Pomona and Claremont Heights basins.
- **Groundwater divide to the west.** A natural groundwater divide near Pomona separates the Chino Basin from the Spadra Basin in the west. The divide, which extends from the eastern tip of the San Jose Hills southward to the Puente Hills, is produced by groundwater seepage from the Pomona Basin across the southern portion of the San Jose Fault (Eckis, 1934).
- **Puente Hills/Chino Hills to the southwest.** The Chino Fault extends from the northwest to the southeast along the western boundary of the Chino Basin. It is, in part, responsible for uplift of the Puente Hills and Chino Hills, which form a continuous belt of low hills west of the fault. The Chino and Puente Hills, primarily composed of consolidated sedimentary rocks, form an impermeable barrier to groundwater flow.
- **Flow system boundary with Temescal basin to the south.** Comparison of groundwater elevation contour maps over time suggests a consistent distinction between flow systems within the lower Chino Basin and Temescal Basin. As groundwater within Chino Basin flows southwest into the Prado Basin area, it converges with groundwater flowing northwest out of the Temescal Valley (Temescal Basin). These groundwaters commingle and flow southwest toward Prado Dam and can rise to become surface

water in Prado Basin. This area of convergence of Chino and Temescal groundwaters is indistinct and probably varies with changes in climate and production patterns. As a result, the boundary that separates Chino Basin from Temescal Basin was drawn along the legal boundary of the Chino Basin (Chino Basin Municipal Water District v. City of Chino, *et al*., San Bernardino Superior Court, No. 164327).

- **La Sierra Hills to the south.** The La Sierra Hills outcrop south of the Santa Ana River and are primarily composed of impermeable bedrock and form a barrier to groundwater flow between the Chino Basin and the Arlington and Riverside basins.
- **Shallow bedrock at the Riverside Narrows to the southeast.** Between the communities of Pedley and Rubidoux, the impermeable bedrock that outcrops on either side of the Santa Ana River narrows considerably. In addition, the alluvial thickness underlying the Santa Ana River thins to approximately 100 feet or less (*i.e.*, shallow bedrock). This area of narrow and shallow bedrock along the Santa Ana River is commonly referred to as the Riverside Narrows. Groundwater upgradient of the Riverside Narrows within the Riverside basins is forced to the surface to become rising water within the Santa Ana River (Eckis, 1934). Downstream of the Riverside Narrows, the bedrock configuration widens and deepens, and surface water within the Santa Ana River can infiltrate to become groundwater in Chino Basin.
- **Jurupa Mountains and Pedley Hills to the southeast.** The Jurupa Mountains and Pedley Hills are primarily composed of impermeable bedrock and form a barrier to groundwater flow that separates the Chino Basin from the Riverside basins.
- **Bloomington Divide to the east.** A flattened mound of groundwater exists beneath the Bloomington area as a likely result of groundwater flow from the Rialto-Colton basin through a gap in the Rialto-Colton Fault north of Slover Mountain (Dutcher and Moyle, 1963; Gosling, 1966; DWR, 1970). This mound of groundwater extends from the gap in the Rialto-Colton Fault to the southwest towards the northeast tip of the Jurupa Mountains. Groundwater to the northwest of this divide recharges the Chino Basin and flows westward staying north of the Jurupa Mountains. Groundwater southeast of the divide recharges the Riverside basins and flows southwest towards the Santa Ana River.
- **Rialto-Colton Fault to the northeast.** The Rialto-Colton Fault separates the Rialto-Colton Basin from the Chino and Riverside basins. The fault is a known barrier to groundwater flow along much of its length – especially in its northern reaches (south of Barrier J) where groundwater elevations can be hundreds of feet higher within the Rialto-Colton Basin (Dutcher and Garrett, 1963; DWR, 1970; Woolfenden and Kadhim, 1997). The disparity in groundwater elevations across the fault decreases to the south. To the north of Slover Mountain, a gap in the Rialto-Colton Fault exists. Groundwater within the Rialto-Colton Basin passes through this gap to form a broad groundwater mound (divide) in the vicinity of Bloomington and, hence, is called the Bloomington Divide (Dutcher and Moyle, 1963; Gosling, 1966; DWR, 1970).
- **Extension of the Rialto-Colton Fault north of Barrier J.** Little well data exist to support the extension of the Rialto-Colton Fault north of Barrier J (although hydraulic gradients are steep through this area). Groundwater flowing south out of Lytle Creek Canyon, in part, is deflected by Barrier J and likely flows across the extension of the Rialto-Colton Fault north of Barrier J and into the Chino Basin.

2.3.2.2 Groundwater Recharge, Flow, and Discharge

Predominant recharge to the groundwater reservoirs of Chino Basin is from percolation of direct precipitation and infiltration of stream flow within tributaries exiting the surrounding mountains and hills and within the Santa Ana River. The following is a list of all potential sources of recharge in Chino Basin:

- Infiltration of flow (and, locally, imported water) within unlined stream channels overlying the basin.

- Infiltration of storm water flow and municipal wastewater discharges within the channel of the Santa Ana River.
- Underflow from the saturated sediments and fractures within the bounding mountains and hills.
- Artificial recharge at spreading grounds of storm water, imported water, and recycled water.
- Underflow from seepage across the bounding faults, including the Red Hill Fault (from Cucamonga Basin), the San Jose Fault (from the Claremont Heights and Pomona basins), and the Rialto-Colton Fault (from the Rialto-Colton Basin).
- Intermittent underflow from the Temescal Basin.
- Deep percolation of precipitation and returns from use.

In general, groundwater flow mimics surface drainage patterns: from the forebay areas of high elevation (areas in the north and east flanking the San Gabriel and Jurupa Mountains) towards areas of discharge near the Santa Ana River within Prado Flood Control Basin. Figure 2-3 is a groundwater elevation contour map for Fall 2000 that shows this general groundwater flow pattern (perpendicular to the contours). Comparing this contour map to groundwater elevation contour maps from other periods shows similar flow paths, indicating consistent flow systems within Chino Basin (WEI, 2000a).

While considered one basin from geologic and legal perspectives, the Chino Basin can be hydrologically subdivided into at least five flow systems that act as separate and distinct hydrologic units. Each flow system can be considered a management zone. Each management zone has a unique hydrology, and water resource management activities that occur in one management zone have limited impact on the other management zones.

Figure 2-3 shows the location of the five management zones in Chino Basin that were developed during the TIN/TDS Study (WEI, 2000a) of which Watermaster, the Chino Basin Water Conservation District (CBWCD), and the Inland Empire Utilities Agency (IEUA) were study participants. Nearing the southwestern (lowest) portion of the basin, these flows systems become less distinct as all groundwater flow within Chino Basin converges and rises beneath Prado Basin. In detail, groundwater discharge throughout Chino Basin primarily occurs via:

- Groundwater production.
- Rising water within Prado Basin (and potentially other locations along the Santa Ana River depending on climate and season).
- Evapotranspiration within Prado Basin (and potentially other locations along the Santa Ana River depending on climate and season) where groundwater is near or at the ground surface.
- Intermittent underflow to the Temescal Basin.

2.3.2.3 Aquifer Systems

The saturated sediments within Chino Basin comprise one groundwater reservoir, but the reservoir can be sub-divided into distinct aquifer systems based on the physical and hydraulic characteristics of the aquifer-system sediments and the contained groundwater. These aquifer systems include a shallow aquifer system and at least one deep aquifer system.

The sediments that comprise the shallow aquifer system are saturated in the southern portion of Chino Basin, but are unsaturated in the northern forebay regions where they provide a thick vadose zone for percolating groundwater (see Figure 2-3). The sediments that comprise the deep aquifer system are always at least partially saturated, but pinch out near bedrock outcrops and in the southern-most portion of Chino Basin. Section 2.3.2.4—*Hydrostratigraphy* describes and illustrates the detailed configurations of the shallow and deep aquifer systems.

The shallow aquifer system is generally characterized by unconfined to semi-confined groundwater conditions, high permeability within its sand and gravel units, and high concentrations of dissolved solids and nitrate. The deep aquifer system is generally characterized by confined groundwater conditions, lower permeability within its sand and gravel units, and lower concentrations of dissolved solids and nitrate. Where both aquifer systems are present and saturated, hydraulic head tends to be higher in the shallow aquifer system, indicating a downward vertical hydraulic gradient.

To illustrate the above generalizations, Figure 2-4 shows the location of Well 1A and Well 1B owned by the City of Chino Hills. These two wells are physically located within 30 feet of each other on the west side of Chino Basin, but their non-pumping water-level time histories are dramatically different. Figure 2-5 is a water-level time history of Well 1A (perforated within the shallow aquifer system), which maintains a relatively stable water level that fluctuates annually by about 20 feet (and a maximum of about 50 feet), probably in response to seasonal production and recharge. Depth to water averages about 80 feet-bgs. Comparatively, Well 1B (perforated within the deep aquifer system) displays a wildly fluctuating piezometric level that can vary seasonally by as much as 250 feet. Depth to water in Well 1B averages about 220 feet-bgs. The water level fluctuations observed in the deep aquifer system are typical of confined groundwater conditions where small changes in storage can generate large changes in piezometric levels.

Wells 1A and 1B also display significant differences in water quality. Nitrate concentrations in 1A and 1B averaged 7 mg/L and 1 mg/L, respectively from 1997 to 2002. Total dissolved solids concentrations in 1A and 1B averaged 288 mg/L and 175 mg/L, respectively from 1997 to 2002. Arsenic concentrations are relatively high in the deep aquifer system (average of 66 micrograms per liter [µg/L] in Well 1B from 1997 to 2002 compared to non-detectable in Well 1A). Similar water quality disparities have been noted between deep and shallow groundwater in the area of the Chino-1 Desalter well field (see Figure 2-4) and its eastward expansion currently under construction (GSS, 2001; Dennis Williams, GSS, pers. comm., 2003).

Also shown in Figure 2-4 – near Wells 1A and 1B – is Watermaster's recently constructed Ayala Park Extensometer facility. At this facility are 11 piezometers with screens of 5-20 feet in length that were completed at various depths that range from 139-1,229 ft-bgs. Slug tests were performed at a number of these piezometers to, among other objectives, determine the permeabilities of the sediments at various depths within the total aquifer-system. In general, the piezometers in the shallow aquifer system (less than about 350 ft-bgs) display relatively high hydraulic conductivities of 20 to 27 ft/day. The piezometers within the deep aquifer system display relatively low hydraulic conductivities of 1.6 to 0.5 ft/day. A notable exception is a piezometer completed in gravelly sand in the uppermost portion of the deep aquifer system (438-448 ft-bgs) that displays a relatively high hydraulic conductivity of 48 ft/day, indicating the existence of some higher permeability zones within the deep aquifer system.

The distinction between aquifer systems is most pronounced within the west-southwest portions of Chino Basin. This is likely because of the relative abundance of fine-grained sediments in the southwest (multiple layers of clays and silts). Groundwater flowing from high-elevation forebay areas in the north and east become confined beneath these fine-grained sediments in the west-southwest, and effectively isolate the shallow aquifer system from the deep aquifer system(s).

The three-dimensional extent of these fine-grained sedimentary units and their effectiveness as confining layers has never been mapped in detail across Chino Basin. However, the following data, shown on Figure 2-4, can be used to estimate the lateral extent of these units:

- Historical flowing-artesian conditions were mapped in the early 1900s in the southwest portion of Chino Basin (Mendenhall, 1905, 1908; Fife *et al*., 1976), which indicates the existence of confining layers in these areas.
- Remote sensing studies were conducted to analyze land subsidence in Chino Basin (Peltzer, 1999a, 1999b). These studies employed Synthetic Aperture Radar Interferometry (InSAR), which utilizes radar imagery from an Earth-orbiting spacecraft to map ground surface deformation. InSAR has indicated the occurrence of persistent subsidence across the western portion of Chino Basin from 1992 to 2000 – likely due to the compaction of fine-grained sediments as a result of lower pore pressures within the aquifer system (WEI, 2002). The southern extent of persistent subsidence is currently unknown because InSAR data are difficult to obtain in areas of agricultural land uses, but may extend southward to encompass the historical artesian area.

North and east of these areas, the distinction between aquifer systems is less pronounced because:

- the fine-grained layers in the west-southwest thin and/or pinch-out to the north and east, and
- much of the shallow aquifer system is unsaturated in the forebay regions of Chino Basin.
- geologic descriptions from driller's logs in Chino Basin confirm the predominance of fine-grained sediments in the west-southwest portion of Chino Basin, and the predominance of coarser-grained sediments in the north and east portions of Chino Basin. These observations are described and illustrated in more detail in the following two Sections (2.3.2.4 – *Hydrostratigraphy* and 2.3.2.5 – *Aquifer Properties*).

2.3.2.4 Hydrostratigraphy

As described in Section 2.3.1.2, the water-bearing sediments of Chino Basin are composed of interbedded, discontinuous layers of gravel, sand, silt, and clay. These layers and their geometries are too numerous and complex to characterized on a basin-wide scale. A simplified geologic model was created to characterize the three-dimensional distribution of the water-bearing sediments and their hydrogeologic properties for input to a numerical groundwater flow model.

In order to develop this conceptual model, 10 hydrogeologic cross-sections were constructed across Chino Basin. The plan-view locations of these cross-sections are shown in Figure 2-6 and the profile-view cross-sections are shown in Figures 2-7 through 2-14. Plotted on these cross-sections are selected well and borehole data, including borehole lithology, short-normal resistivity logs, well casing perforations, and water levels.

Through analyses of these cross-sections and other hydrogeologic data, the water-bearing sediments were grouped into three hydrostratigraphic units (layers):

- Layer 1 consists of the upper 200-300 feet of sediments, and is generally representative of the shallow aquifer system (see Section 2.3.2.3). Layer 1 sediments are typically coarse-grained (sand and gravel layers) and, where saturated, transmit large quantities of groundwater to wells due to high hydraulic conductivities. On the west side of Chino Basin, Layer 1 sediments are composed of a greater fraction of finer-grained sediments (silt and clay layers), especially in the uppermost 100 feet.

- Layer 2 consists of 200-500 feet of sediments underlying Layer 1, and is representative of the upper portion of the deep aquifer system (see Section 2.3.2.3). On the west side of Chino Basin, Layer 2 sediments are primarily fine-grained (silt and clay layers) with few interbedded sand and gravel layers. Layer 2 sediments become increasingly coarse-grained in the northern and eastern portions of Chino Basin, and as a result, the distinction between Layer 1 and Layer 2 sediments becomes less pronounced.
- Layer 3 consists of 100-500 feet of sediments underlying Layer 2, and is representative of the lower portion of the deep aquifer system (see Section 2.3.2.3). Layer 3 sediments are confined to the deepest (central) portions of Chino Basin, and pinch-out toward the basin margins. Layer 3 sediments are typically coarse-grained (sand and gravel layers), but due to their greater age, consolidation, and state of weathering, these sediments have lower permeability than the coarse-grained sediments of Layer 1.

The top and bottom elevations of the three layers were brought into a Geographic Information System (GIS) as point values. These elevation values were then used as input to create a series of grids that represent the three-dimensional conceptual model of the water-bearing sediments of Chino Basin.

2.3.2.5 Aquifer Properties

The aquifer properties of critical importance for this study are effective porosity (specific yield) and hydraulic conductivity.

Effective Porosity. The effective porosity of the water-bearing sediments in Chino Basin was estimated through the analysis of lithologic descriptions from driller's logs. Watermaster maintains a library of driller's logs of all known well boreholes that have been drilled in Chino Basin. The lithologic descriptions from the driller's logs were input into a relational database along with corresponding US Geological Survey (USGS) estimates of effective porosity by sediment type (Johnson, 1967).

Effective porosity was averaged at each borehole for each layer. These values were plotted and gridded using a Kriging method within the ArcGIS Spatial Analyst extension for each layer, and are shown in Figures 2-15 through 2-17.

Figure 2-15 displays average effective porosity for Layer 1. Average effective porosities are highest, ranging up to 20 percent, in the northern (Upland) and eastern (Fontana) portions of Chino. A belt of similarly high effective porosity runs north of and parallels the Santa Ana River near Norco. This belt may represent coarse-grained sediments deposited by an ancestral Santa Ana River. Average effective porosities are lowest, ranging down to 6 percent, on the west side of Chino Basin (Pomona and Chino). This area of relatively low effective porosity overlaps the historical artesian area, and may represent fine-grained sediments that historically acted as confining layers.

Figure 2-16 displays average effective porosity for Layer 2. As with Layer 1, average effective porosities are highest, ranging up to 20 percent, in the northern (Upland) and eastern (Fontana) portions of Chino Basin. A belt of similarly high effective porosity runs north of the Jurupa Mountains from Fontana to Norco. As with Layer 1, this belt may represent coarse-grained sediments deposited by an ancestral Santa Ana River. Average effective porosities are lowest, ranging down to 3 percent, on the west side of Chino Basin (Pomona, Chino, and west Ontario). This area of relatively low effective porosity overlaps the historical artesian area and the area of historical subsidence as indicated by InSAR, and may represent fine-grained sediments that have experienced compaction due to reduced pore pressures.

Figure 2-17 displays average effective porosity for Layer 3. Again, the primary observation is coarser-grained sediments comprising the east side of Chino Basin, and finer-grained sediments comprising the west side.

Hydraulic Conductivity. The hydraulic conductivity of water-bearing sediments is a measure of its capacity to transmit water. Generally, sands and gravels have high hydraulic conductivities while clays and silts have low hydraulic conductivities. Since the effective porosity Figures (Figure 2-15 through 2-17) were created from lithologic descriptions of well bore cuttings, they also qualitatively indicate the distribution of hydraulic conductivity of the water-bearing sediments. On average, hydraulic conductivities are highest in the northern (Upland) and eastern (Fontana) portions of Chino Basin. A belt of similarly high hydraulic conductivity runs north of the Jurupa Mountains from Fontana to Norco. Average hydraulic conductivities are lowest on the west side of Chino Basin (Pomona, Chino, and west Ontario). Generally, hydraulic conductivities decrease with depth because deeper sediments typically have experienced a greater degree of secondary alteration (*e.g.* weathering of feldspars to clay minerals, cementation of pore space, *et cetera*).

2.3.2.6 Internal Faults

- Barrier “J.” Barrier "J" appears to be a significant impediment to groundwater flow in the Rialto Basin. However, there is no conclusive evidence that Barrier "J" acts as barrier in the Chino Basin. The displacement in the effective base of the aquifer in the Chino Basin and barrier effects in Rialto Basin suggest potential for Barrier "J" to be a groundwater barrier in the Chino Basin.
- Central Avenue Fault. The effect of the Central Avenue fault on groundwater flow is unknown. The sediments west of the fault are generally finer than the sediments east of the fault and it unclear if the relatively poor production capabilities of the area west of the fault are the result of marginal aquifer properties, the Central Avenue fault acting as a hydrologic barrier, or both.

2.3.3 Southern Chino Basin

2.3.3.1 Previous Investigations

As noted in Section 2.1, the general hydrogeology of the Chino Basin area has been documented by various entities and authors (Eckis, 1934; Gleason, 1947; Burnham, 1953; MacRostie and Dolcini, 1959; Dutcher & Garrett, 1963; Gosling, 1966; DWR, 1970; Woolfenden and Kadhim, 1997). However, relatively few investigations have been focused on the southern portion of the Chino Basin. Notable exceptions include:

- French (1972) estimated groundwater outflow from Chino Basin. He utilized Darcy’s equation to calculate outflow through a cross-sectional area of water-bearing sediments that extended from the Puente Hills to the Pedley Hills (approximately parallel to Pine Avenue, which is about one mile south of the Chino-1 Desalter well field). To construct the cross-section, he utilized existing borehole data, new borehole data from test holes drilled for the study, and geophysical data (seismic and gravity traverses). To estimate permeability of the sediments along the cross-section, he utilized aquifer test data and specific capacity data from nearby wells. To estimate the hydraulic gradient perpendicular to the cross-section, he constructed piezometric contour maps.

To summarize his hydrogeologic findings along this cross-section: east of Archibald Avenue, the base of the water-bearing sediments is the buried irregular surface of the basement complex. The maximum thickness of the water-bearing sediments in this area is about 300 feet. West of Archibald Avenue, the basement complex is depressed by thousands of feet – likely by fault displacement. The base of the water-bearing sediments in this area occurs within the sedimentary bedrock formations that overlie the basement complex, and is recognized as a vertical transition to very low permeability sediments. The maximum thickness of the water-bearing sediments in this area is about 600 feet. The permeability of the water-bearing sediments generally increases from west to east along the cross-section, and generally decreases with depth. Below a depth of about 350 ft-bgs, French notes a decrease in permeability by at least an order of magnitude in comparison to shallower aquifer sediments.

- Fox (1989) documented a test hole and production well drilling/construction project that was conducted for the City of Chino Hills. In this effort, a total of 14 boreholes were drilled within the City of Chino – located about 2 to 3 miles northwest of the Chino-1 Desalter well field. Ten of these boreholes were completed and tested as production wells. Fox (1990) also conducted a hydrogeologic investigation of a proposed well field site for the City of Chino Hills located just north of the Chino-1 Desalter well field. He named this site the Euclid Avenue Well Field, which included the area bounded by Euclid Avenue, Merrill Avenue, Grove Avenue, and Riverside Drive. In both publications, Fox documents the existence of distinct shallow and deep aquifer systems separated by a laterally extensive sequence of fine-grained sediments. Nitrate concentrations were stated to be significantly higher in the shallow aquifer system, commonly exceeding federal MCL (10 mg/L as nitrogen). Fox also stated that the clay content of the total aquifer system in southwestern Chino Basin was relatively high, thus limiting the productive capacity of water wells drilled in this locale.
- Montgomery Watson (1999) conducted the drilling and construction of the Chino-1 Desalter Well Field. None of the well boreholes penetrated basement complex – the deepest borehole stopping at 700 ft-bgs within sediments of probable Tertiary age. Much of the basic data collected and published by Montgomery Watson was utilized in this investigation.
- Geoscience (2003) conducted the drilling and construction of three wells that will increase the number of Chino-1 Desalter wells from 11 to 14. These wells are located just east of the Chino-1 Desalter well field (east of Archibald Avenue). Two of these wells penetrated basement complex at relatively shallow depths (310 to 360 ft-bgs), confirming the conceptual model of southern Chino Basin as described by French (1972). Spinner tests were performed at these wells, which help to define the transition between the shallow and deep aquifer systems at about 250-300 ft-bgs at this locale (see Section 2.3.3.2 below).

2.3.3.2 Hydrostratigraphy

Three detailed hydrostratigraphic cross-sections were constructed across the southern Chino Basin. The objective of this exercise was to better characterize and document the hydrogeology in this region, which will aid in the placement and construction details of proposed monitoring wells. Data to construct these cross-sections came from all previous studies and well construction projects (see Section 2.3.3.1), as well as Watermaster's comprehensive water well database, and includes:

- Borehole lithologic descriptions from well driller's logs
- Borehole geophysical logs
- Spinner logs
- Well construction information
- Water level data
- Slug test data

- Specific capacity data

Figure 2-18 shows the map view locations of the three cross-sections. Cross-sections A-A'-A" and B-B' both are aligned west-east through the Chino-1 Desalter well field. However, cross-section A-A'-A" extends from the Desalter well field to the northwest to include hydrogeologic data that are currently being studied as part of Watermaster's subsidence monitoring efforts. Cross-section C-C' is aligned north-south and bisects the Desalter well field.

The sub-sections below describe the bottom of the aquifer-system and the hydrostratigraphic layering – which are shown on all three cross-sections – as well as the details of each cross-section.

Bottom of the Aquifer-System. A common observation at wells in this region that were drilled to significant depths (>500 ft) is the penetration of dark gray to black clays toward the bottom of the boreholes. Fox (1989) interpreted these black clays to be part of the sedimentary bedrock formations that comprise the Chino and Puente Hills directly to the west (see Figure 2-18). Slug test and specific capacity data (discussed below) collected from wells that are perforated below these black clays support Fox's bedrock interpretation (*e.g.* very low hydraulic conductivities and specific capacities). Where encountered, the top of the black clays are interpreted as the bottom of the aquifer-system. However, unpublished data from Watermaster's subsidence monitoring efforts indicate that the sedimentary bedrock below the black clays is water-bearing and is in hydraulic connection with the overlying aquifer-system.

East of about Archibald Avenue, well boreholes that penetrate bedrock encounter crystalline rocks, similar to the igneous and metamorphic rocks that outcrop in the La Sierra, Pedley, and Jurupa Hills located to the south and east (see Figure 2-18).

Hydrostratigraphic Layering. As discussed in Section 2.3.3.2 – *Hydrostratigraphy*, the aquifer-system sediments were grouped into three hydrostratigraphic layers to formulate the conceptual model for a basin-wide computerized groundwater flow model (WEI, 2003). The detailed work in southern Chino Basin (cross-sections and piezometric maps in the southern Chino Basin) did not significantly change the conceptual model and hydrostratigraphic layering in this region:

- In the vicinity of the Chino-1 Desalter well field, Layer 1 consists of the upper 200-250 feet of sediments, and is generally representative of the shallow aquifer-system (see Section 2.3.2.3). Layer 1 sediments are predominantly coarse-grained (sand and gravel layers) with interbedded silt and clay layers and, where saturated, transmit large quantities of groundwater to wells due to high hydraulic conductivities. Groundwater exists under unconfined to semi-confined conditions in Layer 1. Water quality in Layer 1 is generally poor, with relatively high concentrations of TDS and nitrate.
- In the vicinity of the Chino-1 Desalter well field, Layer 2 consists of 50-250 feet of sediments underlying Layer 1, and is representative of the deep aquifer system (see Section 2.3.2.3). Layer 2 sediments are predominantly fine-grained (silt and clay layers) with interbedded sand and gravel layers. As the bedrock surface rises to shallower depths from northwest to southeast, the Layer 2 sediment package becomes thinner and pinches out to the south and to the east. Groundwater exists under semi-confined to confined conditions in Layer 2. Water quality in Layer 2 is generally better than in Layer 1, with relatively low concentrations of TDS and nitrate.
- In the vicinity of the Chino-1 Desalter well field, the Layer 3 sediment package, also representative of the deep aquifer system (see Section 2.3.2.3), is very thin (<50 ft) or non-existent.

Cross-Section A-A'-A". Figure 2-19 (an E-sized drawing in an Acrobat portable document format [pdf] format on CD only) displays the profile view of cross-section A-A'-A". Where available, specific capacity and slug test data are shown on this cross-section for selected wells.

The westernmost well along A-A'-A" is Chino Hills 16, a deep municipal production well (960 ft) with a long and deep screened interval (430-940 ft-bgs). The lithologic and geophysical data collected at this well borehole indicate that Layer 2 is comprised almost entirely of clay-rich sediments. A relatively low specific capacity of 7.5 gpm/ft is consistent with its perforated interval that spans the low permeability sediments of Layer 2, Layer 3 and the upper 200 ft of sedimentary bedrock.

Two boreholes containing multiple piezometers at the Ayala Park extensometer facility are located about 7,000 ft to the southwest of Chino Hills 16. The black clays are first encountered at this site at about 975 ft-bgs, indicating an eastward thickening of the aquifer-system sediments. At this location, Layer 2 has become interbedded with coarser-grained sediments (sands and gravels). Several piezometers, completed at various depths, were slug tested to obtain estimates of hydraulic conductivity. As expected, the Layer 1 sediments have higher hydraulic conductivities (20-27 ft/day) compared to deeper sediments. However, one thin gravelly sand layer in Layer 2 displayed a relatively high hydraulic conductivity of 48 ft/day, indicating the existence of some very permeable layers, at least in the upper portions of the deep aquifer system. The hydraulic conductivity of the sedimentary bedrock is a very low 0.5 ft/day.

About two miles to the southeast of the Ayala Park extensometer (to A'), there are three deep production wells: YTS-3, and Chino-1 Desalter wells 1 and 4. The black clays are first encountered at the Desalter wells at about 510 ft-bgs, indicating an eastward thinning of the aquifer-system sediments from Ayala Park to the Desalter well field. Layer 3 sediments beneath the Desalter wells have pinched-out to practical zero thickness. However, Layer 1 and 2 sediments appear similar to Layer 1 and 2 sediments beneath Ayala Park. All three wells are perforated within the deep aquifer system (Layers 2, 3, and/or sedimentary bedrock), which is consistent with their very low specific capacities that range from 0.5 to 6.1 gpm/ft. All three wells were perforated within the deep aquifer system to capture groundwater of better quality – the Desalter wells 1 and 4 being "by-pass" wells for blending with treated water pumped from the shallow Desalter wells to the east.

From A' to A" the cross-section encounters test boreholes and production wells that pump shallow groundwater for treatment at the Chino-1 Desalter facility: from west to east, wells 5, 7, and 14. The black clays are encountered at progressively shallower depths from A' to well 7 (500 to 360 ft-bgs). Well 14 did not encounter the black clays, but instead encountered crystalline bedrock (granite) at a depth of about 500 ft-bgs. Desalter wells 13 and 15 (not shown on the cross-section, but located within 1,000 ft to the east and west of Well 14) penetrate crystalline bedrock at about 320 ft-bgs, which depicts an undulating crystalline bedrock surface in this region that gradually shallows to the east. This abrupt transition from sedimentary to crystalline bedrock is represented by an inferred fault that strikes north-south along Archibald Avenue with downward displacement on the west side of the fault. This interpretation is consistent with those advanced by French (1972; see Section 2.3.3.1). Within the overlying aquifer sediments, Layer 2 becomes thinner from A' to A" while Layer 1 becomes thicker. Wells 5, 7 and 14 are perforated within the shallow and deep aquifer system (Layers 1 and 2). Specific capacities at wells 5 and 7 are high (40 and 27 gpm/ft, respectively) compared to the deeper wells located to the west along A-A' (YTS-3 and Desalter wells 1 and 4), suggesting that the shallow aquifer system provides the majority of water to these wells. A spinner log at Well 14 supports this interpretation by demonstrating that approximately 80% of the groundwater pumped from this well originates from sediments within Layer 1 (Geoscience, 2003).

Cross-Section B-B' Figure 2-20 displays the profile view of cross-section B-B'. This cross-section is nearly identical to eastern portion of A-A'-A", except that Desalter Well 3 replaces Well 1 on the western edge of B-B' and Desalter Well 13 replaces Well 14 on the eastern edge. Neither well reveals new observations nor warrants changes of interpretations as described for A-A'-A".

Cross-section B-B' also shows water-level data, where available, at individual wells for Spring 2003. Also shown is the regional piezometric surface for Layer 1 as mapped and contoured for Spring 2003. This surface broadly undulates with piezometric lows centered around the Desalter wells that are perforated within the shallow aquifer system (wells 5 and 7). Also, note that the piezometric heads at wells perforated solely in the deep aquifer system (Desalter wells 3 and 4) are lower than the piezometric surface for the shallow system. This is a common observation in this region, especially along the western portions of B-B' and A-A'-A", due to the confined nature of the deep aquifer system where small changes in storage due to pumping result in relatively large drawdown of piezometric head. To the east, this observation is not as apparent due to 1) the progressive thinning of the deep aquifer sediments, 2) the progressive thickening of the shallow aquifer sediments, and 3) the lack of wells in the east that are perforated solely in the deep aquifer system.

Cross-Section C-C' Figure 2-21 displays the profile view of cross-section C-C' which is aligned north-south and bisects the Desalter well field just east of Grove Avenue. This cross-section shows the downward slope of the ground surface from north to south. Conversely, the black clays are penetrated in deep boreholes at increasingly shallower depths from north to south, depicting an upward slope of the bottom of the aquifer. As a result, the total aquifer system sediment package becomes thinner from north to south, with the deep aquifer system pinching-out just north of Chino-Corona Road.

Cross-section C-C' also shows water-level data, where available, at individual wells for Spring 2003. Also shown is the regional piezometric surface for Layer 1 as mapped and contoured for Spring 2003. This surface slopes from north to south along with the topographic surface, but becomes virtually flat as it encounters the Desalter wells that are perforated within the shallow aquifer system (wells 5 and 8).

2.3.4 MZ-1 Groundwater Barrier

One significant result of the subsidence investigations in MZ-1 is the discovery of a groundwater barrier in this region. The barrier exists within the deep (> 300 ft) aquifer-system sediments, and is aligned with the historic zone of ground fissuring in the City of Chino. Multiple lines of evidence support the existence of this barrier including:

- Aquifer stress test (pumping test) data
- Inverse analytical modeling of the pumping test data
- InSAR analyses
- Ground level survey data

See Section 5 for a detailed discussion of the MZ-1 barrier.

2.4 On-Going and Recommended Activities

Nine nested, multi-depth monitoring wells are being drilled in southern Chino Basin as part of the Hydraulic Control Monitoring Program. The drilling of these monitoring wells, and subsequent data collection, will be used to characterize the state of hydraulic control (see Section 8) and to improve the hydrogeologic characterization of this region.

Additional monitoring wells are currently being planned to support monitoring of recycled water recharge in the northern portions of Chino Basin. The drilling of these monitoring wells, and subsequent data collection, will improve the hydrogeologic characterization of this northern region as well.

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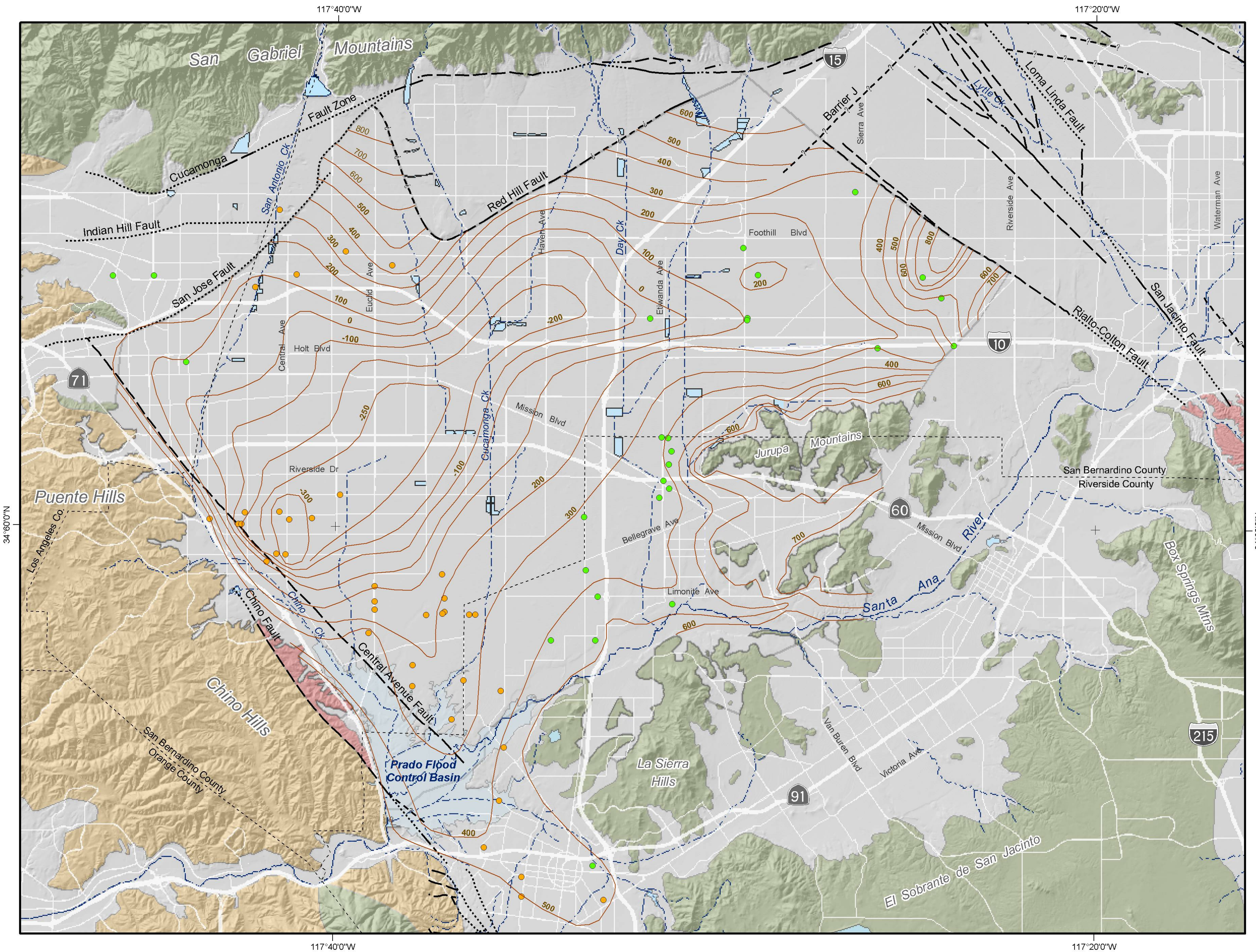
Chino Basin Dry-Year Yield Program
Geology and Hydrogeology

Inland Empire Utilities Agency

Chino Basin
and Other Surrounding Groundwater Basins

Figure 2-1



Main Features

- Well Borehole Penetrated Sedimentary Bedrock
- Well Borehole Penetrated Crystalline Bedrock
- 600 Equal Elevation Contour of Base of Freshwater Aquifer (ft-above msl)

Geology

Water-Bearing Sediments

- Quaternary Alluvium

Consolidated Bedrock

- Plio-Pleistocene Sedimentary Rocks
- Cretaceous to Miocene Sedimentary Rocks
- Pre-Tertiary Igneous and Metamorphic Rocks

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain

Other Features

- Flood Control and Conservation Basins

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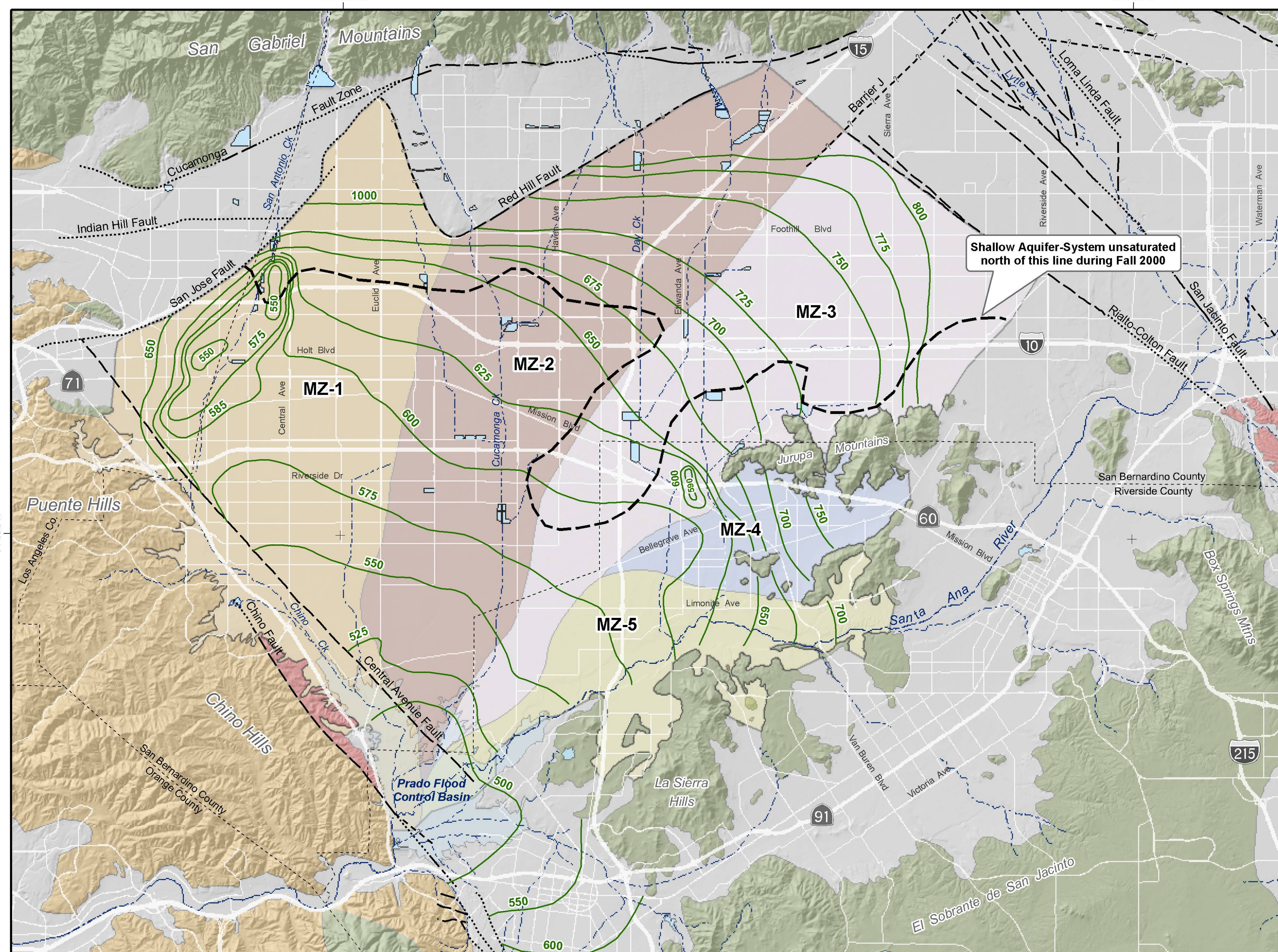
0 1 2 3 4 Miles
0 2 4 6 KM

Chino Basin Dry-Year Yield Program
Geology and Hydrogeology

Base of Freshwater Aquifer
Including Bedrock Type

Figure 2-2



Main Features

800 / 775 — Groundwater Elevation Contours -- Fall 2000 (feet above mean sea level)

Geology

Water-Bearing Sediments

- Quaternary Alluvium

Consolidated Bedrock

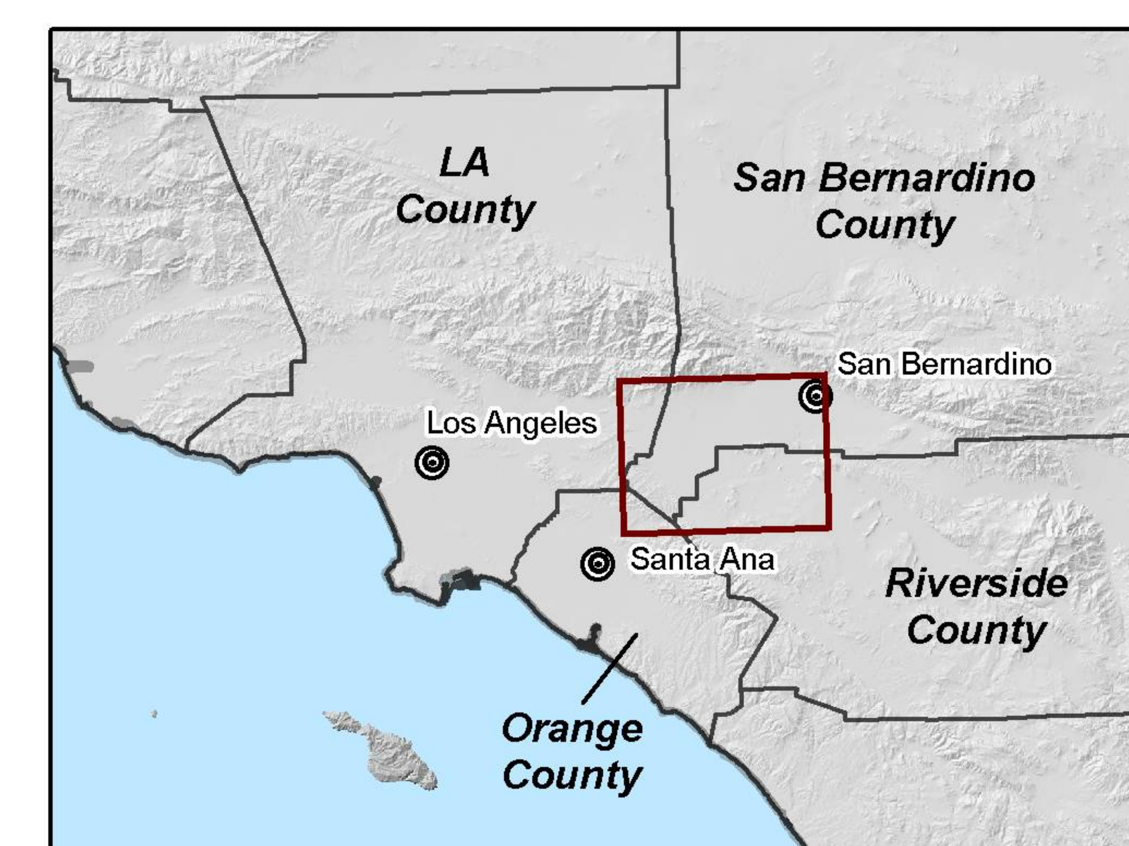
- Plio-Pleistocene Sedimentary Rocks
- Cretaceous to Miocene Sedimentary Rocks
- Pre-Tertiary Igneous and Metamorphic Rocks

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain

Other Features

- Flood Control and Conservation Basins



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File: figure_2-3.mxd

0 1 2 3 4 Miles
0 2 4 6 KM

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Chino Basin Dry-Year Yield Program
Geology and Hydrogeology

Groundwater Elevation Map
Fall 2000

Figure 2-3

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Date: 20030616
File: figure_2-4.mxd

0 1 2 3 4 Miles
0 2 4 6 KM

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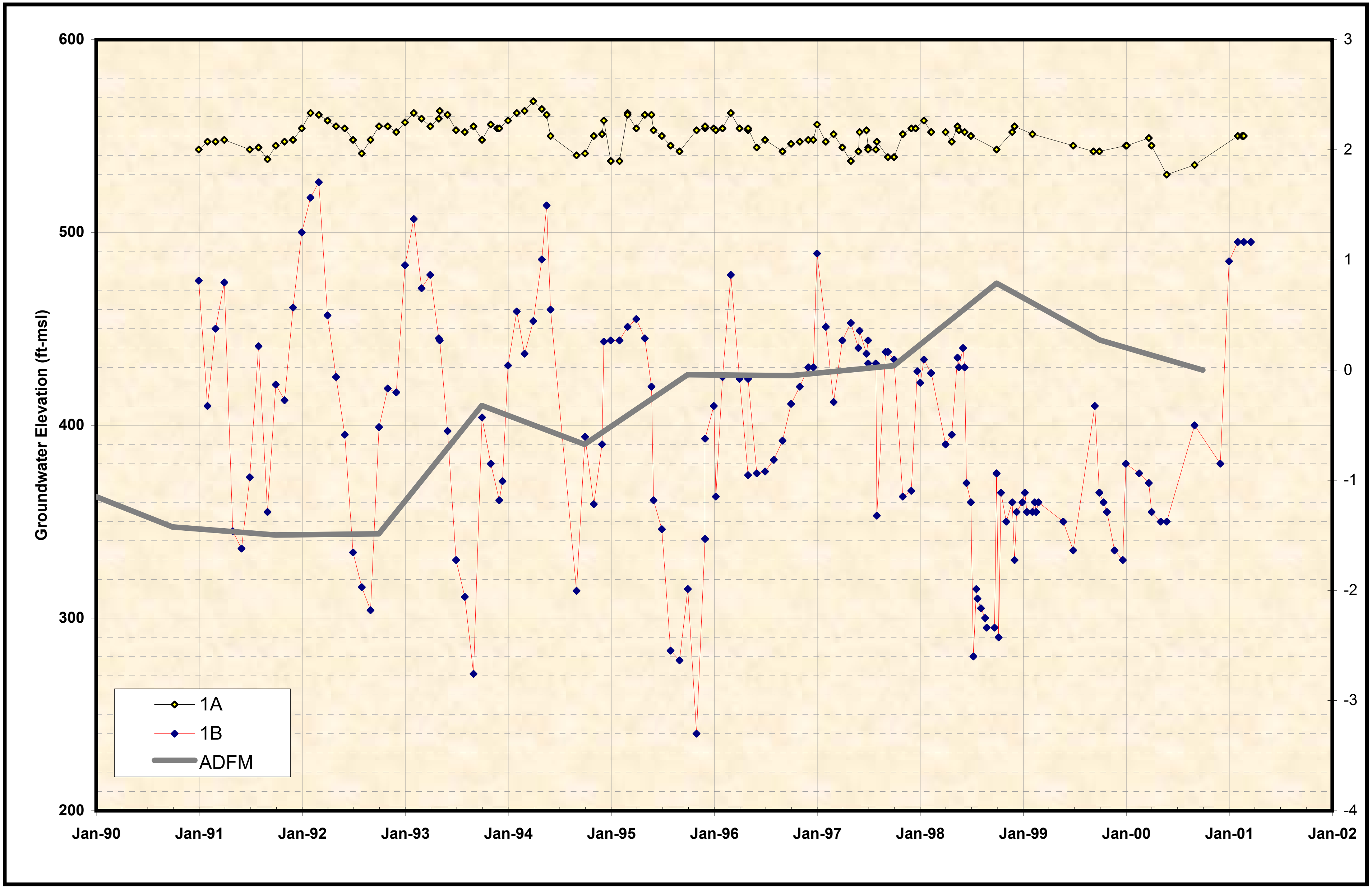
Chino Basin Dry-Year Yield Program
Geology and Hydrogeology

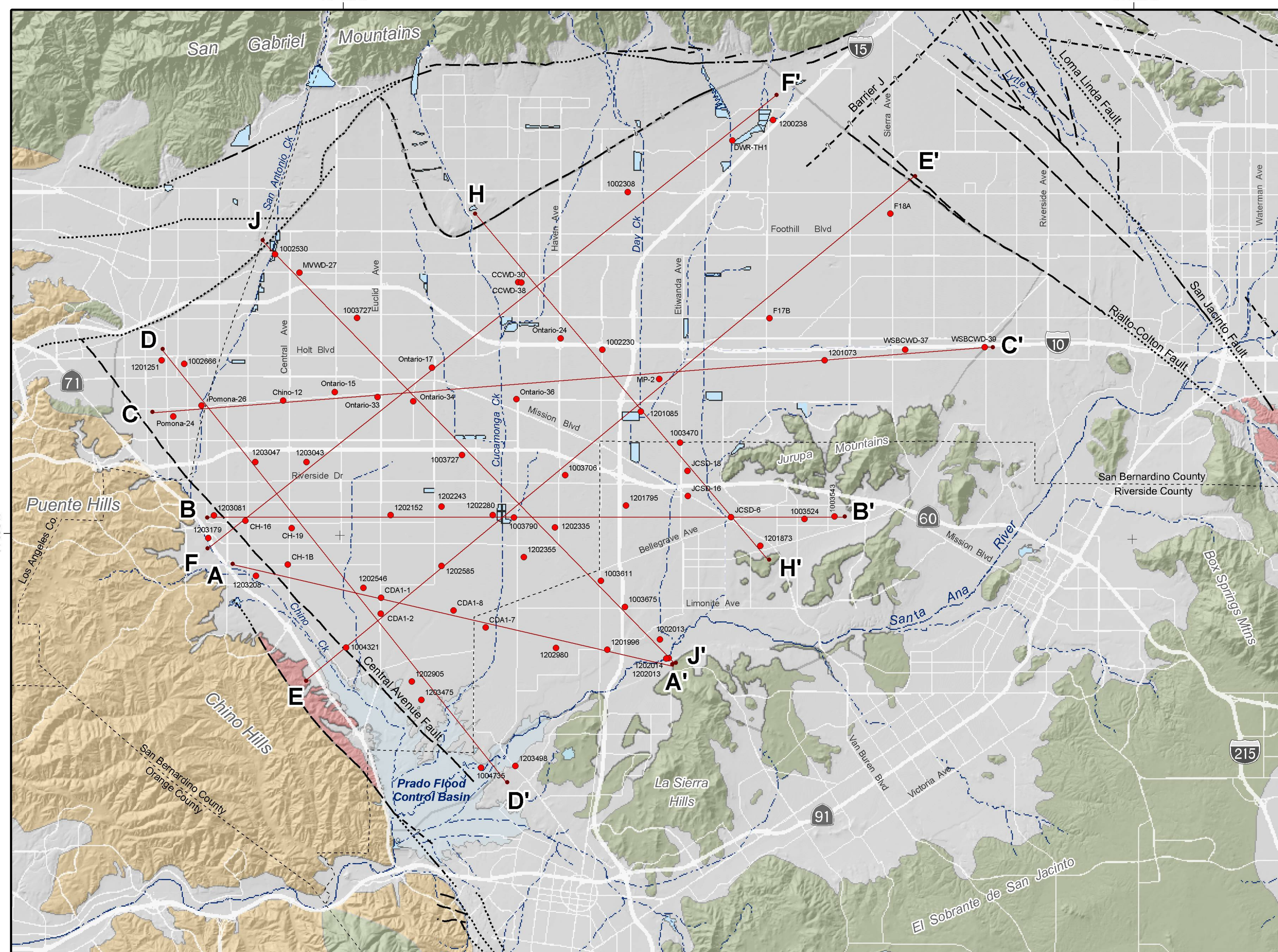
Chino Basin Hydrogeology
Areas of Subsidence and Historical Artesian Conditions

Figure 2-4

Figure 2-5
Water-Level Time Histories (Non-Pumping)
at City of Chino Hills Wells 1A and 1B



Wildermuth Environmental



Main Features

- Line of Geologic Cross-Section *{shown in Figures 2-7 thru 2-14}*
- Well Used in Cross-Section

Geology

Water-Bearing Sediments

- Quaternary Alluvium

Consolidated Bedrock

- Plio-Pleistocene Sedimentary Rocks
- Cretaceous to Miocene Sedimentary Rocks
- Pre-Tertiary Igneous and Metamorphic Rocks

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain

Miles 0 1 2 3 4
KM 0 2 4 6

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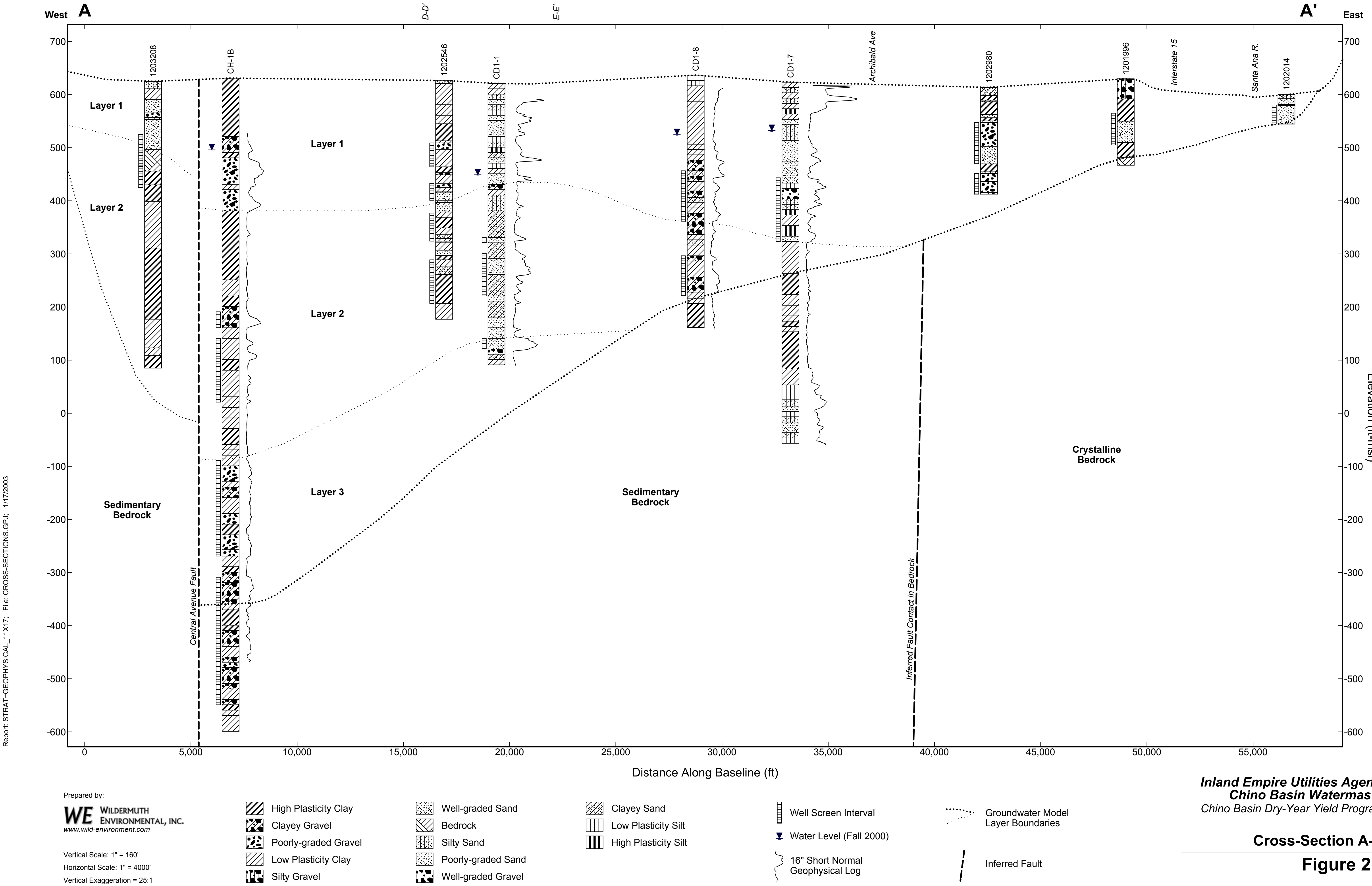
Chino Basin Watermaster
Inland Empire Utilities Agency

Chino Basin Dry-Year Yield Program
Geology and Hydrogeology

Map View of Geologic Cross-Sections
Chino Basin

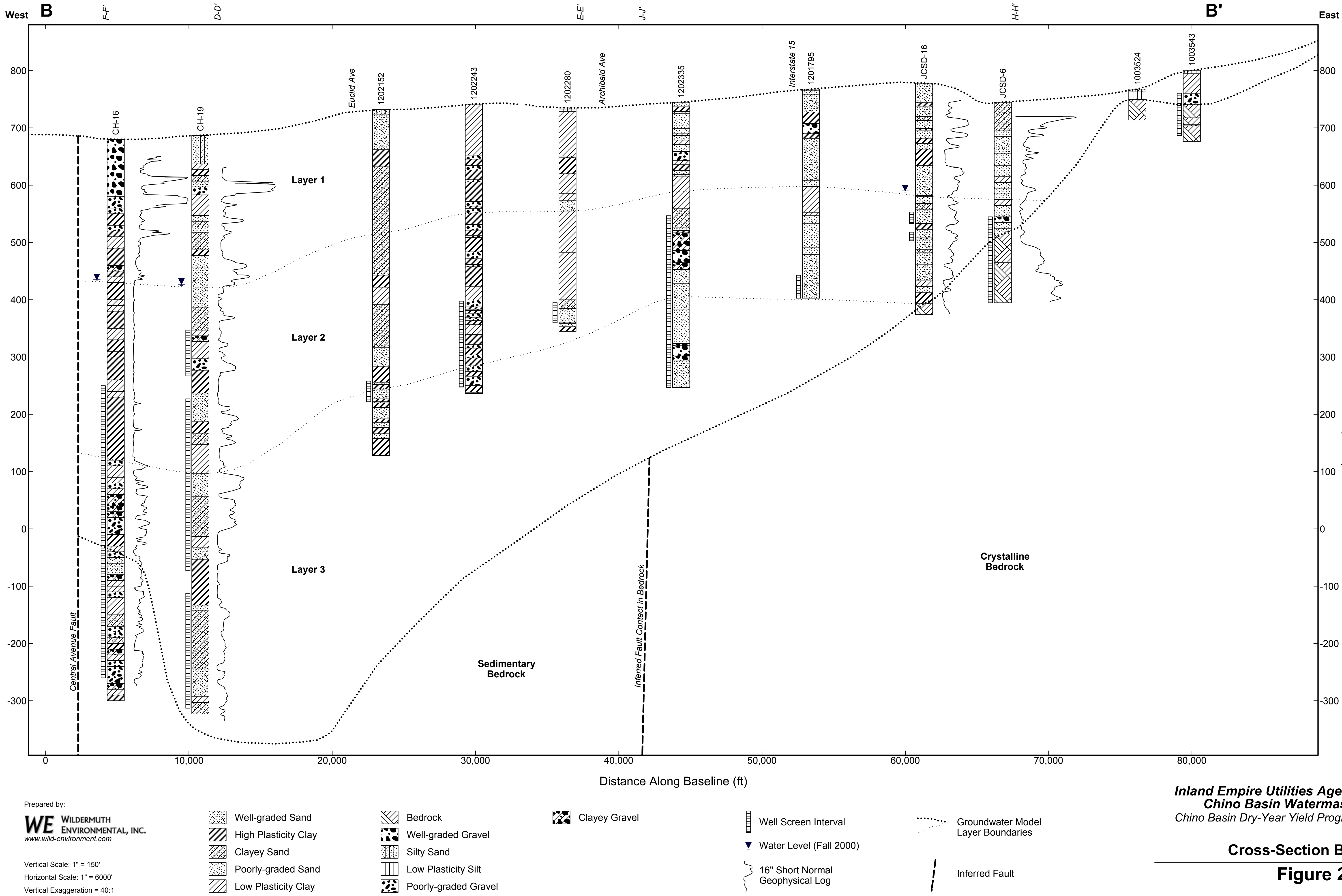
Figure 2-6



Inland Empire Utilities Agency
Chino Basin Watermaster
Chino Basin Dry-Year Yield Program

Cross-Section A-A'

Figure 2-7



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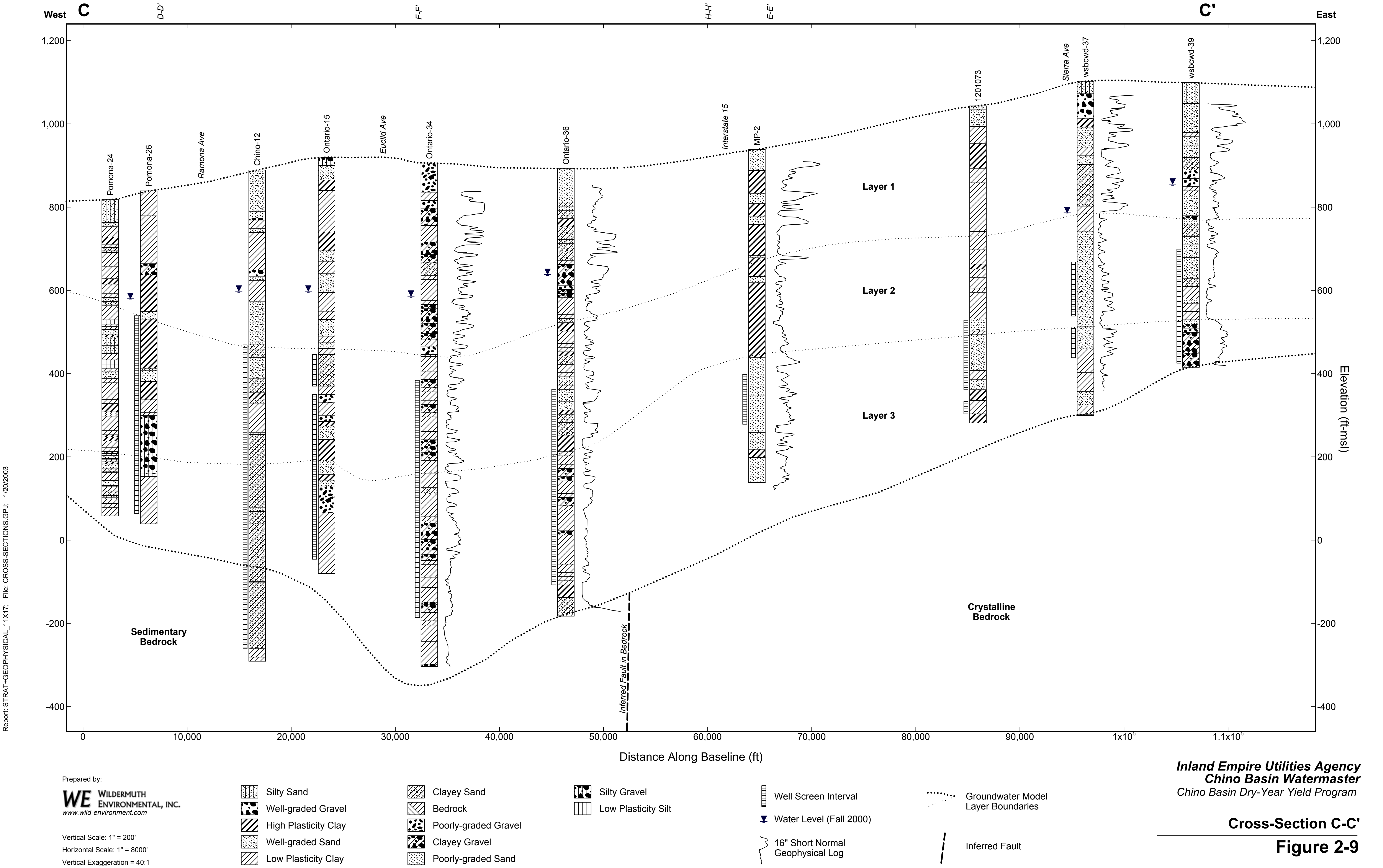
Chino Basin Watermaster
Chino Basin Dry-Year Yield Program

Cross-Section B-B'

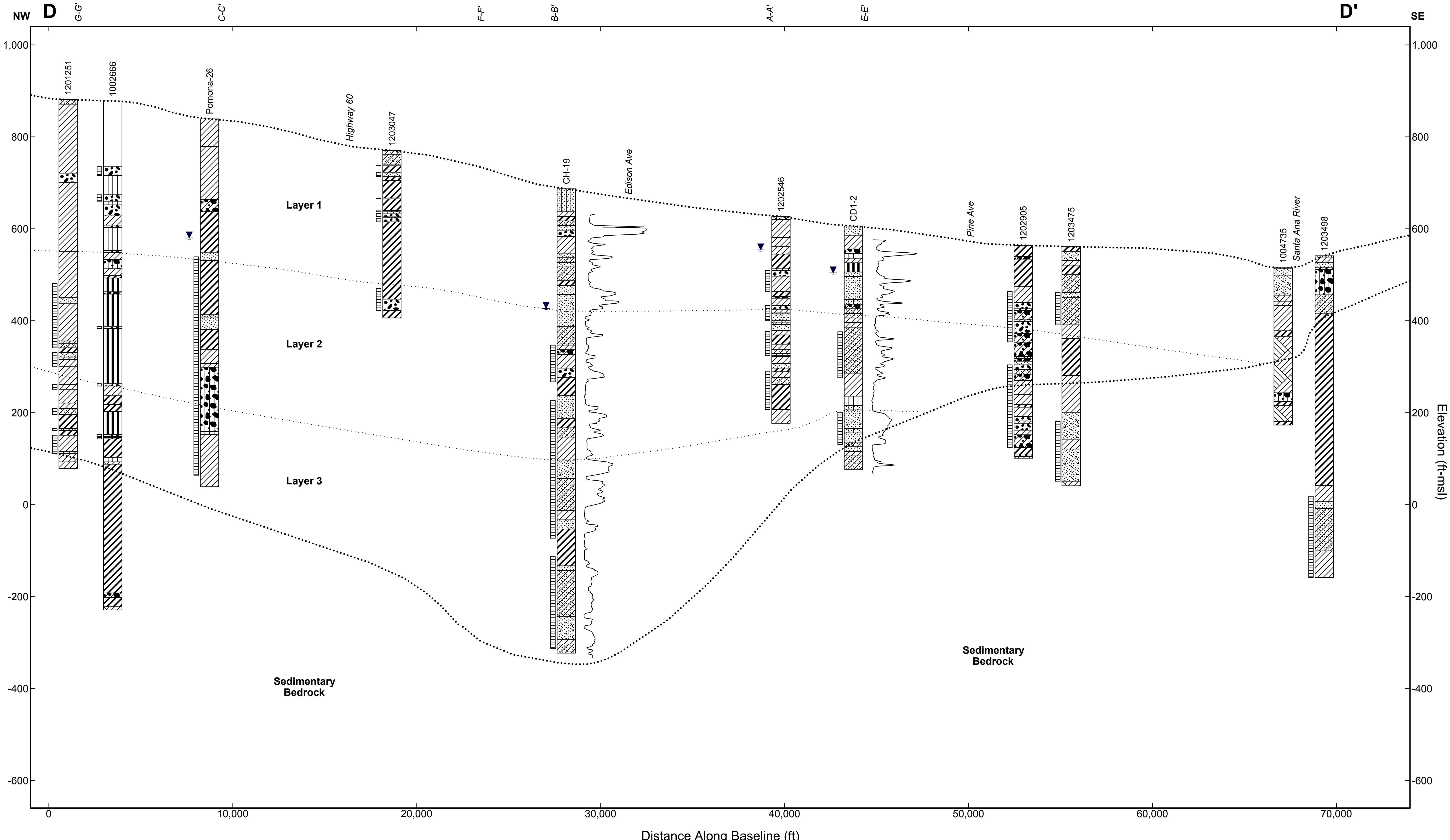
Figure 2-8



Inland Empire Utilities Agency
Chino Basin Watermaster
Chino Basin Dry-Year Yield Program

Cross-Section C-C'

Figure 2-9



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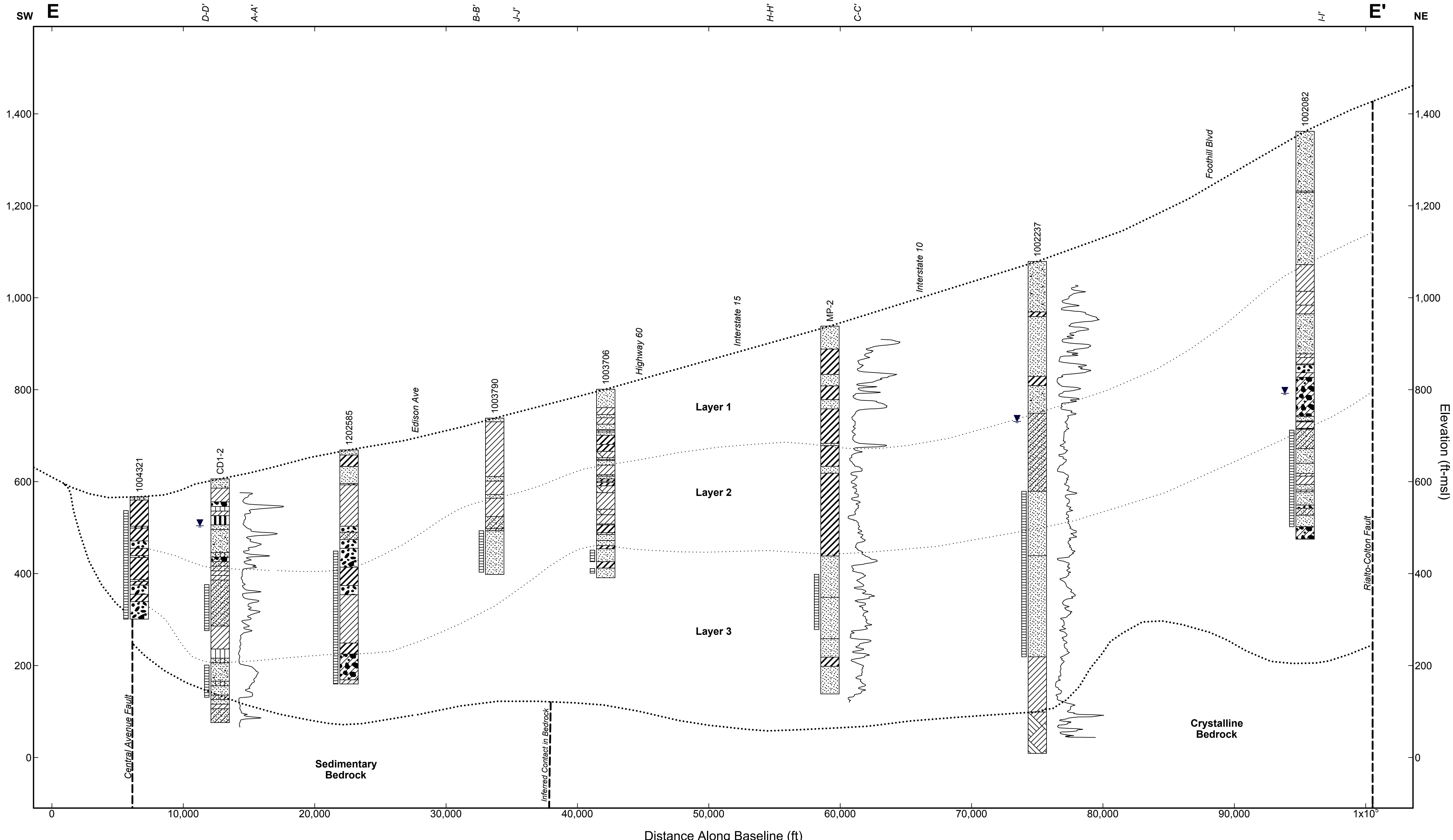
Vertical Scale: 1" = 200'
Horizontal Scale: 1" = 5000'
Vertical Exaggeration = 25:1

- Poorly-graded Gravel
- Low Plasticity Silt
- Low Plasticity Clay
- Silty Gravel
- High Plasticity Clay
- High Plasticity Silt
- Clayey Gravel
- Bedrock
- Well-graded Sand
- Poorly-graded Sand
- Clayey Sand
- Silty Sand
- Well-graded Gravel
- Well Screen Interval
- Water Level (Fall 2000)
- 16" Short Normal Geophysical Log
- Groundwater Model Layer Boundaries
- Inferred Fault

Inland Empire Utilities Agency
Chino Basin Watermaster
Chino Basin Dry-Year Yield Program

Cross-Section D-D'

Figure 2-10



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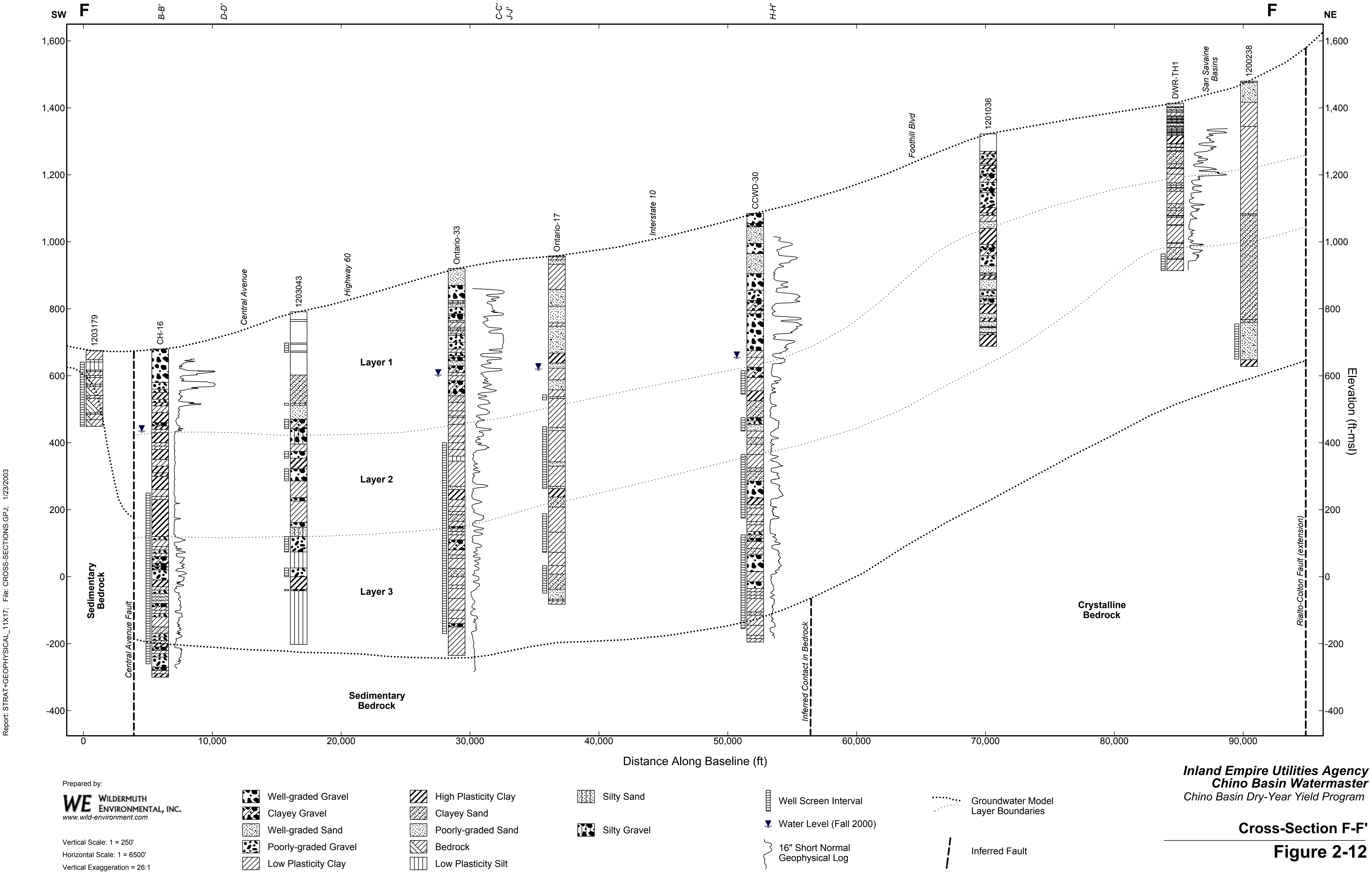
Vertical Scale: 1" = 200'
Horizontal Scale: 1" = 7000'
Vertical Exaggeration = 35:1

Well-graded Sand
Low Plasticity Clay
Poorly-graded Gravel
Clayey Gravel
Clayey Sand
Poorly-graded Sand
High Plasticity Clay
Bedrock
Silty Sand
Well-graded Gravel
Low Plasticity Silt
High Plasticity Silt
Well Screen Interval
Water Level (Fall 2000)
16" Short Normal Geophysical Log
Groundwater Model Layer Boundaries
Inferred Fault

Inland Empire Utilities Agency
Chino Basin Watermaster
Chino Basin Dry-Year Yield Program

Cross-Section E-E'

Figure 2-11


SW
F
B-B'
D-D'
C-C'
J-J'
H-H'
F
NE
1203179
CH-16
Central Avenue
1203043
Highway 60
Ontario-33
Ontario-17
Interstate 10
CCWD-30
Foothill Blvd
1201036
DWR-TH1
San Savaine Basins
1200238
Layer 1
Layer 2
Layer 3
Sedimentary Bedrock
Central Avenue Fault
Sedimentary Bedrock
Inferred Contact in Bedrock
Crystalline Bedrock
Rialto-Colton Fault (extension)
Elevation (ft-msl)
1,600
1,400
1,200
1,000
800
600
400
200
0
-200
-400
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
Distance Along Baseline (ft)
Report: STRAT+GEOPHYSICAL_11X17; File: CROSS-SECTIONS.GPJ; 1/23/2003
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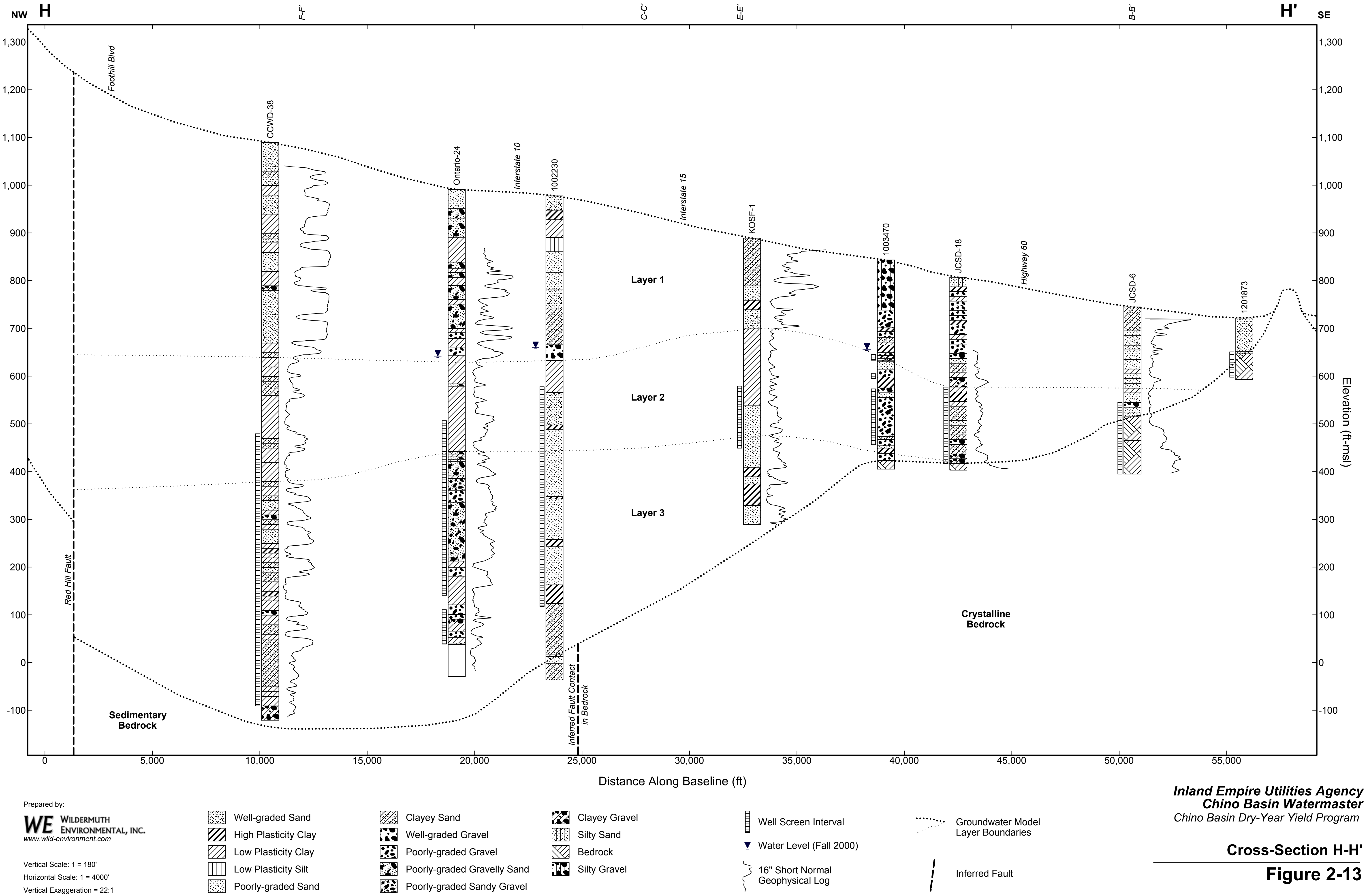
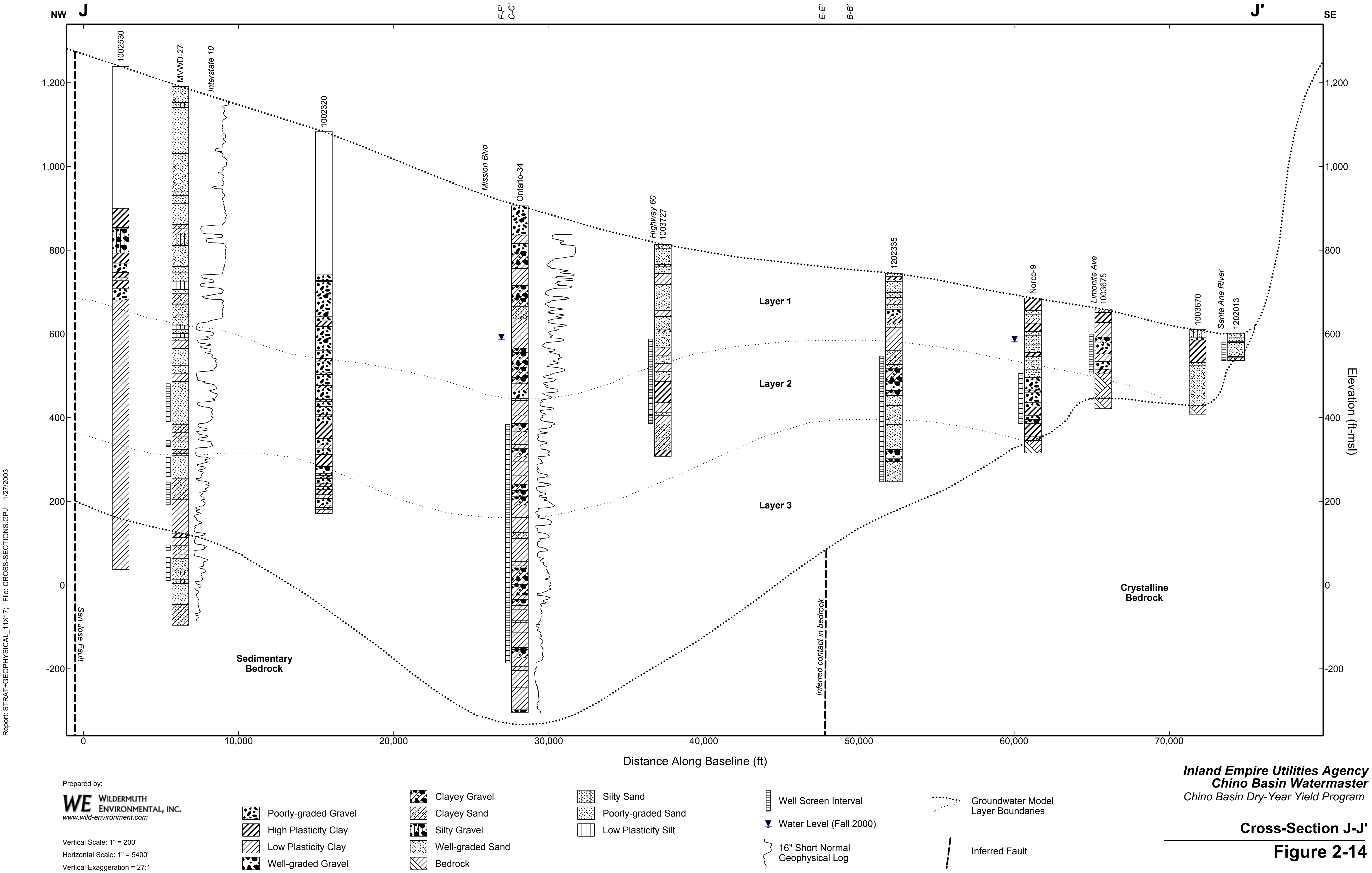
Vertical Scale: 1 = 250'
Horizontal Scale: 1 = 6500'
Vertical Exaggeration = 26:1
Well-graded Gravel
Clayey Gravel
Well-graded Sand
Poorly-graded Gravel
Low Plasticity Clay
High Plasticity Clay
Clayey Sand
Poorly-graded Sand
Bedrock
Low Plasticity Silt
Silty Sand
Silty Gravel
Well Screen Interval
Water Level (Fall 2000)
16" Short Normal Geophysical Log
Groundwater Model Layer Boundaries
Inferred Fault
Inland Empire Utilities Agency
Chino Basin Watermaster
Chino Basin Dry-Year Yield Program
Cross-Section F-F'
Figure 2-12



Report: STRAT+GEOPHYSICAL_11X17; File: CROSS-SECTIONS.GPJ; 3/6/2003



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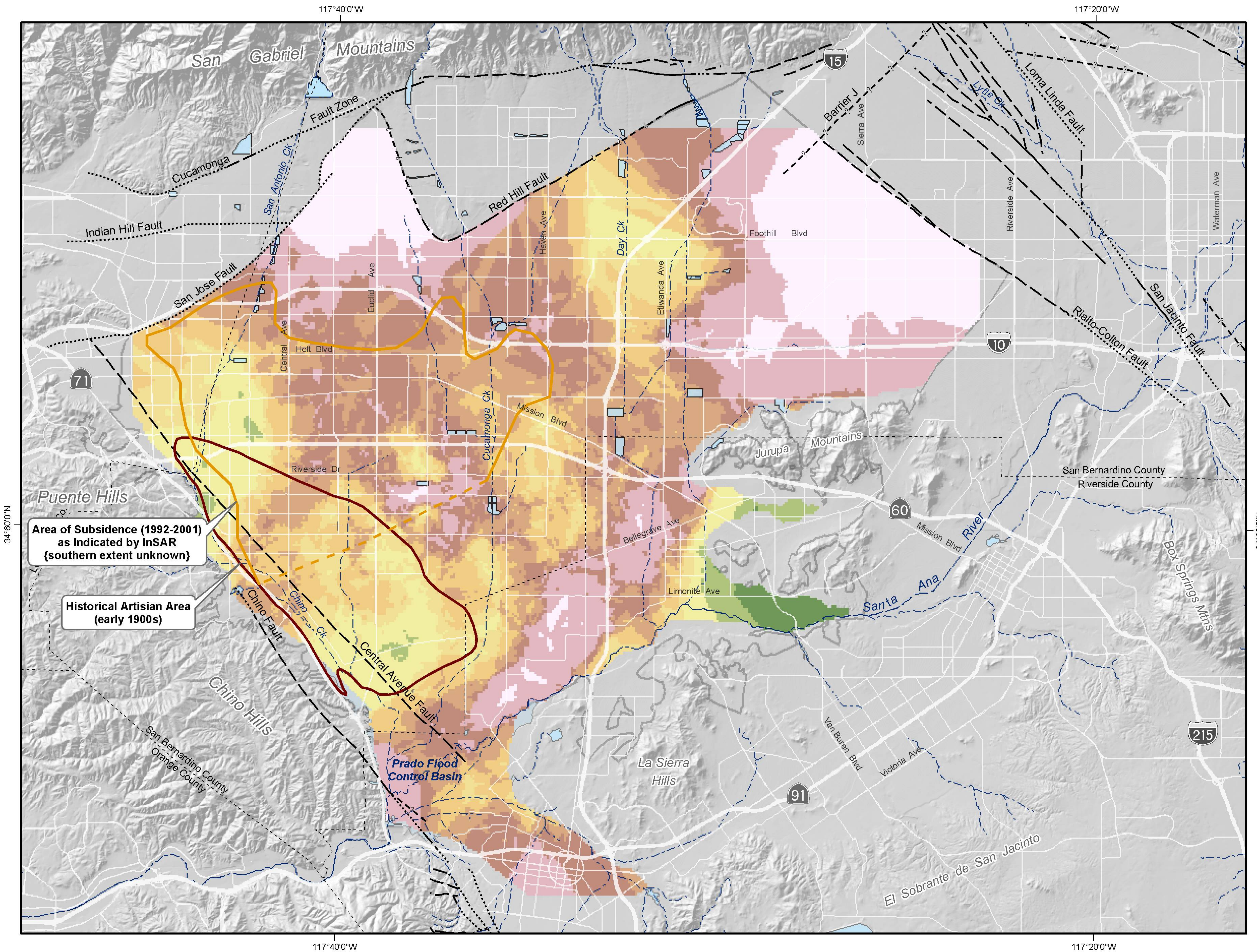
Chino Basin Watermaster
Chino Basin Dry-Year Yield Program

Cross-Section J-J'

Figure 2-14



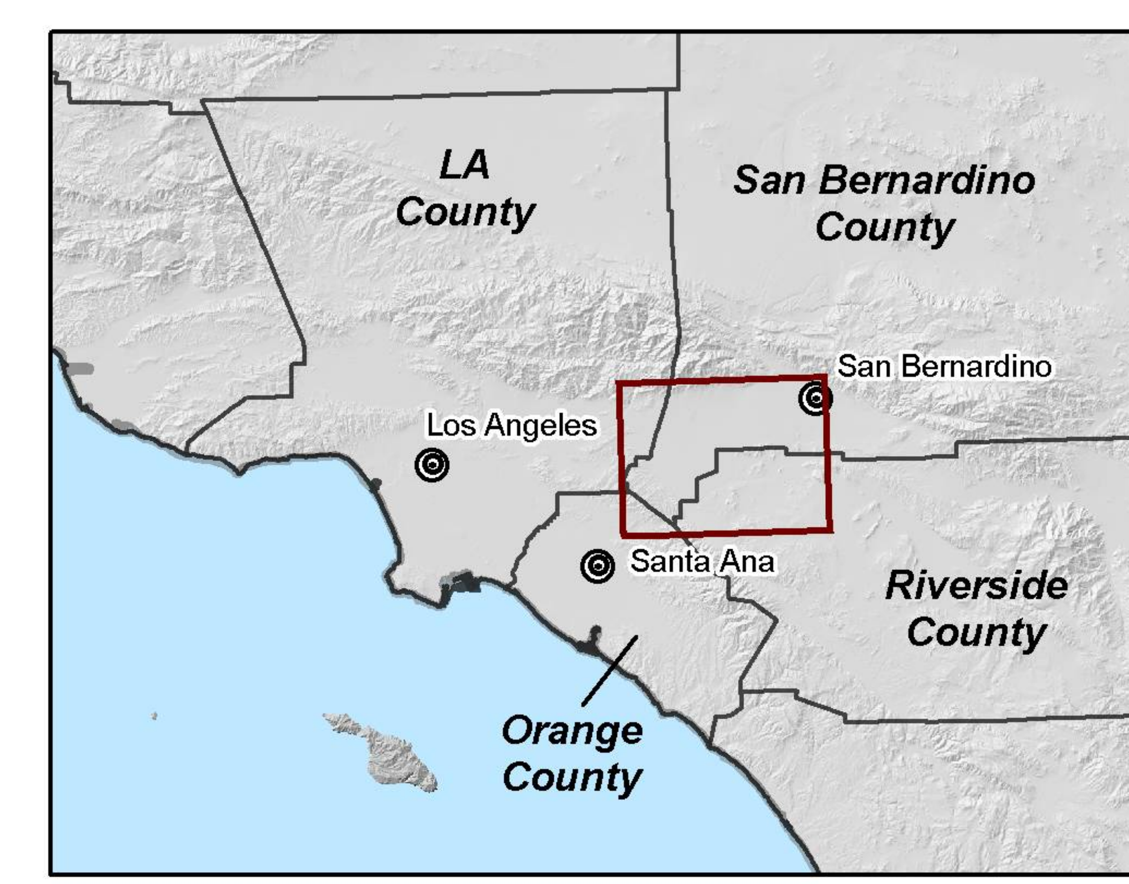
Specific Yield of Water-Bearing Sediments

- 0 - 5%
- 5 - 7%
- 7 - 9%
- 9 - 10%
- 10 - 11%
- 11 - 12%
- 12 - 13%
- 13 - 15%
- 15 - 20%

Geology

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain



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0 1 2 3 4 Miles
0 2 4 6 KM

Chino Basin Dry-Year Yield Program
Geology and Hydrogeology

Average Specific Yield of Sediments

Layer 1

Figure 2-15

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0 1 2 3 4 Miles
0 2 4 6 KM

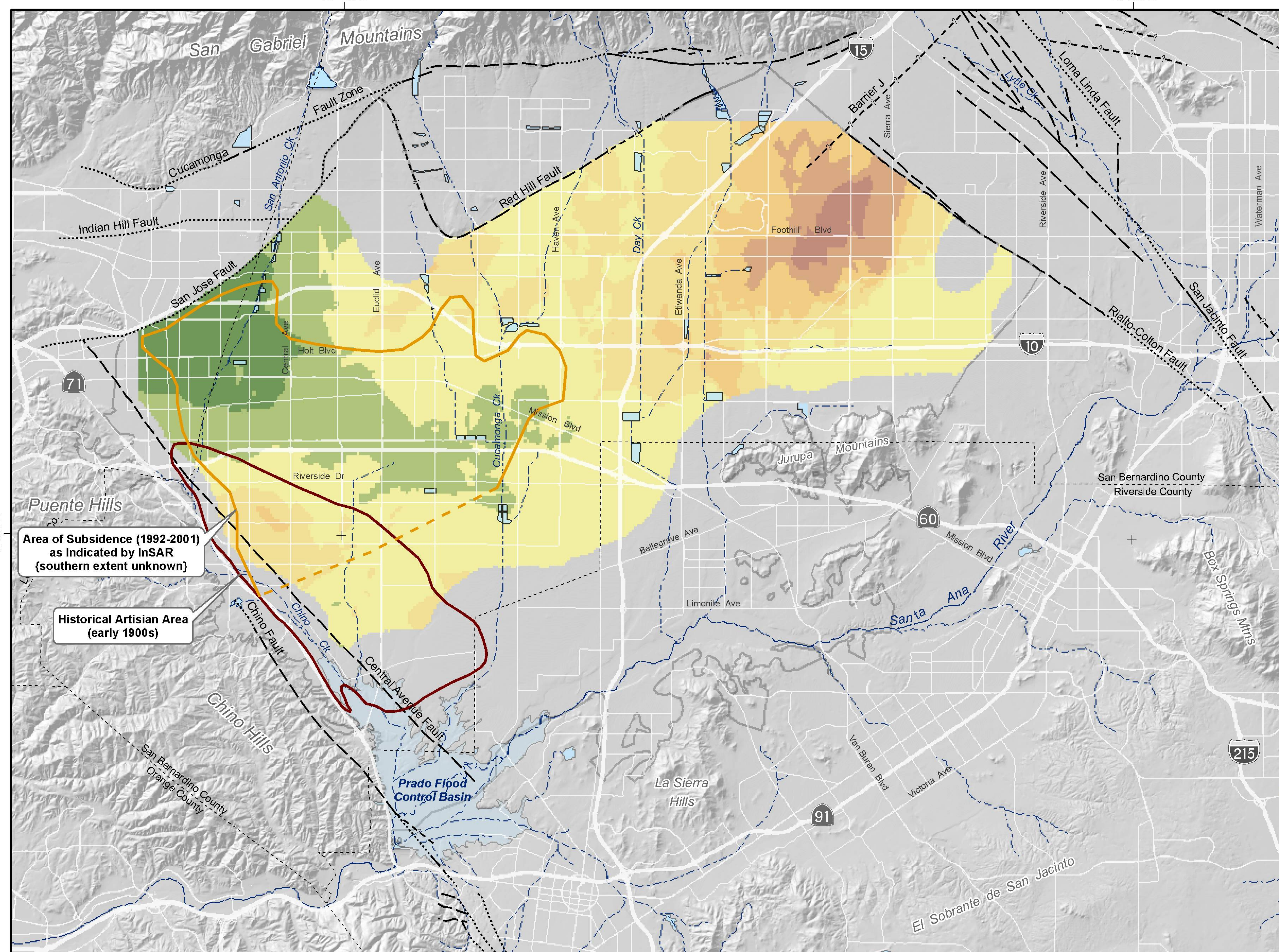
Inland Empire Utilities Agency

Chino Basin Dry-Year Yield Program
Geology and Hydrogeology

Average Specific Yield of Sediments

Layer 2

Figure 2-16



Specific Yield of Water-Bearing Sediments

- 0 - 5%
- 5 - 7%
- 7 - 9%
- 9 - 10%
- 10 - 11%
- 11 - 12%
- 12 - 13%
- 13 - 15%
- 15 - 20%

Geology

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain

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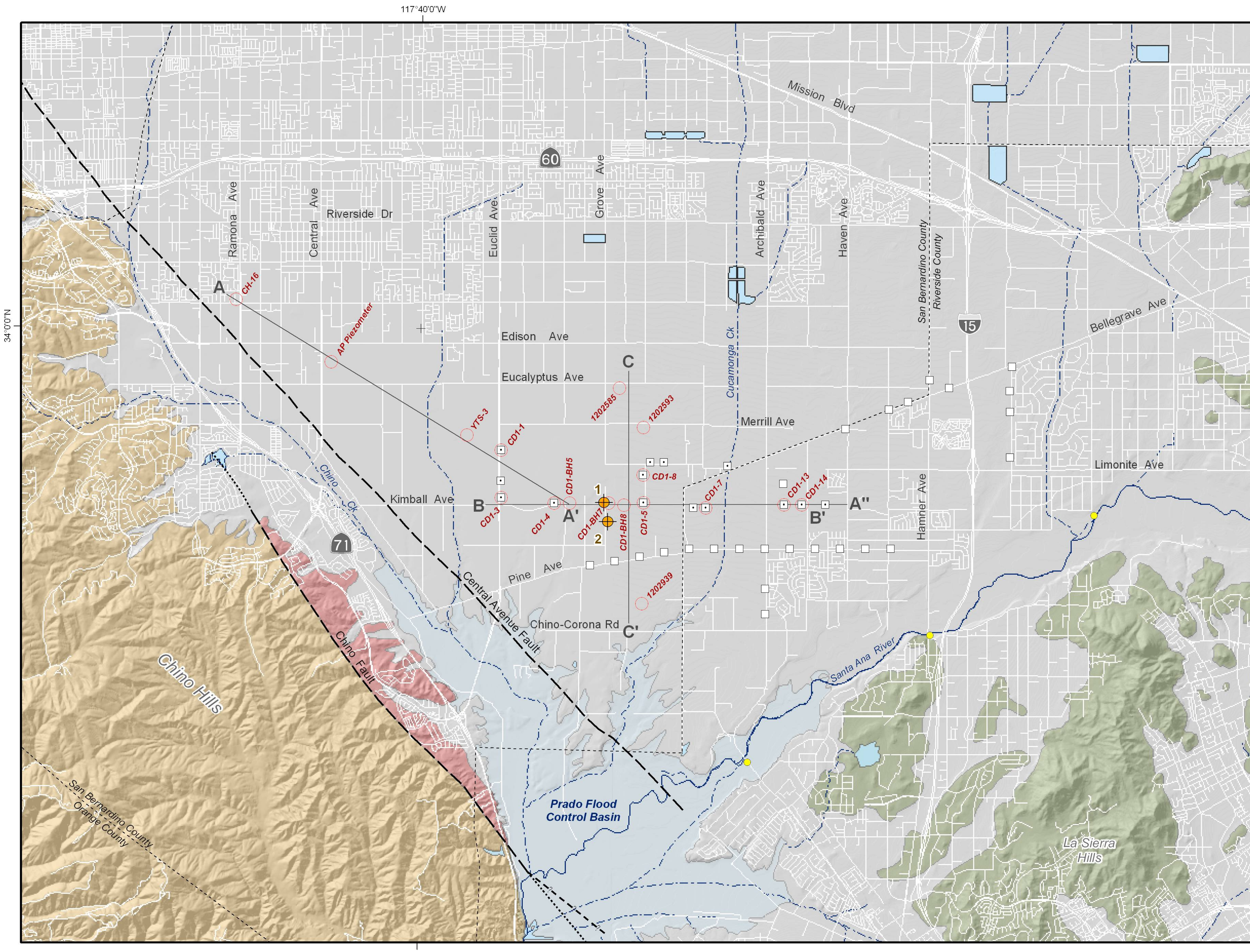
0 1 2 3 4 Miles
0 2 4 6 KM

Chino Basin Dry-Year Yield Program
Geology and Hydrogeology

Average Specific Yield of Sediments

Layer 3

Figure 2-17



Main Features

- Proposed HCMP Piezometric Monitoring Well
- Line of Geologic Cross-Section
- Well/Borehole Used in Cross-Section
- Chino-1 Desalter Well (Existing)
- Chino Desalter Well (Proposed)
- HCMP Surface Water Gaging Station

Geology

Water-Bearing Sediments

- Quaternary Alluvium

Consolidated Bedrock

- Plio-Pleistocene Sedimentary Rocks
- Cretaceous to Miocene Sedimentary Rocks
- Pre-Tertiary Igneous and Metamorphic Rocks

Faults

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain

0 1 2 Miles

0 2 4 KM

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Author: AEM

Date: 20030903

File: figure_2-18.mxd

Inland Empire Utilities Agency

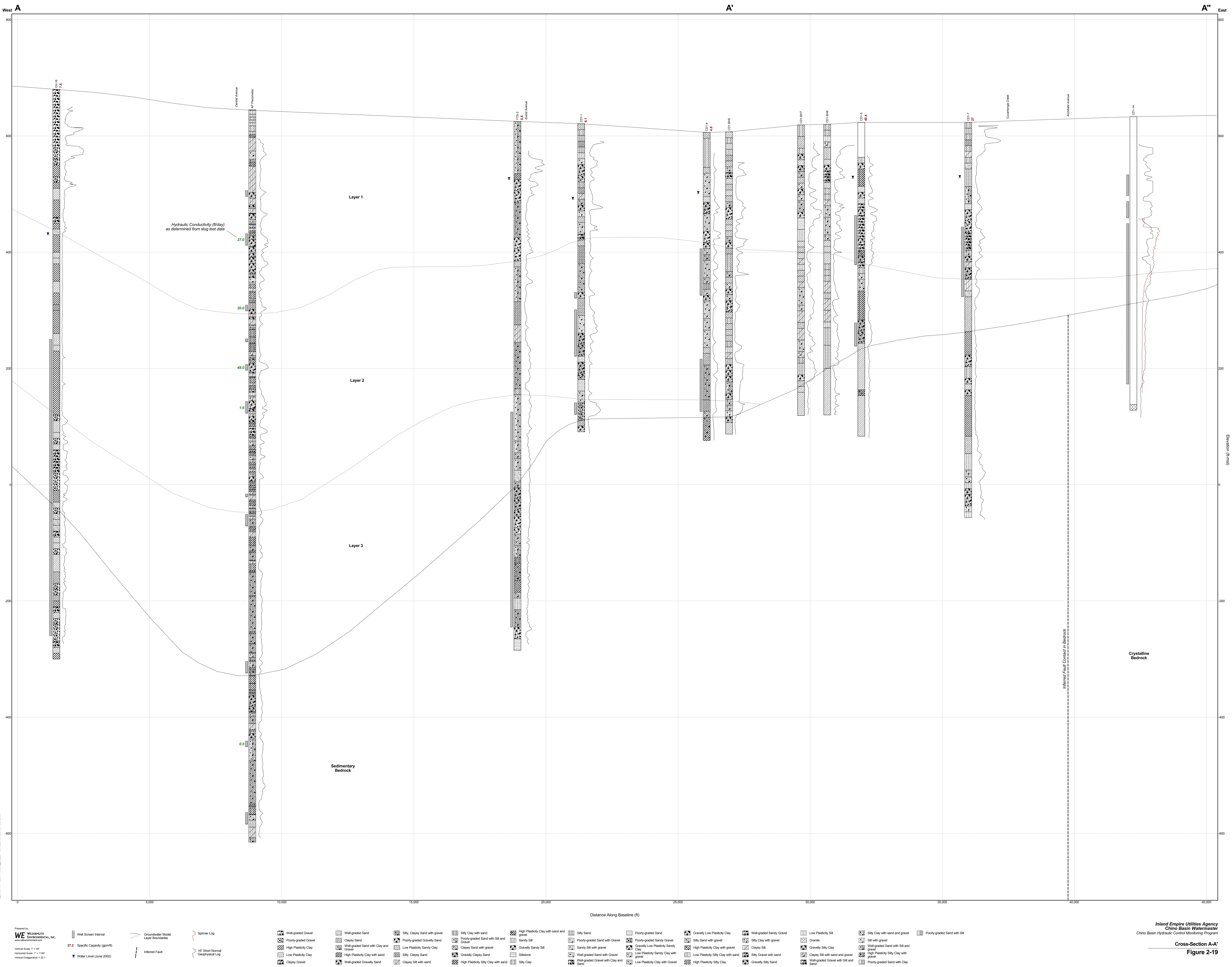
Chino Basin Hydraulic Control Monitoring Program

Geology and Hydrogeology

Map View of Geologic Cross-Sections

Southern Chino Basin

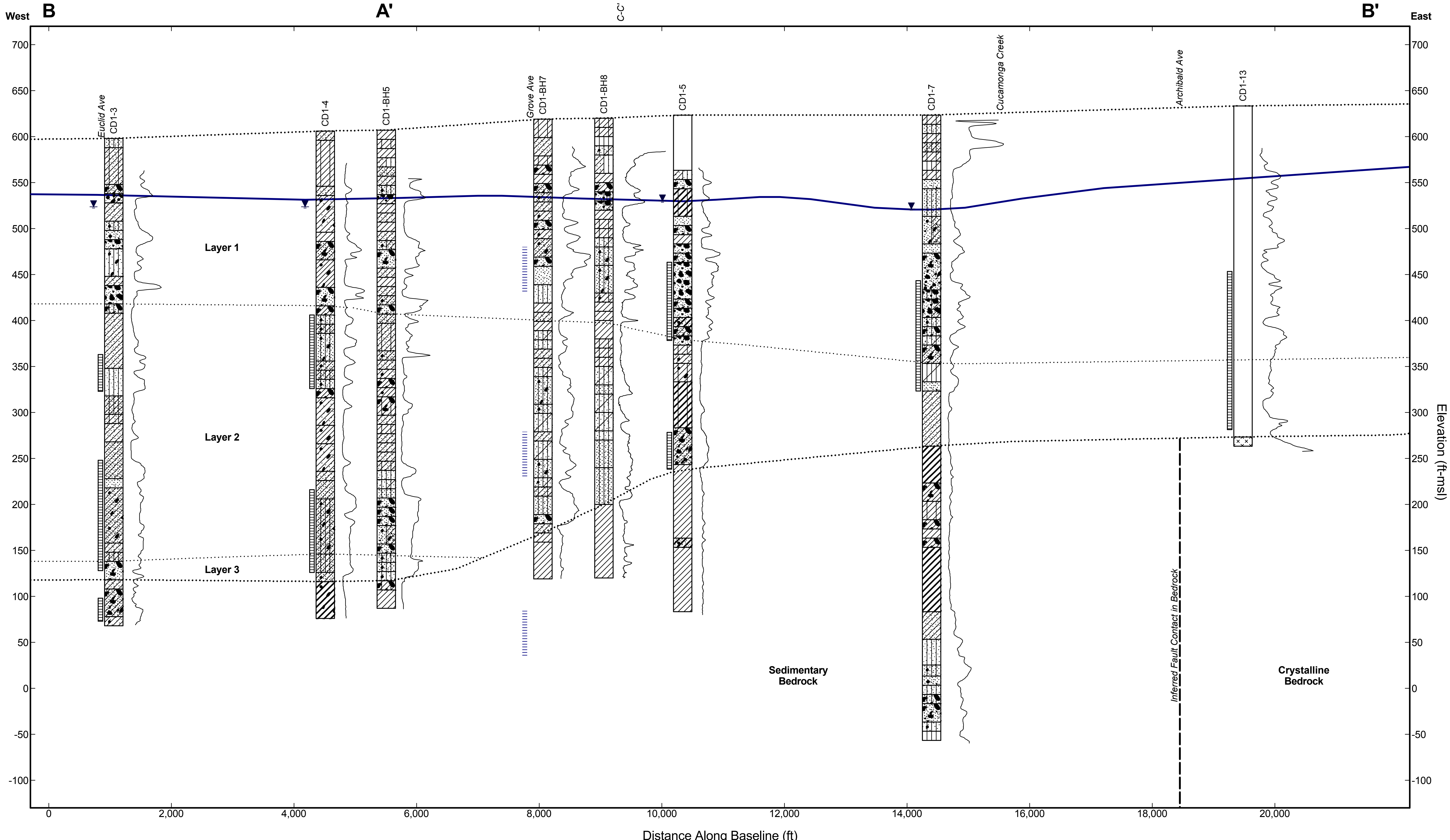
Figure 2-18



Inland Empire Utilities Agency
Chino Basin Watermaster
Chino Basin Hydraulic Control Monitoring Program

Cross-Section A-A'

Figure 2-19



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Vertical Scale: 1 = 100'
Horizontal Scale: 1 = 1500'
Vertical Exaggeration = 15:1

Gravel
Sand
Silt
Clay

Well Screen Interval
Water Level (Spring 2003)
16" Short Normal Geophysical Log

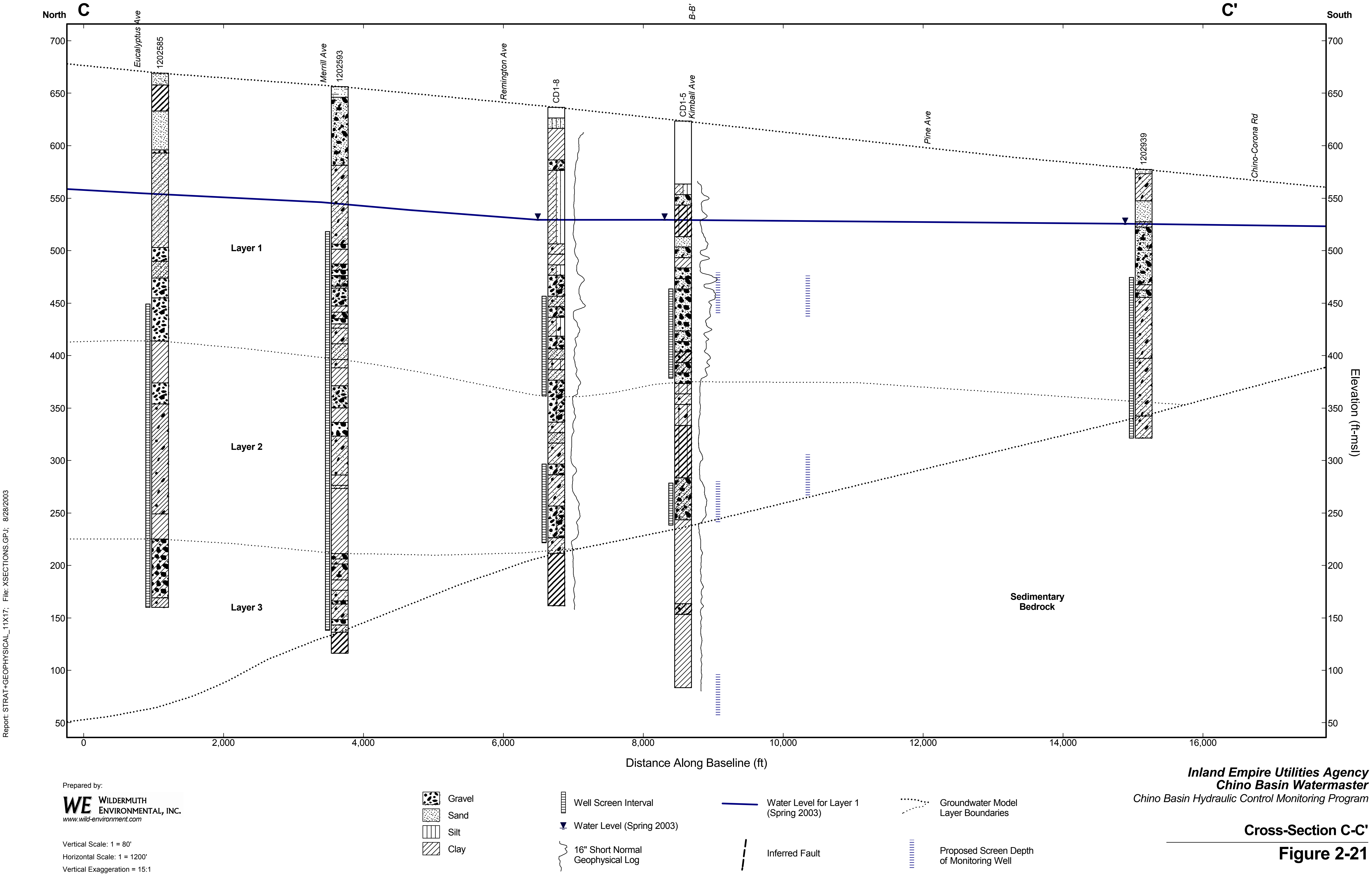
Water Level for Layer 1 (Spring 2003)
Inferred Fault

Groundwater Model Layer Boundaries
Proposed Screen Depth of Monitoring Well

Inland Empire Utilities Agency
Chino Basin Watermaster
Chino Basin Hydraulic Control Monitoring Program

Cross-Section B-B'

Figure 2-20


North
C
C'
South
B-B'
Eucalyptus Ave
1202585
Merrill Ave
1202593
Remington Ave
CD1-8
CD1-5
Kimball Ave
Pine Ave
1202939
Chino-Corona Rd
Layer 1
Layer 2
Layer 3
Sedimentary Bedrock
Elevation (ft-msl)
Distance Along Baseline (ft)
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
Report: STRAT+GEOPHYSICAL_11X17; File: XSECTIONS.GPJ; 8/28/2003
Prepared by:
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Vertical Scale: 1 = 80'
Horizontal Scale: 1 = 1200'
Vertical Exaggeration = 15:1
Gravel
Sand
Silt
Clay
Well Screen Interval
Water Level (Spring 2003)
16" Short Normal Geophysical Log
Water Level for Layer 1 (Spring 2003)
Inferred Fault
Groundwater Model Layer Boundaries
Proposed Screen Depth of Monitoring Well
Inland Empire Utilities Agency
Chino Basin Watermaster
Chino Basin Hydraulic Control Monitoring Program
Cross-Section C-C'
Figure 2-21

3. GROUNDWATER-LEVELS AND STORAGE

3.1 Background

Groundwater-level monitoring is a key element of *OBMP Program Element 1 – Develop and Implement a Comprehensive Monitoring Program*. Program Element 1 was developed, in part, to address the first impediment to *OBMP Goal 1 – Enhance Basin Water Supplies,* which can be stated as: "Unless certain actions are taken, safe yield of the Basin will be reduced … due to groundwater outflow from the southern part of the Basin." This impediment speaks to the possibility of increased groundwater outflow to the Santa Ana River as a result of (1) reduced groundwater production in the southern part of the Basin as agricultural land is converted to urban uses, and (2) increased groundwater storage due to other management activities such as artificial recharge and storage and recovery programs. In other words, increased groundwater levels in south Chino Basin (via reduced groundwater production and/or increased groundwater storage) may result in increased discharge of groundwater to the Santa Ana River (*i.e.* loss of basin yield). The potential loss of safe yield due to these activities will need to be computed periodically and used in the administration of the Judgment – otherwise the basin could be overdrafted.

The OBMP states that re-determination of safe yield and estimation of losses from groundwater storage programs require comprehensive groundwater-level mapping across the Basin, analysis of groundwater-level time histories at wells, and accurate estimations of groundwater production.

Prior to OBMP implementation, groundwater-level monitoring was not adequate. The primary problems with historical groundwater-level monitoring included an inadequate areal distribution of wells in monitoring programs, short time histories, questionable data quality, and insufficient resources to develop and conduct a comprehensive program.

The OBMP Phase 1 Report defined a new, comprehensive groundwater-level monitoring program. The program consisted of two parts – an initial survey from 1998 to 2001, followed by long-term monitoring at a set of key wells.

The data collected for the groundwater-level monitoring program are intended to be used to:

- estimate changes in storage over time, which pertains to future safe-yield computations;
- establish a groundwater-level and groundwater storage baseline for future storage and recovery programs;
- estimate desalter well field impacts on surrounding producers,
- assist in computer simulations of groundwater flow, subsidence, and other phenomena, and
- other purposes as required by the Watermaster.

3.2 Activities and Accomplishments to Date

Watermaster has established three groundwater-level monitoring programs for the Chino Basin – a semiannual basin-wide program; an intensive key well monitoring program associated with the Chino Desalter well fields and the Hydraulic Control Monitoring Program (HCMP); and an intensive piezometric monitoring program associated with the land subsidence and ground fissuring investigations in Management Zone 1 (MZ1).

3.2.1 Basin-Wide Groundwater Level Monitoring Program

The objective of the basin-wide groundwater-level monitoring program is to collect groundwater-level data from all wells in the Chino Basin that can be monitored for groundwater-levels. Figure 3-1 shows the locations of wells within this monitoring program. All wells in the Chino Desalter, HCMP, and MZ-1 monitoring programs are, by definition, also part of the basin-wide monitoring program.

Private wells are monitored for groundwater-levels by Watermaster staff, while the industrial and municipal wells are monitored by the well owners. The data collected by the industrial and municipal users are mailed or faxed to Watermaster along with quarterly groundwater production data, or as otherwise requested by Watermaster. All data collected and received are entered into Watermaster's groundwater-level database.

About 662 wells are monitored as part of the basin-wide program. About 491 wells are private wells measured by Watermaster staff; the remaining 171 wells are measured by the well owners. The frequency of data collection is at least two times per year – once in the spring and once in the fall.

Other sources of groundwater-level data are cooperating agencies that monitor groundwater-levels in Chino Basin. These agencies include:

- California Department of Toxic Substances and Control (Stringfellow Superfund Site);
- Orange County Water District (Prado Basin);
- Santa Ana Regional Water Quality Control Board (various remediation sites);
- USGS (special investigations);
- County of San Bernardino (landfill monitoring); and
- Private consultants (various remediation sites).

3.2.2 Key Well Monitoring Program

Watermaster has developed and implemented a key well monitoring program in the southern portion of Chino Basin. The objective of this program is to increase the measurement frequency and quality of data at a reduced (but representative) network of wells. Most importantly, this network of wells and the monitoring program must satisfy the requirements for the monitoring of Desalter impacts to local producers and the determination of hydraulic control (see Section 8 for a detailed description of the HCMP).

The criteria used to select the key wells were:

- Wells in the key well program require a spatial distribution such that water elevation contour maps drawn using data from only these wells are comparable to a map that used data from all wells in the following respects: (1) regional (study area) gradients are comparable, and (2) local pumping depressions are represented by the key well program.
- Wells with construction information (perforated intervals) are selected preferentially over other wells.
- The time history of water level at a well is compared to those at adjacent or nearby wells to determine if there are differences in responses to aquifer stresses over time. If so, this may indicate that the adjacent wells are perforated in different aquifer zones, especially on the southwest side of Chino Basin. In that situation, both wells would be retained in the key well program.

- The density of key wells near the desalter well fields would be greater than outlying areas, given that hydraulic gradients are expected to be steeper near the desalter well fields.
- The wells must have access ports for groundwater level sounders and that reference points are marked and well documented.

About 116 wells are included in the key well network. Watermaster staff manually measures water levels at the key wells once per month. Recently, Watermaster staff installed pressure transducers/data loggers in 10 of these key wells to automatically record water levels once every 15 minutes.

3.2.3 MZ-1 Interim Monitoring Program

The MZ-1 Interim Monitoring Program (IMP) is described in detail in Section 5 – *Ground-Level Monitoring.* Part of this program includes an intensive aquifer-system monitoring element. An aquifer system monitoring facility was constructed in 2002-03 at Ayala Park in Chino, and includes multi-depth piezometers that record depth-specific head once every 15 minutes. In addition, about 25 production wells and monitoring wells surrounding this facility are equipped with pressure transducers that record water levels once every 15 minutes. All these data are uploaded to Watermaster's water level database.

3.3 Results of All Active Groundwater Level Monitoring Programs

3.3.1 Fall 2003 Groundwater Levels

The data collected from the various groundwater-level monitoring programs described in Section 3.2 were used to create a groundwater-level elevation contour map of Chino Basin for Fall 2003 (Figure 3-2). The procedures used to create this map are:

1. Extract the entire time history of groundwater-level data from the database for all wells in the Chino Basin.
2. Plot groundwater elevation time histories for all wells versus an accumulative departure from the mean (ADFM) curve (Appendix B).
3. Choose one "static" groundwater-level elevation data point per well for the Fall 2003 period.
4. Plot groundwater-level elevation data on maps with background geologic/hydrologic features.
5. Contour and digitize groundwater elevation data.

The groundwater elevation contours for Fall 2003 are shown in Figure 3-2, and are generally consistent with past groundwater elevation contour maps. For example, Figure 3-3 which shows groundwater elevation contours for Fall 2000. Figures 3-2 and 3-3 both show that groundwater generally flows in a south-southwest direction – from the primary areas of recharge in northern parts of Chino Basin toward Prado Flood Control Basin in the south. Notable pumping depressions in the groundwater-level surface that interrupt the general flow pattern are in the northern portion of MZ-1 (Montclair and Pomona areas) and directly southwest of the Jurupa Hills. The Fall 2003 map also shows an incipient depression in groundwater levels surrounding the Chino-I Desalter well field – a probable result of production at these wells beginning in 2000.

Close inspection of the groundwater-level data used to construct Figure 3-2 suggests the existence of hydraulically-distinct aquifer systems – primarily in MZ-1 and the western parts of MZ-2. Previous investigations have concluded that two or more distinct aquifer systems exist in Chino Basin – a shallow un-confined aquifer and deeper semi-confined and confined aquifers. The high density of wells sampled in this monitoring program has revealed that adjacent wells sometimes have water-level differences on the order of 50-100 feet (Appendix A). For areas with significant piezometric level differences among underlying aquifers, the groundwater levels shown in Figure 3-2 correspond to the upper-most aquifer.

3.3.2 Changes in Groundwater Storage

Groundwater-level data can be used to determine changes in groundwater storage in Chino Basin over time, which, in turn, will be used in future safe-yield computations. Watermaster has developed a Geographic Information Systems (GIS) model to estimate storage changes from groundwater level data. In preparation of this model, Watermaster has compiled a comprehensive library of well driller's and geophysical logs for wells in Chino Basin. The geologic descriptions of borehole cuttings, and associated depth intervals, were digitized and added to Watermaster's database. All geologic descriptions were then assigned a value of specific yield (effective porosity) based on US Geological Survey (USGS) estimates (Johnson, 1967). These data were then used to estimate average specific yield for each model layer across Chino Basin (see Section 2 and Figures 2-15 to 2-17).

The storage change model and the procedures to estimate storage change are summarized below:

- create groundwater elevation contour maps of Chino Basin for the beginning and ending of the period for which a storage change will be estimated (*e.g.*, Fall 2000 and Fall 2003)
- create three-dimensional surfaces (ESRI grid) of groundwater elevation contour maps
- create a 400-meter by 400-meter grid of Chino Basin
- assign attributes to each grid cell in 400-meter grid for (1) surface area of grid cell and (2) overlying management zone (3) beginning groundwater elevation surface (Fall 2000), (4) ending groundwater elevation surface (Fall 2003), (5) top and bottom elevations for the model layers, and (6) specific yield of sediments for each model layer
- export attribute table of 400-meter grid to spreadsheet format for calculation of volumetric storage change

Figure 3-4 shows the 400 by 400-meter grid symbolized by storage change between Fall 2000 and Fall 2003. Basin-wide, the groundwater storage model estimates that storage decreased by about 93,000 acre-feet over this three-year period. Inspection of Figure 3-4 shows that sub-areas that experienced a decrease in storage are:

- in the northwest near Pomona and Montclair
- in the northeast near Fontana and eastern Ontario and Rancho Cucamonga
- near the Chino-I Desalter well field, which began producing water in 2000

Sub-areas that experienced an increase in storage are:

- in the southwest near Chino
- in the south, just north of the Santa Ana River where many agricultural wells are being destroyed as urban land uses replace agricultural

3.4 Ongoing and Recommended Activities

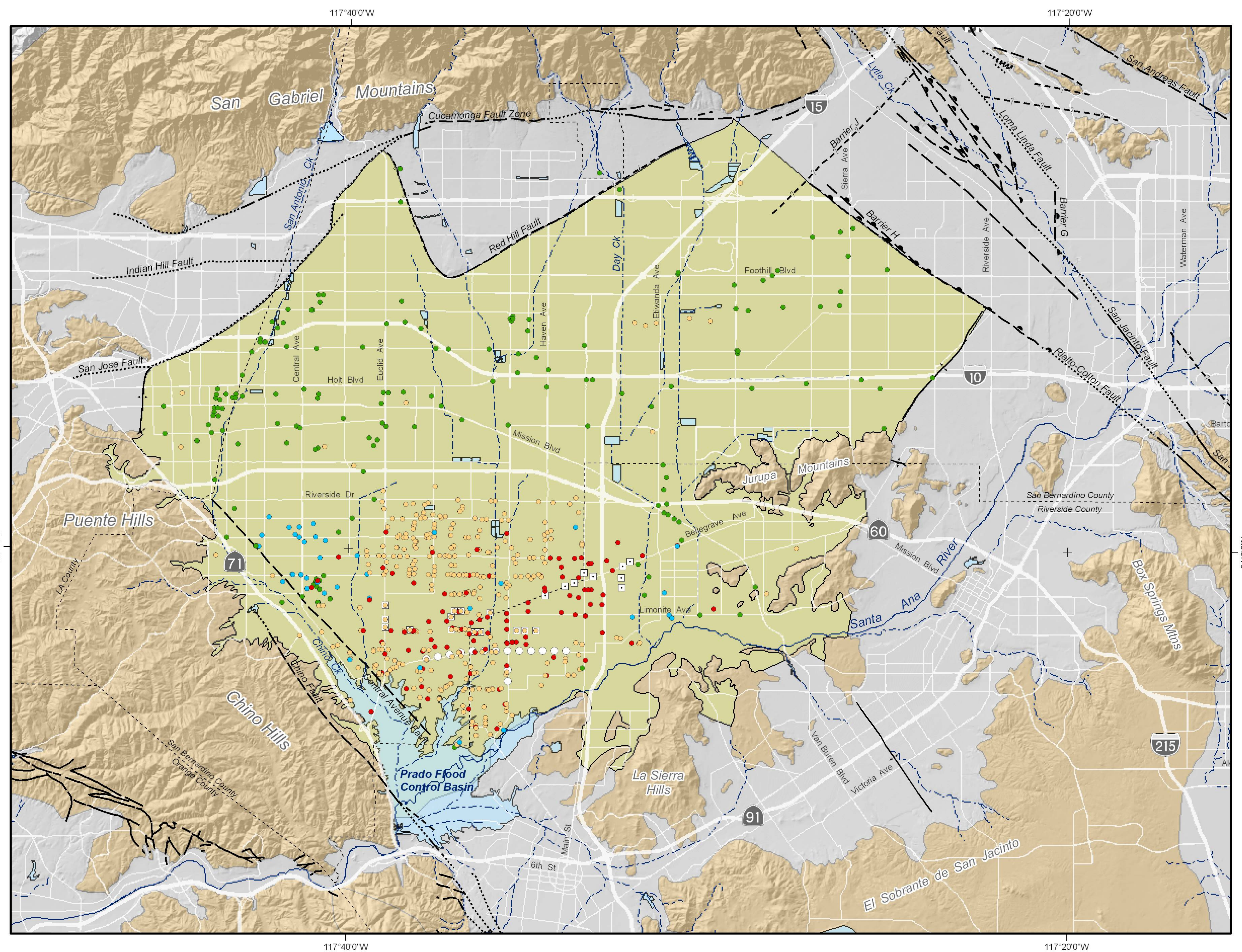
Watermaster will continue to expand the use of pressure transducers/data loggers at:

- wells within the key well network in southern Chino Basin
- selected wells in the northern portions of Chino Basin

Water level recording transducers provide highly-detailed groundwater level data that can reveal aquifer-system details (*e.g.* groundwater barriers, head responses to nearby pumping) that are not typically revealed or provided through analysis of infrequent (semi-annual, or even monthly) water level data.

In addition, nine nested sets of monitoring wells are currently being installed in the southern Chino Basin for the HCMP (see Section 8), and will be equipped with transducers as well.

Additional monitoring wells will likely need to be constructed in southern Chino Basin as more private wells (that are currently within the key well program) are destroyed. This recommendation will likely be associated with interim findings of the HCMP.



Main Features

Groundwater Level Monitoring Wells (by monitoring frequency and type)

- Monthly (106 wells)
- Semi-Annual (340 wells)
- Owner Determined (171 wells)
- Transducer (45 wells)

Other Features

- Existing Desalter Well
- Proposed Desalter Well
- Chino Basin Hydrologic Boundary
- Flood Control and Conservation Basins

Geology

Water-Bearing Sediments

- Quaternary Alluvium

Consolidated Bedrock

- Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

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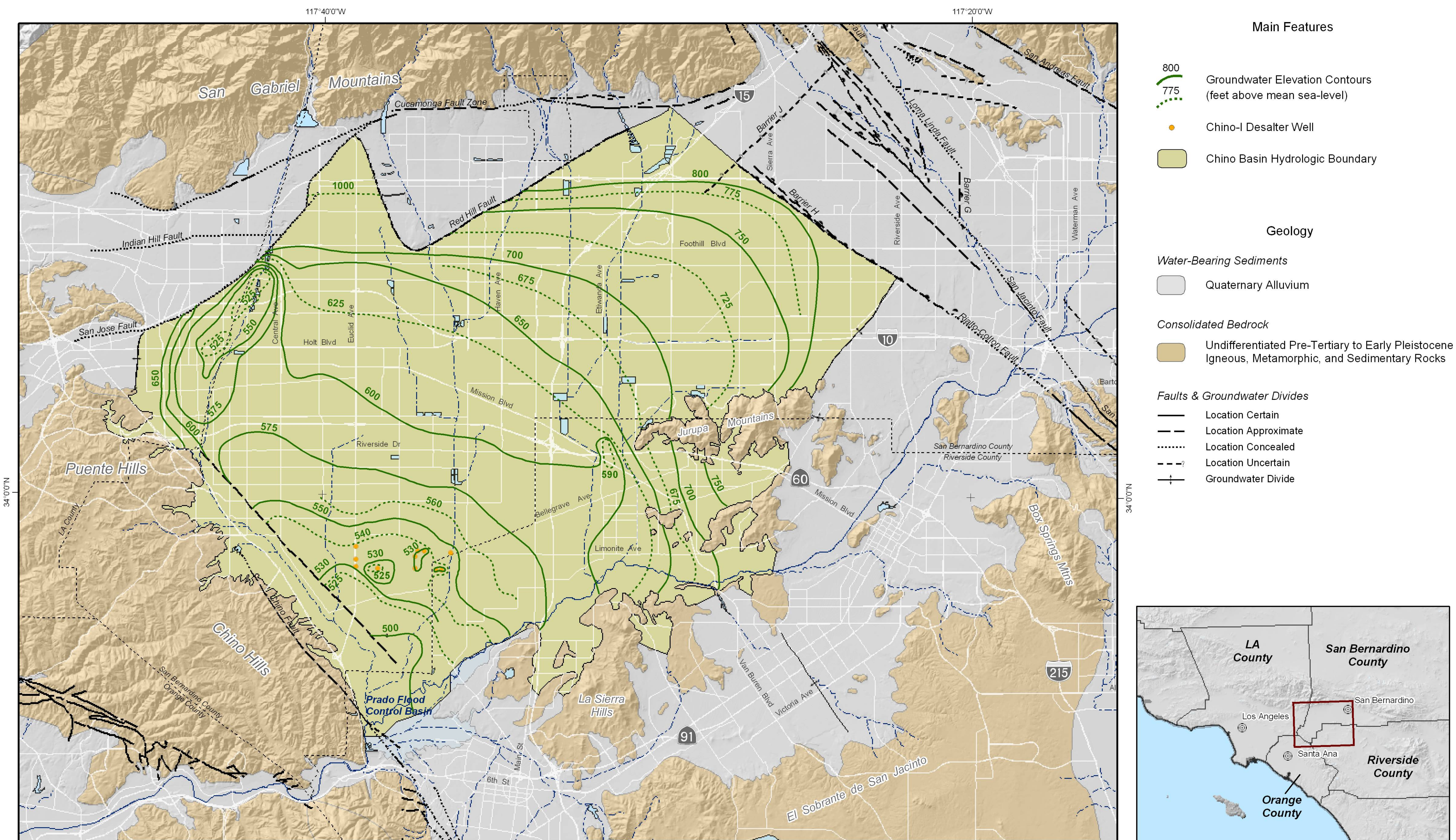
0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Levels

Groundwater Level Monitoring Network
Wells By Sampling Frequency

Figure 3-1



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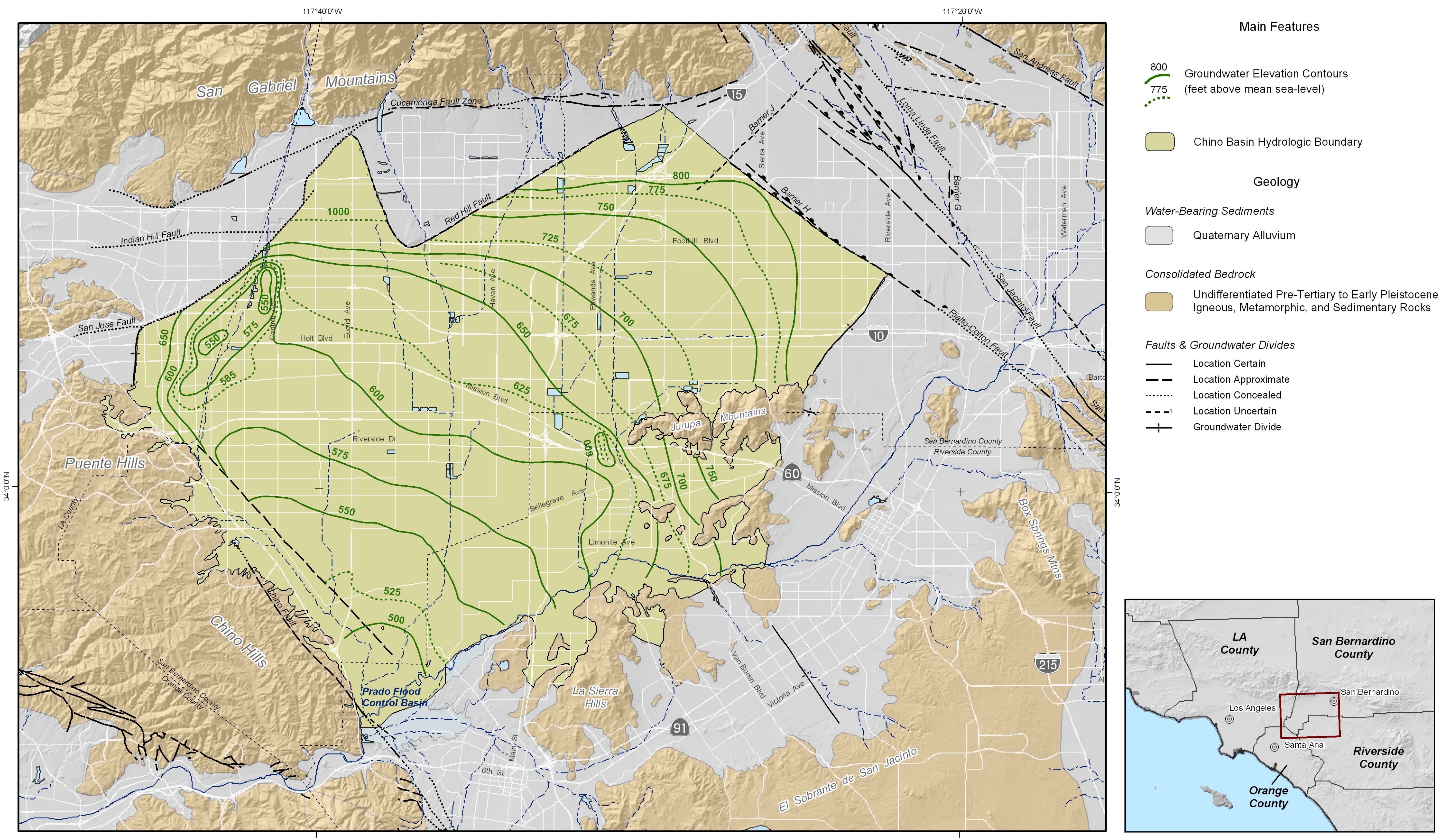
State of the Basin Report -- 2004
Groundwater Levels

Groundwater Elevation Contours
Fall 2003 -- Chino Basin

Figure 3-2



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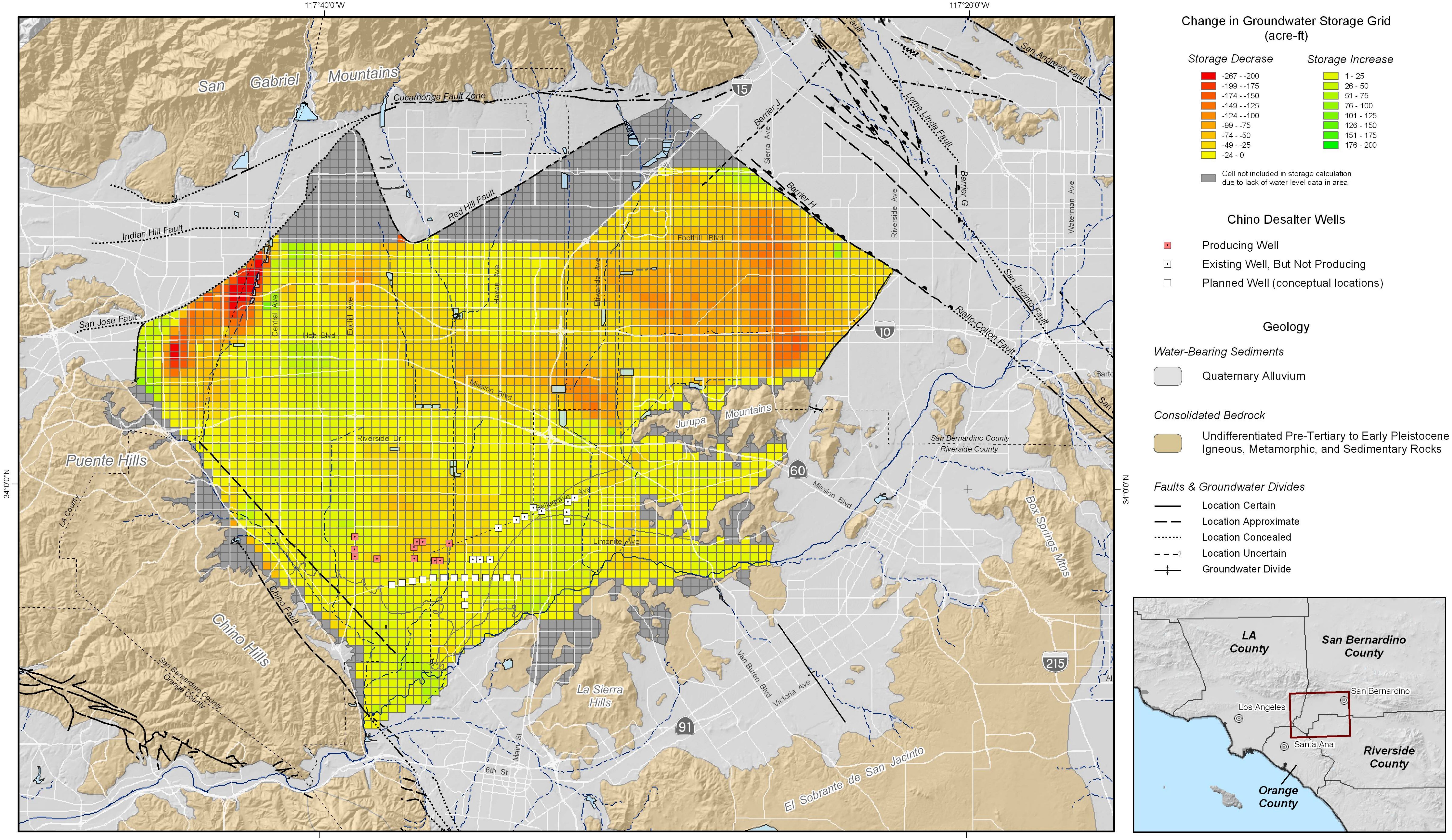
State of the Basin Report -- 2004
Groundwater Levels

Groundwater Elevation Contours

Fall 2000 -- Chino Basin

Figure 3-3



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0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Levels

Change in Groundwater Storage
Fall 2000 to Fall 2003

Figure 3-4

4. GROUNDWATER QUALITY

4.1 Background

Chino Basin groundwater is not only a critical resource to overlying producers of water; it is a critical resource to the entire Santa Ana Watershed. From a regulatory perspective, the use of Chino Basin groundwater to serve potable demands will be limited by drinking water standards, groundwater basin water quality objectives, and Santa Ana River water quality objectives. In August 1999, Phase 1 of the OBMP established a necessity for conducting groundwater quality and water level monitoring in order to obtain current water quality and water level data in Chino Basin (WEI, 1999). These data are necessary to define and evaluate specific strategies and locations for the mitigation of nitrate, total dissolved solids (TDS), and other constituents of potential concern (COPCs), new recharge sites, and pumping patterns resulting from the implementation of the OBMP.

In the past, various entities have collected groundwater quality data. Municipal and agricultural water supply entities have collected groundwater quality data to comply with the Department of Health Services' requirements in the California Code of Regulations Title 22 or for programs that range from irregular study-oriented measurements to long-term periodic measurements. Groundwater quality observations have been made by the California Department of Water Resources (DWR), by participants in the 1969 Judgment on the Santa Ana River (Orange County Water District vs. City of Chino *et al.*), by dischargers under orders from the RWQCB, and by the County of San Bernardino. The DWR and the San Bernardino County Flood Control District (SBCFCD) were very active in collecting groundwater quality data in the Chino Basin prior to the settlement of the Chino Basin adjudication. After the Judgment was entered in 1978, monitoring south of State Route 60 stopped almost completely, except for monitoring conducted by the cities of Chino, Chino Hills, and Norco, the Jurupa Community Services District (JCSD), and the Santa Ana River Water Company (SARWC). Most of the pre-1978 measurements were digitized by the DWR. In 1986, Metropolitan Water District of Southern California (MWDSC) conducted the first comprehensive survey of groundwater quality covering all constituents regulated under Title 22.

In 1989, Watermaster initiated a regular monitoring program for Chino Basin. Groundwater quality data were obtained in 1990 and periodically from then on until 1998.

4.2 Activities and Accomplishments to Date

Watermaster implemented a more aggressive monitoring program as part of the OBMP implementation. Watermaster's program relies on municipal producers and other government agencies supplying their groundwater quality data on a cooperative basis. Watermaster supplements these data with data obtained through its sampling and analysis program in the area generally south of State Route 60. Water quality data are also obtained from special studies and monitoring that takes place under the orders of the Regional Water Quality Control Board (RWQCB), the California Department of Toxic Substances Control (DTSC), and others. Watermaster has combined previously digitized groundwater quality data from all known sources into a comprehensive database.

4.2.1 Title 22 Compliance Monitoring

Water quality samples from wells operated by members of the Appropriative Pool and some members of the overlying Non-agricultural Pool are typically collected as part of the formalized monitoring programs. Constituents include those: (i) regulated for drinking water purposes in the California Code of

Regulations, Title 22; (ii) regulated in the 1995 Water Quality Control Plan for the Santa Ana River Basin (Basin Plan); or (iii) that are of special interest to the pumper.

4.2.2 Historical Water Quality Monitoring Programs for Private Wells

Historically, private wells were sampled less methodically and less frequently than wells owned by members of the Appropriative Pool. There is little historical groundwater quality information for most of the 600 private wells in the southern part of Chino Basin; thus, the historical water quality of groundwater that was produced at a majority of the wells in southern Chino Basin is unknown. Watermaster did have a limited groundwater quality monitoring program in the southern part of Chino Basin, wherein general minerals and physical properties were measured at about 60 wells. Prior to the Comprehensive Water Quality Monitoring Program completed in 2001 discussed in Section 4.2.3, there was only one other monitoring program to date that included a systematic water quality sampling program of the private wells in the southern portion of the Chino Basin:

In 1986, the MWDSC (1988) sampled 149 wells in Chino Basin, including 45 privately-owned wells in the southern portion of the Chino Basin. These wells were analyzed for major cations and anions, general physical parameters, volatile organic chemicals (VOCs), base/neutral/acid-extractable organic chemicals (BNAs), organochlorine pesticides and polychlorinated biphenyls (PCBs), organophosphorous pesticides, carbamate pesticides, and triazine herbicides and soil fumigants.

4.2.3 Comprehensive Water Quality Monitoring Program (1999 – 2001)

Watermaster developed the OBMP in 1999 (WEI, 1999), and the Peace Agreement that implemented the OBMP in 2000. The OBMP established management goals for Watermaster. The management plan in the OBMP describes actions that, when implemented, will achieve the goals of the OBMP. These actions are referred to as Program Elements. A groundwater quality monitoring program is a key part of the OBMP; hence, Program Element 1 – Develop and Implement a Comprehensive Monitoring Program. Watermaster developed and conducted the Comprehensive Water Quality Monitoring Program to provide comprehensive long-term information on groundwater quality for use in managing the groundwater basin.

The Comprehensive Water Quality Monitoring Program (CMP) consisted of water quality sampling and analysis from all known active production and monitoring wells in the Chino Basin. Watermaster staff obtained and analyzed samples from all known and active private wells, and obtained water quality for all other known and active wells from cooperating well owners. From October 1999 to March 2001, Watermaster sampled 602 private wells for the private well monitoring program (PWMP) portion of the CMP (The PWMP is a subset of the CMP). These wells were analyzed for:

- general mineral analyses (including cation and anion balances);
- general physical analyses;
- dissolved inorganic chemical analyses;
- perchlorate (US Environmental Protection Agency [US EPA] 300.0-IC);
- VOCs, including MTBE (US EPA 524.2);
- semivolatile organic compounds (US EPA 525.2);

- cyanide (SM 4500 CN-F);
- 1,2-dibromo-3-chloropropane (DBCP)/1,2-dibromoethane (EDB)/1,2,3-trichloropropane (US EPA 504.1); and
- gross alpha and beta (US EPA 900.0).

All known active private wells within the Agricultural Pool of the Chino Basin were selected for sampling; active, as defined by DWR, is "an operating water well." For each of the two years in the monitoring program, wells were selected to provide sufficient aerial coverage of the entire southern portion of the Chino Basin. The selected wells for Year 1 of the PWMP were located approximately within the capture zones of existing and proposed well fields for desalter facilities. Wells known to be within another entity's regular monitoring program were excluded from the PWMP, but the data collected by the other entities were added to the program data set, if available (*e.g.*, California Institution for Men [CIM] wells).

4.2.4 205(j) Groundwater Monitoring Program

Following the completion of the CMP, the Chino Basin 205(j) Groundwater Monitoring Program (CB205JMP) provided a continued evaluation of water levels and water quality in the groundwater of Chino Basin. Approximately 200 wells located in the southern portion of the Chino Basin were sampled. The water quality data included general minerals with a focus on TDS and nitrogen species. The collected water quality and water level data were used to develop detailed water quality and water level contour maps.

Partial funding for the CB205JMP was provided through the California State Water Resources Control Board (SWRCB) under Section 205(j) of the Federal Clean Water Act, Agreement Number 00-199-250-0. Funding from the 205(j) grant program was used to partially offset the cost for the necessary water quality and water level monitoring at 200 wells located in the southern portion of Chino Basin in the capture zone of Chino-1 and Chino-2 Desalters. The sampling program took place from February 2002 to June 2002.

4.2.5 Private Well Monitoring Program - 2002/2003 (PWMP-2002/03)

Continued monitoring of water levels and water quality influent to the desalter well fields is critical to optimizing the performance of these treatment facilities. One hundred fifty-five private wells were sampled in the PWMP-2002/03 and analyzed for general mineral and general physical parameters. In addition to these parameters, the following constituents were included in the on-going groundwater quality monitoring program:

- Perchlorate (all wells). Perchlorate is a contaminant of state and national prominence and importance. Perchlorate was detected in several private wells in the PWMP and, therefore, all private wells in this program were re-tested for perchlorate so that an accurate distribution of the contaminant can be made.
- 1,2,3-Trichloropropane (all wells). 1,2,3-TCP has a new California Notification Level (NL) of 0.005 µg/L. The detection limit for 1,2,3-TCP in the previous monitoring program was 50 µg/L and there was 1,2,3-TCP detected at greater than that detection limits. Because 1,2,3-

TCP may be a basin-wide water quality issue, all wells in this program were re-tested at a lower detection limit – 0.005 µg/L.

- VOCs (wells within or near VOC plumes). Those wells that were within VOC plumes or were within 1000 feet of the suspected edge of a plume were re-tested for VOCs.
- Hexavalent chromium, silica, strontium, barium, total and fecal coliforms (selected wells). These constituents were added during the CMP-PWMP, and hence, not all wells were tested for these constituents during that monitoring program. Those wells that were not tested for these constituents were tested during the PWMP-2002/03.

4.2.6 Information Management

As with groundwater level and groundwater production data, groundwater quality data are being managed by Watermaster in order to perform the requisite scientific and engineering analyses to ensure that the goals of the OBMP are being met. Watermaster has a relational database that contains information on well location, construction, lithology, specific capacity, groundwater level, and water quality. Historical water quality data for the period prior to the mid 1980s were obtained from the DWR and were supplemented with data from producers in the Appropriative and Overlying Non-Agricultural Pools and others. For the period from the mid 1980s forward, Watermaster loaded the database with water quality data from its own sampling programs, the State of California database – State Water Quality Information System (SWQIS), and from other cooperators. Occasionally problems have been found with the SWQIS data, usually in the form of incorrect constituent identification. In 2003, Watermaster launched the Chino Basin Relational Database effort (CBDB) to collect water quality data directly from each member agency and thereby circumvent the past data problems. All data, including geologic, geophysical, water levels, water quality, production, and recharge that are used to address the hydraulic control issue, will be provided by Watermaster to stakeholders in raw (uninterpreted) and complete form upon their request.

4.3 Results of Groundwater Quality Monitoring in Chino Basin

Figure 4-1 shows all wells in that have groundwater quality monitoring results for the period ranging from 1999 to 2004. The locations of existing and proposed desalter supply wells are shown in Figure 4-1 for aerial reference.

Inorganic and organic constituents that were detected in groundwater samples from wells in the Chino Basin through 2004 were analyzed synoptically; the analysis contained all available data, including data from several monitoring programs and studies. The water quality data reviewed in this synoptic analysis are derived from production wells and monitoring wells. Hence, the data do not represent a programmatic investigation of potential sources nor do they represent a randomized study designed to ascertain the water quality status of the Chino Basin. However, the data do represent the most comprehensive information available to date. Monitoring wells targeted at a potential source will likely have a greater concentration than a municipal or agricultural production well. Wells with constituent concentrations greater than one-half the MCL represent areas that warrant concern and inclusion in a long-term monitoring program. Additionally, groundwater in the vicinity of wells with samples greater than the MCL may be impaired from a beneficial use standpoint.

As discussed previously, the database includes both production wells and monitoring wells, including many monitoring wells associated with the Stringfellow NPL Site.

There are numerous water quality standards in place by both Federal and state agencies. Primary maximum contaminant levels are (MCL) are enforceable criteria set due to health effects. Secondary standards are related to aesthetic qualities of the water such as taste and odor. In addition, for some chemicals there are "notification level" criteria set by the state. These notification levels have been set due to health concerns but are not enforceable. The following constituents exceeded at least one water quality criteria for more than 10 wells in Chino Basin for the period of January 1999 through June 2004:

Analyte Group Constituent		Wells with Exceedances
Inorganic Constituents		
	total dissolved solids	479
	nitrate	606
	aluminum	57
	arsenic	12
	chloride	50
	fluoride	11
	iron	75
	manganese	40
	perchlorate	128
	sulfate	69
General Physical		
	color	13
	odor	14
Chlorinated VOCs		
	1,1-dichloroethene	12
	1,2,3-trichloropropane	55
	cis-1,2-dichloroethene	10
	tetrachloroethene (PCE)	30
	trichloroethene (TCE)	101
Radiological		
	gross alpha	153
	total radon 222	21

Figure 4-1 shows the chino basin wells with one or more set of water quality results included in the report. In the Figures that depict distributions of water quality in Chino Basin, the following convention is typically followed in setting the class intervals in the legend (where WQS is the applicable water quality standard. Variations from this convention may be employed to highlight certain aspects of the data.

Symbol	Class Interval
○	Not Detected
●	<0.5•WQS, but detected
●	0.5•WQS to WQS
●	WQS to 2•WQS
●	2•WQS to 4•WQS
●	> 4•WQS

4.3.1 Total Dissolved Solids

In Title 22, TDS is regulated as a secondary contaminant. The recommended drinking water maximum contaminant level (MCL) for TDS is 500 mg/L; however, the upper limit is 1,000 mg/L. Figures 4-2 through 4-4 show the distribution of TDS concentrations in Chino Basin for three periods:

- pre-1980;
- 1980 through 1998; and
- 1999-Present.

As discussed in Section 4.2.2, the data queried from the database are a combination of data from the Watermaster database and the State of California database (SQWIS).

In Figure 4-2 (pre-1980s), the TDS concentrations in the northern portion (*e.g.*, north of the 60 Freeway) of the Chino Basin are generally less than 250 mg/L. TDS concentrations south of the 60 Freeway were typically in the range of 250 to 500 mg/L, with the exception of the following areas, which have higher TDS concentrations: east of the Puente and Chino Hills, south of the Jurupa Hills, along the Santa Ana River, Temescal and Riverside Basins, and downgradient of the former RP1 discharge point. This pattern is replicated in the period 1980 to 1998 (Figure 4-3), with the following changes:

- TDS concentrations up to about 500 mg/L exist in the Pomona and Claremont basins and City of Pomona Water Service Area.
- More wells in the southern Chino Basin area have TDS concentrations in the 500 to 1000 and 1000 to 2000 mg/L class intervals.

Figure 4-4 shows the distribution of TDS concentrations in Chino Basin for the post 1998 period. This sampling period reflects primarily the PWMP data in the southern part of Chino Basin. The distribution of private wells sampled since 1998 by class intervals is:

Class Interval	Percent of wells in each class		
	CMP	205J	PWMP 2002-2003
< 125 mg/L	0	0	0
125 – 250 mg/L	6	3.5	2
250 –500 mg/L	22	18.5	10
500 – 1000 mg/L	36	39.5	33
1000 – 2000 mg/L	34	36.5	45
> 2000 mg/L	2	2.5	10

Seventy-two percent of the private wells in the CMP had TDS concentrations above the secondary MCL. With each consecutive sampling program the percent of wells with concentrations above the secondary MCL has decreased.

In places, wells with low TDS concentrations are found to be proximate to wells with higher TDS concentrations, suggesting a vertical stratification of water quality. However, there is a paucity of information concerning well construction/perforation intervals; therefore, the vertical differences in water quality are currently unverifiable.

While the drinking water MCL for TDS is 500 mg/L, for irrigation uses, TDS should generally be less than 700 mg/L. Additionally, the RWQCB has established TDS limitations for all municipal wastewater plants that discharge recycled water to the Santa Ana River. This results in a problem due to the fact that TDS concentrations increase through municipal use, typically by about 150 to 250 mg/L. The TDS limitations for water recycling plants that discharge to the Santa Ana River in the Chino Basin are listed below:

Plant	TDS Limit (mg L)
IEUA RP1	540
IEUA RP2	610
IEUA Carbon Canyon	555
IEUA RP4	505
Western Riverside Regional	625
City of Riverside	650
Jurupa Indian Hills	650

Therefore, in general, the TDS concentration in source (drinking) water must be kept well below 500 mg/L (preferably less than 300 mg/L) to ensure that recycled water discharged to the Santa Ana River and its tributaries meets RWQCB limitations.

TDS concentrations in the northeast part of Chino Basin range from about 170 to about 300 mg/L for the pre-1980 period ranging, with typical concentrations in the mid to low 200s. TDS concentrations in excess of 200 mg/L would indicate degradation from overlying land use. With a few exceptions, areas with either significant irrigated land use or dairy waste disposal histories overlie groundwater with elevated TDS concentrations. The exceptions are areas where point sources have contributed to TDS degradation; for instance, the former Kaiser Steel site in Fontana and the former wastewater disposal ponds near the IEUA Regional Plant No. 1 (RP1) in South Ontario.

The impacts of agriculture on TDS in groundwater are primarily caused by fertilizer use on crops, consumptive use, and dairy waste disposal. As irrigation efficiency increases, the impact of consumptive use on TDS in groundwater also increases. For example, if source water has a TDS concentration of 250 mg/L and the irrigation efficiency is about 50 percent (flood irrigation); the resulting TDS concentration in the returns to groundwater will be 500 mg/L, exclusive of the mineral increments from fertilizer. If the irrigation efficiency were increased to 75 percent, the resulting TDS concentration in the returns to groundwater will be 1,000 mg/L, exclusive of the mineral increments from fertilizer. For modern irrigated agriculture, the TDS impacts of consumptive use are more significant than mineral increments from fertilizers.

4.3.2 Nitrate-Nitrogen

In Title 22, nitrate is regulated in drinking water with an MCL of 10 mg/L (as nitrogen). [As discussed previously, the data queried from the database are a combination of data from the Watermaster database and the State of California database (SWQIS). By convention, all nitrate values are reported in this document as nitrate-nitrogen (NO_3-N). Hence, the values of nitrate-nitrogen reported in this document should be compared with an MCL of 10 mg/L.] Nitrate measurements in the surface water flows of the San Gabriel Mountains and in the groundwater near the foot of these mountains are generally less than 0.5 mg/L (Montgomery Watson, 1993). Nitrate concentrations in excess of 0.5 mg/L may indicate degradation from overlying land use.

Figures 3-5 through 3-7 show the distribution of nitrate-nitrogen concentrations in Chino Basin for three periods:

- pre-1980;
- 1981 through 1996; and
- 1997 through 2002.

In Figure 3-5 (pre-1980), most of the nitrate concentrations in the northern portions (north of the 60 Freeway) of Chino-North MZ are generally less than 5 mg/L. However, the Pomona-Claremont area (up to 25 mg/L), the eastern Fontana area (up to 10 mg/L), and the Cucamonga Basin (up to 25 mg/L), all have elevated nitrate concentrations. The following areas, south of the 60 Freeway, have somewhat elevated nitrate concentrations: east of the Puente and Chino Hills, south of the Jurupa Hills, along the Santa Ana River, the Temescal and Riverside Basins, and downgradient of the former RP1 discharge point.

This pattern is generally replicated in the period ranging from 1981 to 1997 (Figure 3-6); however, several wells in the southern portion of Chino Basin have nitrate concentrations greater than the MCL and 21 wells exceed 40 mg/L (4 times the MCL).

Figure 3-7 shows the distribution of nitrate concentrations in Chino Basin for the post-1997 period. This sampling period primarily reflects the PWMP data in the southern portion of Chino Basin. The distribution of private wells sampled since 1998 by class interval is:

Class Interval	Percent of wells in each class		
	CMP	205J	PWMP 2002-2003
< 2.5 mg/L	2	1	2
2.5 – 5 mg/L	6	8	1
5 –10 mg/L	9	8	5
10 – 25 mg/L	23	20	15
25 – 50 mg/L	28	36	33
> 50 mg/L	32	27	44

The results from the CMP indicate that about eighty-three percent of the private wells in had nitrate concentrations greater than the MCL and 60 percent are more than 2.5 times greater than the MCL. As with TDS, each consecutive sampling program saw a shift toward higher nitrate concentrations.

As explained in Section 3.4.1 areas with either significant irrigated land use or dairy waste disposal histories overlie groundwater with elevated nitrate concentrations. The primary areas of nitrate degradation are the areas formerly or currently overlain by:

- Citrus in the northern parts of the Chino-North MZ; and
- Dairy areas in the southern parts of the Chino-North MZ, the Chino-South MZ, the Chino-East MZ, and the Prado Basin MZ (PBMZ).

Nitrate concentrations in groundwater have increased slightly or remained relatively constant in the northern parts of the Chino-North MZ over the period ranging from 1960 to the present. These are areas formerly occupied by citrus groves and vineyards. Nitrate concentrations underlying these areas rarely exceed 20 mg/L (as nitrogen). Over the same period, nitrate concentrations have increased significantly in the southern parts of southern parts of the Chino-North MZ, the Chino-South MZ, the Chino-East MZ, and the PBMZ. These are areas where land use was progressively converted from irrigated/non-irrigated agricultural land to dairies, and nitrate concentrations typically exceed the 10 mg/L MCL and frequently exceed 20 mg/L.

4.3.3 Other Constituents of Potential Concern

A query was developed to analyze the data from the Watermaster database. Combined these data provide a fairly comprehensive coverage of the area, although critical water quality data may still be missing from the query. The summary results of this query are provided in Appendix B. The report in Appendix B contains the following information:

- Chemical constituent (listed alphabetically);
- Period – data were queried for 3 periods:
  - pre-1980s
  - 1980-1998
  - 1999 to present
- Reporting units;
- Water quality standards (detailed explanations are provided in the table's footnote):
  - status
  - Primary EPA MCL
  - Secondary MCL
  - Primary California MCL
  - Secondary MCL
  - California Notification Level
- Average – this is the average concentration of the given constituent for the given period. Non-detect values were assigned a value of zero.
- Median or Second Quartile. The second value that divides the items of a frequency distribution or ordered data set into four classes with each containing one fourth of the total population.
- Upper or Third Quartile. The third value that divides the items of a frequency distribution or ordered data set into four classes with each containing one fourth of the total population.
- Number of Wells Sampled. This is the number of wells sampled in the period (not the number of samples collected).
- Number of Wells with Detects. This is the number of wells in the period in which the constituent was detected at any concentration (not the number of samples greater than the detection limit).
- Number of Wells with Exceedances. This is the number of wells in the period with any value that exceeded any of the five water quality standards.

This section discusses the constituents whose water quality standards were exceeded in ten or more wells in Chino Basin (with the exception of nitrate and total dissolved solids). The details of these exceedances are displayed graphically in Figures 4-2 through 4-26. Chromium, hexavalent chromium and MTBE are not discussed in the section that follows because standards were not exceeded in 10 or more wells. However, in the future, these constituents may be problematic, depending on the promulgation of future standards.

4.3.3.1 VOCs

The following five volatile organic chemicals (VOCs) were detected at or above their MCL in more than 10 wells:

- 1,1-dichloroethene;
- 1,2,3-trichloropropane;

- *cis*-1,2-dichloroethene;
- tetrachloroethene (PCE); and
- trichloroethene (TCE).

Tetrachloroethene and Trichloroethene

PCE and TCE were/are widely used industrial solvents PCE is commonly used in the dry-cleaning industry. About 80 percent of all dry cleaners use PCE as their primary cleaning agent (Oak Ridge National Laboratory, 1989). TCE was commonly used for metal degreasing and as a food extractant. The aerial distributions of PCE and TCE are shown in Figures 4-8 and 4-9. In general, PCE is below detection limits for wells in the Chino Basin. The wells with detectable levels tend to occur in clusters such as those seen around Milliken Landfill, south and west of the Ontario Airport and along the margins of the Chino Hills. The spatial distribution of TCE resembles that of PCE. TCE was not detectable in most of the wells in the basin. Similar clustering of wells was also seen around Milliken Landfill, south and west of Ontario Airport, south of Chino Airport and in the Stringfellow plume.

Dichloroethene and *cis*-1,2-Dichloroethene

Dichloroethene (1,1-DCE) and *cis*-1,2-dichloroethene (*cis*-1,2-DCE) are degradation by-products of PCE and TCE (Dragun, 1988) formed by the reductive dehalogenation, and their aerial distributions are shown in Figures 4-10 and 4-11. In a majority of wells in the Chino Basin, dichloroethene and *cis*-1,2-dichloroethene are not detected. Dichloroethene is found in near Milliken Landfill, south and west of Ontario Airport, south of Chino Airport and at the head of the Stringfellow plume. *cis*-1,2-Dichloroethene is found in the same general locations.

1,2,3-Trichloropropane

1,2,3-Trichloropropane (1,2,3,-TCP) is a colorless liquid that is used primarily as a chemical intermediate in the production of polysulfone liquid polymers and dichloropropene, synthesis of hexafluoropropylene, and as a cross linking agent in the synthesis of polysulfides. It has been used as a solvent, extractive agent, paint and varnish remover, cleaning and degreasing agent, and it has been formulated with dichloropropene in the manufacturing of soil fumigants, such as D-D.

The current California State Notification Level for 1,2,3-TCP is 0.005 µg/L. The adoption of the Unregulated Chemicals Monitoring Requirements (UCMR) regulations occurred before a method capable of achieving the required detection limit for reporting (DLR) was available. According to the DHS, some utilities moved ahead with monitoring and the samples were analyzed using higher DLRs. Unfortunately, findings of non-detect with a DLR higher than 0.005 µg/L do not provide DHS with adequate information needed for possible standard setting. New methodologies to analyze for 1,2,3-TCP with a DLR of 0.005 µg/L have since been developed and the DHS is requesting that any utility with 1,2,3-TCP findings of nondetect with reporting levels of 0.01 µg/L or higher do follow-up sampling using a DLR of 0.005 µg/L. Private wells in the PWMP in 1999 through 2001 were analyzed for 1,2,3-TCP at a DLR of 50 µg/L. Because 1,2,3-TCP may be a basin-wide water quality issue, all private wells are being re-tested at a lower detection limit – 0.005 µg/L.

Figure 4-12 show the distribution of 1,2,3-trichloropropane in Chino Basin, based on the data limitations discussed previously, using the legend convention typically employed throughout this report. Figure 4-12 shows that the very high values of 1,2,3-TCP are associated with the Chino Airport VOC plume. In addition, there is a cluster of wells that have 1,2,3-TCP in concentrations greater than the Notification Level north of the Chino Airport and a scattering of wells exceeding the Notification Level on the western margins of the basin.

4.3.3.2 Aluminum, Arsenic, Fluoride, Iron, and Manganese

The concentrations of aluminum, arsenic, iron, and manganese depend on mineral solubility, ion exchange reactions, surface complexations, and soluble ligands. These speciation and mineralization reactions, in turn, depend on pH, oxidation-reduction potential, and temperature.

Aluminum and Iron

In general, across the Chino Basin, aluminum and iron were non-detect (Figures 4-13 and 4-14, respectively. However, both constituents were high in the Stringfellow plume. Furthermore, iron was found at detectable levels (but still below one-half the MCL) in 2 clusters of wells on either side of Ontario Airport. Outside of the Stringfellow plume, there were 18 wells with concentrations greater then the MCL. Aluminum concentrations exceeded the primary California MCL in 5 wells outside of the Stringfellow plume. Exceedances may be an artifact of sampling methodology – relatively high concentrations of aluminum, iron, and trace metals are often the result of dissolution of aluminosilicate particulate matter and colloids caused by the acid preservative in unfiltered samples.

Arsenic

The current arsenic MCL is 50 µg/L. In January 2001, EPA mandated that compliance with the new federal arsenic MCL of 10 µg/L would be required by 2006. After adopting 10 µg/L as the new standard for arsenic in drinking water, the US EPA decided to review the decision to ensure that the final standard was based on sound science and accurate estimates of costs and benefits. In October 2001, the US EPA decided to move forward with implementing the 10 µg/L standard for arsenic in drinking water (US EPA, 2001). Figure 4-15 shows the distribution of arsenic in Chino Basin. Fourteen wells in the Chino Wells had arsenic concentrations that exceed the 2006 MCL. Only 4 wells in the basin exceeded the current MCL of 50 µg/L. Three of these wells belong to the City of Chino Hills, the remaining well is at the northern tip of the Stringfellow plume. Higher concentrations of arsenic in the Chino Hills area are found at depths greater than about 350 feet below ground surface:

Well	Arsenic Concentrations 1999 – 2004 (mg L)			Perforated Intervals (ft bgs)
	Minimum	Maximum	Average	
Chino Hills 16	ND	67	39	430 – 940
Chino Hills 15B	13	72	51	360 – 440 480 – 900
Chino Hills 1B	58	80	66	440 – 470

Well	Arsenic Concentrations 1999 – 2004 (mg L)			Perforated Intervals (ft bgs)
	Minimum	Maximum	Average	
				490 – 610 720 – 900 940 – 1180

Chino Hills 1A is a production well that is located about 30 feet from Chino Hills 1B, the well with the highest concentration of arsenic in the period from 1999 to 2004. During this period samples from Chino Hills 1A (perforated interval: 166 – 317 ft bgs) were all non-detect.

Fluoride

Fluoride occurs naturally in groundwater in concentrations ranging from less than 0.1 mg/L to 10-20 mg/L (Freeze and Cherry, 1979). However, site-specific monitoring wells may reveal point sources (*e.g.*, wells near landfills have shown relatively high concentrations of manganese). Figure 4-16 displays the distribution of fluoride found in wells in the Chino Basin. Fluoride was detected in 954 wells within the basin, only 7 of which have concentrations that exceed the California primary MCL.

Manganese

Manganese is a naturally-occurring element that is a component of over 100 minerals. Because of the natural release of manganese into the environment by the weathering of manganese-rich rocks and sediments, manganese occurs ubiquitously at low levels in soil, water, air, and food. Manganese compounds are used in a variety of products and applications including water and wastewater treatment, matches, dry-cell batteries, fireworks, fertilizer, varnish, livestock supplements, and as precursors for other manganese compounds. Manganese is often found near landfills, especially when oxidation-reduction conditions promote its mobility in groundwater. Neither manganese nor any manganese compounds are regulated in drinking water. However, the US EPA has set a secondary standard MCL of 0.05 mg/L as has California. All these standards though are non-enforceable. Most of the wells sampled for manganese have resulted in non-detect. High concentrations of manganese in groundwater have been observed along the Santa Ana River in Reach 3, scattered throughout the southern portion of Chino Basin and near the Milliken Landfill (Figure 4-17).

4.3.3.3 Perchlorate

Perchlorate has recently been detected in several wells in the Chino Basin (Figure 4-18), in other basins in California, and in other states in the West. The probable reason that perchlorate was not detected in groundwater until recently is that analytical methodologies did not previously exist that could attain a low enough detection limit. Prior to 1996, the method detection limit for perchlorate was 400 µg/L. By March 1997, an ion chromatographic method was developed with a detection limit of 1 µg/L and a reporting limit of 4 µg/L.

Perchlorate (ClO_4^-) originates as a contaminant in the environment from the solid salts of ammonium perchlorate (NH_4ClO_4), potassium perchlorate ($KClO_4$), or sodium perchlorate ($NaClO_4$). The perchlorate salts are quite soluble in water. The perchlorate anion (ClO_4^-) is exceedingly mobile in soil and groundwater environments. Because of its resistance to react with other available constituents, it can persist for many decades under typical groundwater and surface water conditions. Perchlorate is a kinetically stable ion, which means that reduction of the chlorine atom from a +7 oxidation state in perchlorate to a -1 oxidation state as a chloride ion requires activation energy or the presence of a catalyst to facilitate the reaction. Since perchlorate is chemically stable in the environment, natural chemical reduction in the environment is not expected to be significant.

Ammonium perchlorate is manufactured for use as an oxygenating component in solid propellant for rockets, missiles, and fireworks. Because of its limited shelf life, inventories of ammonium perchlorate must be periodically replaced with a fresh supply. Thus, large volumes of the compound have been disposed of since the 1950s in Nevada, California, Utah, and possibly in other states. While ammonium perchlorate is also used in certain munitions, fireworks, the manufacture of matches, and in analytical chemistry, perchlorate manufacturers estimate that about 90 percent of the substance is used for solid rocket fuel.

Speculation has arisen that perchlorate in groundwater may be the result of using "Chilean fertilizer" for agricultural purposes. The EPA recently completed a comprehensive survey of fertilizers and other raw materials for perchlorate to determine whether these could be significant contributors to environmental perchlorate contamination (Urbansky *et al.*, 2001). Four laboratories analyzed 48 fertilizer products from manufacturers of major commodity chemicals. Samples were collected from representative sites in the United States during the Spring of 2000.

Except for those products derived from Chilean caliche (a natural perchlorate source), the specific natures of the manufacturing processes suggest that perchlorate should not be present in most fertilizers. Chilean nitrate salts constitute about 0.14% of U.S. fertilizer application. Perchlorate was positively detected only in those materials known to be derived from Chilean caliche. The data obtained here fail to suggest that fertilizers contribute to environmental perchlorate contamination other than in the case of natural saltpeters or their derivatives. (Urbansky *et al.*, 2001)

Fertilizers derived from Chilean caliche are currently used in small quantities, on specialized crops, including tobacco, cotton, fruits, and vegetables (Renner, 1999). However, there is some evidence to suggest that there may have been wider-spread usage for citrus crops in Southern California from the late 1800s through the 1930s.

The requisite toxicology data available to evaluate the potential health effects of perchlorate are extremely limited. The US Environmental Protection Agency (EPA) Superfund Technical Support Center issued a provisional reference dose (RfD) in 1992 and a revised provisional RfD in 1995. Standard assumptions for ingestion rate and body weight were then applied to the RfD to calculate the reported range in the groundwater cleanup guidance levels of 4 to 18 µg/L. In 1997, the DHS and the California EPA's Office of Environmental Health Hazard Assessment (OEHHA) reviewed the EPA's risk assessment reports for perchlorate. Consequently, California established its provisional action level of 18 µg/L. On August 1, 1997, DHS informed drinking water utilities of its intention to develop a regulation to require monitoring for perchlorate as an unregulated chemical. Legislative action to establish a state drinking water standard for perchlorate has been introduced, but has not been brought to a vote (CA Senate Bill 1033).

The California DHS (2002a) has stated that perchlorate in groundwater in California likely reflects its use in the aerospace industry as a solid rocket propellant (in the form of ammonium perchlorate). To protect the public from perchlorate's adverse health effects – and in the absence of a drinking water standard for the contaminant – DHS established an action level of 18 µg/L, which was derived from available risk assessments. "Following the release of US EPA's 2002 draft risk evaluation, DHS concluded that its Action Level needed to be revised downward. Accordingly, on January 18, 2002, DHS reduced the perchlorate Action Level to 4 µg/L, the lower of the 4- to 18-µg/L range. The 4-µg/L Action Level also corresponds to the current detection limit for purposes of reporting (DLR)" (DHS, 2002c). DHS subsequently revised the Action Level for perchlorate to 6 µg/L on March 11, 2004.

Perchlorate has been detected in 152 wells in the Chino Basin. Historical values of perchlorate exceeding the State Action Level have occurred in the following areas of Chino Basin (Figure 3-18):

- There is a significant perchlorate plume in the Rialto-Colton Basin. The source of the plume is being investigated by the RWQCB and it appears to be located near the Mid-Valley Sanitary Landfill. According to the RWQCB, other companies including B.F. Goodrich, Kwikset Locks, American Promotional Events Inc., and Denova Environmental Inc. operated nearby and used or produced perchlorate. These companies were located on a 160-acre parcel at T1N R5W S21 SW1/4. Denova Environmental also operated on a 10-acre lot at T1N R5W S20 S1/2 (along the boundary between Sections 20 and 29). The perchlorate in the Fontana area of Chino Basin may be a result of (i) the Rialto-Colton perchlorate plume migrating across the Rialto-Colton fault; (ii) other point sources in Chino Basin; and (iii) non-point application of Chilean nitrate fertilizer in citrus groves.
- Downgradient of the Stringfellow Superfund Site. Concentrations have exceeded 600,000 µg/L in on-site observation wells and the plume has likely reached Pedley Hills and may extend as far as Limonite Avenue.
- City of Pomona well field (source unknown).
- Wells in the City of Ontario water service area, south of the Ontario Airport (source(s) unknown).
- Scattered wells in the Monte Vista water service area (source(s) unknown).
- Scattered wells in the City of Chino water service area (source(s) unknown).

4.3.3.4 Radon and Gross Alpha

Radon (Figure 4-19) is a radioactive gas found in nature. It has no color, odor, or taste and is chemically inert. Its source is uranium – as the uranium molecule decays to form stable lead, a process taking many, many years, it changes from one radioactive element to another in a sequence known as the Uranium Decay Cycle. Partway through this cycle, the element radium becomes radon, which, as a gas moves up through the soil to atmosphere. Uranium is found in most soils and in granite. Radon may be found in drinking water and indoor air. Some people who are exposed to radon in drinking water may have an increased risk of getting cancer over the course of their lifetime, especially lung cancer. The US EPA has established a proposed MCL of 300 pCi/L (Macler, 2000).

Similarly, alpha radiation is a type of energy released when certain radioactive elements decay or break down. For example, uranium and thorium are two radioactive elements found naturally in the earth's crust. Over billions of years, these two elements slowly change form and produce "decay products" such as radium and radon. During this change process, energy is released. One form of this energy is alpha radiation.

Higher concentrations of radon and gross alpha in groundwater typically occur near granitic bedrock outcrops; one might expect to see higher occurrences of these constituents near the San Gabriel Mountains, Jurupa Hills, Puente Hills, and Chino Hills and along fault zones – Rialto-Colton Fault, San Jose Fault, and the Red Hill Fault. The aerial distributions of radon and gross alpha do not show the expected pattern, however, there are no spatial patterns or outside evidence to suggest a source other than naturally-occurring (Figures 4-19 and 4-20). Based on water quality results from 1999 to the present, 58 wells in the basin are at or above the US EPA proposed MCL for Radon. For gross alpha results, while 165 wells are at or above the US EPA MCL.

4.3.3.5 Chloride and Sulfate

Chloride and sulfate both exceeded secondary MCLs. As discussed previously, secondary MCLs apply to chemicals in drinking water that adversely affect its aesthetic qualities and are not based on direct health effects associated with the chemical. Chloride and sulfate are major anions associated with TDS. Most wells in the basin had detectable levels of sulfate (Figure 4-21) but most were less then 125 mg/L (one-half the water quality standard). A total of 83 wells had concentrations at or above the sulfate MCL. In general, these wells were distributed in the southern portion of the basin, along the margins of the Chino Hills and in the Stringfellow plume. All wells had detectable levels of chloride (Figure 4-22) but most concentrations were less 125 mg/L (one-half the MCL). The secondary MCL for chloride is exceeded in 68 wells almost all of which are located in the southern portions of the basin.

4.3.3.6 Color, Odor and Turbidity

Color, odor, and turbidity were detected at greater than their secondary MCLs in more than 10 wells in the last 5 years (Figure 4-23, Figure 4-24 and Figure 4-25 respectively). These parameters are monitored purely for aesthetic reasons and should not limit water quality in Chino Basin.

4.3.4 Point Sources of Concern

The previous water quality discussion broadly described water quality conditions across the entire basin. The discussion presented below describes the water quality anomalies associated with known point source discharges to groundwater. Figure 4-26 shows the location of various point sources and areas of water quality degradation associated with these sources.

4.3.4.1 Chino Airport

The Chino Airport is located approximately four miles east of the City of Chino and six miles south of Ontario International Airport, and occupies an area of about 895 acres. From the early 1940s until 1948, the airport was owned by the federal government and used for flight training and aircraft storage. The County of San Bernardino acquired the airport in 1948 and has operated and/or leased portions of the facility ever since. Since 1948, past and present businesses and activities at the airport include modification of military aircraft, crop dusting, aircraft-engine repair, aircraft painting, stripping and washing, dispensing of fire-retardant chemicals to fight forest fires, and general aircraft maintenance. The use of organic solvents for various manufacturing and industrial purposes has been widespread throughout the airport's history (RWQCB, 1990). From 1986 to 1988, a number of groundwater quality investigations were performed in the vicinity of Chino Airport. Analytical results from groundwater sampling revealed the presence of VOCs above MCLs in six wells downgradient of Chino Airport. The most common VOC detected above its MCL was TCE. TCE concentrations in the contaminated wells ranged from 6.0 to 75.0 µg/L.

Figure 4-26 shows the approximate aerial extent of TCE in groundwater in the vicinity of Chino Airport at concentrations exceeding its MCL as of 2002. The plume is elongate in shape, up to 3,600 feet wide and extends approximately 14,200 feet from the airport's northern boundary in a south to southwestern direction. During the period from 1997 to 2002, the maximum TCE concentration in groundwater detected at an individual well within the Chino Airport plume was 570 µg/L.

In 2002, the County of San Bernardino submitted a work plan to the Regional Board for installing up to five monitoring wells at and around Chino Airport in Summer 2003. The concentrations of TCE observed by in the five monitoring wells are entirely consistent with a conceptual model of a plume that has migrated away from Chino Airport. These new data corroborate other data generated by the Watermaster and others.

4.3.4.2 California Institute for Men

The California Institute for Men (CIM) located in Chino is bounded on the north by Edison Avenue, on the east by Euclid Avenue, on the south by Kimball Avenue, and on the west by Central Avenue. CIM is a state correctional facility and has been in existence since 1939. It occupies approximately 2,600 acres – about 2,000 acres are used for dairy and agricultural uses and about 600 acres are used for housing inmates and related support activities (Geomatrix Consultants, 1996). In 1990, PCE was detected at a concentration of 26 µg/L in a sample of water collected from a CIM drinking water supply well. Analytical results from groundwater sampling indicated that the most common VOCs detected in groundwater underlying CIM were PCE and TCE. Other VOCs detected included carbon tetrachloride, chloroform, 1,2-DCE, bromodichloromethane, 1,1,1-trichloroethane (1,1,1-TCA), and toluene. The maximum PCE concentration in groundwater detected at an individual monitoring well (GWS-12) was 290 µg/L. The maximum TCE concentration in groundwater detected at an individual monitoring well (MW-6) was 160 µg/L (Geomatrix Consultants, 1996).

Figure 4-26 shows the approximate aerial extent of VOCs in groundwater at concentrations exceeding MCLs as of 2004. The plume is up to 2,900 feet wide and extends about 5,800 feet from north to south. During the period from 1999 to 2004, the maximum PCE and TCE concentrations in groundwater detected at an individual well within the CIM plume were 1,990 µg/L and 141 µg/L, respectively.

4.3.4.3 General Electric Flatiron Facility

The General Electric Flatiron Facility (Flatiron Facility) occupied the site at 234 East Main Street, Ontario, California from the early 1900s to 1982. Its operations primarily consisted of the manufacturing of clothes irons. Currently, the site is occupied by an industrial park. The RWQCB issued an investigative order to General Electric (GE) in 1987 after an inactive well in the City of Ontario was found to contain TCE and chromium above drinking water standards. Analytical results from groundwater sampling indicated that VOCs and total dissolved chromium were the major groundwater contaminants. The most common VOC detected at levels significantly above its MCL is TCE, which reached a measured maximum concentration of 3,700 µg/L. Other VOCs periodically detected, but commonly below MCLs, included PCE, toluene, and total xylenes, (Geomatrix Consultants, 1997).

Figure 4-26 shows the approximate aerial extent of TCE in groundwater at concentrations exceeding MCLs as of 2002. The plume is up to 3,400 feet wide and extends about 9,000 feet south-southwest (hydraulically downgradient) from the southern border of the site. During the period from 1999 to 2004, the maximum TCE and total dissolved chromium concentrations in groundwater detected at an individual well within the Flatiron Facility plume were 7,990 µg/L and 1,700 µg/L, respectively.

4.3.4.4 General Electric Test Cell Facility

The General Electric Company's Engine Maintenance Center Test Cell Facility (Test Cell Facility) is located at 1923 East Avon, Ontario, California. Primary operations at the Test Cell Facility include the testing and maintenance of aircraft engines. A soil and groundwater investigation, followed by a subsequent quarterly groundwater-monitoring program, began in 1991 (Dames & Moore, 1996). The results of these investigations showed that VOCs exist in the soil and groundwater beneath the Test Cell Facility and that the released VOCs have migrated off site. Analytical results from subsequent investigations indicated that the most common and abundant VOC detected in groundwater beneath the Test Cell Facility was TCE. Other VOCs detected included PCE, *cis*-1,2-DCE, 1,2-dicholoropropane, 1,1-DCE, 1,1-DCA, benzene, toluene, and xylenes, among others. The historical maximum TCE concentration measured at an on-site monitoring well (directly beneath the Test Cell Facility) was 1,240 µg/L. The historical maximum TCE concentration measured at an off-site monitoring well (downgradient) was 190 µg/L (BDM International, 1997).

Figure 4-26 shows the aerial extent of VOC contamination exceeding federal MCLs as of 2004. The plume is elongate in shape, up to 2,400 feet wide and extends approximately 10,300 feet from the Test Cell Facility in a southwesterly direction. During the period from 1997 to 2002, the maximum TCE and PCE concentrations in groundwater detected at an individual well within the Test Cell Facility plume were 1,100 µg/L and 29 µg/L, respectively.

4.3.4.5 Kaiser Steel Fontana Steel Site

Between 1943 and 1983, the Kaiser Steel Corporation (Kaiser) operated an integrated steel manufacturing facility in Fontana. During the first 30 years of the facility's operation (1945-1974), a portion of the Kaiser brine wastewater was discharged to surface impoundments and allowed to percolate into the soil. In the early 1970s, the surface impoundments were lined to eliminate percolation to groundwater (Wildermuth, 1991). In July of 1983, Kaiser initiated a groundwater investigation that revealed the presence of a plume of degraded groundwater under the facility. In August of 1987, the RWQCB issued Cleanup and Abatement Order Number 87-121, which required additional groundwater investigations and remediation activities. The results of these investigations showed that the major constituents of the release to groundwater were inorganic dissolved solids and low molecular weight organic compounds. Wells sampled during the groundwater investigations measured concentrations of total dissolved solids (TDS) ranging from 500-1,200 mg/L and concentrations of total organic carbon (TOC) ranging from 1 to 70 mg/L. As of November 1991, the plume had migrated almost entirely off the Kaiser site.

Figure 4-26 shows the approximate aerial extent of the TDS/TOC groundwater plume as of 2002. Based on a limited number of wells, including City of Ontario Well No. 30, the plume is up to 3,400 feet wide and extends about 17,500 feet from northeast to southwest.

4.3.4.6 Mid-Valley Sanitary Landfill

The Mid-Valley Sanitary Landfill (MVSL) is a Class III Municipal Solid Waste Management Unit located at 2390 North Adler Avenue in the City of Rialto. The facility is owned by the County of San Bernardino and managed by the County's Waste System Division. VOCs and perchlorate have been detected in groundwater beneath and downgradient from the MVSL. The most common and abundant VOCs in groundwater are PCE, 1,1-DCA, and 1,1-DCE. TCE, *cis*-1,2-DCE, 1,2-DCA, vinyl chloride, and benzene also have been detected. The VOC plume from the MVSL does not appear to extend into the Chino Basin as of 2002 (Figure 4-26).

Perchlorate has been detected in the Rialto-Colton and Chino Basins (Figure 4-18). The sources of the perchlorate plume are being investigated by the RWQCB and it appears that one set of sources is located near the MVSL. According to the RWQCB, other companies including B. F. Goodrich, Kwikset Locks, American Promotional Events Inc., and Denova Environmental Inc. operated nearby and used or produced perchlorate. These companies were located on a 160-acre parcel at T1N R5W S21 SW1/4. Denova Environmental also operated on a 10-acre lot at T1N R5W S20 S1/2 (along the boundary between Sections 20 and 29). The perchlorate plume appears to migrate initially to the southeast prior to moving to the southwest in the direction of regional groundwater flow. The local groundwater flow direction at the landfill is to the southeast, potentially influenced by the Alder Avenue Barrier (GeoLogic, 2002). The perchlorate plume in the Rialto Basin appears to extend well into the Chino Basin, crossing the Rialto-Colton Fault. The plume is about seven miles long from the middle of the Mid-Valley Sanitary Landfill.

4.3.4.7 Milliken Sanitary Landfill

The Milliken Sanitary Landfill (MSL) is a Class III Municipal Solid Waste Management Unit located near the intersections of Milliken Avenue and Mission Boulevard in the City of Ontario. The facility is owned by the County of San Bernardino and managed by the County's Waste System Division. The facility was opened in 1958 and continues to accept waste within an approximate 140-acre portion of the 196-acre permitted area (GeoLogic Associates, 1998). Groundwater monitoring at the MSL began in 1987 with five monitoring wells as part of a Solid Waste Assessment Test investigation (IT, 1989). The results of this investigation indicated that the MSL has released organic and inorganic compounds to the underlying groundwater. At the completion of an Evaluation Monitoring Program (EMP) investigation (GeoLogic Associates, 1998), a total of 29 monitoring wells were drilled to evaluate the nature and extent of groundwater impacts identified in the vicinity of the MSL. Analytical results from groundwater sampling indicated that VOCs are the major constituents of the release. The most common VOCs detected were TCE, PCE, and dichlorodifluoromethane. Other VOCs detected above MCLs included vinyl chloride, benzene, 1,1-dichloroethane, and 1,2-dichloropropane. The historical maximum total VOC concentration in an individual monitoring well was 159.6 µg/L (GeoLogic Associates, 1998).

Figure 4-26 shows the approximate aerial extent of VOCs in groundwater at concentrations exceeding MCLs as of 2002. The plume is up to 1,800 feet wide and extends about 2,100 feet south of the MSL's southern border. During the period from 1999 to 2004, the maximum TCE and PCE concentrations in groundwater detected at an individual well within the MSL plume were 64 µg/L and 81 µg/L, respectively.

4.3.4.8 Municipal Wastewater Disposal Ponds

Treated municipal wastewater has been disposed into ponds located near the current IEUA Regional Plant 1 (RP1), located in south Ontario, and the former Regional Plant 3 (RP3), located in south Fontana. The ponds located just east of RP1, commonly called the Cucamonga ponds, were used to dispose of untreated effluent collected by the Cucamonga County Water District (CCWD) and the IEUA. RP3 and its disposal ponds are located on the southwest corner of Beech and Jurupa Avenues in the City of Fontana. Discharge to the Cucamonga ponds and the ponds of RP3 ceased between the early 1970s and the mid-1980s. The areas downgradient of these recharge ponds typically have elevated TDS and nitrate concentrations. Contaminant plumes emanating from these ponds have never been fully characterized.

4.3.4.9 Upland Sanitary Landfill

The closed and inactive Upland Sanitary Landfill (USL) is located on the site of a former gravel quarry at the southeastern corner of 15th Street and Campus Avenue in the City of Upland. The facility operated from 1950 to 1979 as an unlined Class II and Class III municipal solid waste disposal site. In 1982, USL was covered with a 10-inch thick, low permeability layer of sandy silt over the entire disposal site (GeoLogic Associates, 1997). Groundwater monitoring at the USL began in 1988 and now includes three on-site monitoring wells, an upgradient well, a cross-gradient well, and a downgradient well (City of Upland, 1998). The results of historic groundwater monitoring indicate that USL has released organic and inorganic compounds to underlying groundwater (GeoLogic Associates, 1997). Groundwater samples from the downgradient monitoring well consistently contain higher concentrations of organic and inorganic compounds than samples from the upgradient and cross-gradient monitoring wells. Analytical results from historic groundwater sampling indicate that VOCs are the major constituents of the organic release. All three monitoring wells have shown detectable levels of VOCs. The most common VOCs detected above MCLs are dichlorodifluoromethane, PCE, TCE, and vinyl chloride. Other VOCs that have been periodically detected above MCLs include methylene chloride, *cis*-1,2-DCE, 1,1-DCA, and benzene. The 1990 to 1995 average total VOC concentration in the downgradient monitoring well is 125 µg/L (GeoLogic Associates, 1997).

Figure 4-26 shows the approximate aerial extent of VOCs in groundwater at concentrations exceeding MCLs as of 2002. However, the plume is defined only by the three on-site monitoring wells. The extent of the plume may be greater than currently depicted in Figure 4-26. During the period from 1999 to 2004, the maximum TCE and PCE concentrations detected in the downgradient monitoring well within the USL plume were 4.2 µg/L and 16 µg/L, respectively.

4.3.4.10 VOC Anomaly – South of the Ontario Airport

A VOC plume containing primarily TCE exists south of the Ontario Airport. The plume extends approximately from State Route 60 on the north and Haven Avenue on the east to Cloverdale Road on the south and South Grove Avenue on the west. Figure 4-26 shows the approximate aerial extent of the plume as of 2004. The plume is up to 17,700 feet wide and 20,450 feet long. During the period from 1999 to 2004, the maximum TCE concentrations in groundwater detected at an individual well within this plume was 83 µg/L.

4.3.4.11 Stringfellow NPL Site

One facility in the Chino Basin is on the current National Priorities List (NPL) of Superfund sites. The Stringfellow site is located in Pyrite Canyon, north of Highway 60, near the community of Glen Avon, in Riverside County (Figure 3-21). From 1956 until 1972, the 17-acre Stringfellow site was operated as a hazardous waste disposal facility. More than 34 million gallons of industrial waste, primarily from metal finishing, electroplating, and pesticide production were deposited at the site (USEPA, 2001). A groundwater plume of site-related contaminants exists underneath portions of the Glen Avon area. Groundwater at the site contains various VOCs, perchlorate, N-nitrosodimethylamine (NDMA), and heavy metals such as cadmium, nickel, chromium, and manganese. Soil in the original disposal area is contaminated with pesticides, PCBs, sulfates, and heavy metals. The original disposal area is now covered with a barrier and fenced. Contamination at the Stringfellow site has been addressed by cleanup remedies described in four US Environmental Protection Agency (USEPA) Records of Decision. These cleanup actions have focused on control of the source of contamination, installation of an onsite pretreatment plant, cleanup of the lower part of Pyrite Canyon, and cleanup of the community groundwater area.

Figure 4-26 shows the approximate aerial extent of the Stringfellow plume as of 2002. The plume is elongate in shape, up to 6,000 feet wide and extends approximately 22,500 feet from the original disposal area in a southwesterly direction. During the period from 1999 to 2004, the maximum TCE concentration detected in the Stringfellow plume was greater then 175 µg/L. DTSC has contoured the plume emanating from the Stringfellow site. Watermaster has requested a copy of these plume contours. Once received, they will be added to Figure 4-26.

4.3.5 Current State of Groundwater Quality in Chino Basin

As discussed in Section 1, the baseline for the Initial State of the Basin is on or about July 1, 2000 – the point in time that represents the start of OBMP implementation. This initial state or baseline is one metric that can be used to measure progress from implementation of the OBMP. In terms of TDS and nitrate, the initial state of groundwater quality in Chino Basin is illustrated by Figures 3-4 and 3-7. These figures were developed from data derived from Watermaster's water quality database. This database can be queried in future studies to determine the state of the basin's groundwater quality for any constituent.

The groundwater quality in Chino Basin is generally very good, with better groundwater quality found in the northern portion of Chino Basin where recharge occurs. Salinity (TDS) and nitrate concentrations increase in the southern portion of Chino Basin. Twenty-eight percent of the private wells south of the 60 Freeway (169 wells) had TDS concentrations below the secondary MCL. In places, wells with low TDS concentrations are found to be proximate to wells with higher TDS concentrations, suggesting that there is a vertical stratification of water quality. About 83 percent of the private wells south of the 60 Freeway had nitrate concentrations greater than the MCL.

The other constituents that have the potential to impact groundwater quality from a regulatory or Basin Plan standpoint are certain VOCs, arsenic, and perchlorate. As discussed in Sections 4.3.3.1 and Section 4.5, there are a number of point source releases of VOCs in Chino Basin. These are in various stages of investigation or cleanup. Likewise, there are known point source releases of perchlorate (MVSL area, Stringfellow, *et cetera*) as well as what appears to be non-point source related perchlorate contamination from currently undetermined sources. Arsenic at levels above its WQS appears to be limited to the deeper aquifer zone near the City of Chino Hills. Total chromium and hexavalent chromium, while currently not groundwater issue for Chino Basin, may become so, depending on the promulgation of future standards.

4.4 On-Going and Recommended Activities

4.4.1 Water Quality Key Well Program

In the Initial State of the Basin Report the water quality section was concluded with by stating the need for future long-term monitoring.

> "A recommendation regarding the long-term groundwater quality-monitoring program is currently being developed. In developing the recommendation, consideration is being given to aerial distribution, changing land uses, sampling frequency, constituents, and the overall OBMP time frame and implementation information needs. The recommended water quality monitoring program will be presented for consideration during the Watermaster budget process for implementation in fiscal 2002/03."

This need has become even more urgent due to the rapid commercial and residential development occurring within the Chino Basin. Many of the private agricultural wells that have been used for monitoring activities are being destroyed as the land is developed. As a response to the need stated in the ISOB and the loss of wells historically utilized, CBWM has developed a water quality key well program which designates a series of well across a wide aerial distribution for monitoring activities (the key well program is described in detail in Section 7). A grid was laid out across the basin and where possible at least one well was chosen per grid cell. Wells that were part of the water level monitoring program and located on property not likely to be developed were preferentially chosen (refer to Section 7 for a more detailed description of the selection process and the program). Sampling of wells in the Key well program began in Fall 2005 and will run in two-year cycles. As has been done with past agricultural water quality monitoring, the results will be added to the Watermaster database.

4.4.2 Chino Basin Relational Database

Water quality results for appropriative wells have typically been downloaded from SWQIS (as discussed in Section 4.3). However, quality assurance issues have arisen. For this reason, Watermaster has begun collecting current water quality data directly from each agency or the contract lab conducting the analyses. This will help eliminate parameter identification (from STORET number conflicts) and unit conversion issues that are frequently the root of problems with SWQIS. Watermaster has also set up protocols for periodic updates with each agency to ensure site information is kept current. To augment this effort, archived water quality data are being collected directly from each agency for the period of 1997 to present (thereby capturing the OBMP baseline period). Most of the appropriative agencies in the basin keep past water quality data in hardcopy form. Watermaster is currently having the data entered into electronic form, checked for quality assurance and entered into the database. Table 4-1 summarizes the progress of these efforts to date.

4.4.3 Water Quality Committee

Chino Basin Watermaster formed the Water Quality Committee (WQC) in Spring 2003 to reflect that Watermaster is the "go-to" entity because of its role as an arm of the Court. The WQC is reviewing both existing and emerging contaminants. WQC is developing plans to collect data on the active cleanup of basin contaminants, so that lessons learned concerning mitigation measures and cleanup technologies can be effectively shared. The WQC is developing a database of water quality, but may not be the lead agency for cleanup. The following specific objectives of the WQC were developed in the April and May 2003 WQC meetings:

1. Identify, review, and compile relevant data to create a comprehensive database of water quality in the Chino Basin, including data from adjoining basins to the extent that they may impact water quality in Chino Basin.
2. The committee should develop strategies and a management plan to improve basin water quality.
3. The committee will work through the Watermaster process and its available resources to take a lead role on funding and legislative strategies on behalf of its member agencies.
4. The committee will assist and provide input to Watermaster and to IEUA on implementation of the recharge master plan
5. The Committee will assist Watermaster in gathering and sharing data with the RWQCB to the greatest extent practicable.
6. The committee will conduct an assessment and evaluation of existing production and recharge patterns to determine their effect on water quality conditions within the basin. This should also extend to production adjacent to existing barriers and faults.
7. The committee will meet to monitor and measure progress of management plans and recommend adjustments where necessary.
8. The committee, working with Watermaster and its consultant team will provide written reports to the WM Board and to the Pools and Committee relative to its findings, work product and recommendations. The annual "State of the Basin Report" will continue to dedicate a section of the report to water quality issues.

4.4.3.1 Funding Acquisition

The WQC assisted IEUA in submitting a Local Groundwater Assistance Fund Grant Application for $250,000 in January 2004. This grant application was resubmitted after changes requested by DWR were made in December 2004. The project described in this application will help IEUA to continue implementation of critical program elements identified in the OBMP. The project proposed in the application will further Watermaster's understanding of the Basin characteristics to meet the goals and objectives of the OBMP. Specifically, the grant funding would be used to install piezometric monitoring wells in Chino Basin Management Zone 3 (MZ3), where there are sources of groundwater contamination. IEUA and Watermaster will conduct groundwater investigations to characterize the MZ3 area. In addition to sampling existing wells, IEUA and Watermaster proposes to drill, install, develop, and sample two nested, multiple-depth piezometers in the projected path of the Kaiser Steel Mill plume. The two piezometers – requested to be funded through this AB303 grant – will help to characterize and monitor the Kaiser plume, which is currently the most immediate threat to the downgradient potable supply wells. This is discussed further in Section 4.6.1.2.4.

4.4.3.2 Database Development

As discussed in Section 4.6.2, water quality data are routinely collected by Watermaster from appropriators, the SQWIS database, other entities monitoring plumes (*e.g.*, DTSC for the Stringfellow plume, the County of San Bernardino for landfill data and Chino Airport, *et cetera*), and from samples the

Watermaster collects from private wells. These data are routinely uploaded into a relational database management system managed by Watermaster. This database is used to supply the underlying data for time history analyses, map development (through Watermaster's GIS), and other analyses. The Watermaster database will be a key component of the Watermaster/IEUA integrated data management system called Chino Watershed Information System (CWIS, see Section 9.4).

4.4.3.3 Assessment of the State of the Basin's Water Quality

Watermaster analyzes the water quality data collected (Section 4.6.1.2.1) on an on-going basis. Exceedance tables are completed to determine which constituents currently exceed any water quality standard. Time histories are developed to examine trends of key constituents and any parameter with ten or more exceedances is mapped using Watermaster's GIS. These water quality data are discussed in the State of the Basin report (this section) as mandated by Objective 8 of the WQC.

4.4.3.4 Known and Managed Water Quality Anomalies

Table 4-2 shows Watermaster activities regarding known water quality anomalies. All of these anomalies are under regulatory oversight – either Regional Board or DTSC – except for the Kaiser Steel plume and the specific occurrences of perchlorate throughout Chino Basin.

WEI was tasked at the July 21, 2003 WQC meeting to prepare a list of tasks to help define potential source areas and/or potentially responsible parties (PRPs). This section describes WEI/Watermaster activities to date and proposed on-going activities:

- Monitor the cleanup activities at CIM, GE Flatiron and Test Cell, Milliken and Upland Landfills, and the Stringfellow Acid Pits.
- Identify source(s) of the Chino Airport VOC plume. The Regional Water Quality Control Board (Regional Board) has identified a PRP and a groundwater investigation to better characterize the plume prior to mitigation is already underway. Watermaster is tracking the progress of this investigation.
- Identify the source(s) of the VOC anomaly located south of the Ontario Airport and north of the Chino-1 Desalter well field.
- Locate the leading edge of the total dissolved solids/total organic carbon/volatile organic chemicals (TDS/TOC/VOC) plume created by Kaiser Steel.
- Identify the potential sources of perchlorate throughout the basin.

The goal of these water quality investigations in Chino Basin is to compile enough evidence for the Regional Board to issue Investigation Orders to the PRPs. This will facilitate the regulatory process, while shifting the majority of the investigation/cleanup cost burden to the PRPs.

<u>Chino Airport Plume</u>

Current Situation. Tetra Tech, Inc. prepared the Groundwater Monitoring Report, Winter 2003/2004 and Spring 2004. Chino Airport, San Bernardino County, California. May 2004 for the County of San Bernardino, Department of Architecture and Engineering. Chino Airport was an operating airfield since the 1940s and was operated at different stages by the Department of Defense, Pacific Aeromotive, and most recently by the County of San Bernardino. The County has owned the airfield since 1948. Activities at the airport over the last 60 plus years include: aircraft operation, storage, maintenance, aircraft and munitions manufacturing, and aircraft salvage operations. These activities involved the use of aviation fuel, lubricants, and solvents.

A timeline of activities associated with the volatile organic chemical (VOC) plume in groundwater is provided below.

- 1986 – Trichloroethene (TCE) detected in groundwater during sampling conducted as part of Metropolitan Water District's Chino Basin Storage Program Environmental Impact Report (EIR).
- 1988 – Regional Water Quality Control Board (RWQCB) suspects Chino Airport based on additional samples.
- 1990 – RWQCB issues Cleanup & Abatement Order 90-134 for County of San Bernardino, Department of Airports, Chino Airport, and San Bernardino County.
- 1991-1992 – Contractors dispose of 310 containers of hazardous waste. 81 soil borings drilled. VOCs, including TCE, found in soil samples.
- 2002 – Tetra Tech is hired by the County and completes a work plan for the installation of groundwater monitoring wells.
- 2003 – Five shallow, water table wells are drilled, installed, developed and sampled in June/July.

Watermaster Staff Activities. Watermaster technically reviewed Tetra Tech's *Groundwater Monitoring Report* and had the following comments, which were transmitted to the Regional Board in a letter dated July 8, 2004:

- Groundwater level and groundwater quality data generated by the Tetra Tech investigation are consistent with data generated by Watermaster and others and indicates that the Chino Airport is the most likely source of this contamination.
- The Chino Airport plume has degraded groundwater quality in Chino Basin, affecting several private wells and Chino Desalter Well No. 3.
- In addition to continued groundwater level and groundwater quality monitoring, active groundwater remediation needs to begin. The County should develop a work plan for the installation of extraction wells and a treatment facility as soon as possible in order to comply with Cleanup & Abatement Order 90-134, Requirement 5a: "submit a work plan and a time schedule…[for] mitigation of groundwater contamination attributable to the Airport." The remediation of this groundwater plume is consistent with the goals and objectives of the Chino Basin Watermaster's Optimum Basin Management Program.

It was due to Watermaster's robust water level and water quality database that Watermaster was able to demonstrate that the source of the Chino Airport plume originated at the Chino Airport and not at CIM or the Ontario International Airport as speculated by Tetra Tech. Watermaster also worked closely with the Agricultural Pool to release water level and water quality data from private wells to Tetra Tech and the County of San Bernardino. Watermaster will continue to review Tetra Tech monitoring reports when they are published.

VOC Plume South of the Ontario International Airport

Current Situation. A VOC plume containing primarily TCE exists south of the Ontario International Airport (OIA). The plume extends approximately from State Route 60 on the north and Haven Avenue on the east to Cloverdale Road on the south and Grove Avenue on the west. Figure 4-26 shows the approximate aerial extent of the plume as of 2004. The plume is up to 17,700 feet wide and 20,450 feet long. During the period from 1997 to 2004, the maximum TCE concentrations in groundwater detected at an individual well within this plume was 83 µg/L.

Watermaster Staff Activities. The Regional Board has identified PRPs at the Ontario Airport. The WQC tasked WEI to assist the Regional Board in reviewing and assessing information available regarding PRPs at the OIA so that the Regional Board staff could determine whether further investigation is necessary or cleanup and abatement orders could be issued. During this review, the work focused on PRPs previously identified for the Regional Board, specifically those having a high probability of being responsible for the volatile organic chemical (VOC) contamination tributary to the Chino Desalter 1.

The criteria for the Regional Board to issue clean-up and abatement or investigative orders under Section 13267 of the California Water Code was clarified in a February 11, 2002 internal memorandum by the State Water Resources Control Board's (SWRCB) Chief Counsel, Craig M. Wilson, regarding recent amendments to the Porter-Cologne Water Quality Control Act, resulting from Assembly Bill No. 1664 (2001). According to Mr. Wilson's memorandum, the Regional Board can issue a Cleanup and Abatement Order provided that:

a. there is a basis for suspicion;
b. the suspected dischargers are provided with a written explanation as to why the requirement is being made; and
c. the evidence on file is identified.

Draft Cleanup and Abatement Orders have been written (but not sent) for the following entities:

- Aerojet General Corporation
- Lockheed Martin Corporation
- McDonnell Douglas Aircraft Company
- Northrop Aviation Corporation

Kaiser Plume

Current Situation. The estimated location of the Kaiser plume as the mid 1980s is shown in Figure 4-26. Figure 4-26 also shows the estimated location of the Kaiser plume as of 2004. The mid-1980 location is based on modeling studies conducted by James M. Montgomery, Consulting Engineers (JMM, 1986) and was confirmed in part by groundwater monitoring in the late 1980s and early 1990s. The estimated 2003 plume location is based on recent groundwater modeling studies (WEI, 2003), where the plume as located in the mid-1980s was translated using the 2003 Watermaster model. The 2003 Watermaster model was used to simulate the movement of the Kaiser plume from its year 2003 location for a 25-year period starting in 2003. The model projections suggest that the Kaiser plume will enter the well field of Jurupa Community Services District (JCSD) – specifically JCSD wells 6, 13, 17, 19, 20 and Mira Loma #4 – during the simulation period. The Cleanup and Abatement Order Number 87-121 that concerned the Kaiser plume was rescinded in 1993 and there has been no formal monitoring of the Kaiser plume since the order was rescinded. In summary, recent model projections suggest that the Kaiser plume may impact the JCSD within the next 10 to 15 years and there is no monitoring in place that could be used to confirm this projection or to warn JCSD of the attendant changes in water quality if the modeling projection is correct.

Watermaster Staff Activities. Watermaster activities are currently concentrated in two areas: reactivation of the Kaiser off-site monitoring wells and an assessment of what the chemical signature of the Kaiser plume would look like if it were to impact the JCSD wells.

Watermaster staff has located the two monitoring wells sites located off the Kaiser site:

- MP-2 located at the K-Mart warehouse facility in Ontario, approximately at the corner of Milliken and San Bernardino Road; and
- KOFS-1 well located adjacent to Etiwanda Creek on the Inland Container property.

MP-2 has four piezometers each screened at different depths and KOFS-1 has one piezometer. As mentioned above, these and the other wells used to locate and characterize the Kaiser plume have not been sampled since 1993. MP-2 and KOFS-1 are the most downstream monitoring wells for the plume. KOFS-1 was constructed to find the leading edge of the plume and to provide early warning of the plume to downstream well owners.

These wells can be sampled to determine the location of the main part of the Kaiser plume. Prior to sampling these wells, the pumps within these wells will need to be removed and the wells will need to be redeveloped. The estimate cost for redevelopment is about $15,000. All development and purge water must be hauled away and discharged to the Non-Reclaimable Waste Line (NRWL). Samples would be collected for chemical analyses, including: general mineral and physical, VOCs, semi-volatile organic chemicals (SVOCs), and TOC. The result of these analyses would be compared to past analyses to determine is the Kaiser plume has moved substantially east or west (MP-2, and other wells, *e.g.*, Ontario Wells 30 and 31) and has passed the KOFS-1 wells.

Contact of the plume with the KOFS-1 well could suggest that the plume is on track to reach the JCSD wells in the near future. The plume could also miss the JCSD wells altogether and enter the Chino-2 desalter well field.

Watermaster staff reviewed past work regarding the chemistry of the Kaiser discharge and groundwater contaminated by this discharge. Staff used piper diagrams to show how JCSD well chemistry could change if the Kaiser plume enters the JCSD well field. This information can be used by JCSD and Watermaster to determine if and when the JCSD wells are being impacted by the Kaiser plume. If the Kaiser plume were to move into the JCSD wells field, the anion-cation distribution would start to shift from the calcium-carbonate character currently seen in the JCSD wells to the calcium sulfate character exhibited by wells impacted by the Kaiser plume. Watermaster (or JCSD) should review the anion-cation distribution annually in JCSD and Desalter 2 wells to determine if the Kaiser plume is being captured by these wells.

Perchlorate in Chino Basin

Current Situation. Perchlorate has recently been detected in several wells in the Chino Basin (Figure 4-18), in other basins in California, and in other states in the West. The probable reason that perchlorate was not detected in groundwater until recently is that analytical methodologies did not previously exist that could attain a low enough detection limit. Prior to 1996, the method detection limit for perchlorate was 400 μg/L. By March 1997, an ion chromatographic method was developed with a detection limit of 1 μg/L and a reporting limit of 4 μg/L.

As discussed extensively in the WQC meetings, a number of wells in the Chino Basin have been impacted and shut down due to relatively low levels of perchlorate (but above the State Notification Level of 6 micrograms per liter [µg/L]):

- There is a significant perchlorate plume in the Rialto-Colton and Chino Basins. The source of the plume in Rialto-Colton Basin is being investigated by the RWQCB and it appears to be located near the Mid-Valley Sanitary Landfill. According to the RWQCB, other companies including B. F. Goodrich, Kwikset Locks, American Promotional Events Inc., and Denova Environmental Inc. operated nearby and used or produced perchlorate. These companies were located on a 160-acre parcel at T1N R5W S21 SW1/4. Denova Environmental also operated on a 10-acre lot at T1N R5W S20 S1/2 (along the boundary between Sections 20 and 29).
- Management Zone-3 in Chino Basin, across the Rialto-Colton Fault from the Mid-Valley Landfill site.
- Downgradient of the Stringfellow Superfund Site. Concentrations have exceeded 600,000 µg/L in on-site observation wells and the plume has likely reached Pedley Hills and may extend as far as Limonite Avenue.
- City of Pomona well field (source unknown).
- Wells in the City of Ontario Water Service Area, south of the Ontario Airport (source(s) unknown).
- Scattered wells in the Monte Vista Water Service Area (source(s) unknown).
- Scattered wells in the City of Chino Water Service Area (source(s) unknown).

The WQC initially concentrated on perchlorate in MZ-3. There are three potential sources of perchlorate in MZ-3: (i) an unidentified point source(s) of man-made perchlorate physically located in MZ-3; (ii) a point source in the Rialto-Colton Basin that has "leaked" into Chino Basin; or (iii) non-point source application of Chilean fertilizer in the early 1900s.

Literature indicates that perchlorate has been associated with the manufacture, use, or operation of solid rocket/missile propellants, fireworks, matches, road flares, air bag inflators, analytical chemistry (ionic strength stabilization), nuclear reactors, electronic tubes, lubricating oil additives, leather tanning and finishing, fabric and dye fixers, electroplating, aluminum refining, rubber products, paints and enamels, and fertilizers.

The process of attempting to locate potential point sources of perchlorate in MZ-3 involved a multi-step approach that included groundwater modeling, securing an EDR report for the entire Chino Basin region, and sifting through the EDR report data using ArcMap techniques. This review was done as a due diligence effort on the part of Watermaster, with an understanding that considerable additional effort may be required to locate a perchlorate point source in MZ-3 – if one exists.

1. Environmental Data Resources, Inc. (EDR) was contracted to conduct an environmental records search of all applicable federal and state databases. The database search covered Chino, Cucamonga, Rialto, Claremont, Pomona Basins, and a 1-mile buffer zone. The search resulted 16,249 geo-coded listings for the area in a PDF document. The geo-coding allowed the listings to be entered into the regional GIS-based database. A listing search was performed on the document for the following key words: perchlorate, rocket, propellant, pyro, fire works, flare, explosive, air bag, and match.

2. WEI used the existing MODFLOW model that we developed for Watermaster, which showed future groundwater elevation changes under transient conditions over a 25-year period as a basis. We assumed

current groundwater conditions (and calibration parameters) to simulate particle movement backward over a 60-year period from the current perchlorate plume geometry for the region.

3. Using ArcMap, WEI performed a search for listings within the Fontana area that could represent perchlorate sources that may have impacted Fontana Water Company wells. A total of 799 initial listings were identified from the EDR data. The next step involved categorizing these listings into 28 groups, 12 of which could be potentially associated with perchlorate usage based upon the aforementioned literature (162 listings), and 16 of which were not (637 listings). Initially, the listings within each group were assigned one of the following probability rankings indicating the potential for perchlorate usage.

    - Agriculture (6)
    - Auto dismantler (14)
    - Body/paint/finishes/coatings (36)
    - Chemicals (1)
    - Cleaners/tailors/clothing (12)
    - Environmental/hazardous materials/hazardous waste (17)
    - Industry (3)
    - Landfills (3)
    - Oil-based lubricants/refining (9)
    - Machining (10)
    - Unknown (9)
    - Unknown commerce (42)

After reviewing the data from the environmental records search, a strong candidate for a perchlorate point source in MZ-3 was not determined. Additional work (aerial photography review, personal interviews, *etc*.) would need to be conducted to pursue this further.

Some parties in the basin believe that the significant perchlorate source near the Mid-Valley Landfill (Goodrich, Aerojet, Quickset, Emhart Industries, Denova Environmental, Pyro Spectacular, Rialto Ammunition Storage Point, *et al.*) in the Rialto-Colton basin may also be the source of perchlorate in Chino Basin. The proposed transport pathway is leakage across the Rialto-Colton Fault. Members of the WQC proposed that Watermaster perform a hydrogeologic investigation of that area to understand how plausible this may be. The WQC determined that this approach may be prohibitively expensive, given the complexity of the fault system and aquifer heterogeneity.

Non-Point Source Application of Chilean fertilizer

The Regional Water Quality Control Board has done an extensive historical literature review and has produced a sizable volume of circumstantial evidence that large quantities of Chilean fertilizer may have been used for citrus in the Fontana area. This fertilizer was mined from Caliche Ore found in the Atacama Desert of northern Chile, the most arid desert in the world. These deposits are a conglomerate of mineral salts comprised of nitrates, sulfates, sodium, chlorides, calcium, potassium, magnesium, and smaller quantities of trace constituents, such as, iodate and perchlorate. It is believed that these deposits were most likely formed from nitrogen fixation by microorganisms in playa lakes 10-15 million years ago.

Perchlorate was first imported into the US in the 1830s and large-scale importation began in the 1880s. Chilean fertilizer was the most important source of nitrogen until 1921. During World War I, Chilean nitrate was needed for the manufacturing of explosives and world demand dramatically increased. Germany was banned from importing Chilean nitrate in World War I. In response, two German scientists, Fritz Haber and Carl Bosch developed the Haber-Bosch process for directly synthesizing ammonia from hydrogen and nitrogen. As a result, worldwide demand for Chilean fertilizer dropped and by 1950, Chilean nitrate production was 15 percent of the world's supply and by 1980 it was only 0.14 percent. Below are a couple of trade advertisements that suggest that Chilean fertilizer was indeed imported into California, and specifically Fontana and San Bernardino County.

CITRUS GROWERS!
You Can't Afford to Ignore This!

San Bernardino County with 18.63 per cent of the bearing citrus acreage (California Crop Report) produces 25 per cent of the citrus fruits of the state. (San Bernardino County Associated Chambers of Commerce.)

Or 100 boxes in San Bernardino to 68.68 boxes on equal acreage elsewhere.

WHY?

BECAUSE San Bernardino growers use more Nitrate of Soda in citrus groves than any other county in the state.

The splendid agricultural success at Fontana is largely due to the wisdom of the management in using liberally Chilean Nitrate of Soda.

Another Truth!

The Citrus Experiment Station's experiments at Arlington Heights resulted as follows:

With equal amounts of nitrogen:	Relative Production
Nitrate of Soda	100
Blood	73.66
Sulphate of Ammonia	55.78
3 Check plots nearest to Nitrate plot (regardless of nitrogen)	53.41

If you want more proof that Nitrate of Soda is the best source of nitrogen or the best way to use it write our Los Angeles office.

CHILEAN NITRATE OF SODA,
Educational Bureau,
3413 2nd Ave., Los Angeles, Calif.

Hurt Building, Atlanta, Ga. 55 State St., Columbus, Ohio
701 Cotton Exchange Building, New Orleans, La.
25 Madison Ave., New York.

The Past Six Critical Years

Remember the old-timer who said "I'm an old, old man and I have had many, many troubles...*most of which were imaginary*"?

Folks were plenty worried about their nitrogen supply when war broke out in 1939, but, thanks largely to heavy increases in shipments from Chile, everybody has had enough for essential needs. Yes, west coast fruit and vegetable growers received over a quarter of a million tons of natural nitrate in the six years since 1939-40 – and almost all of it in California.

That's a lot of nitrate . . . it has settled a lot of doubts among folks who feared the consequences of not being able to get their accustomed fertilizers. Results have shown their fears to be groundless. In fact, quite the reverse, because in those same six years, when they used about seven times as much Chilean Nitrate as normally, California growers produced the largest and best citrus and vegetable crops on record – *the best they ever made.*

Yes, Chilean Nitrate saved the day, as far as nitrogen is concerned. These last six years and the quarter of a million tons of nitrate from Chile, made a tremendous field demonstration of its value and effectiveness to California growers.

The old man with his imaginary troubles sure had something.

Much has been accomplished in the past but much more remains to be accomplished. While the going was tough and the results in doubt, Chilean Nitrate was in there, pitching. And this year and in all the years to come, it stands ready and able to continue as in the past – serving – helping out – wherever the opportunity offers.

NATURAL CHILEAN NITRATE

Land use in the MZ-3 area was predominately citrus and vineyards from the 1900s to the 1940s. The land use map on the next page is 1933.

Neil Sturchio, Professor and Head of the Earth and Environmental Sciences at the University of Illinois at Chicago, has developed a technique for using stable isotopes of chloride and oxygen to distinguish the origin of perchlorate (man-made or Chilean fertilizer). There are several per mile shifts in isotopes of both ions between the two sources. He has tested several samples of leachate from fertilizer nitrogen (from the Atacama Desert in Chile) and rocket fuel sources. One of the innovations that Prof Sturchio has developed is the use of a flow-through column with an anion-exchange resin. These bifunctional anion exchange resins were originally developed at Oak Ridge National Laboratory and the University of Tennessee to selectively sorb the pertechnetate ion TcO_4^- – technetium is mobile with a long half-life, much like perchlorate. A resin regeneration step is added to recover the perchlorate ion. The exchange resin is required to concentrate the typically low levels of perchlorate in groundwater so that the perchlorate can be analyzed isotopically.

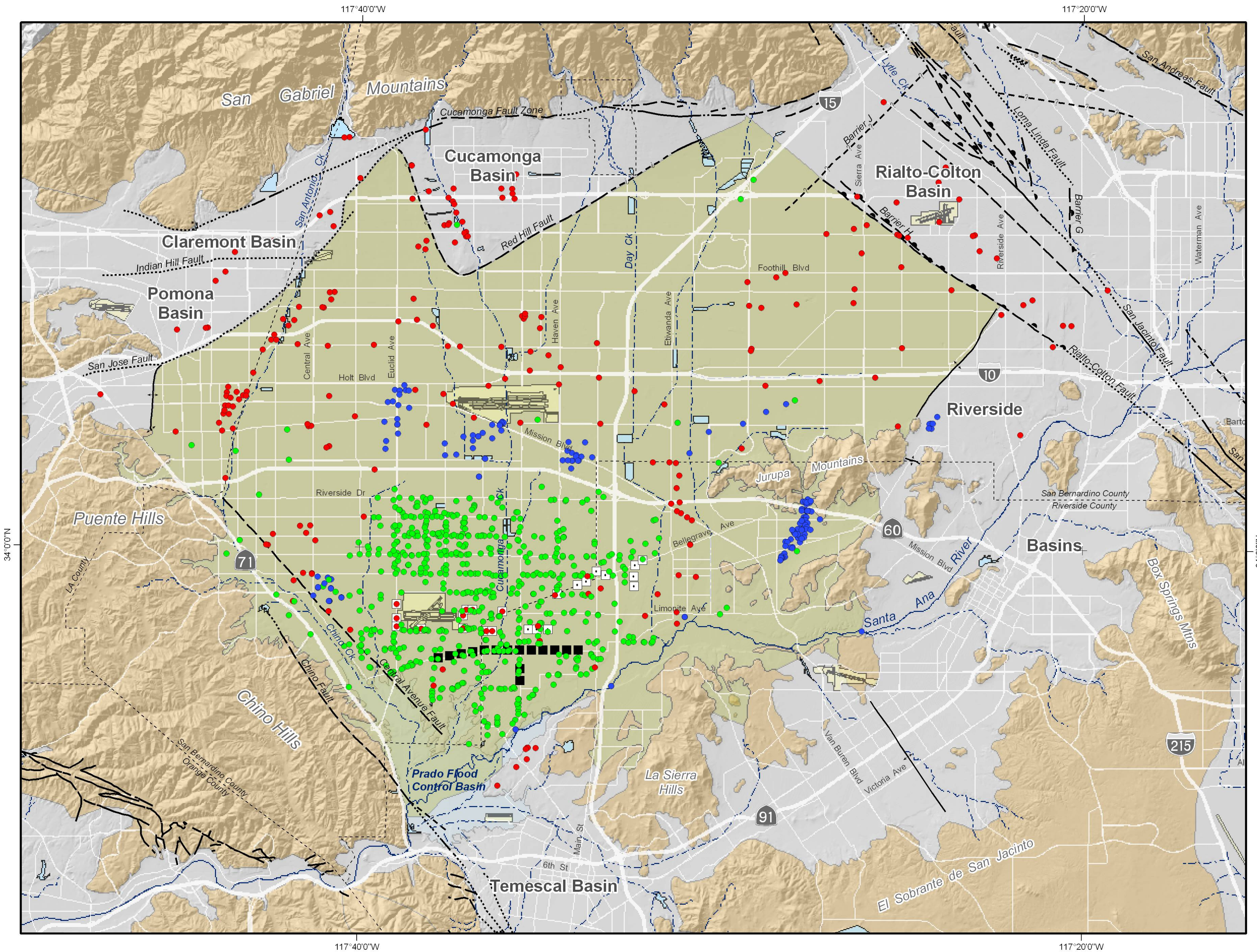
The isotope fractionation analyses may provide a reasonably unequivocal determination of the source of perchlorate in Chino Basin – man-made versus Chilean fertilizer. Watermaster is pursuing the isotope fractionation analyses in selected portions of central and western Chino Basin.

Table 4-1
Current Status of the Chino Basin Relational Database Effort

Agency	Requested	Received	Format	Data In Electronic Form	QA/QC	Upload to Database	Periodically Receiving Current Data
Chino Hills, City of	X	X	Hardcopy	In Progress	In Progress		
Chino, City of	X	X	Hardcopy	X	In Progress		X
Cucamonga Valley Water District	X	X	Spreadsheet	X	X	X	X
Fontana Water Company	X	X	Spreadsheet/DHS	X	In Progress		
Inland Empire Utilities Agency	X	X	Spreadsheet	X	X	X	X
Jurupa Community Services District	X	X	Hardcopy	In Progress			X
Marigold Mutual Water Company	X	X	Hardcopy	X	In Progress		
Norco, City of	X	In Progress	Hardcopy				X
Ontario, City of	X	X	Hardcopy	X	In Progress		
Pomona, City of	X	X	Database Tables	X	In Progress		
San Antonio Water Company	X	X	Hardcopy	X	In Progress		X
Santa Ana River Water Company	X	X	Hardcopy	X	In Progress		X
Southern California Water Company	X	X	Hardcopy	X	In Progress		
Upland, City of	X	X	Hardcopy and Spreadsheet	In Progress			X
West Valley Water District	X	X	Hardcopy	In Queue			

Table 4-2
Watermaster Activities Regarding Known Water Quality Anomalies

Anomaly	Current Regulatory Oversight	Watermaster Activities			
		Monitor Groundwater	Conduct Investigation	Monitor Process	Seek Outside Funding
Chino Airport	Yes	×		×	
California Institute for Men	Yes	×		×	
GE Flatiron	Yes	×		×	
GE Test Cell	Yes	×		×	
Milliken Landfill	Yes	×		×	
Upland Landfill	Yes	×		×	
Stringfellow Acid Pits	Yes	×		×	
Agricultural Area	Yes	×		×	×
Kaiser Steel Mill	No	×	×	×	×
South of Ontario Airport	Yes	×	×	×	
Perchlorate	Maybe	×	×	×	×



Main Features

- Private Wells
- Municipal Wells
- Monitoring/Extraction Wells
- Existing Desalter Wells
- Proposed Desalter Wells

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

Flood Control and Conservation Basins

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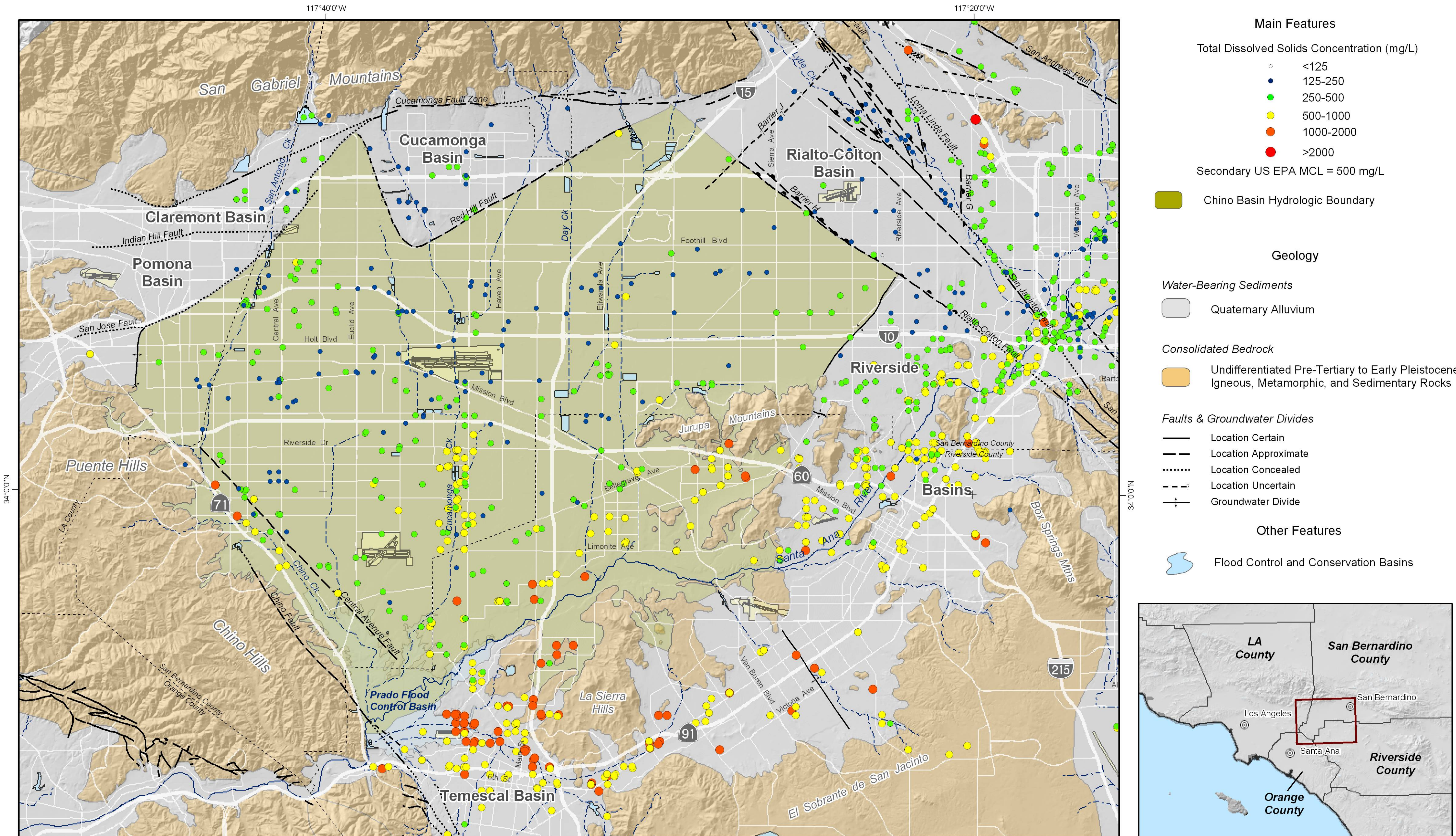
File: Figure_4-1.mxd

0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Groundwater Wells with Water Quality Data
(1999-2004)

Figure 4-1



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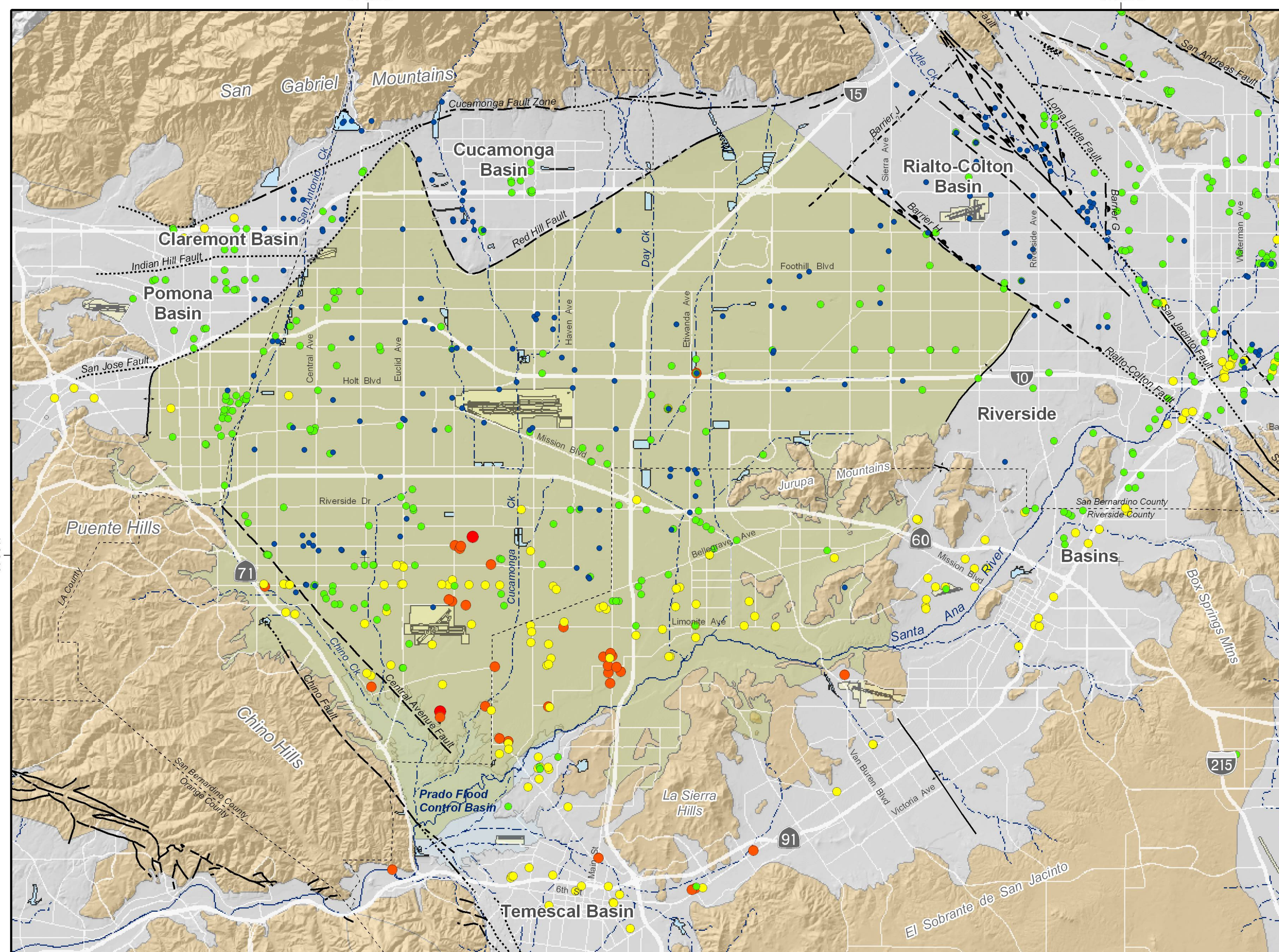
State of the Basin Report -- 2004
Groundwater Quality

Total Dissolved Solids in Groundwater
Maximum Concentration (pre-1980)

Figure 4-2



Main Features

Total Dissolved Solids Concentration (mg/L)

- <125
- 125-250
- 250-500
- 500-1000
- 1000-2000
- >2000

Secondary US EPA MCL = 500 mg/L

- Chino Basin Hydrologic Boundary
- Chino Basin Legal Boundary

Geology

Water-Bearing Sediments

- Quaternary Alluvium

Consolidated Bedrock

- Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

- Flood Control and Conservation Basins

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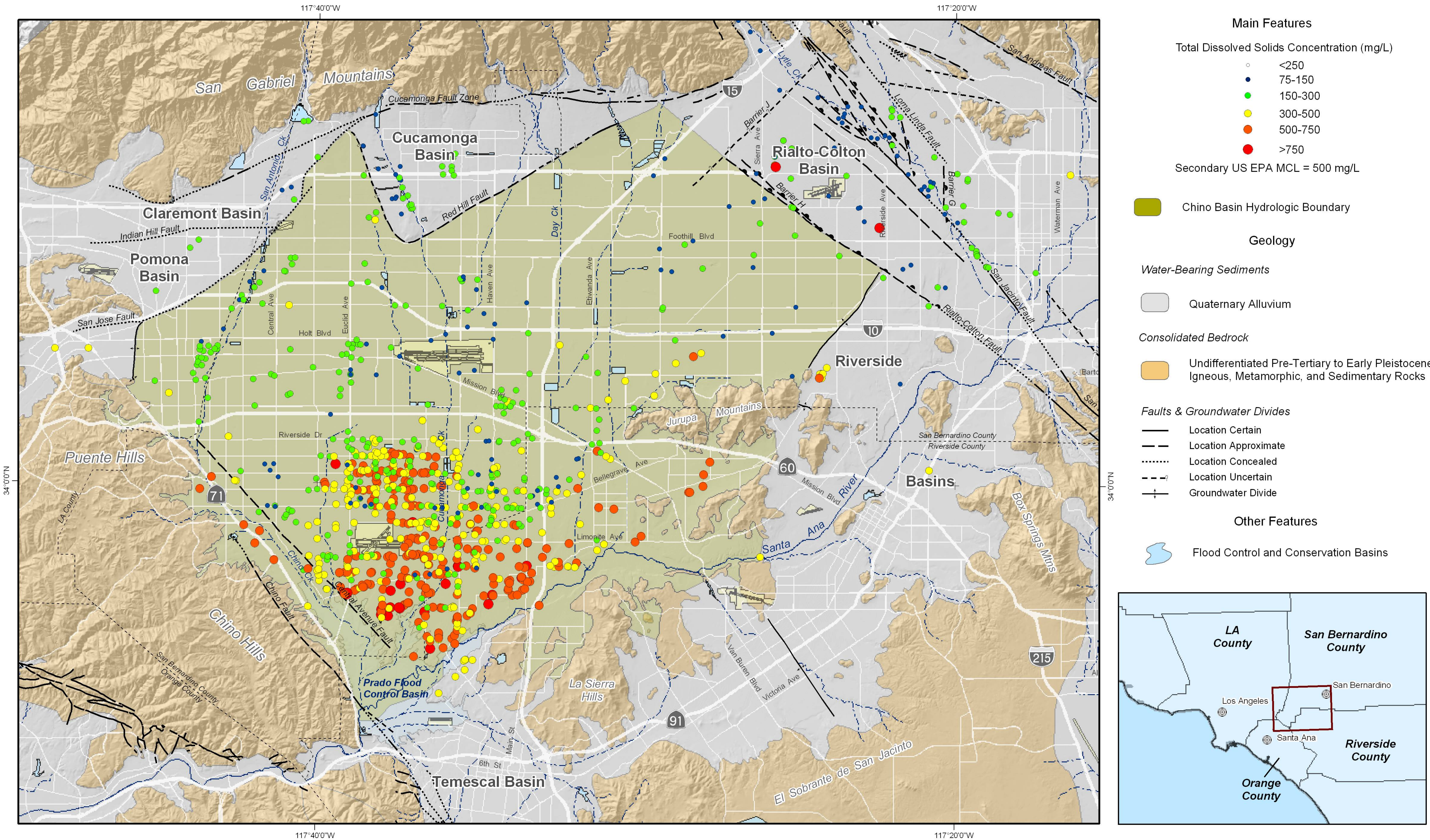
0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Total Dissolved Solids in Groundwater
Maximum Concentration (1980-1998)

Figure 4-3



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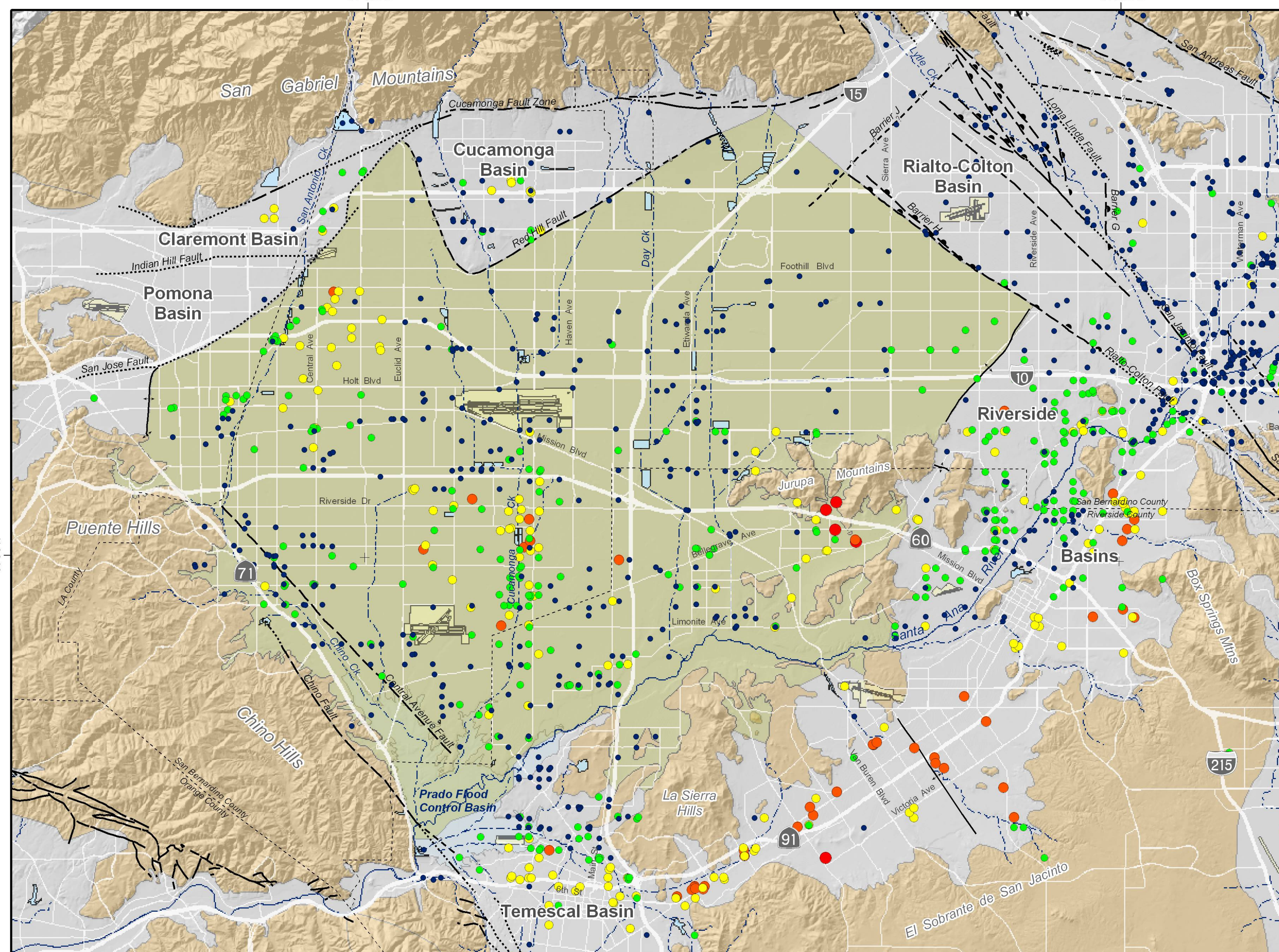
State of the Basin Report -- 2004
Groundwater Quality

Total Dissolved Solids in Groundwater
Maximum Concentration (1999-2004)

Figure 4-4



Main Features

Nitrate-Nitrogen (mg/L)

- ND
- <5
- 5-10
- 10-20
- 20-40
- >40

Primary US EPA MCL = 10 mg/L
Primary Ca MCL = 10 mg/L

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

Flood Control and Conservation Basins

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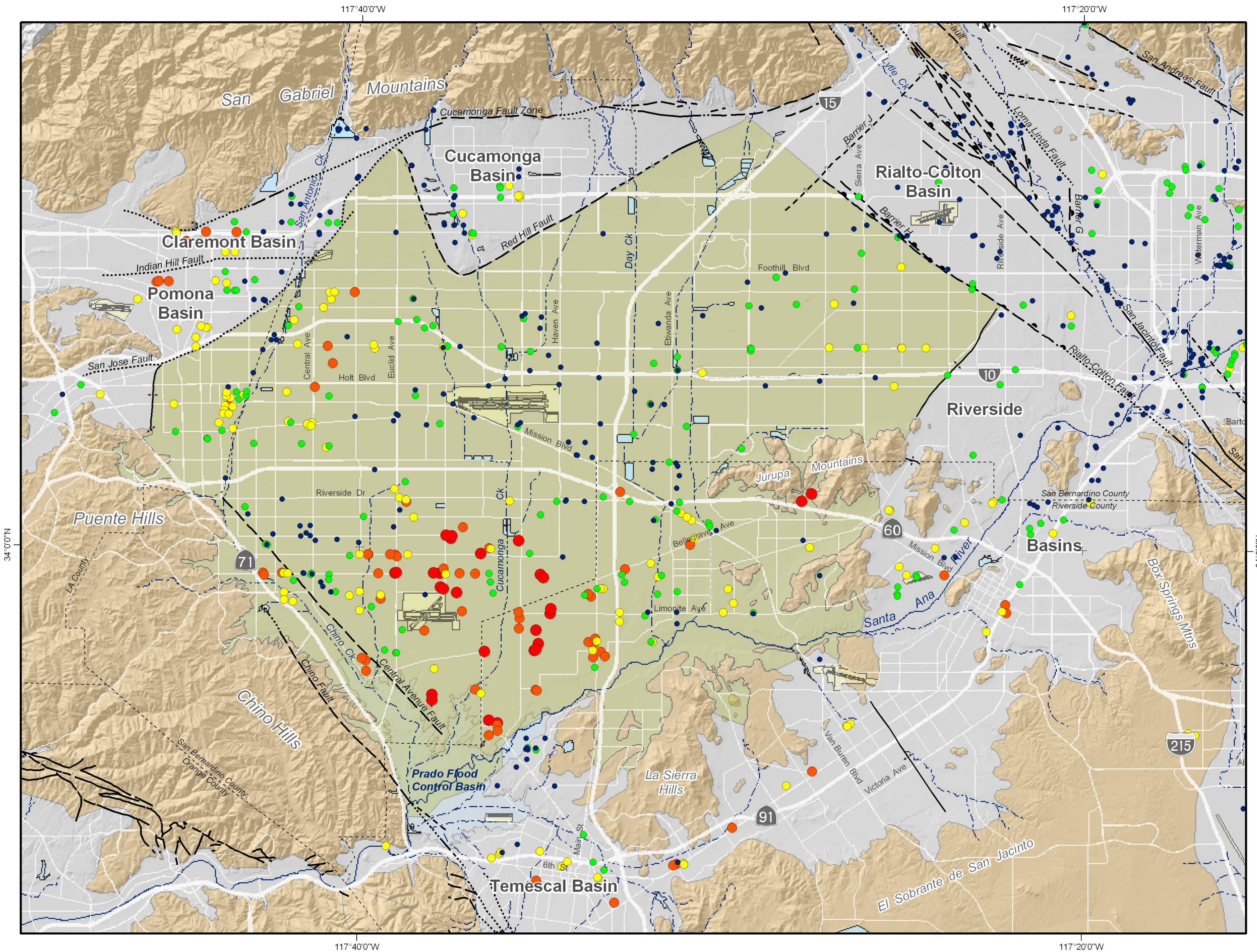
0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Nitrate in Groundwater
Maximum Concentration (pre-1980)

Figure 4-5



Main Features

Nitrate-Nitrogen (mg/L)

- ND
- <5
- 5-10
- 10-20
- 20-40
- >40

Primary US EPA MCL = 10 mg/L
Primary Ca MCL = 10 mg/L

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

Flood Control and Conservation Basins

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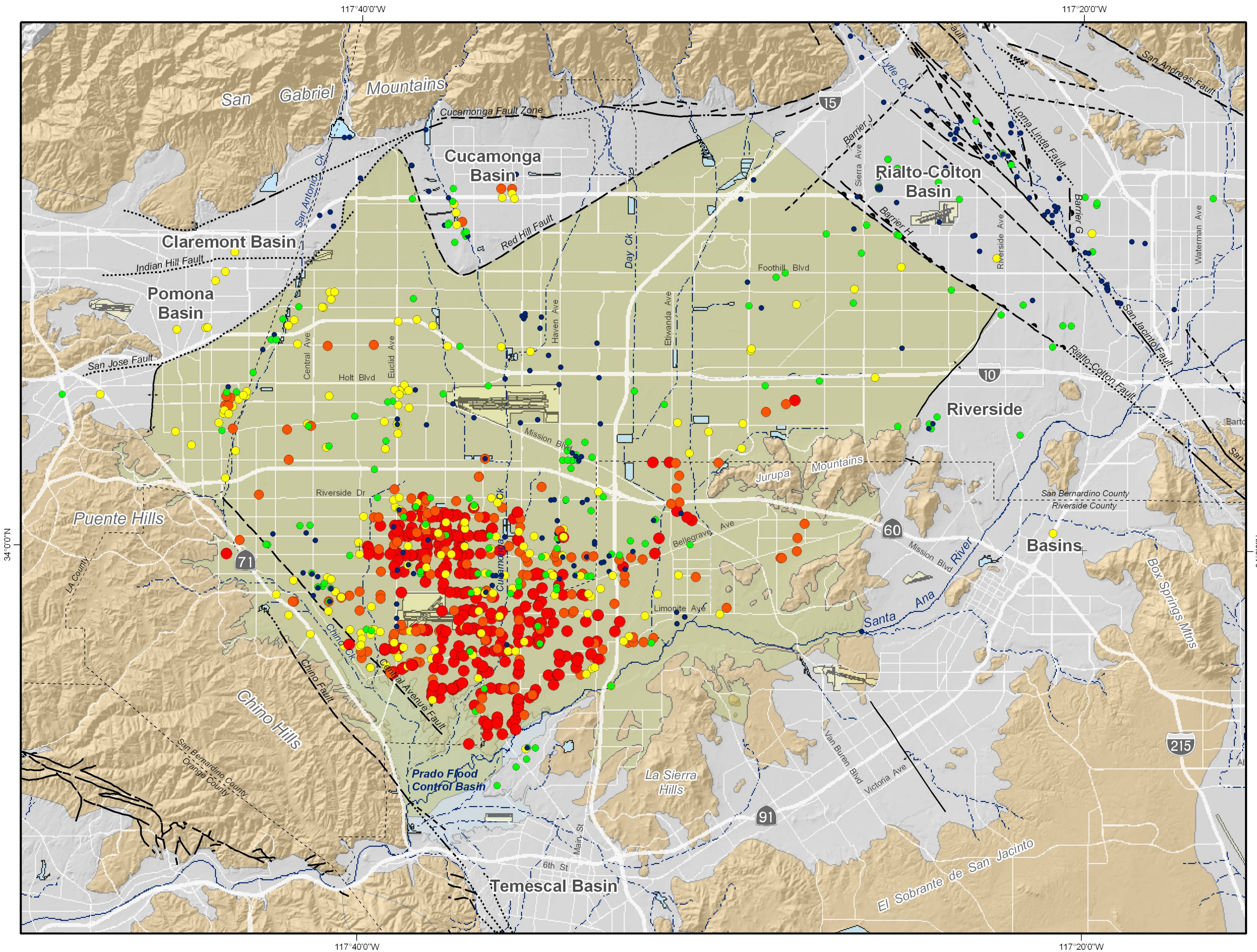
0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Nitrate in Groundwater
Maximum Concentration (1980-1998)

Figure 4-6



Main Features

Nitrate-Nitrogen (mg/L)
- ND
- <5
- 5-10
- 10-20
- 20-40
- >40

Primary US EPA MCL = 10 mg/L
Primary Ca MCL = 10 mg/L

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

Flood Control and Conservation Basins

Miles: 0 1 2 3 4
KM: 0 2 4 6

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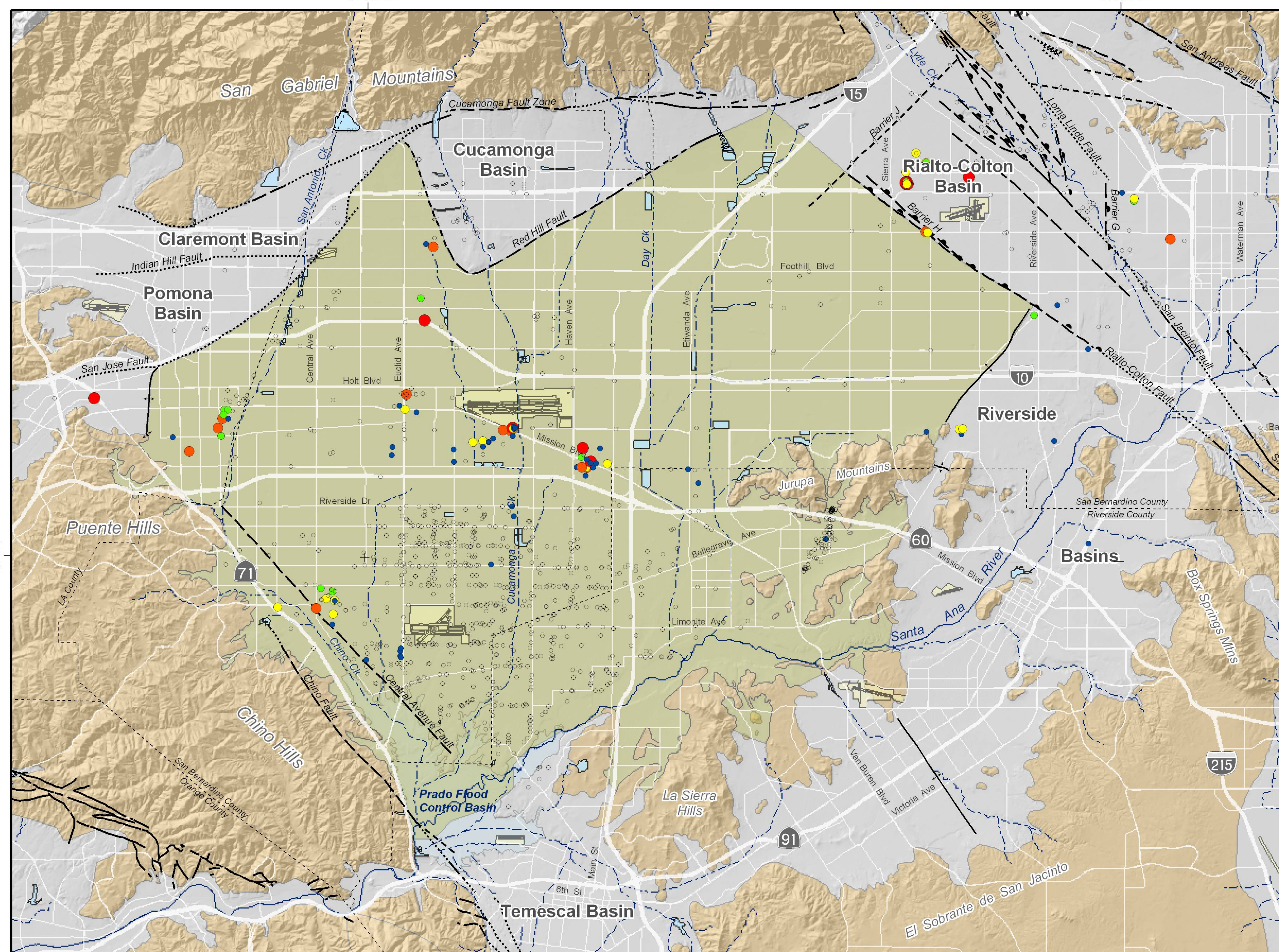
State of the Basin Report -- 2004
Groundwater Quality

Nitrate in Groundwater
Maximum Concentration (1999-2004)

Figure 4-7



Main Features

Tetrachloroethene Concentration (ug/L)

- ND
- <2.5
- 2.5-5
- 5-10
- 10-20
- >20

Primary EPA MCL = 5 ug/L
Primary Ca MCL = 5 ug/L

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
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- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

Flood Control and Conservation Basins

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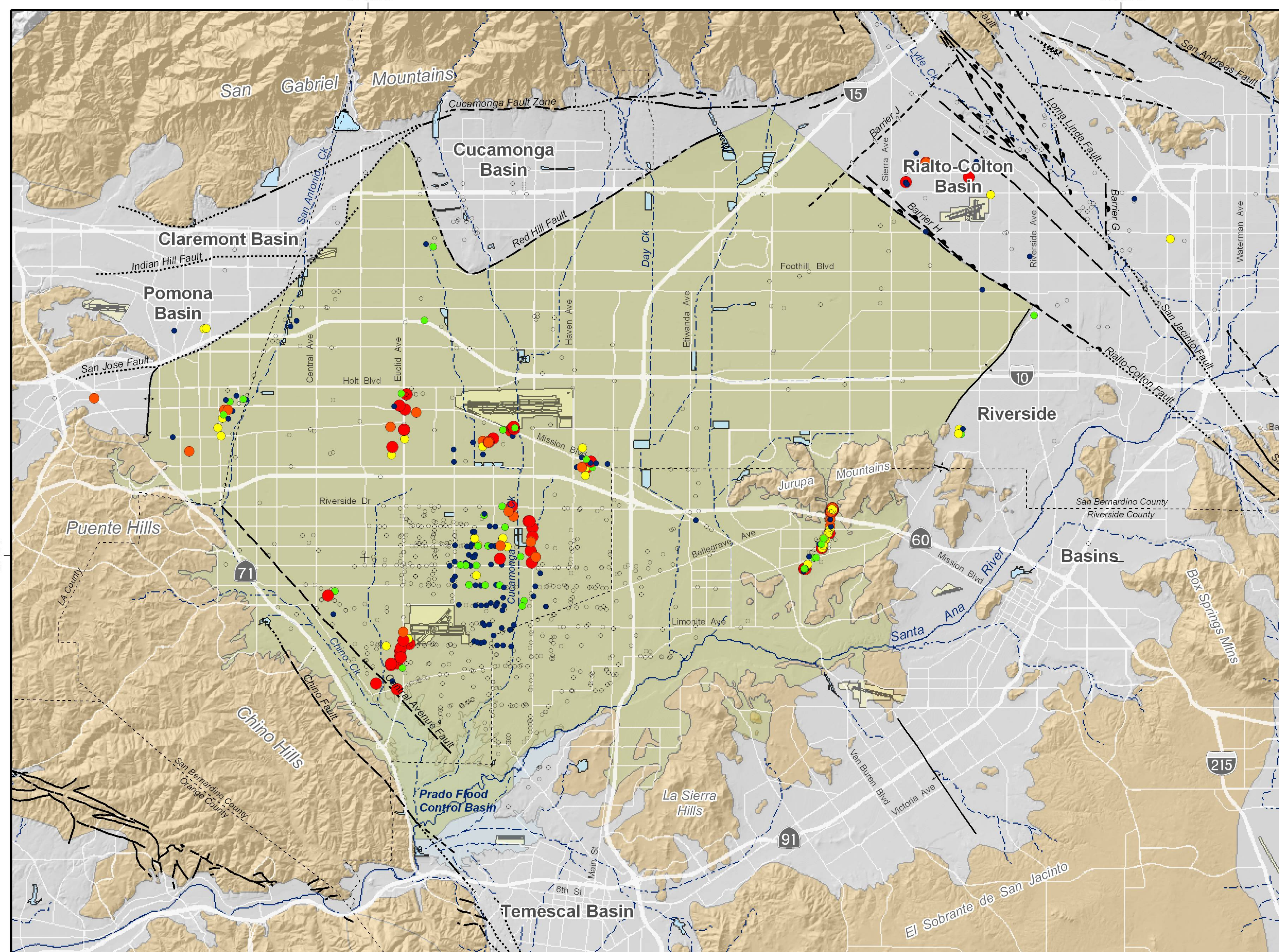
0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Tetrachloroethene in Groundwater
Maximum Concentration (1999-2004)

Figure 4-8



Main Features

Tricholoethene Concentration (ug/L)

- ND
- <2.5
- 2.5-5
- 5-10
- 10-20
- >20

Primary US EPA MCL = 5 ug/L

Primary Ca MCL = 5 ug/L

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

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File:Figure_4-9.mxd

0 1 2 3 4 Miles

0 2 4 6 KM

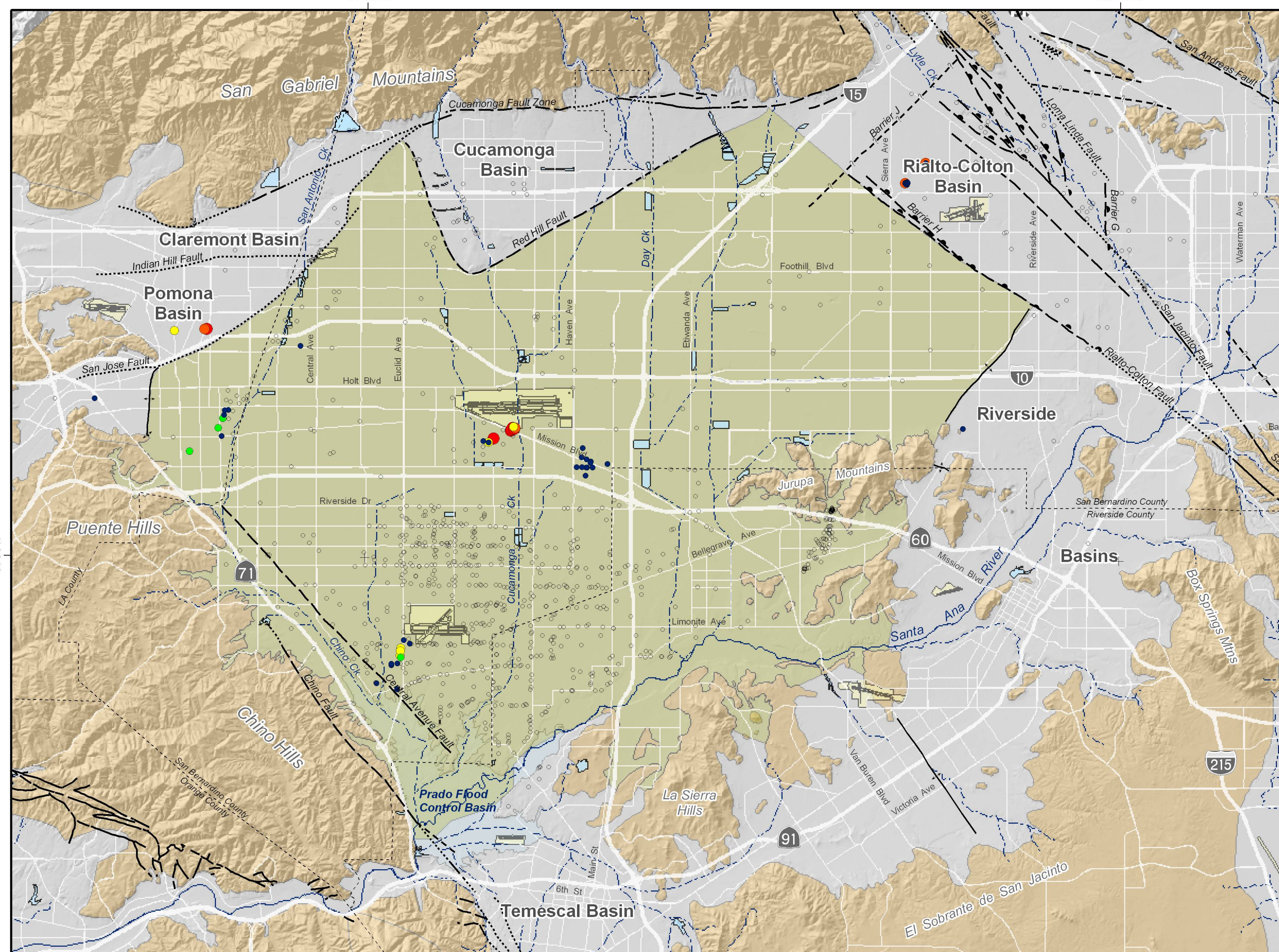
State of the Basin Report -- 2004

Groundwater Quality

Trichloroethene in Groundwater

Maximum Concentration (1999-2004)

Figure 4-9



Main Features

1,1-Dichloroethene Concentration (ug/L)

- ND
- <3
- 3-6
- 6-12
- 12-24
- >24

Primary Ca MCL = 6 ug/L

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
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- Location Uncertain
- Groundwater Divide

Other Features

Flood Control and Conservation Basins

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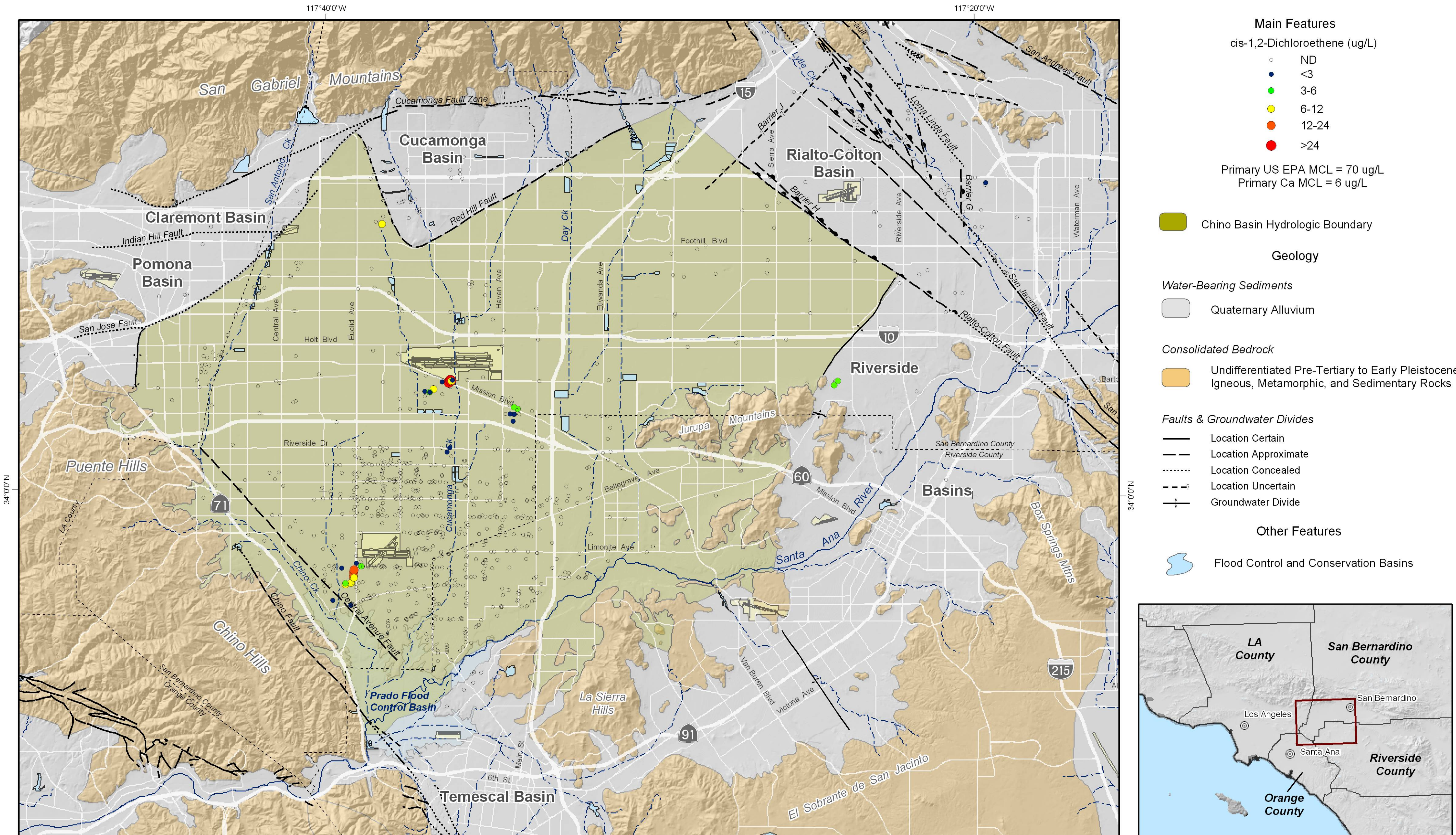
0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

1,1-Dichloroethene in Groundwater

Maximum Concentration (1999-2004)

Figure 4-10



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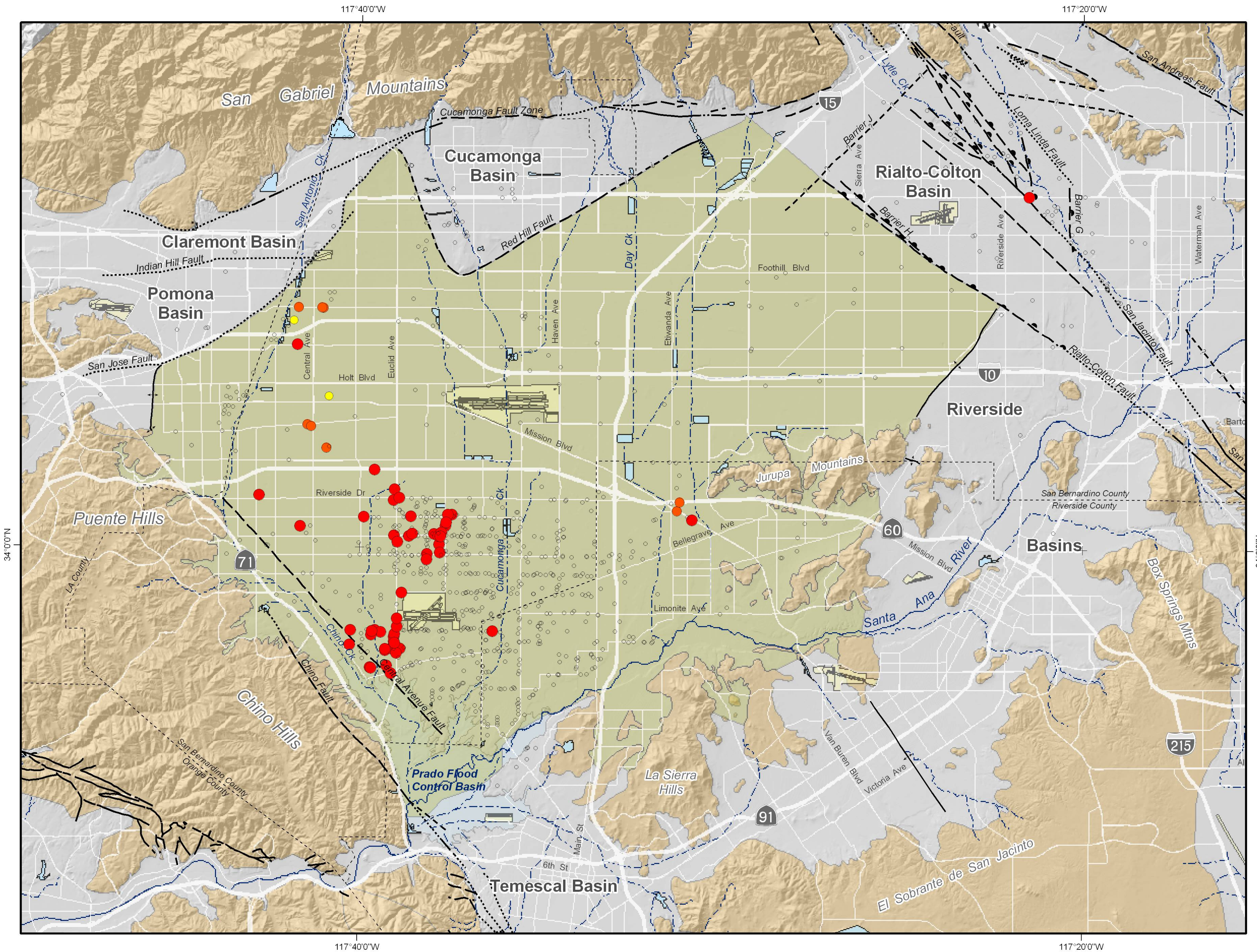
File:Figure_4-11.mxd

State of the Basin Report -- 2004
Groundwater Quality

cis-1,2-Dichloroethene in Groundwater
Maximum Concentration (1999-2004)

Figure 4-11



Main Features

1,2,3-Trichloropropane Concentration (ug/L)

- ND
- <0.0025
- 0.0025-0.005
- 0.005-0.01
- 0.01-0.02
- >0.02

California Notification Level = 0.005 ug/L

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

Flood Control and Conservation Basins

Miles: 0 1 2 3 4

KM: 0 2 4 6

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Date: 20041223

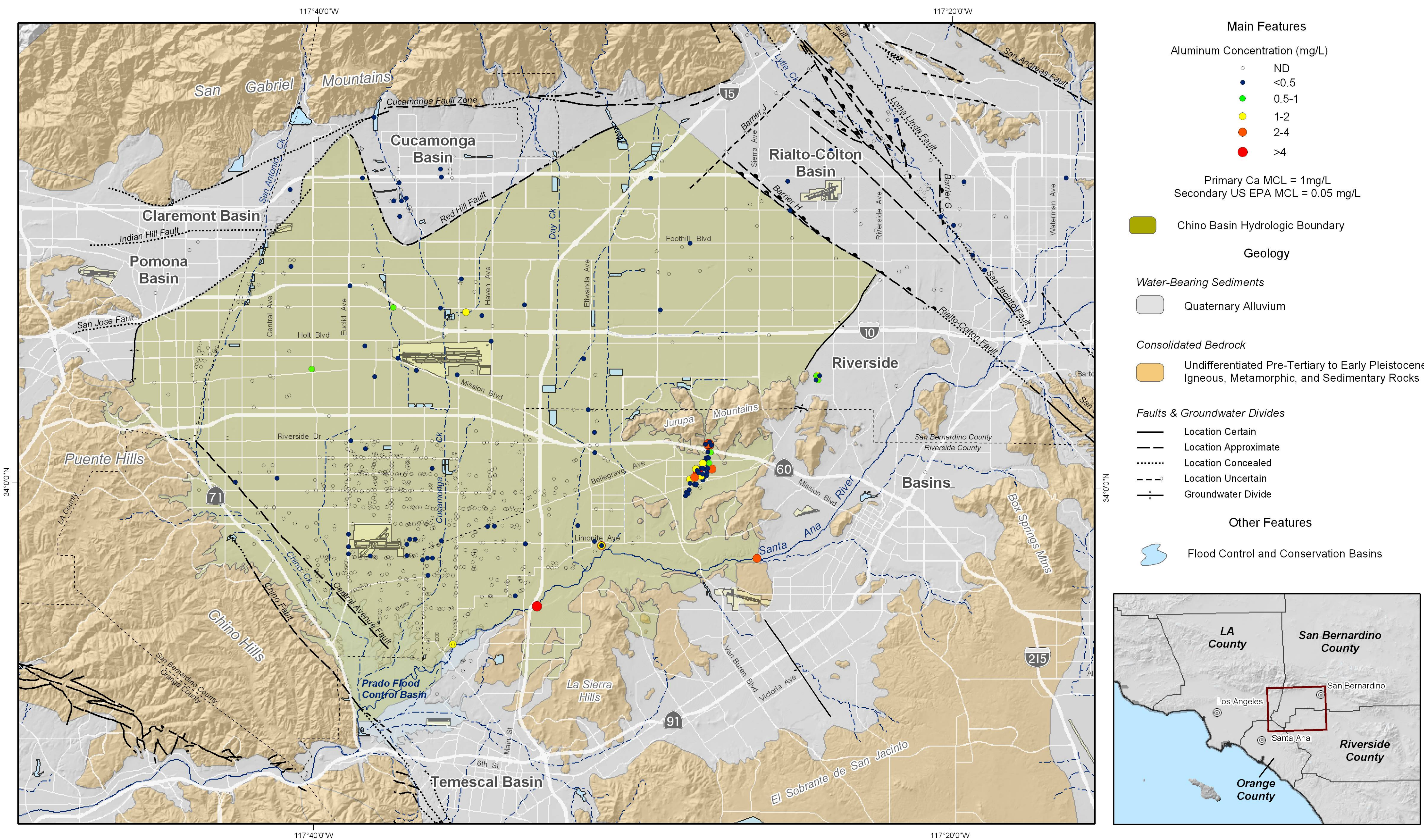
File:Figure_4-12.mxd

State of the Basin Report -- 2004
Groundwater Quality

1,2,3-Trichloropropane in Groundwater

Maximum Concentration (1999-2004)

Figure 4-12



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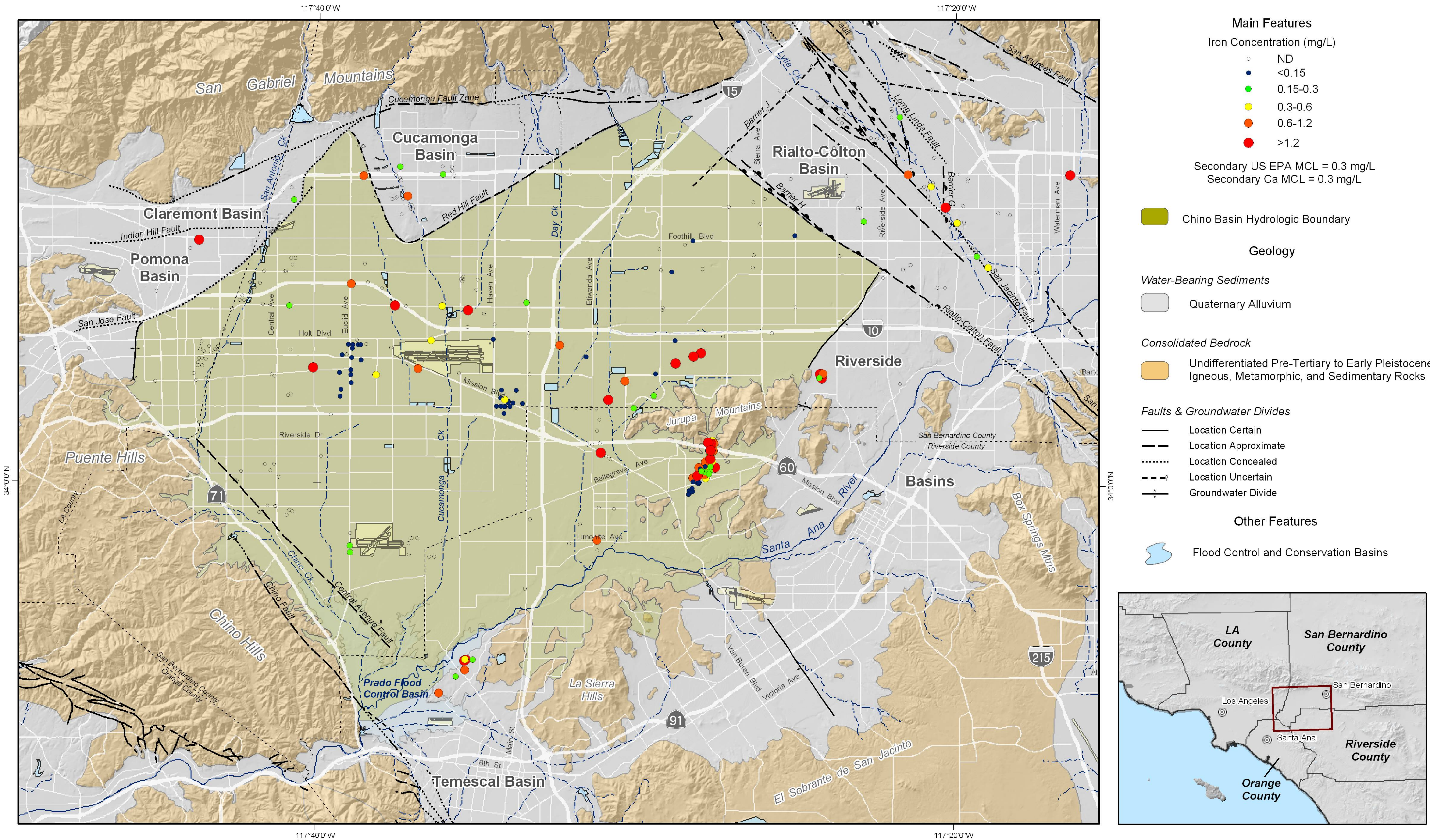
File:Figure_4-13.mxd

0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Aluminum in Groundwater
Maximum Concentration (1999-2004)

Figure 4-13



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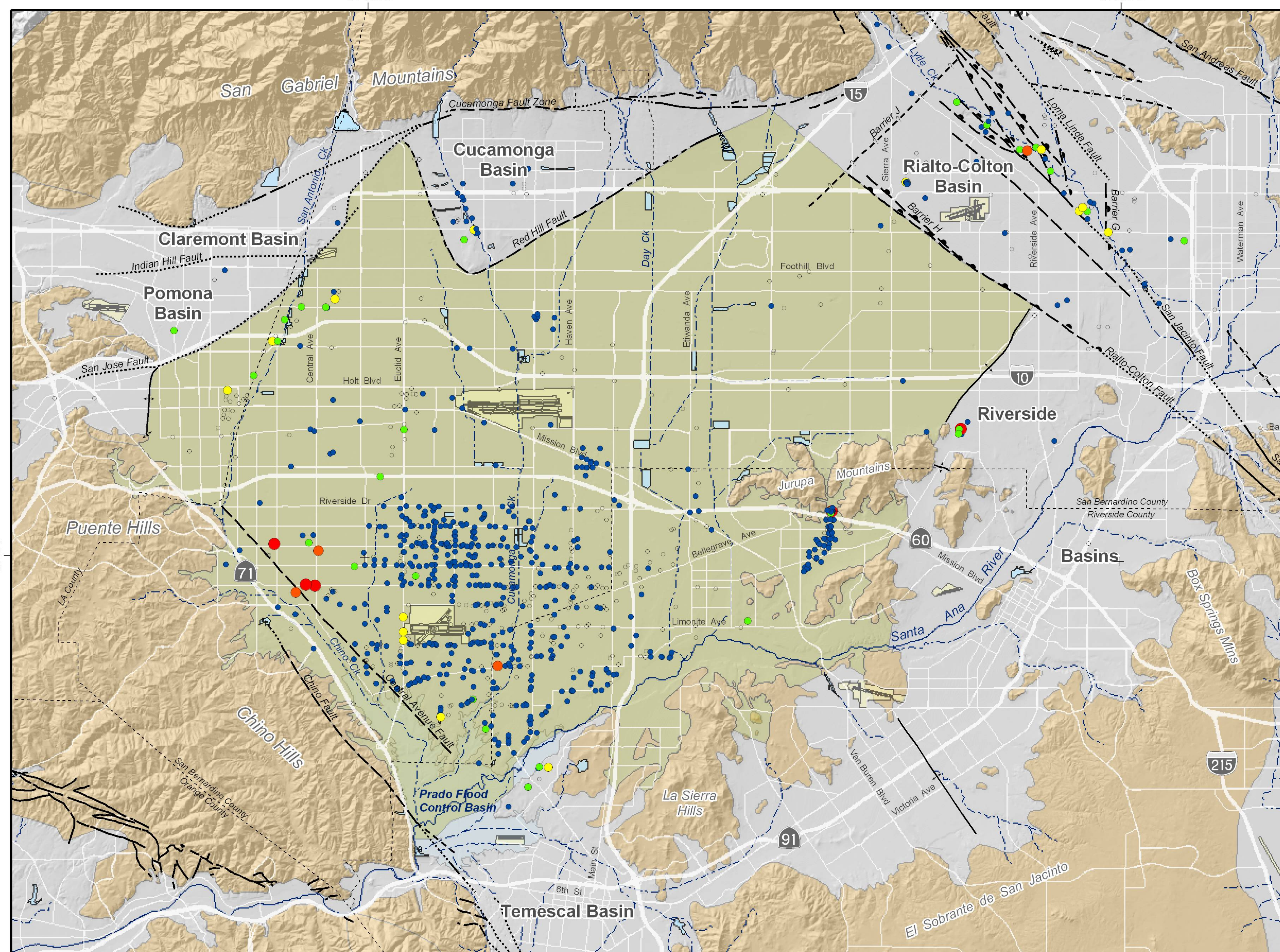
File:Figure_4-14.mxd

0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Iron in Groundwater
Maximum Concentration (1999-2004)

Figure 4-14



Main Features

Arsenic Concentration (ug/L)

- ND
- <5
- 5-10
- 10-20
- 20-40
- >40

Proposed Primary US EPA MCL =10 ug/L
Current Primary US EPA MCL =50 ug/L
Primary Ca MCL =50 ug/L

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

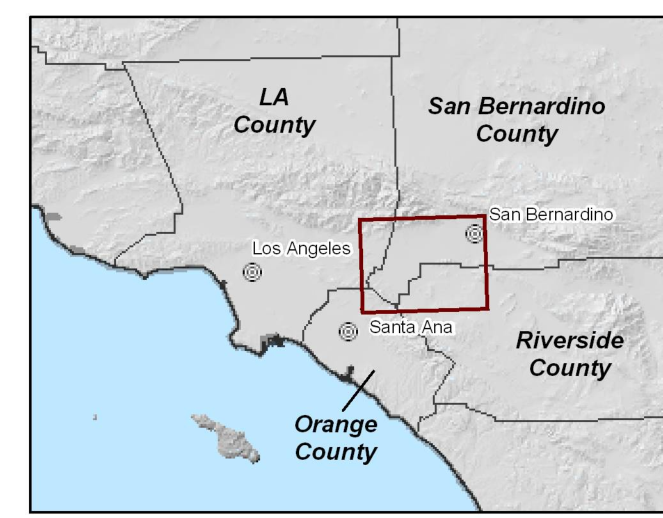
Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

Flood Control and Conservation Basins



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Date: 20041223
File:Figure_4-15.mxd

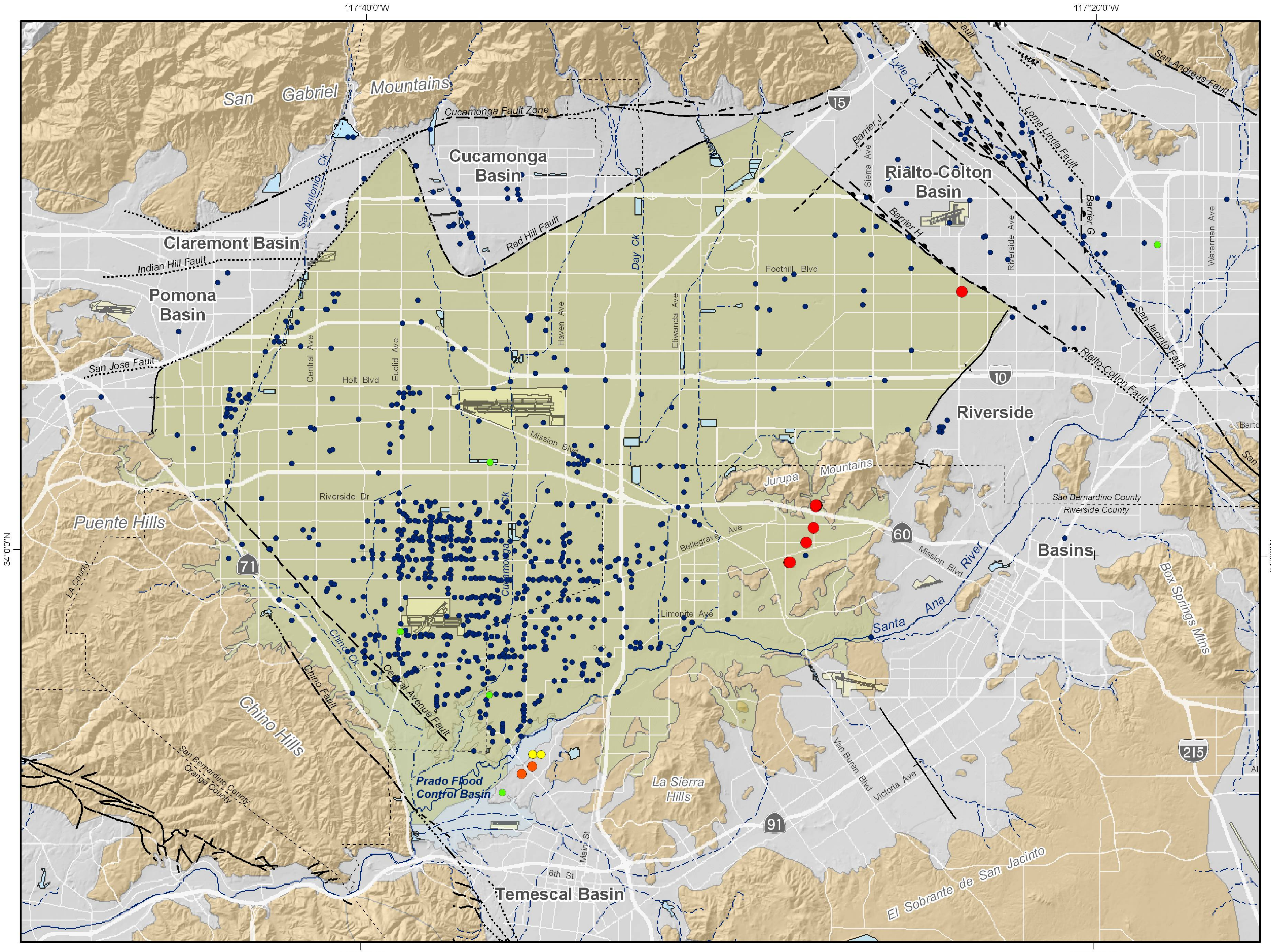
0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Arsenic in Groundwater

Maximum Concentration (1999-2004)

Figure 4-15



Main Features

Fluoride (mg/L)

- ND
- <1
- 1-2
- 2-4
- 4-8
- >8

Primary US EPA MCL = 4 mg/L
Primary Ca MCL = 2 mg/L

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

Flood Control and Conservation Basins

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File:Figure4-16.mxd

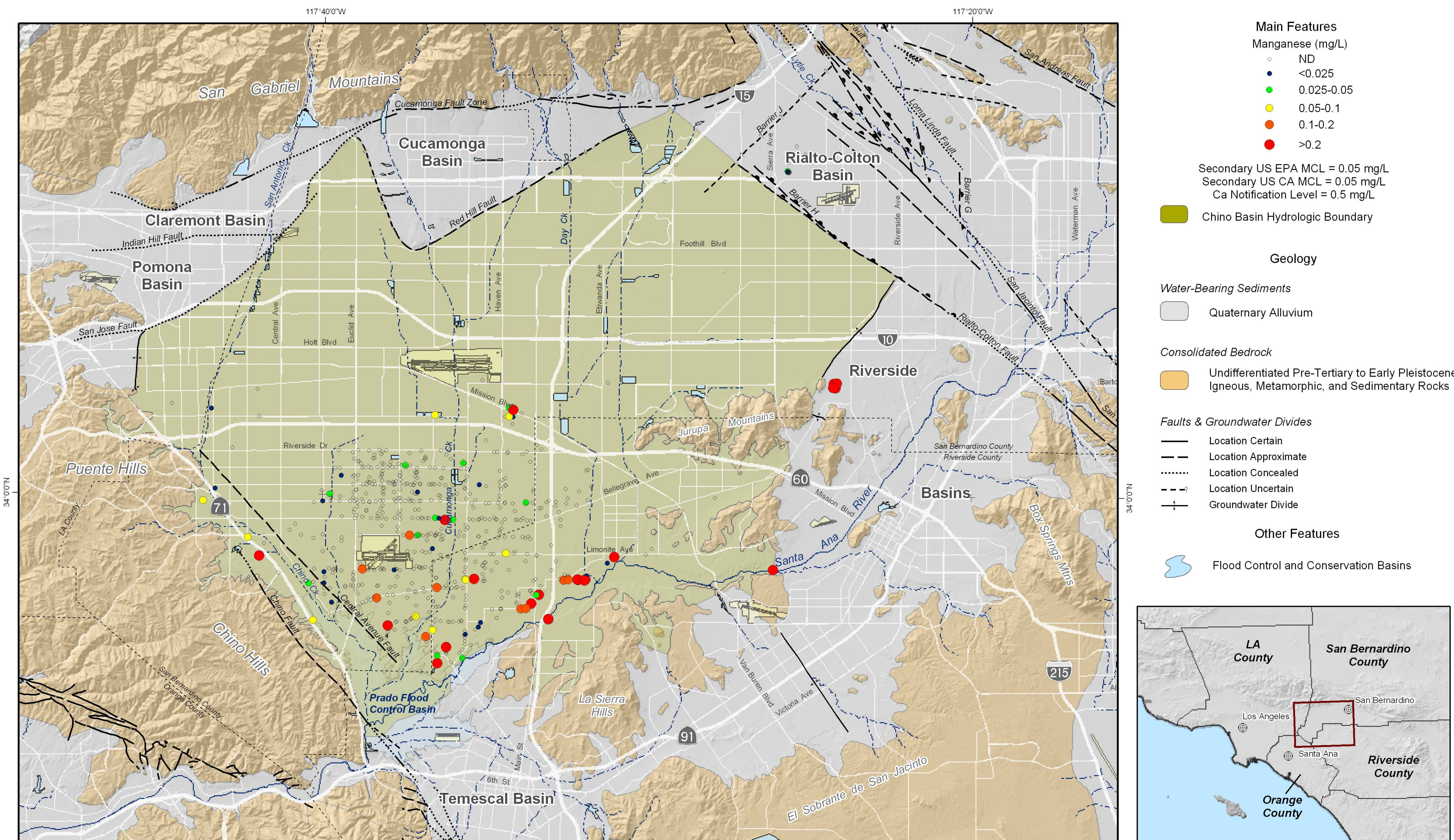
0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Fluoride in Groundwater

Maximum Concentration (1999-2004)

Figure 4-16



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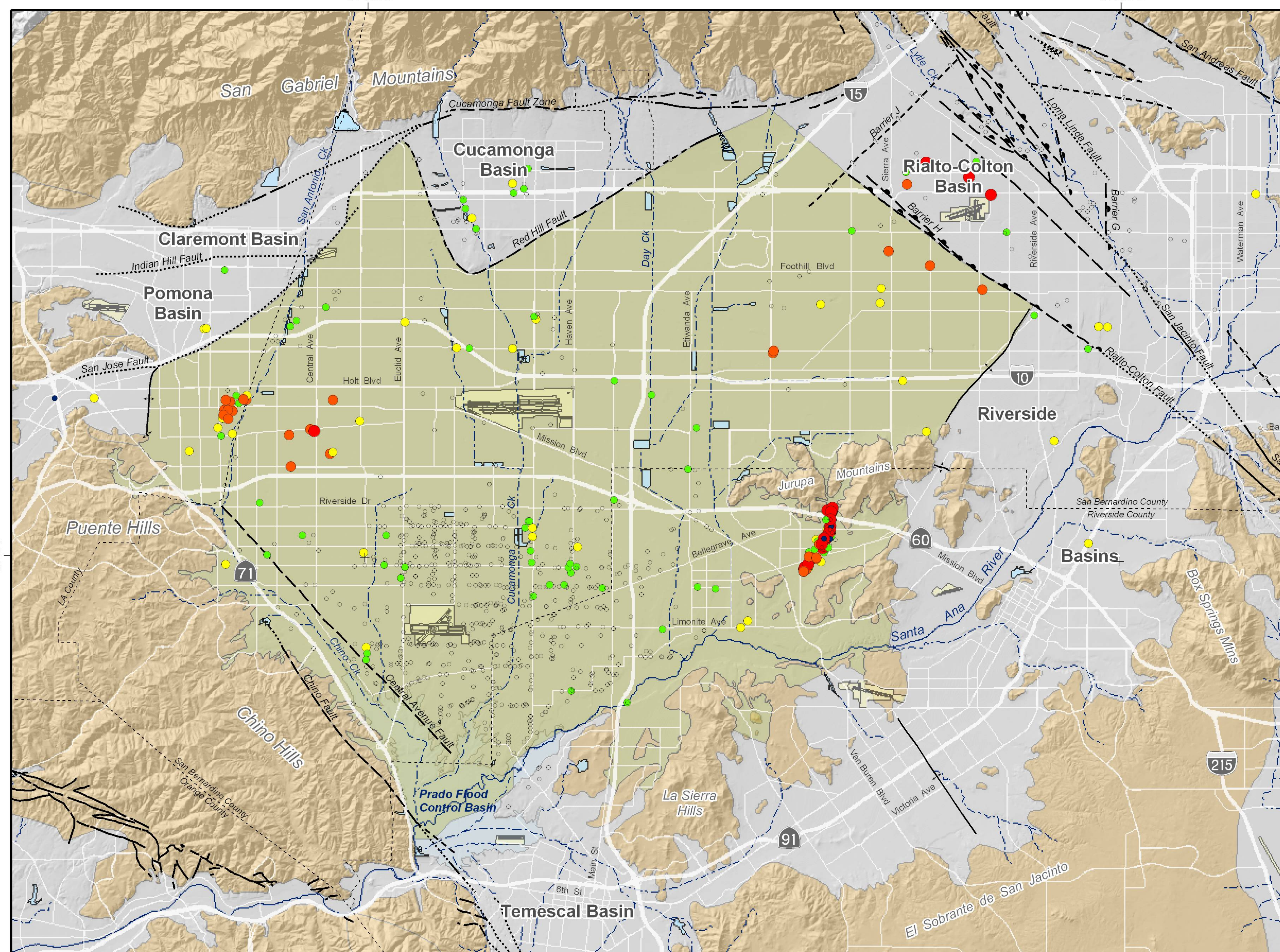
File:Figure_4-17.mxd

State of the Basin Report -- 2004
Groundwater Quality

Manganese in Groundwater
Maximum Concentration (1999-2004)

Figure 4-17



Main Features

Perchlorate Concentration (ug/L)

- ND
- <3
- 3-6
- 6-12
- 12-24
- >24

Ca Notification Level = 6 ug/L

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

Flood Control and Conservation Basins

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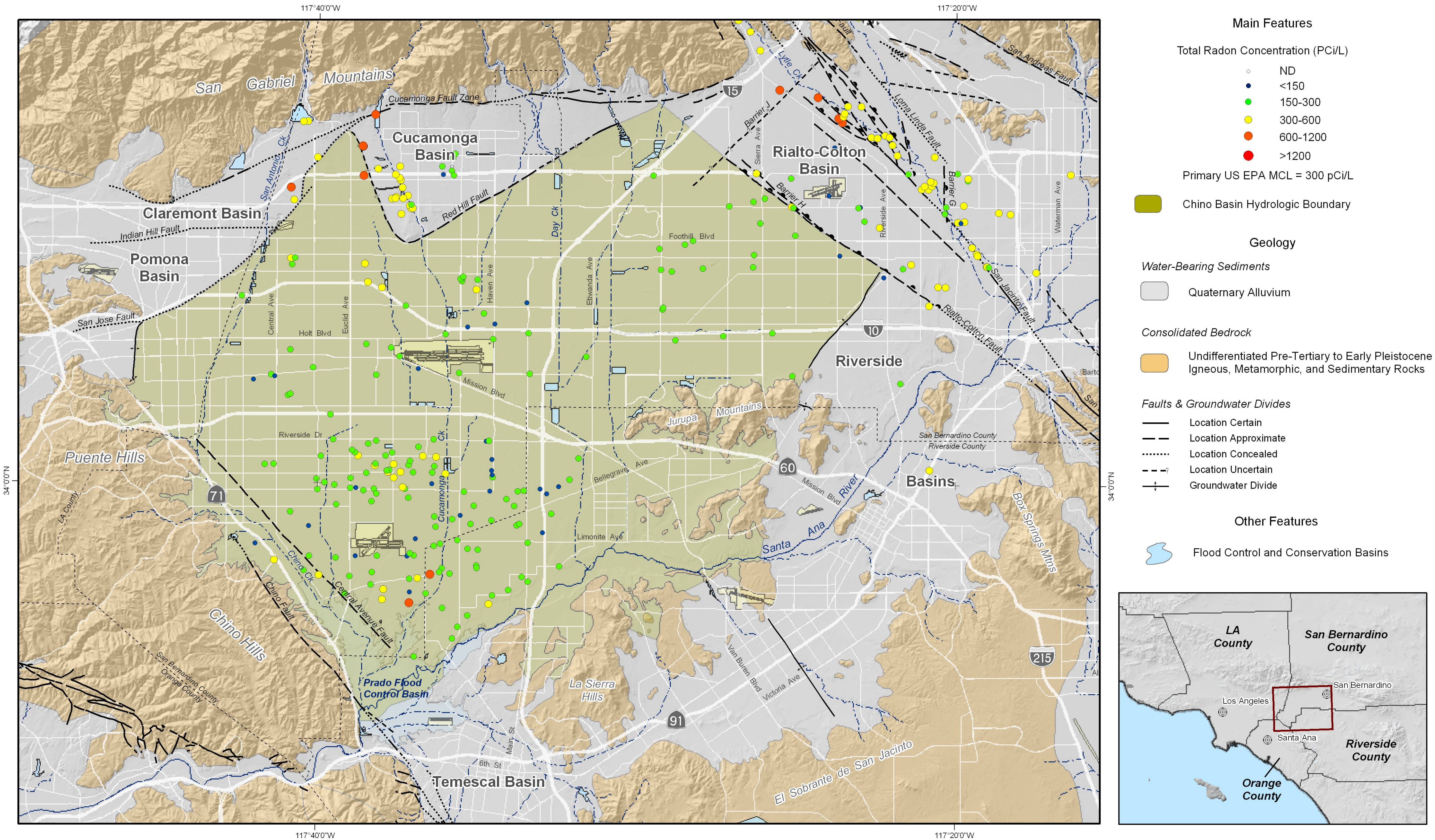
Date: 20041223
File:Figure_4-18.mxd

0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Perchlorate in Groundwater
Maximum Concentration (1999-2004)

Figure 4-18



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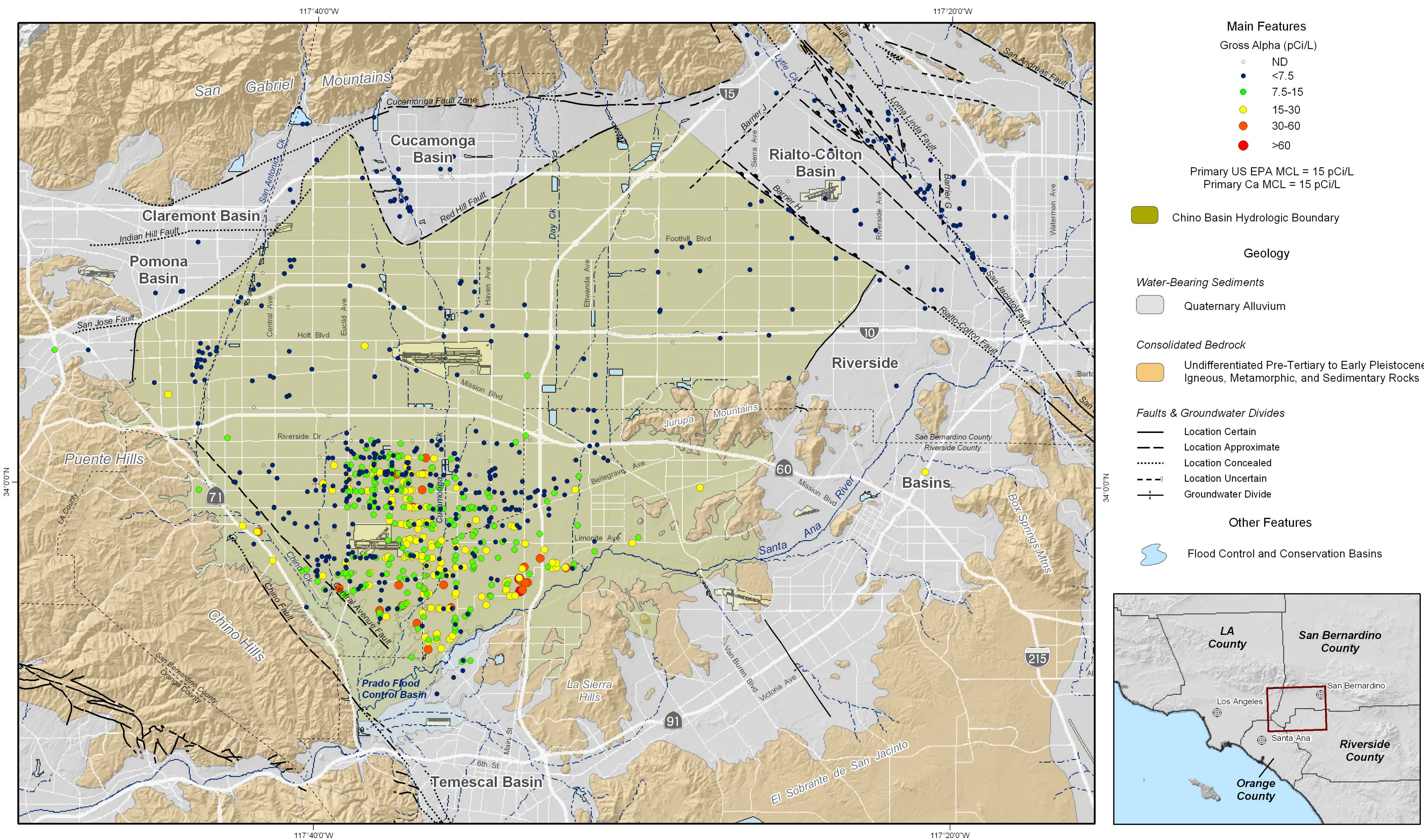
File:Figure_4-19.mxd

0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Total Radon in Groundwater
Maximum Concentration (1999-2004)

Figure 4-19



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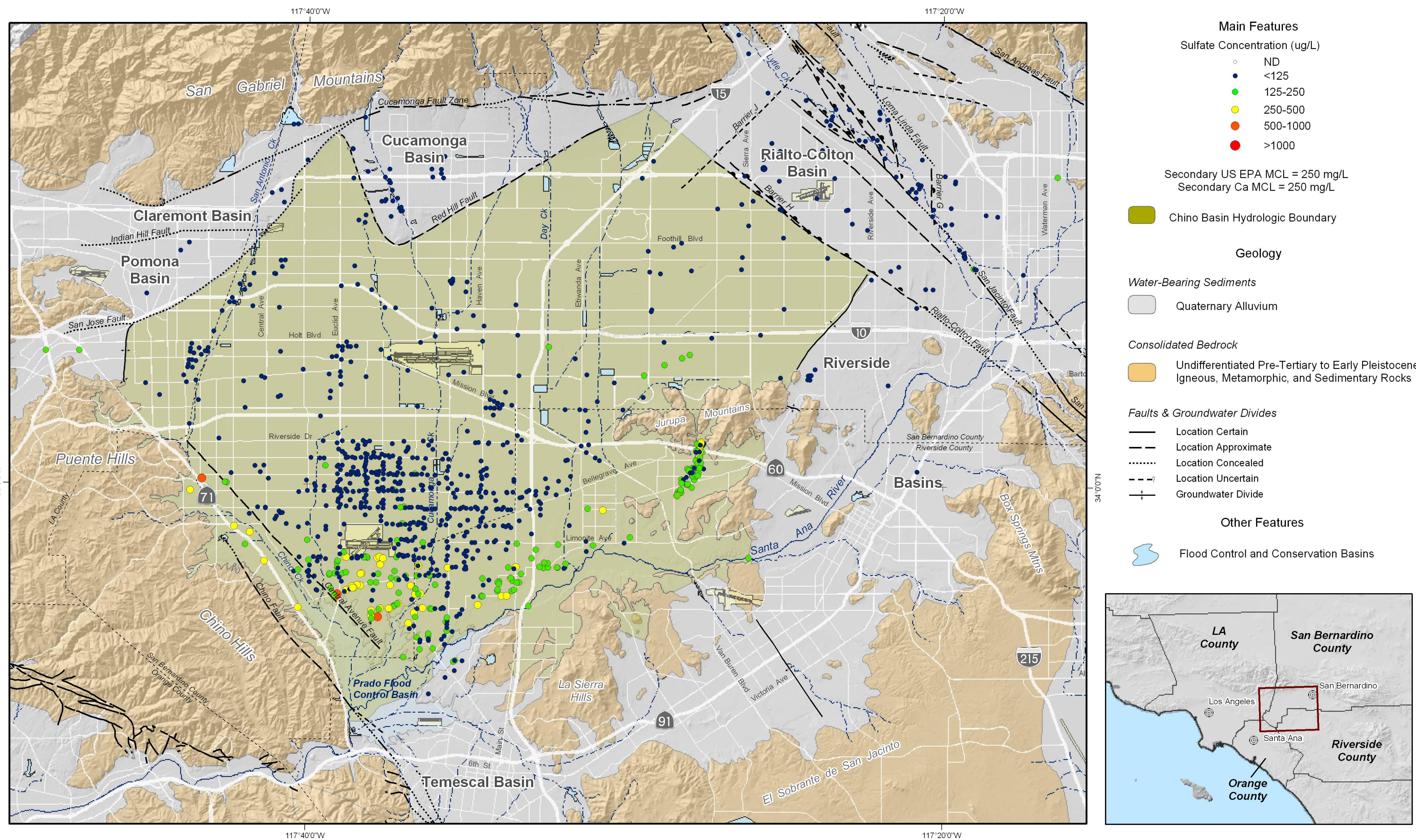
File:Figure_4-20.mxd

0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Gross Alpha in Groundwater
Maximum Concentration (1999-2004)

Figure 4-20



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Author: EMW
Date: 20041223
File:Figure_4-21.mxd

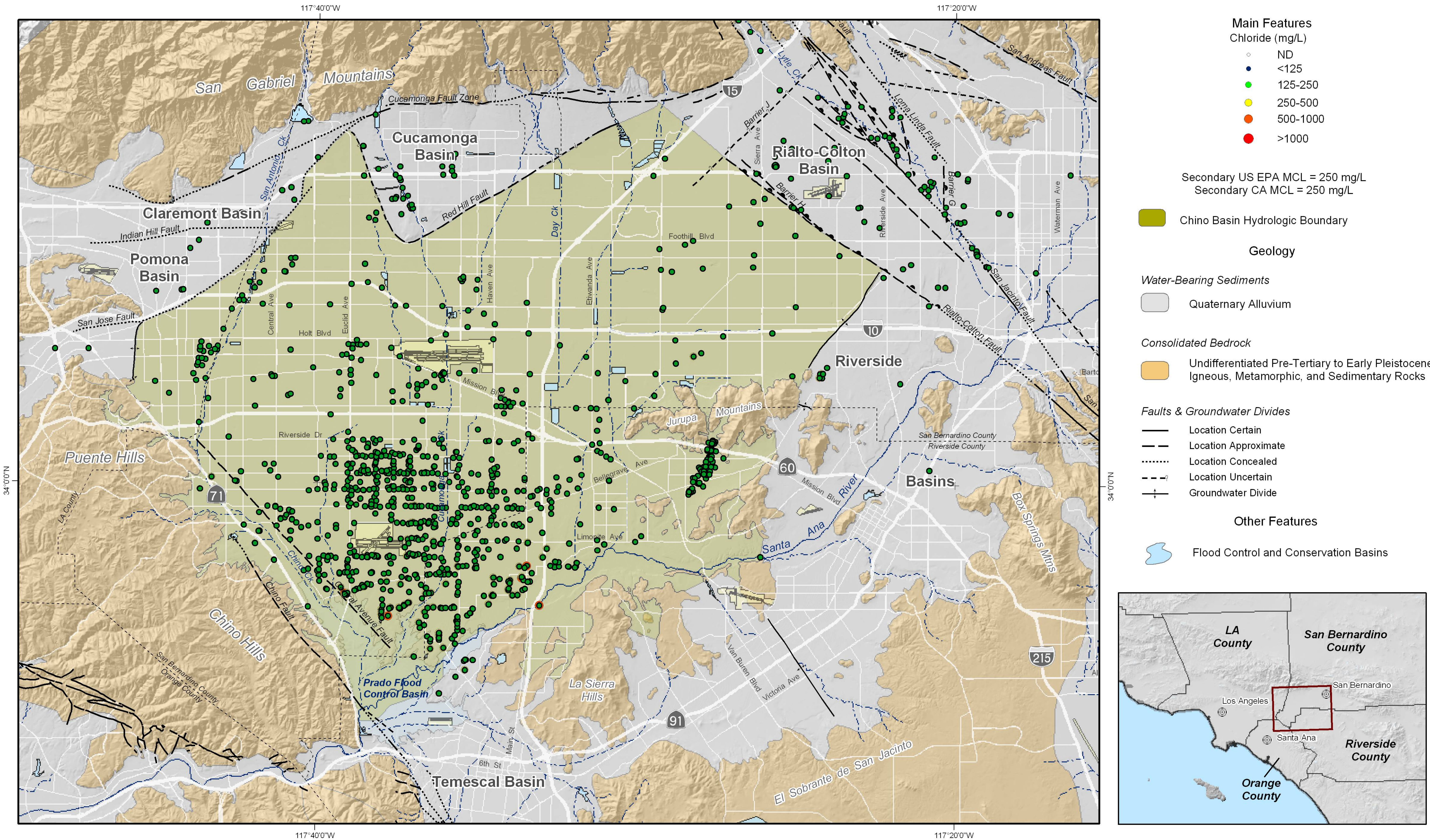
0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Sulfate in Groundwater

Maximum Concentration (1999-2004)

Figure 4-21



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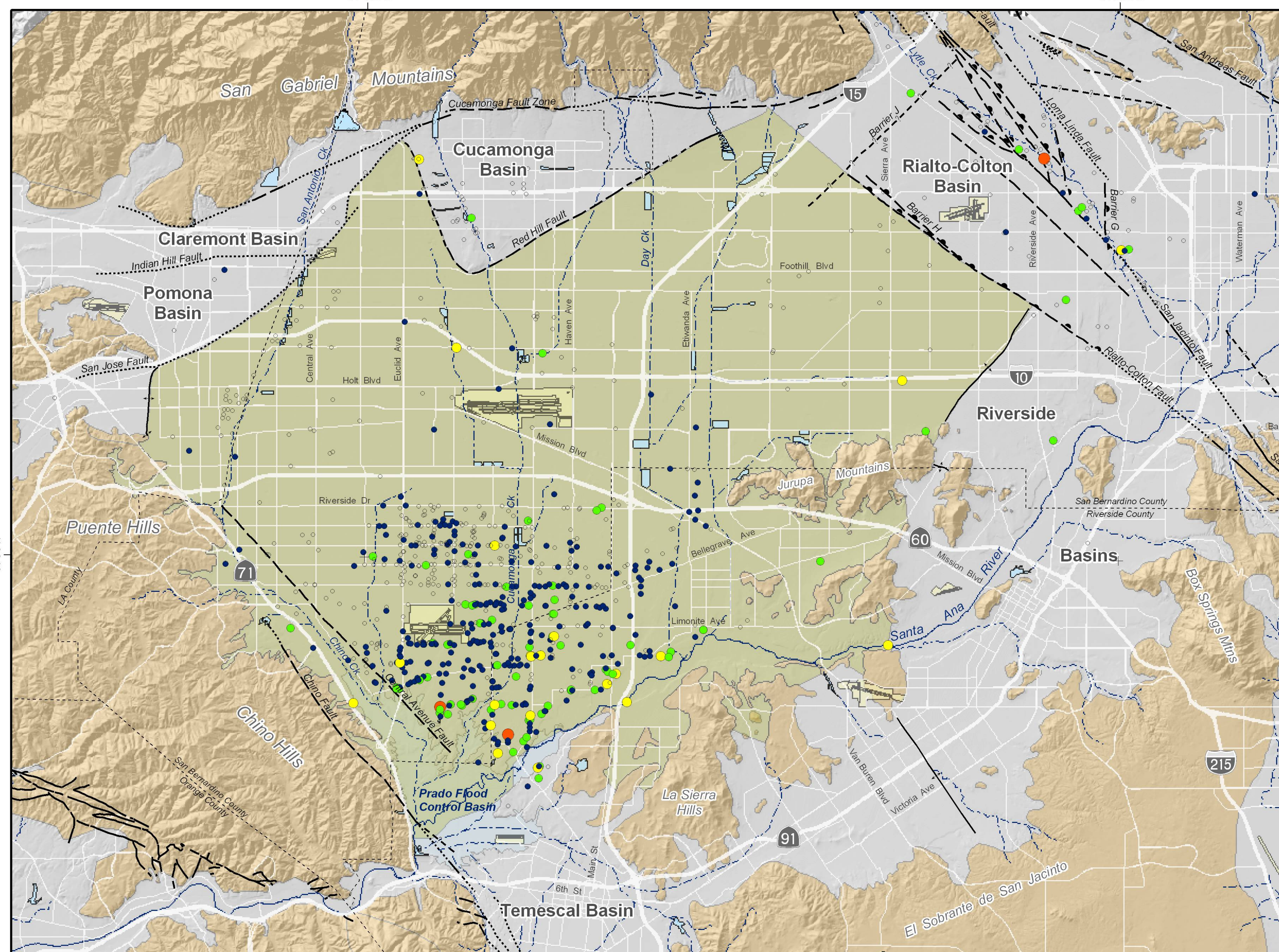
Date: 20050104
File:Figure_4-22.mxd

State of the Basin Report -- 2004
Groundwater Quality

Chloride in Groundwater
Maximum Concentration (1999-2004)

Figure 4-22



Main Features

Color (units)

- ND
- <7.5
- 7.5-15
- 15-30
- 30-60
- >60

Secondary US EPA MCL = 15 mg/L
Secondary Ca MCL = 15 mg/L

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

Flood Control and Conservation Basins

0 1 2 3 4 Miles
0 2 4 6 KM

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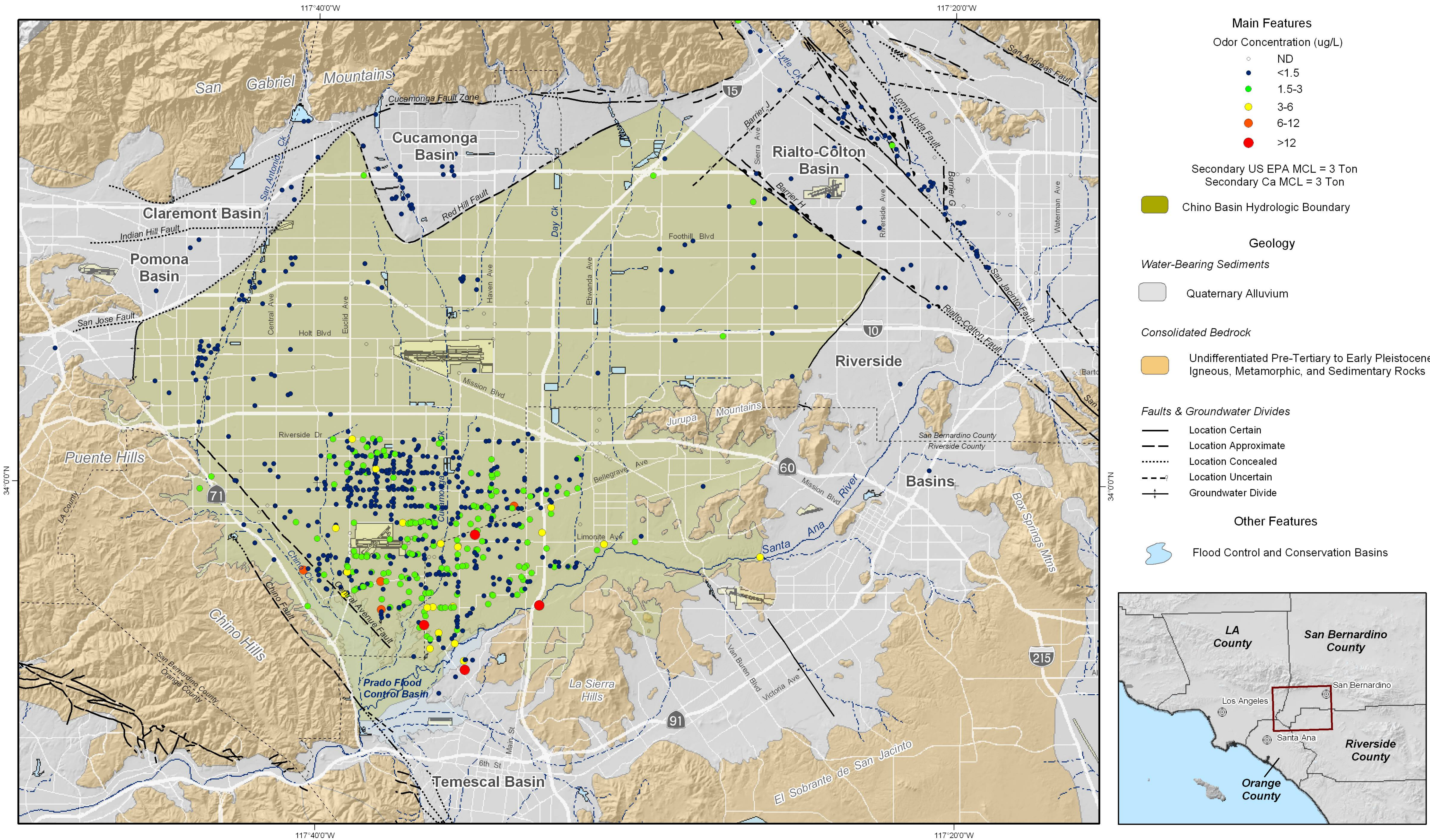
Date: 20041223
File:Figure_4-23.mxd

State of the Basin Report -- 2004
Groundwater Quality

Color in Groundwater
Maximum Concentration (1999-2004)

Figure 4-23



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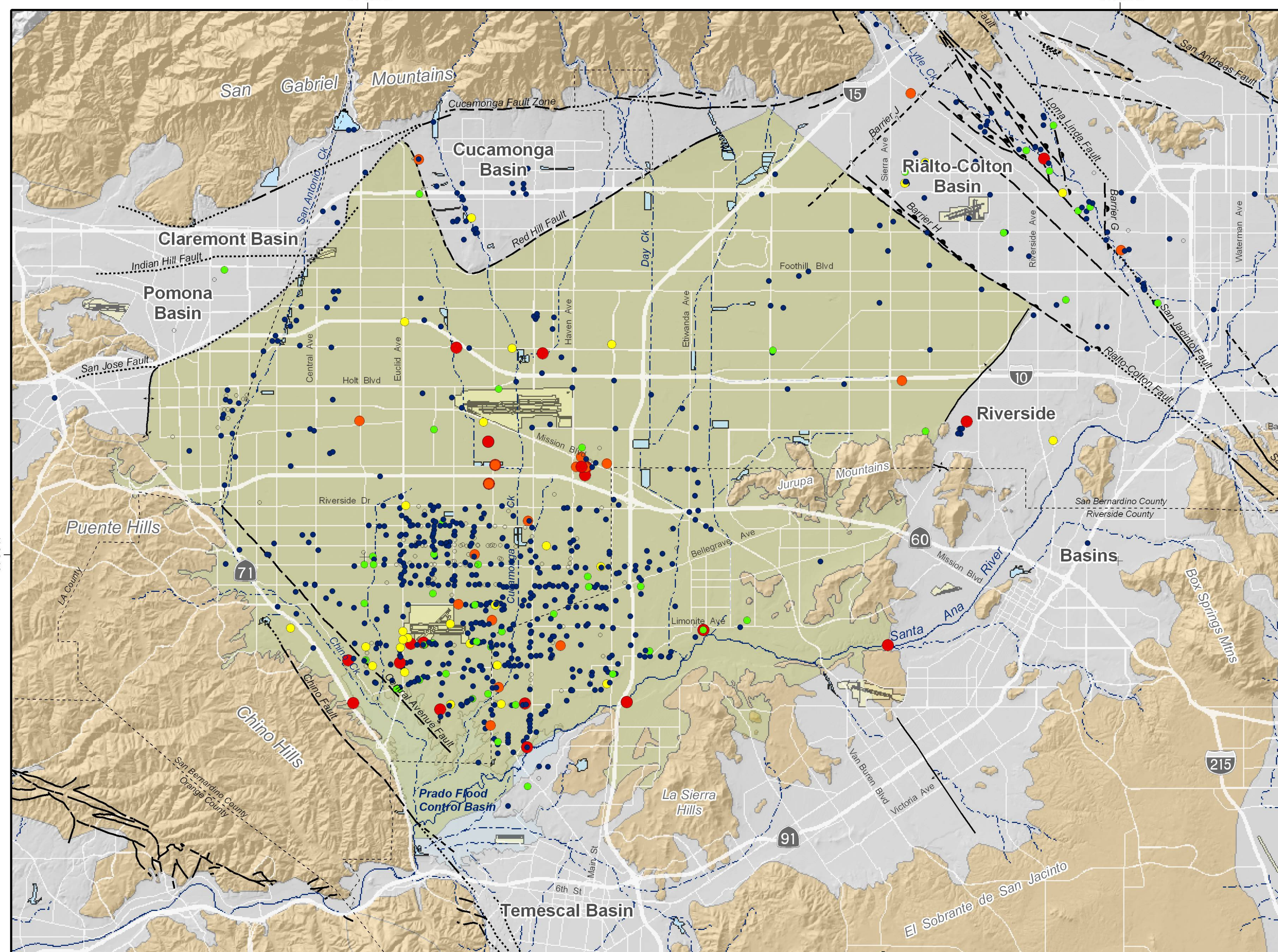
File:Figure_4-24.mxd

State of the Basin Report -- 2004
Groundwater Quality

Odor in Groundwater

Maximum Concentration (1999-2004)

Figure 4-24



Main Features

Turbidity Concentration (NTU)

- ND
- <2.5
- 2.5-5
- 5-10
- 10-50
- >50

Secondary Ca MCL = 5 NTU

Chino Basin Hydrologic Boundary

Geology

Water-Bearing Sediments

Quaternary Alluvium

Consolidated Bedrock

Undifferentiated Pre-Tertiary to Early Pleistocene Igneous, Metamorphic, and Sedimentary Rocks

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide

Other Features

Flood Control and Conservation Basins

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Date: 20041223
File:Figure_4-25.mxd

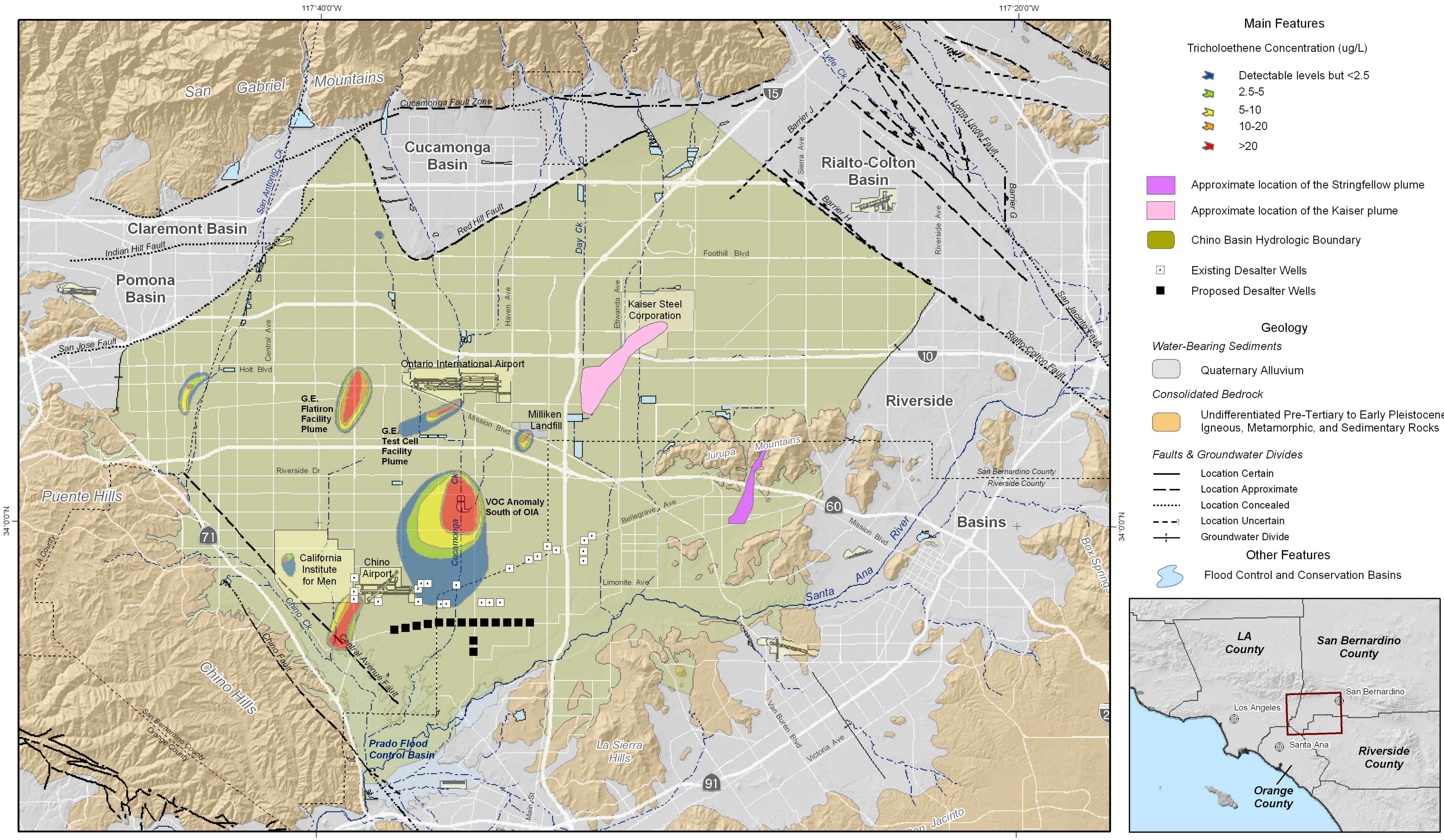
0 1 2 3 4 Miles
0 2 4 6 KM

State of the Basin Report -- 2004
Groundwater Quality

Turbidity in Groundwater

Maximum Concentration (1999-2004)

Figure 4-25



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Author: EMW
Date: 20041223
File: Figure_4-26.mxd

State of the Basin Report -- 2004
Groundwater Quality

VOC plumes in the Chino Basin

Represented by Maximum TCE Concentration (1999-2004)

Figure 4-26

5. GROUND-LEVEL MONITORING

5.1 Background

The area underlying the City of Chino and the California Institution for Men (CIM) has experienced ground fissuring as early as 1973, but an accelerated occurrence of ground fissuring ensued after 1991. Figure 5-1 shows this area within the larger context of MZ-1.

A common cause of ground fissuring within alluvial basins is the removal of subsurface fluids resulting in compaction of poorly-consolidated aquifer materials and land subsidence (Galloway *et al.*, 1998; USGS, 1999). A number of studies have attributed this process to the ground fissuring and land subsidence that has occurred in Chino (Fife *et al.*, 1976, Kleinfelder, 1993, 1996, 1999; Geomatrix, 1994). Figure 5-1 shows the area where ground level surveys conducted within the City of Chino demonstrate that a maximum of about 2.5 ft of subsidence occurred along Central Avenue from 1987-2001 (Kleinfelder, 1993, 1996, 1999, 2001). Figure 5-2 shows a close-up view of this area.

Remote sensing studies of subsidence were conducted for the City of Chino (Peltzer, 1999a, 1999b) to further analyze subsidence in Management Zone 1 (MZ-1). These studies employed Synthetic Aperture Radar Interferometry (InSAR), which utilizes radar imagery from an Earth-orbiting spacecraft to map ground surface deformation. Figures 5-1 and 5-2 show the results of these InSAR studies that independently confirmed the location and relative magnitude of subsidence in MZ-1 as defined by the ground level surveys, and indicated the occurrence of subsidence north and northeast of Chino.

Program Element 4 (of the Optimum Basin Management Program) – *Develop and Implement a Comprehensive Groundwater Management Plan for Management Zone 1* relates specifically to ground fissuring and land subsidence in Chino Basin. This program element calls for the development and implementation of an Interim Management Plan for MZ-1 that will:

- Minimize subsidence and fissuring in the short-term
- Collect information necessary to understand the extent, rate, and mechanisms of subsidence and fissuring
- Formulate a long-term management plan to reduce to tolerable levels or abate future subsidence and fissuring

5.2 Activities and Accomplishments: 2002-2004

Since completion of the Initial State of the Basin Report in 2002, Watermaster has completed the following activities related to ground level monitoring:

1. *Formed the MZ-1 Technical Committee*. The MZ-1 Technical Committee serves as a clearing house for technical information, as well as the source for full professional discussion, input and peer review by its members, for the benefit of Watermaster. The Technical Committee provides comment and assists Watermaster in the development of recommendations for consideration and potential action by Watermaster under the Interim Management Plan. In addition, the Technical Committee provides similar assistance to Watermaster in its effort to develop a long-term plan as provided in Program Element Four. The Technical Committee consists of representatives (and their technical consultants) from those parties to the Judgment that are presently producing groundwater within MZ-1. Each of the following producers is entitled to representation on the Committee: Chino, Chino Hills, Ontario, Upland, Pomona, Monte Vista Water District, San Antonio Water Company, Southern California Water Company, CIM and the Agricultural Pool. Figure 5-1 shows the locations of wells owned by the

producers listed above. The MZ-1 Technical Committee first convened on March 6, 2002, and has continued to meet once every 1-3 months.

2. *Developed and implemented the Interim Monitoring Program*. The MZ-1 Technical Committee approved the scope and schedule for the MZ-1 Interim Monitoring Program (IMP) at the January 29, 2003 meeting. The IMP was developed and implemented to collect the information necessary to understand the extent, rate, and mechanisms of subsidence and fissuring in MZ-1. The data collected and analyzed as part of this effort are being utilized to develop effective management tools and, ultimately, a long-term management plan that will minimize or completely abate ground fissuring and subsidence in MZ-1. The IMP is described in detail in the IMP Work Plan dated January 8, 2003, but generally consists of three main elements: benchmark survey, InSAR, and aquifer-system monitoring. The benchmark surveys and the InSAR analyses monitor deformation of the land surface. Aquifer-system monitoring measures the hydraulic and mechanical changes within the aquifer-system that cause land surface deformation.

3. *Installed benchmark monument network and conducted ground level surveys*. The IMP calls for repeated benchmark surveys to measure vertical (and in some cases horizontal) ground surface deformation along selected profiles within Chino Basin – mainly in MZ-1. The benchmark surveys will (1) establish a datum from which to measure land surface deformation during the IMP period, (2) allow determination of historical subsidence at any historical benchmarks that can be recovered, (3) "ground-truth" the InSAR data, and (4) assist in the evaluation of the effectiveness of the long-term management plan.

   The IMP work plan called for the installation of a network of stable benchmark monuments to supplement an existing network of benchmarks that was installed for the City of Chino in 1987. Associated Engineers (AE) completed monument installations (see Figure 5-3) and an initial survey of all monument elevations in April 2003. Repeat surveys are planned for April of each year during the IMP period.

   The IMP work plan also calls for the deep extensometer, which is anchored in sedimentary bedrock at about 1,400 ft bgs, to be used as the "starting benchmark" for all survey loops. To accomplish this, a Class-A benchmark was constructed outside the extensometer building to serve as the practical (*i.e.* actual) starting benchmark. To link this benchmark to the deep extensometer pipe, each survey event begins by referencing the benchmark to a marked spot on one of the piers that supports the extensometer instrument platform. These piers and the instrument platform represent a stable ground surface datum that is used to measure relative vertical displacement between the ground surface and the deep extensometer pipe (recorded every 15 minutes). The vertical displacement recorded at the deep extensometer between survey events, in addition to any vertical displacement measured between the starting benchmark and the pier, is then used to calculate the elevation at the starting benchmark outside the extensometer building. Then, relative vertical displacement between benchmarks is measured across the entire network to obtain current elevations.

   A key element of the MZ-1 benchmark network is the array of closely spaced benchmarks that have been established across the historic fissure zone in the immediate vicinity of the Ayala Park extensometers (Ayala Park Array). At this array, located along Edison and Eucalyptus Avenues, both vertical and horizontal displacements are measured. These horizontal and vertical displacements are defining two-dimensional profiles of land-surface deformation that can be related to the vertical distribution of aquifer-system compaction and expansion that is being recorded continuously at the extensometers. These surveys are being repeated semi-annually during the late spring and early fall periods of highest and lowest water levels in an attempt to monitor fissure movement, if any, that may be associated with elastic and/or inelastic aquifer-system deformation. (Note: the semi-annual survey frequency of the Ayala Park Array monuments is a modification to the IMP work plan, and was agreed upon by the MZ-1 Technical Committee at the September 24, 2003 meeting).

4. *Performed "proof-of-concept" InSAR analyses to evaluate methodologies for historical analysis*. InSAR is being used to characterize ground surface deformation in Chino Basin. This analysis will be performed for a historical period (1992-2000) and on an on-going basis thereafter. The advantage of InSAR is that it provides an aerially continuous representation of land surface deformation. These data are planned to be used to: (1) characterize the time history of land surface deformation in greater spatial and temporal detail than can be accomplished from the available historical ground-level survey data, (2) calibrate computer simulation models of subsidence and groundwater flow, and (3) assist in the evaluation of the effectiveness of the long-term management plan.

   In 2004, Vexcel Corporation of Boulder, Colorado – a company that specializes in remote sensing and radar technologies – conducted a "proof of concept" study of historical SAR data that was acquired over the MZ-1 area. The objective of this study was to generate cumulative displacement maps over relatively short time steps (April to November 1993). The MZ-1 Technical Group deemed the study successful, and approved follow-up study by Vexcel to perform a comprehensive analysis of all historical SAR data (1992-2003) to characterize in detail the time history of subsidence in MZ-1.

5. *Tested and monitored the aquifer system hydraulics and mechanics*. This work involved the measuring of stresses within the aquifer-system that cause land surface deformation as measured by benchmark surveys, InSAR, and the extensometers (described below). The centerpiece of the aquifer-system monitoring program is the Ayala Park Extensometer – a highly sophisticated monitoring facility consisting of two multi-piezometers and a dual-extensometer. This facility monitors the hydraulics and mechanics of the underlying aquifer-system as the system undergoes various stresses due to groundwater production and recharge. The facility is equipped with pressure transducers to measure water levels in the piezometers, linear potentiometers to measure vertical displacement at the extensometers, and data loggers to record the data at frequent intervals (*e.g.* 15 minutes).

   Piezometer construction and instrumentation was completed in mid-November 2002, at which time collection of piezometric data commenced. Dual-extensometer construction and instrumentation was completed in mid-July 2003, at which time collection of aquifer-system deformation data commenced.

   In addition, nearby wells owned by CIM and the cities of Chino and Chino Hills have been equipped with pressure transducers and data loggers to record (1) water-level data and (2) the specific timing of pumping cycles at production wells. The IMP also called for Watermaster, with the assistance of the well owners, to conduct controlled aquifer stress tests (pumping tests) while monitoring water levels and groundwater production at nearby monitoring wells and production wells, as well as aquifer-system compaction and/or expansion at the dual-extensometer. These tests were performed in Fall 2003, Spring 2004, and Fall 2004.

   The data collected from this monitoring effort are being used to: (1) characterize and quantify the current state of aquifer-system deformation (*i.e.* elastic vs. inelastic), (2) estimate aquifer-system parameters, such as the conductive and storage parameters of the aquifer and aquitard sediments, (3) reveal the existence of groundwater barrier(s) within the aquifer sediments, and (4) use all the above data as input to predictive computer models of compaction, subsidence, and groundwater flow to support the development of a long-term management plan.

6. *Presented interim results of IMP implementation at various professional conferences*. The preliminary results of the IMP (see Section 5.3 below) were presented by Wildermuth Environmental staff in behalf of Watermaster at three professional conferences in 2004: Inland Geological Society in Riverside CA, Groundwater Resource Association of California in Rohnert Park CA, and the American Water Resources Association in Orlando FL.

5.3 Results of Ground-Level Monitoring Program

5.3.1 Benchmark Surveys

In late April 2004, Associated Engineers (AE) performed the annual survey event across the entire network of benchmark monuments, including the measurements of horizontal displacements at the Ayala Park Array of monuments. The results of the April 2004 ground-level surveys were presented to the MZ-1 Technical Committee at its July 21, 2004 meeting. Also at this meeting, the project manager from AE, Jim Elliot, made a presentation to describe survey methodologies, accuracy, results, and challenges.

Figure 5-4 displays the vertical displacement at monuments that occurred from April 2003 to April 2004. Comparing monument elevations over the April to April time period should reveal the inelastic component of compaction, if any that may be occurring in the region. The assumption here is that in April 2004 water levels in the region have recovered to the April 2003 levels, thus the measured vertical displacement does not include the elastic component of aquifer system deformation. Water levels measured as part of the IMP (in the vicinity of Ayala Park) support this assumption. Examination of Figure 5-4 shows that the monuments near Ayala Park experienced little to no subsidence over this time period. However, the monuments located in the northern portions of the surveyed area showed small but measurable subsidence of the land surface (on average about 0.04 feet). Maximum subsidence of about 0.08 feet was recorded at monuments located along Philadelphia Street between Pipeline and Ramona Avenues. Water level data has not yet been measured, collected, or analyzed as part of the IMP in these northern portions of the surveyed area that seemingly are experiencing inelastic subsidence.

The color-coded background in Figure 5-4 represents the subsidence that occurred in the area over the October 1993 to December 1995 period as measured by InSAR. The subsidence shown by this InSAR data has been interpreted as primarily permanent subsidence caused by inelastic aquifer-system compaction. If so, the survey data in Figure 5-4 are indicating that the distribution of inelastic compaction in 2003-04 is significantly different compared to the early 1990s. In particular, maximum subsidence of about 1 foot in 1993-95 was measured in the vicinity of Ayala Park by InSAR, whereas in 2003-04 the survey data are indicating minimal subsidence, if any, in this same area.

Figures 5-5 and 5-6 display the vertical and horizontal displacement at monuments of the Ayala Park Array that occurred from April 2003 to November 2003 and November 2003 to April 2004, respectively. The determination of horizontal displacement of monuments was accomplished through the processing of distance and angle measurements between adjacent monuments, and is based on the assumption that the southeastern monument was stable over the period of measurement.

The methods used to measure the horizontal displacement of monuments at the Ayala Park Array are currently being refined by AE. But preliminary conclusions can be derived from these Figures:

- significant horizontal displacement of the ground surface over the course of the pumping and recovery seasons in the vicinity of the historic fissure zone
- the elastic nature of the land surface displacement over the course of the pumping and recovery seasons
- the apparent presence of a groundwater barrier within the deep aquifer-system (see Section 5.3.4 below).

5.3.2 Interferometer Synthetic Aperture Radar (InSAR)

In 2004, Vexcel Corporation of Boulder, Colorado – a company that specializes in remote sensing and radar technologies – conducted a "proof of concept" study of historical SAR data that was acquired over the MZ-1 area. The objective of this study was to generate cumulative displacement maps over relatively short time steps (months).

In this "proof of concept" study, four SAR images acquired from April 1993 to November 1993 were processed to create three interferograms:

- April 1993 – September 1993
- September 1993 – October 1993
- October 1993 – November 1993

These three interferograms were processed to create three cumulative displacement maps:

- April–September 1993 (Figure 5-7)
- April–October 1993 (Figure 5-8)
- April–November 1993 (Figure 5-9)

The major features to note in these cumulative displacement maps are:

1. The north-south trending trough of subsidence that extends northwest of the Ayala Park Extensometer, and depicts maximum subsidence of about 2.4 inches during the April–November 1993 period (Figure 5-9) in the vicinity of the intersection of Central Avenue and Schaefer Avenue. This pattern and magnitude of subsidence are consistent with past InSAR and ground-level survey analyses.
2. The coincidence of the north-south trending fissure zone (which was active during this general time period) and the sharp eastern edge of the trough of subsidence. This locational coincidence suggests a cause-and-effect relationship that may also be related to an underlying groundwater barrier within the deep aquifer-system sediments (see Section 5.3.4 below).
3. The slight differences between maps that depict the relatively small displacements that occurred from September to November can be recognized through this analysis. The recognition of these displacements at relatively short time steps (months) demonstrates the capability of this method to further resolve the time history of subsidence over the period of available SAR data (1992-2003).
4. The increasing number of "no data" cells as the maps progress through time. This is a result of incoherent cells in an interferogram in areas that were previously coherent in all prior interferograms. This phenomenon will progressively add "no data" cells to the cumulative displacement maps. However, in the opinion of Vexcel, the final map will still provide useful and spatially continuous data in areas typical provide coherence data (*e.g.* urban areas).
5. The large area of "no data" in the agricultural areas of Chino Basin. The analysis did not improve the coherence of the data in these agricultural areas, as was hoped.

The MZ-1 Technical Group deemed the study successful, and approved follow-up study by Vexcel to perform a comprehensive analysis of all historical SAR data (1992-2000) to characterize the historical seasonal and long-term displacements of the land surface in MZ-1.

5.3.3 Aquifer-System Monitoring

The extremely detailed monitoring of the aquifer-system (see Section 5.2) and subsequent data analyses has led to a number of key preliminary conclusions:

1. There appears to be two distinct aquifer systems in this area – a shallow, un-confined to semi-confined system from about 100-300 ft-bgs and a deep, confined system from about 400-1,200 ft-bgs.
2. Under current conditions of aquifer utilization in MZ-1, the aquifer-system deformation appears to be mainly elastic, with up to 0.13 feet of land subsidence and 0.13 feet of rebound during the pumping and recovery seasons, respectively. Minor amounts (~0.02 feet) of permanent compaction and associated land subsidence occurred over this same period.
3. The relationships between aquifer-system stress (water level changes) and aquifer-system strain (vertical deformation of the sediment matrix) have been established by comparing piezometer data versus extensometer data. These relationships indicate the nature of the aquifer-system deformation (*i.e.* elastic vs. inelastic) and provide estimates of aquifer-system parameters for later use in aquifer-system models.
4. A deep aquifer-system pumping test in September 2004 appears to have transitioned the system from elastic to inelastic deformation. This provides a "threshold" water level that when exceeded will result in inelastic compaction, but only under the same conditions imposed by the pumping test (*i.e.* same pumping wells, rates, and durations). The data derived from this test will assist in the creation of management tools for MZ-1 (*e.g.* groundwater flow and subsidence models).
5. Multiple lines of evidence suggest that a previously unknown groundwater barrier exists within the deep aquifer-system in the same location as the historic fissure zone (see Section 5.3.4 below).

A technical discussion related to the above preliminary conclusions follows:

Figure 5-10 shows the changes in thickness of the aquifer systems as recorded by the deep and shallow extensometers, completed at depths of 1,400 and 550 ft-bgs. It also shows the water-level fluctuations in two piezometers, PA-10 and PA-7, which are representative of the shallow aquifer system and the upper part of the deep aquifer system, respectively.

During periods of water-level decline in PA-7, both extensometers are recording compaction of the sediments. During periods of recovery in PA-7, both extensometers are generally recording elastic expansion. Note that for the data available, almost all of the compaction during the drawdown season is recovered as expansion during the recovery season.

During the late-Spring (2004) pumping of the shallow aquifer system, while the deep system was shut down, the shallow extensometer recorded compression while the deep extensometer recorded an overall expansion. Subtracting the shallow record from the deep confirms that the deeper sediments continued a smooth expansion in response to continuing recovery of heads in the deeper parts of the aquifer system, as represented by the data from PA-7, which is screened from 438-448 ft-bgs. The shallow compression is seen to correlate closely with the drawdown recorded by PA-10, screened from 213-233 ft-bgs.

These observations clearly demonstrate the existence of the deep and shallow aquifer-systems in this region of MZ-1. Nearby pumping at wells that are screened in either the deep or shallow aquifer-systems result in distinct hydraulic and mechanical responses that are recorded at the Ayala Park piezometers and extensometers. These observations also demonstrate the importance, for analytical purposes, of independently stressing the deep and shallow systems by pumping from only one at a time, so that the observed deformation can be more accurately attributed to production from a specific depth interval.

The relationships between water levels and aquifer-system deformation are further depicted in the stress-strain diagrams shown in Figure 5-11. In this diagram, increasing depth to water (drawdown due to pumping) is the measure of decreasing pore pressure and increasing effective intergranular stress. Increasing compression of the sediments is the resulting strain. When pumping diminishes or ceases, pore pressures recover, intergranular stress is reduced, and the aquifer systems expand.

Figure 5-11 shows that the full thickness of sediments responds linearly to extended intervals of continuous drawdown or recovery, but with a large seasonal hysteresis attributable to the time lag involved in the delayed vertical propagation of pore pressure changes from the pumped aquifers into adjacent, poorly permeable aquitards. The parallel slopes of the compression and expansion trends represent the overall elasticity of the sedimentary section. Its inverse is the skeletal storativity, in hydrologic terminology.

The parallelism of the seasonal drawdown and recovery stress-strain slopes in Figure 5-11 indicates that seasonal drawdown to 250 ft-bgs at this site is producing essentially elastic, recoverable deformation. However, the slope of the drawdown curve in 2004 begins to deviate from its elastic trend when the seasonal drawdown exceeds 250 ft-bgs indicating a transition to inelastic compaction within draining aquitard interbeds. Minor amounts of nonrecovered compaction (~ 0.02 ft) are indicated by the offset of the recovery curve in 2004 to the right (direction of compression).

Brief intervals of recovery during the drawdown season, and of drawdown during the recovery season, produce steeply sloping, more-or-less tight hysteresis loops. Their much steeper slope represents the (inverse) aggregate compressibility of the permeable pumped aquifers. The longer intervals of recovery and drawdown generate the more open hysteresis loops, as the delayed responses of immediately adjacent portions of the aquitards have time to influence the extensometers.

5.3.4 Discovery of Groundwater Barrier

Controlled aquifer-system stress (pumping) tests in October 2003 and April 2004 provided piezometric response data that revealed a potential groundwater barrier within the sediments below about 300 ft-bgs and aligned with the historic fissure zone. Figure 5-12 is a map that shows the locations of a pumping well perforated in the deep aquifer system (CH-19, 340-1,000 ft-bgs) and other surrounding wells that also are perforated exclusively in the deep system. Figure 5-13 shows the water level responses in these wells during various pumping cycles at CH-19. The groundwater barrier is evidenced by a lack of water level response in CH-18 (east of the fissure zone) due to pumping at CH-19 (west of the fissure zone). Image-well analysis of pumping-test responses also indicates that this barrier approximately coincides with the location of the historic zone of ground fissuring.

Ground level survey data corroborates the water level data – also indicating the existence of the barrier and its coincident location with the fissure zone. Figure 5-5 shows that during the pumping season of 2003 (April to November) vertical displacement of the land surface (*i.e.* subsidence) was generally greater on the west side of the fissure zone where water level drawdown was greatest. Figure 5-6 shows that during the recovery season of 2003-04 (November to April) vertical displacement of the land surface (*i.e.* rebound) was again greater on the west side of the fissure zone where water level recovery was greatest.

In other words, the groundwater barrier in the deep aquifer-system is aligned with the fissure zone and causes greater water level fluctuations on the west side of the barrier where the pumping is concentrated. These greater water level fluctuations on the west side of the barrier, in turn, cause greater deformation of the aquifer-system matrix which, in turn, causes greater vertical land surface deformation on the west side of the barrier. In addition, the pattern of horizontal displacement of benchmarks over the pumping and recovery seasons, as shown in Figures 5-5 and 5-6, likely reflects, in part, the differential compaction of the aquifer system across the fissure zone.

Similarly, the InSAR data in Figures 5-2 and 5-4 also corroborate the existence of the groundwater barrier by showing maximum subsidence west of the barrier and virtually no subsidence east of the barrier.

This spatial coincidence of the groundwater barrier and the historic fissure zone suggests a cause-and-effect relationship: the barrier causes differential water level declines, which causes differential aquifer-system compaction and a steep gradient of subsidence across the barrier, which can and likely has caused ground fissuring directly above the barrier.

5.4 On-Going and Recommended Activities

5.4.1 InSAR

The MZ-1 Technical Group deemed the "proof-of-concept" InSAR study successful (see Section 5.3.2 above), and approved a follow-up study by Vexcel to perform a comprehensive analysis of all historical SAR data (1992-2000) to characterize the historical seasonal and long-term displacements of the land surface in MZ-1. The comprehensive analysis should be completed by the first quarter of 2005. Vexcel will present the results at the following MZ-1 Technical Committee meeting. The data will be used in calibration of future groundwater flow and subsidence models (see Section 5.4.4 below).

5.4.2 Ground Level Survey Lines

The next comprehensive survey event is scheduled for April 2005. These data will be compared to the April 2004 survey event to identify areas where permanent land subsidence, if any, is occurring in MZ-1. These annual surveys are scheduled to continue for the duration of the IMP, and will likely be recommended by the MZ-1 Technical Committee to continue as part of the long-term management plan.

Surveying of the Ayala Park Array of monuments – an exercise used to measure both vertical and horizontal displacements across the historic fissure – will also occur during the April 2005 comprehensive survey event. These data can then be compared to the previous survey data (April and November 2004), in an effort to monitor fissure movement, if any, that may be associated with elastic and/or inelastic aquifer-system deformation. The MZ-1 Technical Committee will review these data and the scope of the "fissure monitoring" efforts, and recommend changes to the scope if warranted. Anecdotal field evidence suggests that the fissure monitoring efforts should be expanded north of Edison Avenue to include the surveying of monuments along Schaefer Avenue.

It is desirable that the calibration period for future groundwater flow and subsidence modeling (see Section 5.4.4 below) begins before significant drawdown in MZ-1 (~1940). Currently available subsidence data in this region begins in 1987. If subsidence data exists prior to 1987, then it needs to be collected and linked to the post-1987 survey data if it is to be used in model calibration. Associated Engineers is currently preparing a cost estimate to conduct this data collection and processing effort.

5.4.3 Aquifer-System Monitoring

The aquifer system monitoring efforts will continue for the duration of the IMP, and will likely be recommended by the MZ-1 Technical Committee to continue, albeit at a reduced scope, as part of the long-term management plan.

The cities of Chino and Chino Hills are contemplating a pilot ASR (aquifer storage and recovery) test at inactive production wells in the region to evaluate ASR as a method to recharge the aquifer-system and manage drawdown and associated subsidence. Watermaster has committed to fund one ASR pilot test as part of the IMP, and monitor the aquifer-system responses to such a test. The cities would be responsible for conducting the test at the production well.

One of the key discoveries of the IMP has been the groundwater barrier located beneath the historic fissure zone. However, the northern and southern extent of this barrier is unknown. The MZ-1 Technical Committee is contemplating the expansion of the aquifer-system monitoring network to the north and south of its current extent to better characterize the location and effectiveness of the barrier. Further aquifer-system testing (*i.e.* pumping test) may be necessary as part of this effort.

5.4.4 Aquifer-System Modeling

The objectives of aquifer-system modeling in MZ-1 are:

- To evaluate fluid withdrawal as the mechanism of historical land subsidence (forensic tool)
- To predict the effects of potential basin management practices on groundwater levels and land subsidence (forecasting tool)

In other words, if a model can be constructed that simulates past drawdown and associated land subsidence, then the model represents an additional line of evidence that fluid withdrawal was the mechanism of historical land subsidence. In addition, the model can be used to predict future drawdown and associated land subsidence that would result from potential basin management practices.

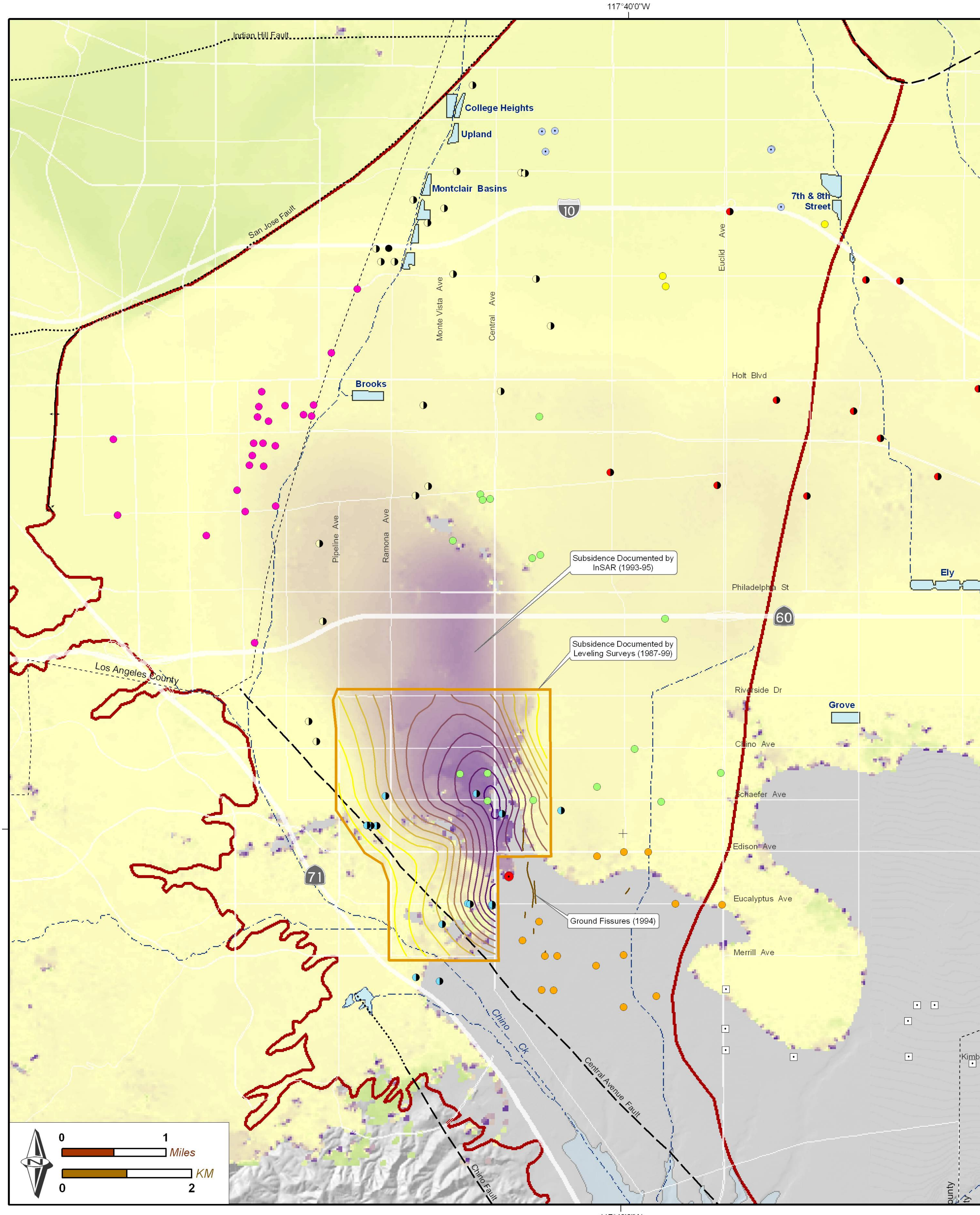
Three distinct modeling efforts will take place in sequence:

1. *Inverse analytical modeling.* This type of modeling will use groundwater level and production data collected as part of the aquifer-system stress testing (pumping tests) that were conducted in 2003 and 2004. The objectives are to determine the hydraulic and mechanical parameters of the aquifer-system and reveal XY-anisotropy. The results will be used in subsequent numerical modeling efforts.
2. *One-dimensional compaction modeling.* This type of modeling will use groundwater level and aquifer-system deformation data collected at the Ayala Park Extensometer facility. The objective is to determine the aquitard properties in the vicinity of Ayala Park. Aerial extrapolation of aquitard properties will be based on geology and InSAR data, and the results will be used in the three-dimensional numerical modeling efforts (below).
3. *Three-dimensional groundwater flow and subsidence modeling.* This type of modeling will use groundwater level and production data at all wells in the area and historical land subsidence data from ground level surveys and InSAR. Again, this model will serve as a forensic and forecasting tool for MZ-1.

5.4.5 Development of Long-Term Management Plan

Recall that the objective of the long-term management plan is to minimize or abate permanent land subsidence and ground fissuring in MZ-1. The modeling efforts described above will be key to the development and evaluation of this plan.

The OBMP implementation plan called for the development of the long-term management plan for MZ-1 by June 2005. Because the modeling efforts will not be completed by June 2005, the long-term management plan will not be completed by June 2005. The Special Referee has been notified, and has indicated that the IMP progress and current activities are sufficient to warrant a delay in the development of the long-term management plan for MZ-1. A workshop will be scheduled for the second quarter of 2005 to update the Special Referee on IMP progress.



Subsidence Features

- -2.2
- -2.1 - -2.0
- -1.9 - -1.6
- -1.5 - -1.4
- -1.3 - -1.2
- -1.1 - -1.0
- -0.9 - -0.8
- -0.7 - -0.6
- -0.5 - -0.4
- -0.3 - 0.0

Relative Change in Land Surface Altitude as Measured by Leveling Surveys 1987 - 1999 (feet)

+ 1.0 / 0.0 / - 1.0

Relative Change in Land Surface Altitude as Measured by InSAR Oct 1993 - Dec 1995 (feet)

Wells in MZ-1 by Owner

- Ontario
- Pomona
- SAWC
- Upland
- SCWC
- CIM
- Chino Hills
- Chino
- MVWD

Other Features

- Ayala Park Extensometer Facility
- Chino Basin Desalter Well (Existing)
- Management Zone 1 Boundary
- No InSAR Data

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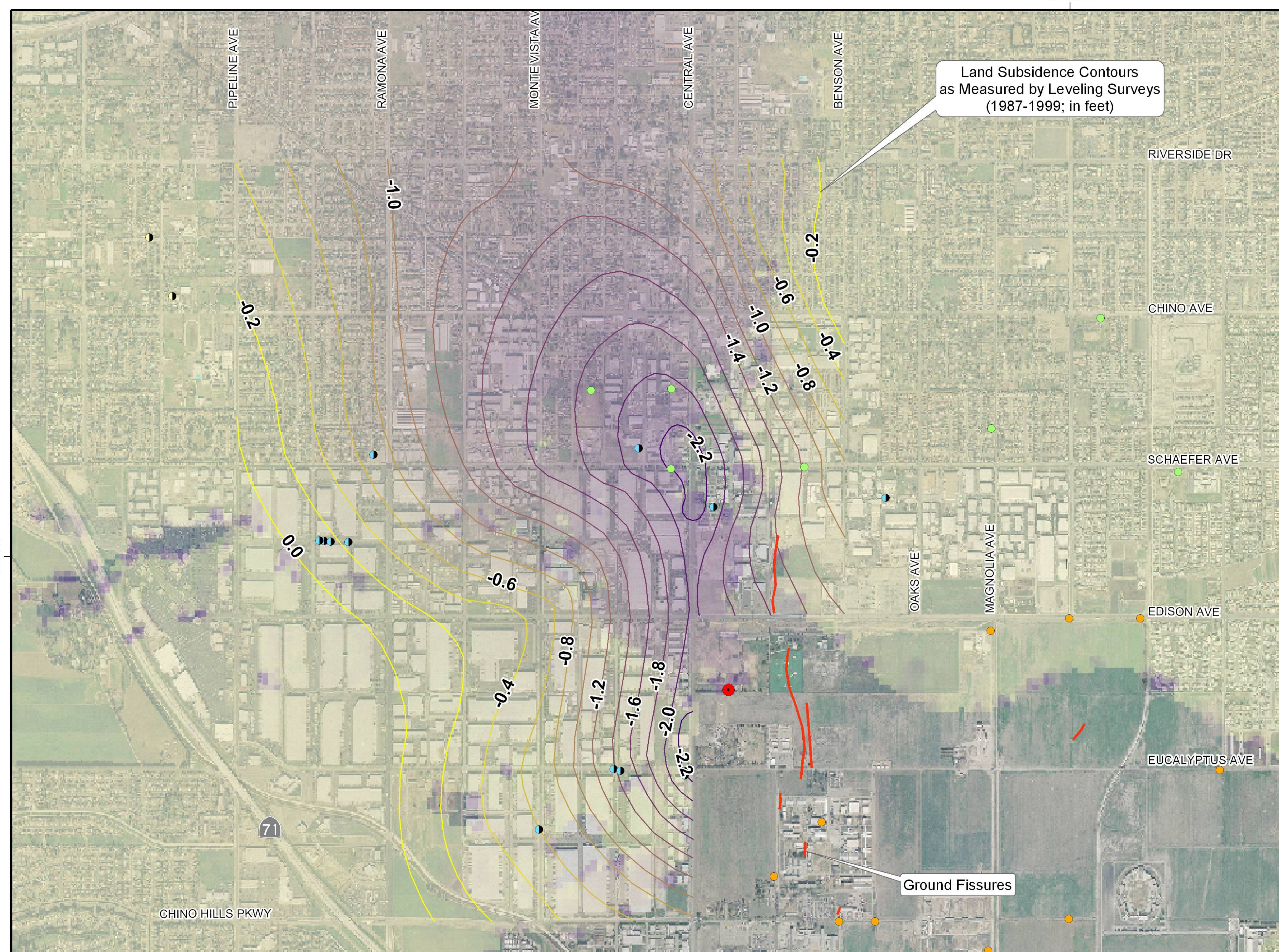
State of the Basin Report -- 2004
Ground Level Monitoring

Author: AEM
Date: 20050106
File: Figure_5-1.mxd

Land Surface Deformation in Management Zone 1
Leveling Surveys and InSAR

Figure 5-1



Subsidence Features

Ground Fissure (mapped in 1994)

Relative Change in Land Surface Altitude as Measured by InSAR Oct 1993 - Dec 1995 (feet)

+ 1.0
0.0
- 1.0

Wells in MZ-1 by Owner

- Ontario
- Pomona
- SAWC
- Upland
- SCWC
- CIM
- Chino Hills
- Chino
- MVWD

Other Features

- Ayala Park Extensometer Facility

Note: Air photo background flown in April 2004.

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0 1,000 2,000 3,000 Feet

0 500 1,000 Meters

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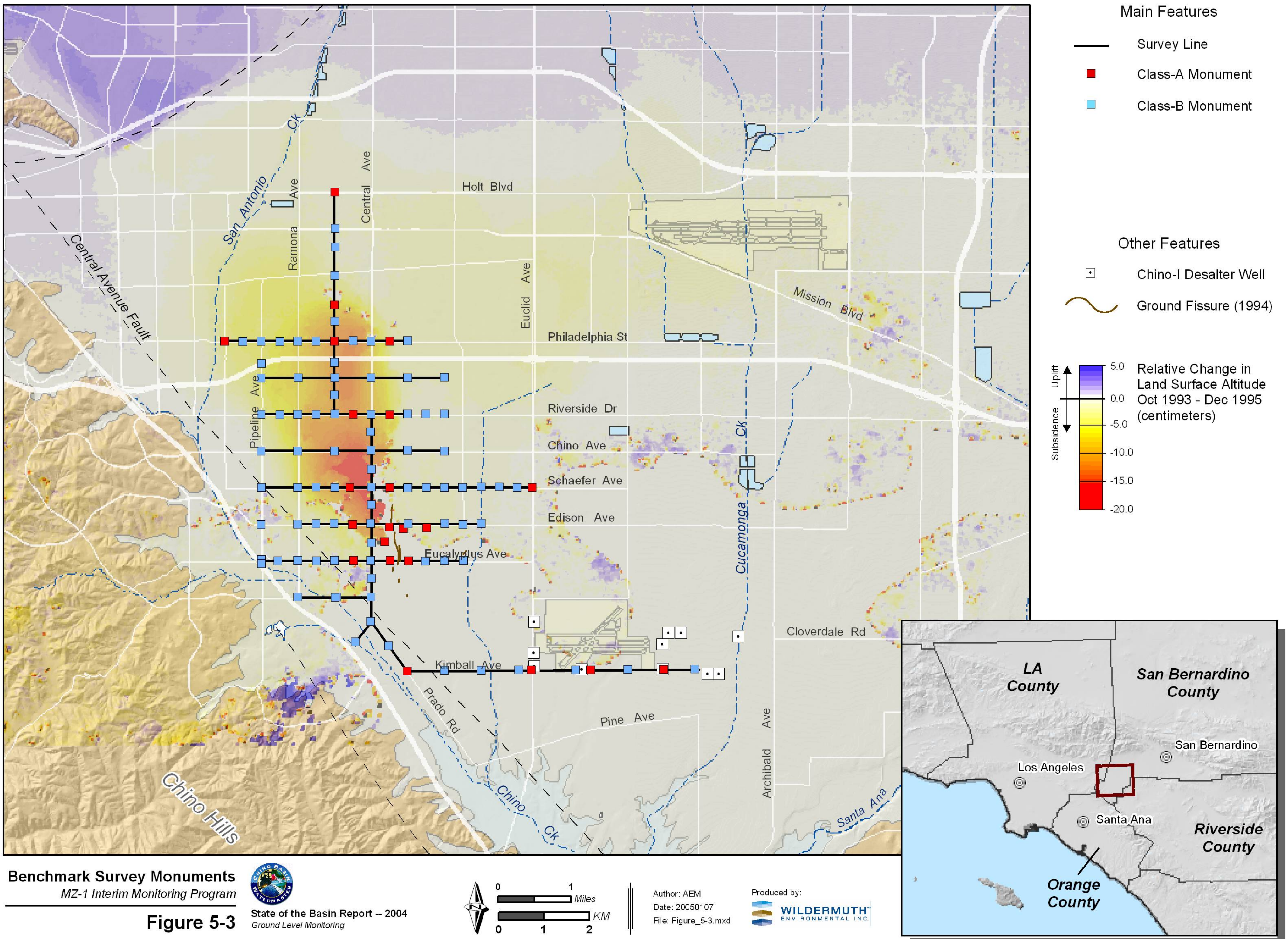
Ground Level Monitoring

Land Surface Deformation in Chino, CA

Leveling Surveys and InSAR

Figure 5-2



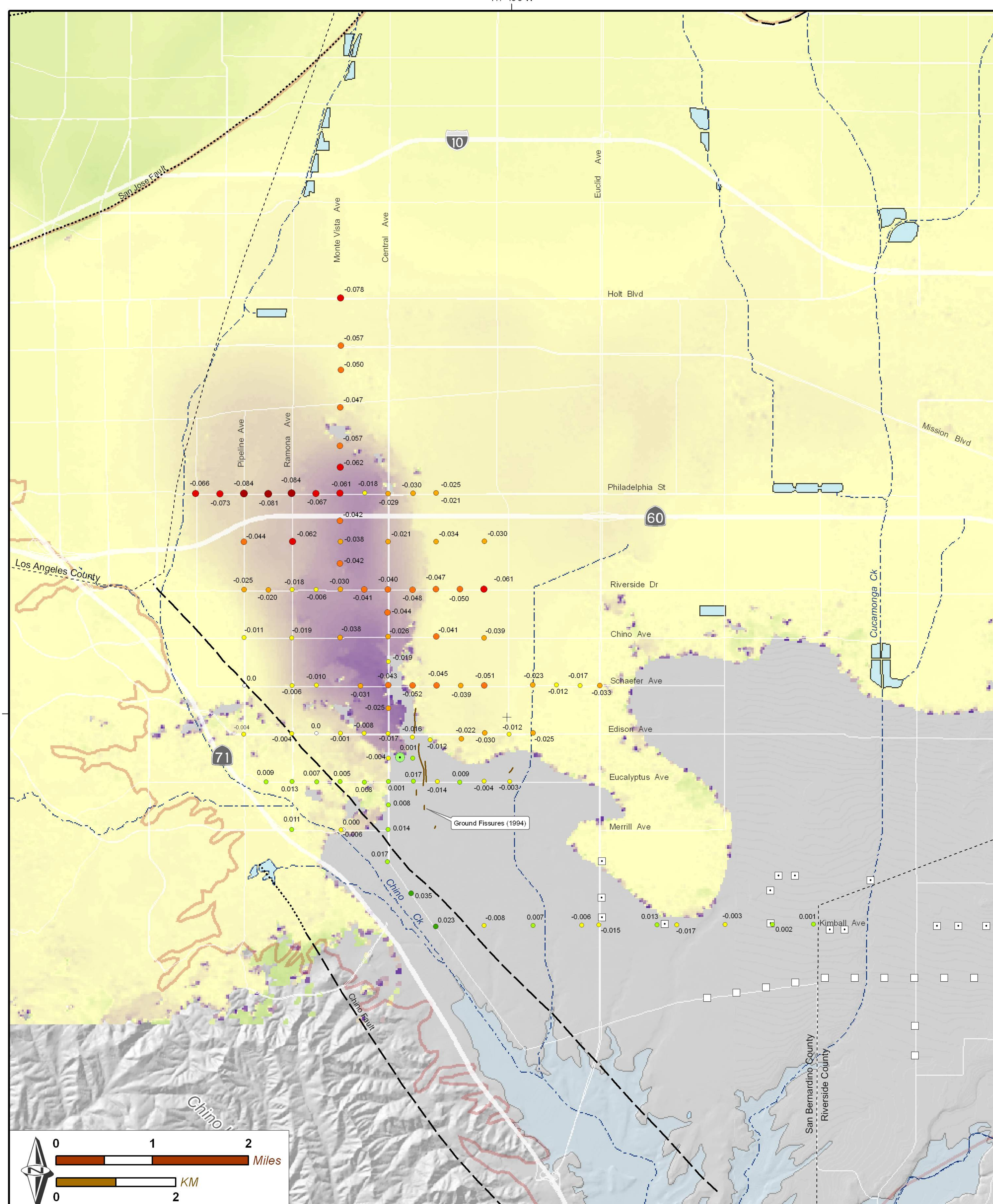
Benchmark Survey Monuments

MZ-1 Interim Monitoring Program

Figure 5-3

State of the Basin Report -- 2004

Ground Level Monitoring



Main Features

- -0.010 to -0.080
- -0.079 to -0.060
- -0.059 to -0.040
- -0.039 to -0.020
- -0.019 to -0.001
- 0.0
- 0.001 to 0.020

Relative Change in Land Surface Altitude as Measured by Leveling Surveys April 2003 - April 2004 (feet)

+ 1.0
0.0
- 1.0

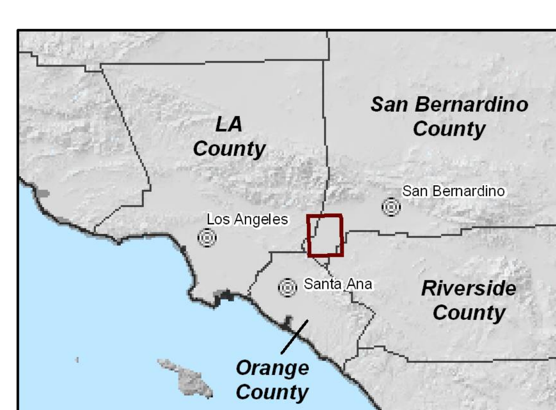
Relative Change in Land Surface Altitude as Measured by InSAR Oct 1993 - Dec 1995 (feet)

Other Features

- Ayala Park Extensometer Facility
- Chino Basin Desalter Well (Existing)
- Chino Basin Desalter Well (Planned)
- Chino Basin Hydrologic Boundary

Faults & Groundwater Divides

- Location Certain
- Location Approximate
- Location Concealed
- Location Uncertain
- Groundwater Divide



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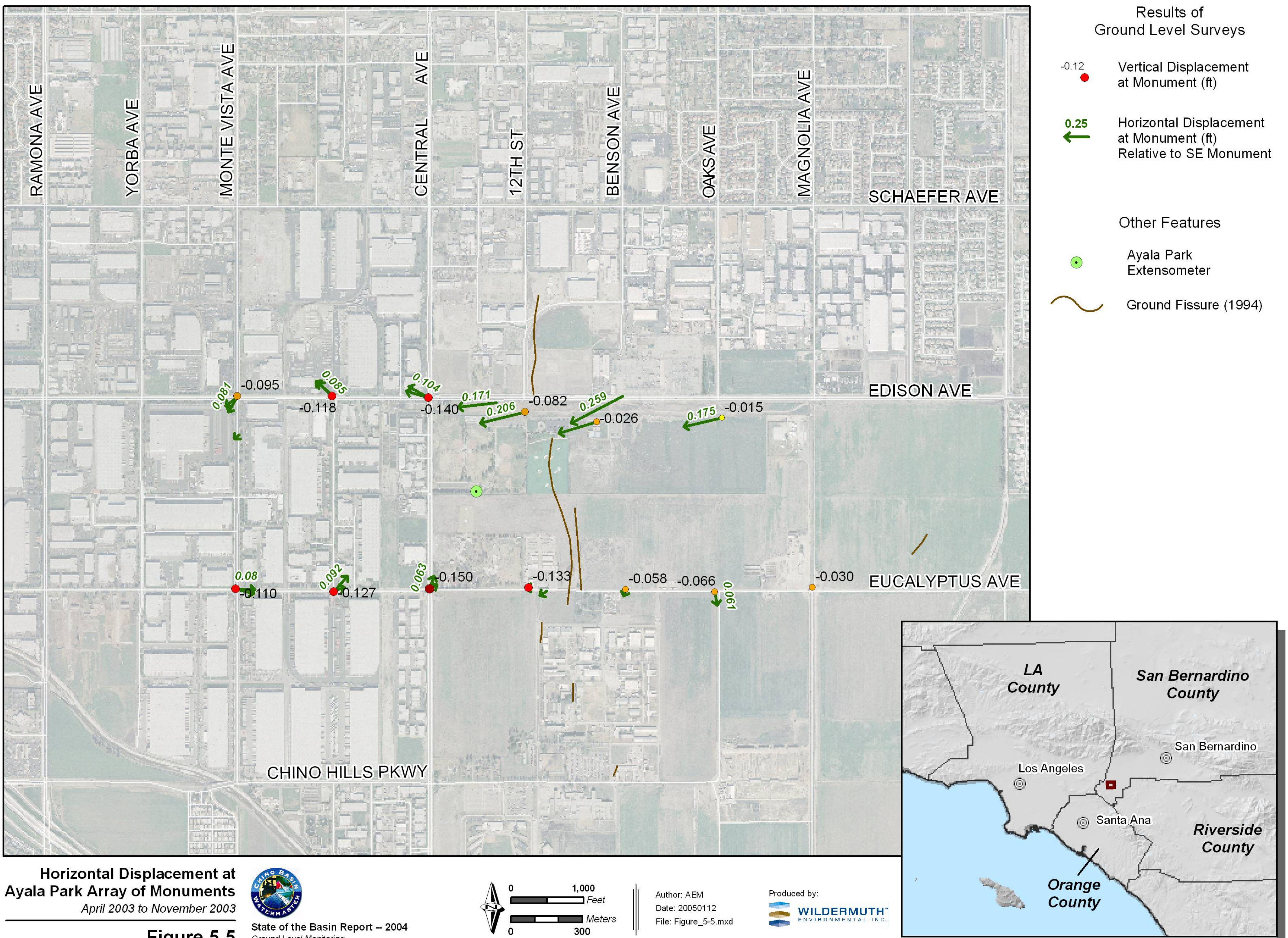
Ground Level Monitoring

Author: AEM
Date: 20050112
File: Figure_5-4.mxd

Ground Level Survey Results

April 2003 to April 2004

Figure 5-4



Horizontal Displacement at Ayala Park Array of Monuments

April 2003 to November 2003

Figure 5-5

State of the Basin Report -- 2004

Ground Level Monitoring

0 1,000 *Feet*

0 300 *Meters*

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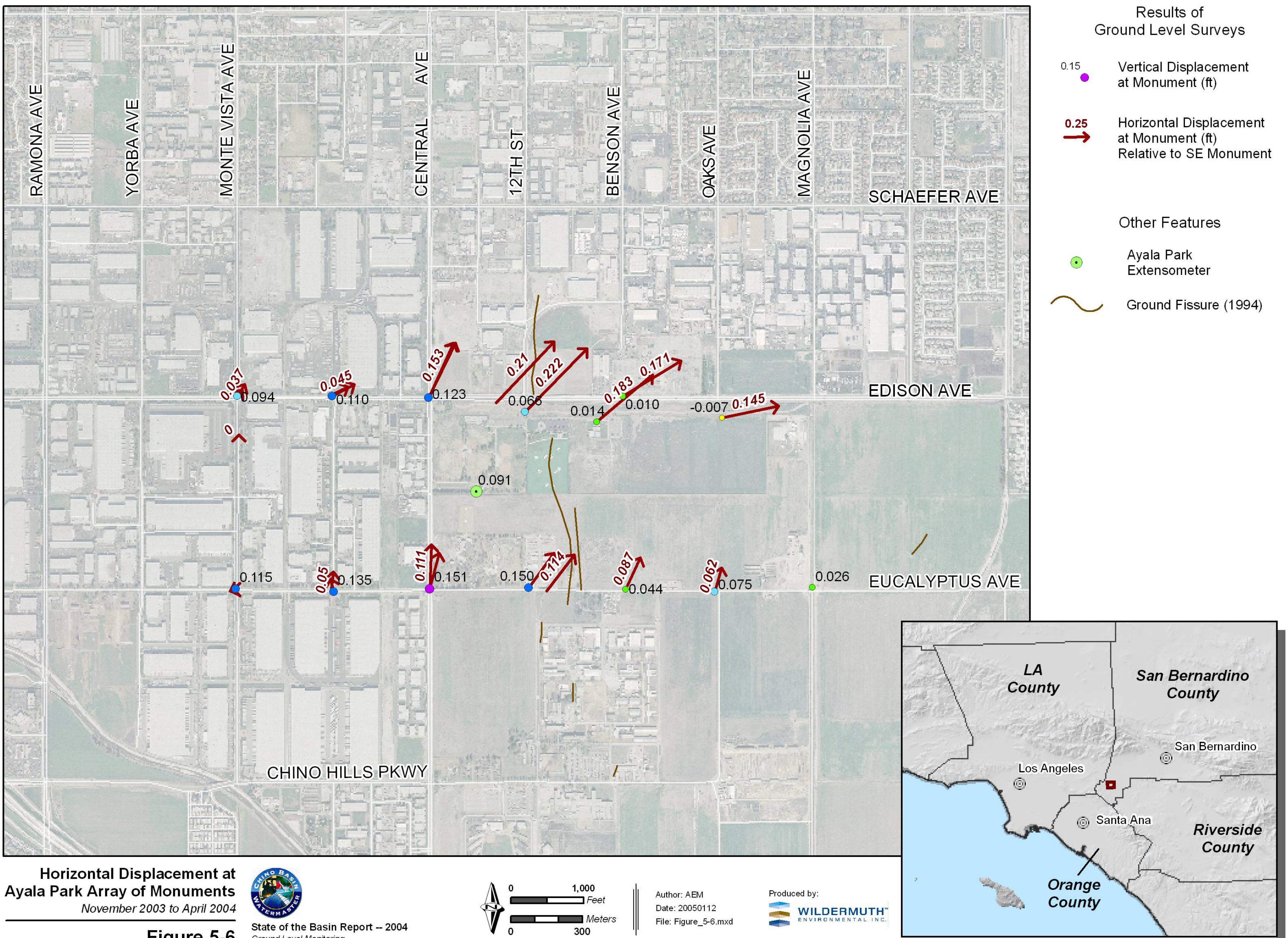

Horizontal Displacement at Ayala Park Array of Monuments

November 2003 to April 2004

Figure 5-6

State of the Basin Report -- 2004

Ground Level Monitoring

0 1,000 *Feet*

0 300 *Meters*

Author: AEM
Date: 20050112
File: Figure_5-6.mxd

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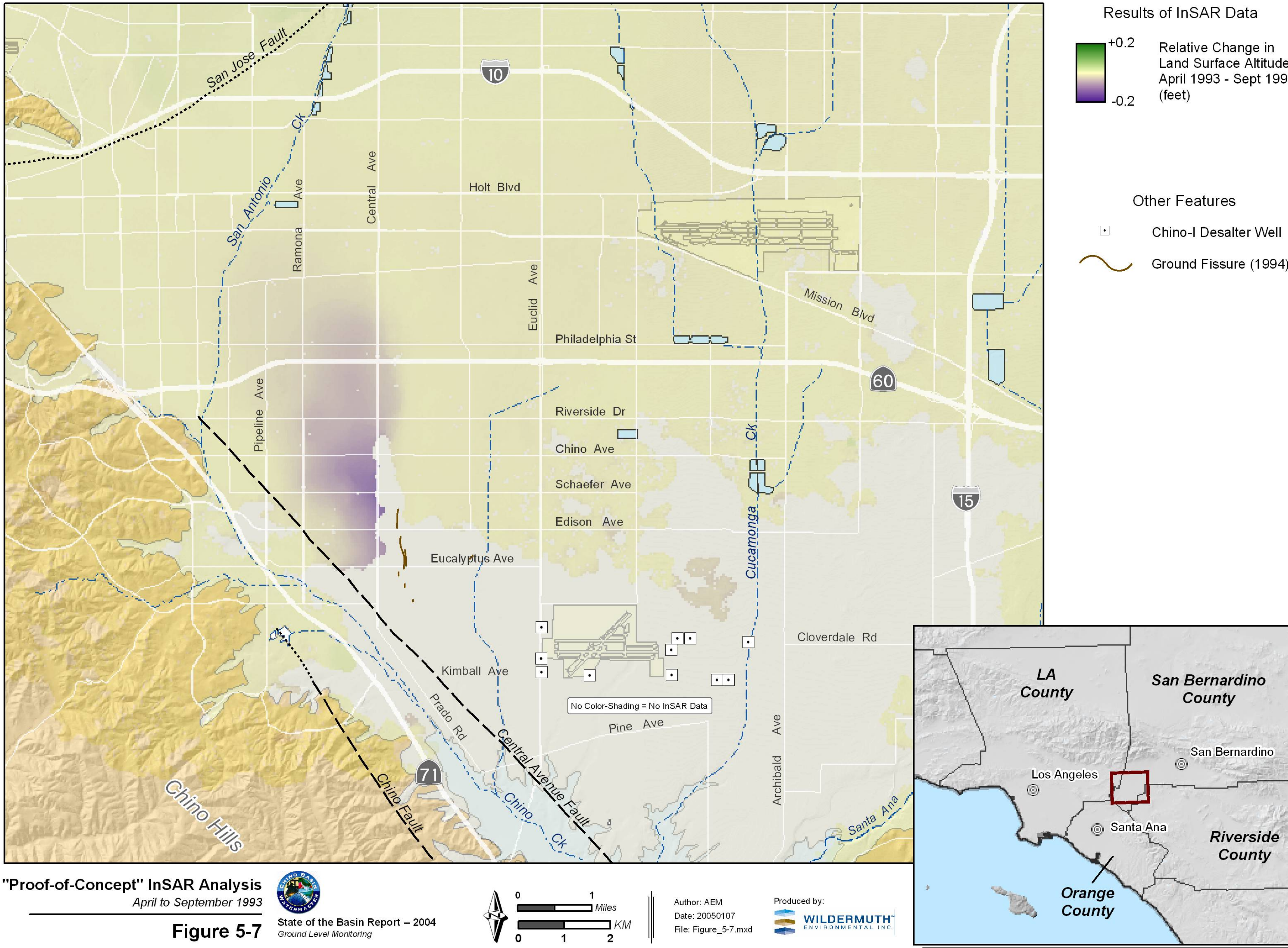

Results of InSAR Data

+0.2
-0.2
Relative Change in Land Surface Altitude April 1993 - Sept 1993 (feet)

Other Features

Chino-I Desalter Well

Ground Fissure (1994)

"Proof-of-Concept" InSAR Analysis

April to September 1993

Figure 5-7

State of the Basin Report -- 2004

Ground Level Monitoring

0 1 *Miles*

0 1 2 *KM*

Author: AEM
Date: 20050107
File: Figure_5-7.mxd

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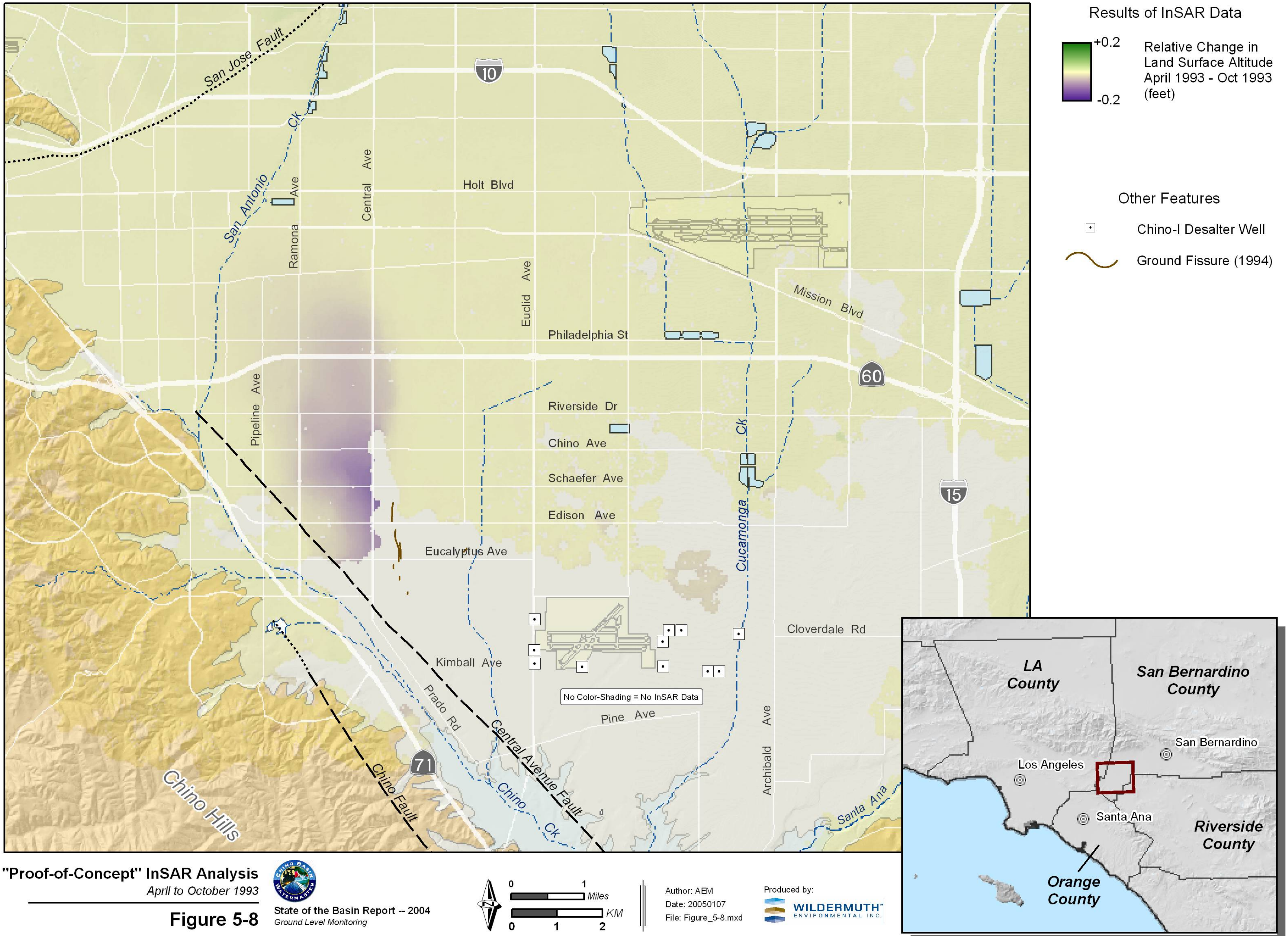

"Proof-of-Concept" InSAR Analysis
April to October 1993

Figure 5-8

State of the Basin Report -- 2004
Ground Level Monitoring

0 1 Miles
0 1 2 KM

Author: AEM
Date: 20050107
File: Figure_5-8.mxd

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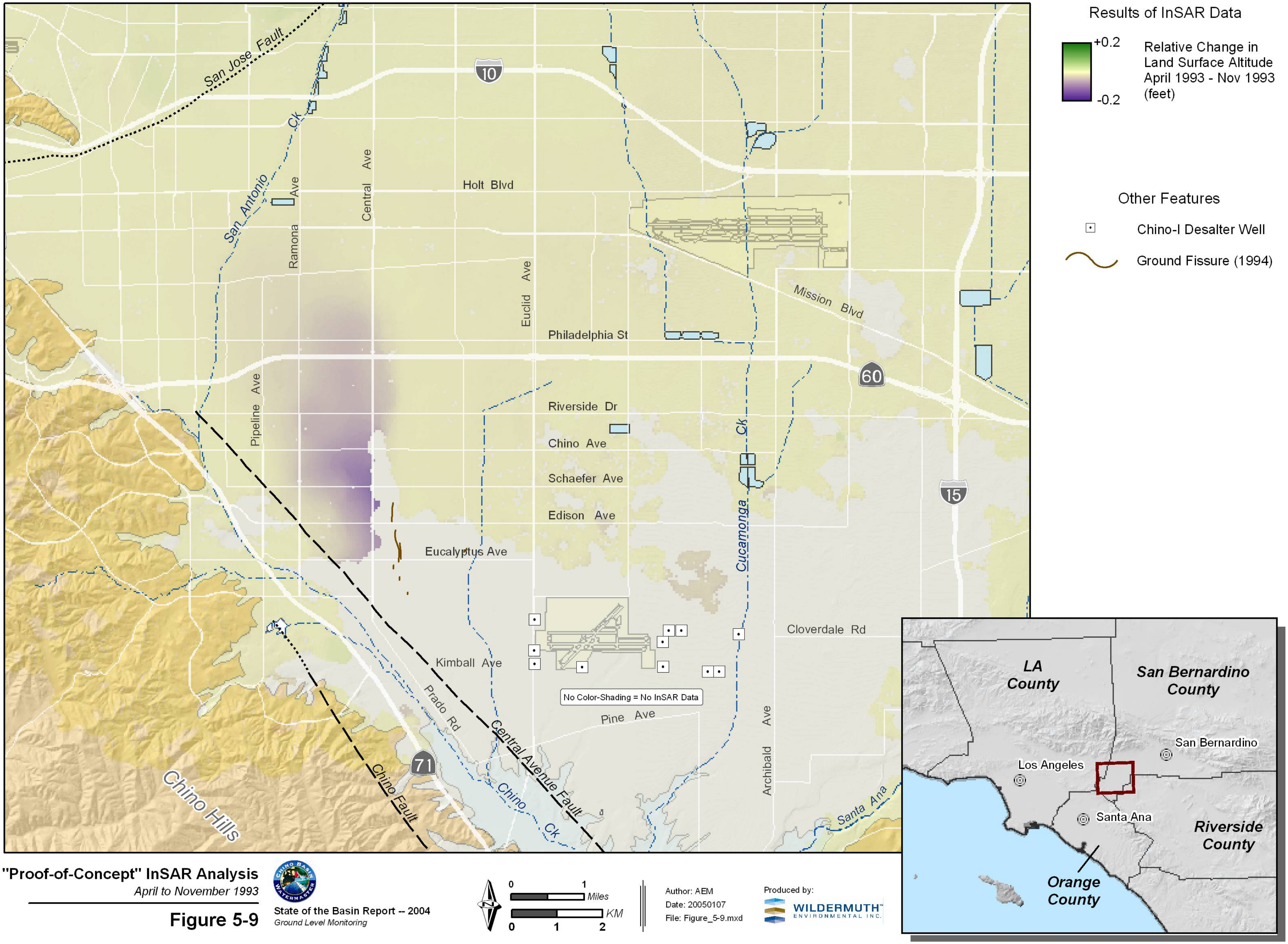

"Proof-of-Concept" InSAR Analysis

April to November 1993

Figure 5-9

State of the Basin Report -- 2004

Ground Level Monitoring

Author: AEM
Date: 20050107
File: Figure_5-9.mxd

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Figure 5-10 - Ayala Park Dual Extensometer Facility

15July-2003 to 06Dec-2004

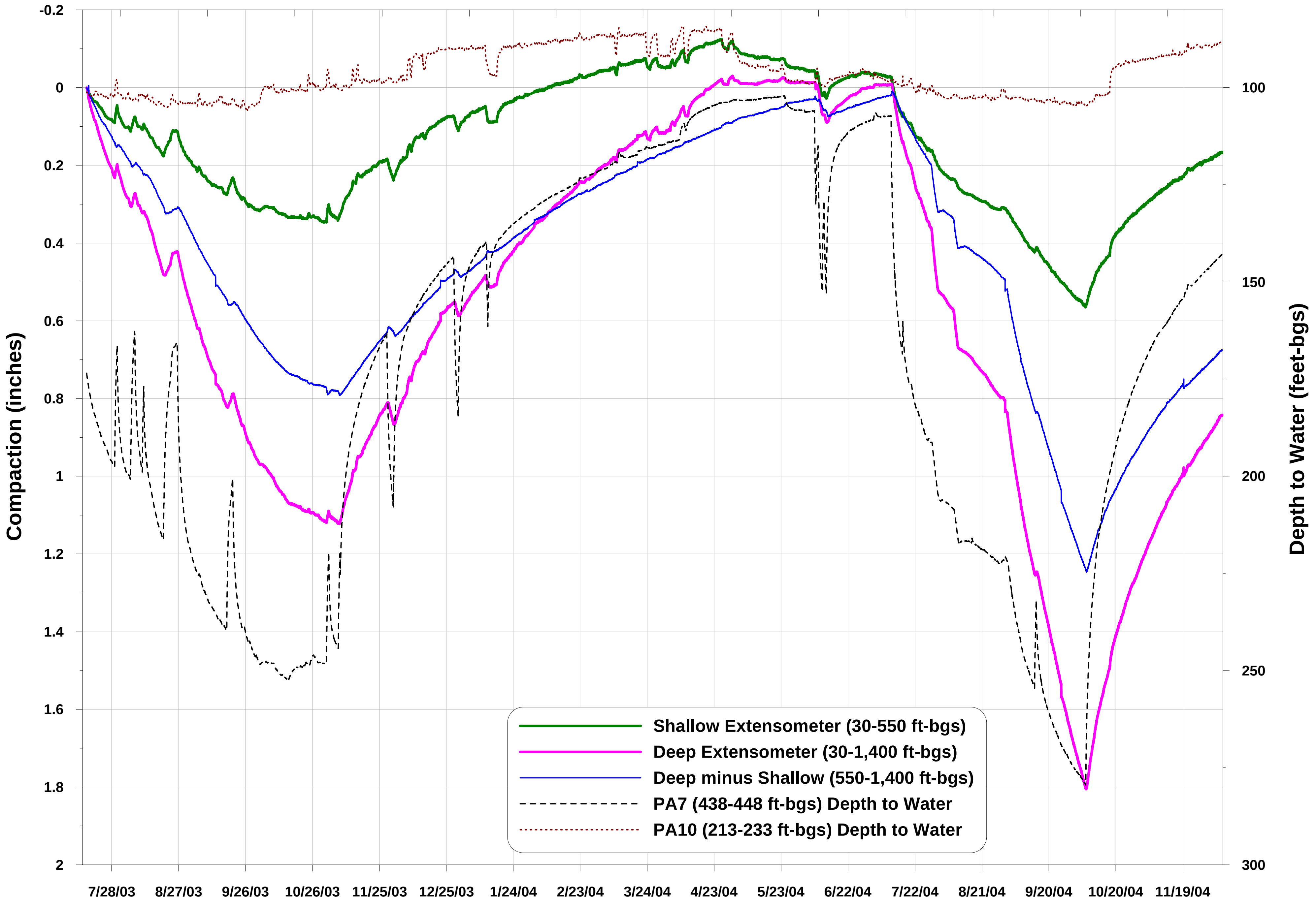
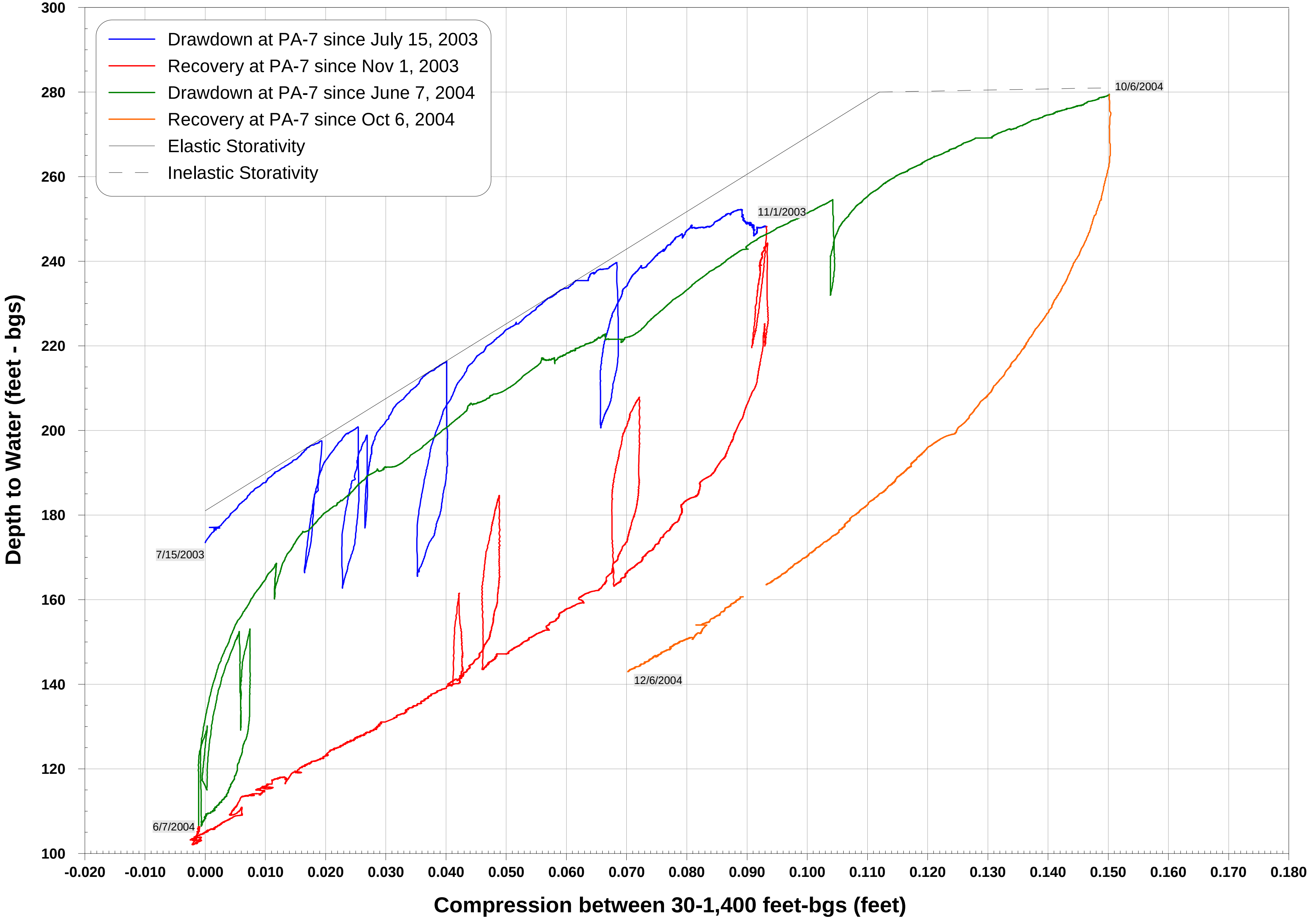
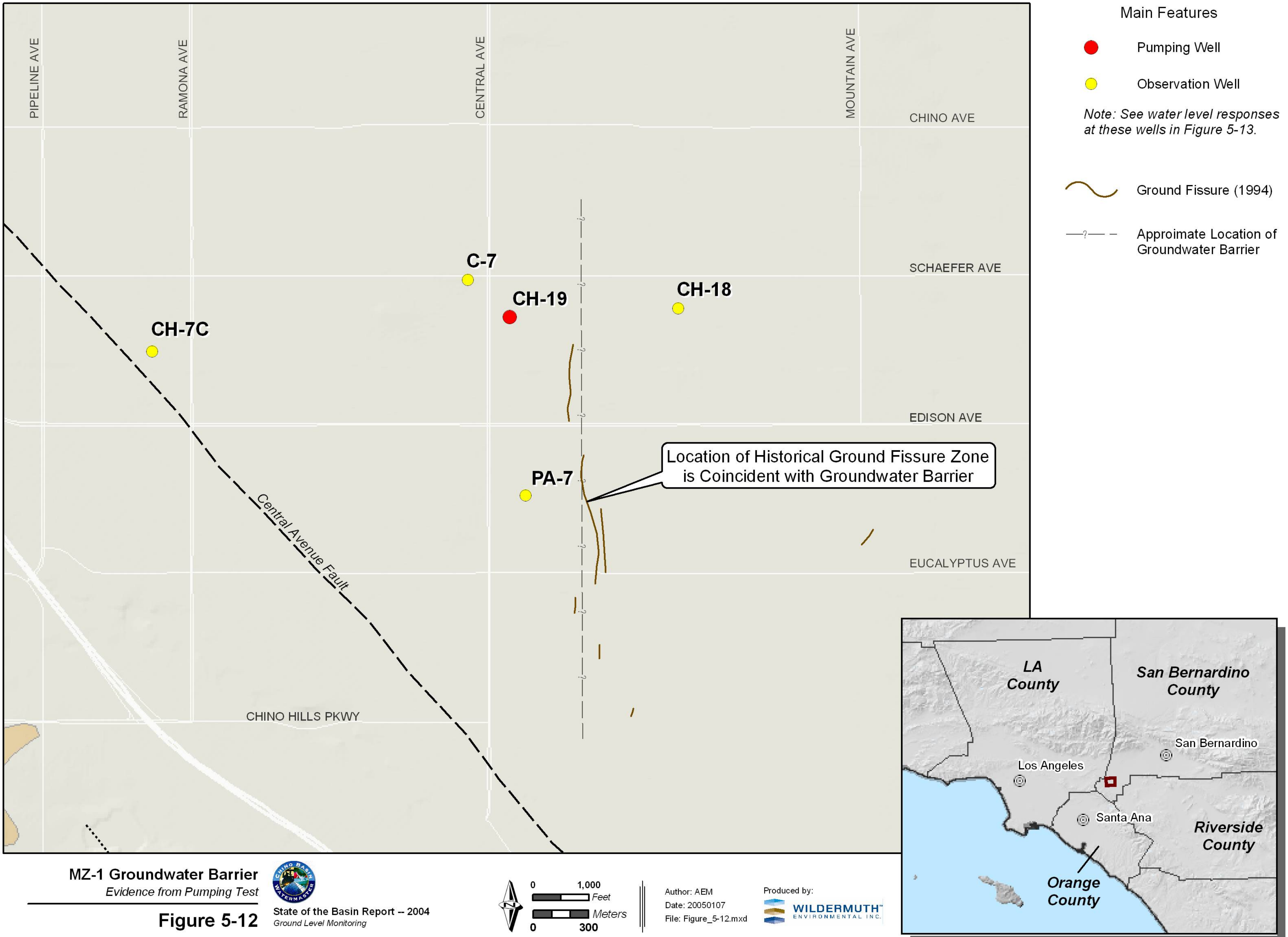


Figure 5-11 -- Stress-Strain Diagram

PA-7 vs. Deep Extensometer



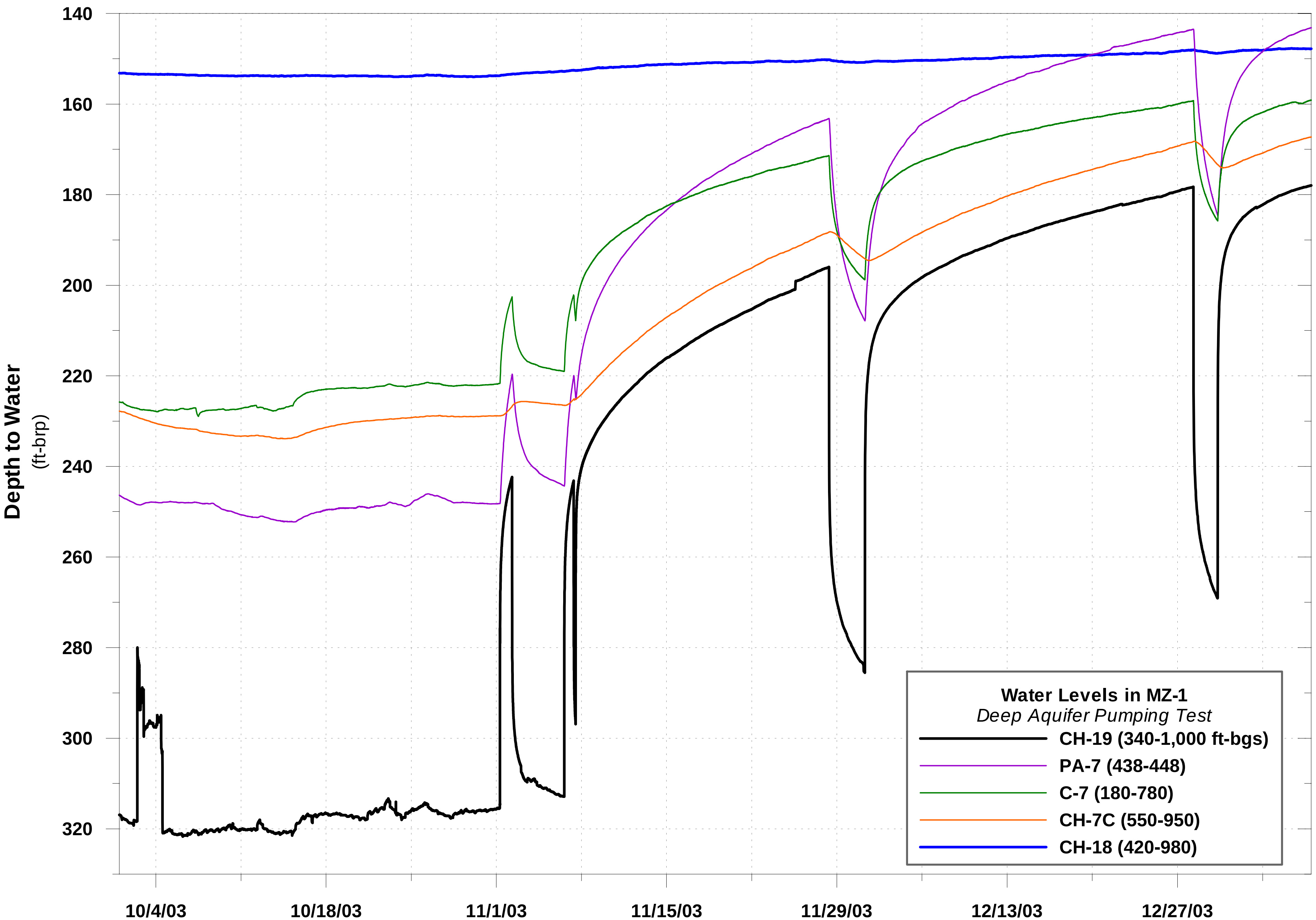


MZ-1 Groundwater Barrier
Evidence from Pumping Test

Figure 5-12

State of the Basin Report -- 2004
Ground Level Monitoring

Figure 5-13 - Water Level Responses at Nearby Wells to Pumping at CH-19



6. RECHARGE BASIN MONITORING AND FUTURE RECHARGE PROJECTIONS

Figure 6-1 shows the location of the flood retention/recharge basins in the Chino Basin. Two types of recharge monitoring occur in the Chino Basin:

- Water level and temperature measurements are obtained and used to estimate inflow, outflow, and recharge for the Montclair Basins 1 – 4, Brooks Street Basin, Turner 1 Basin and Grove Basin
- Storm water quality in the flood retention/conservation basins that have some level of conservation or operable storage and when possible, from basins without conservation or operable storage that temporarily contain storm water.

This recharge monitoring program is important to the Watermaster because of the new yield implications from new recharge. Per the OBMP Peace Agreement, storm water recharge above 5,600 acre-ft/yr is considered new recharge and new yield. TDS and nitrogen concentrations in stormwater collected in flood retention/conservation basins are very low, substantially below existing Basin Plan objectives and drinking water MCLs. New storm water recharge with low TDS and nitrogen concentrations will improve groundwater quality and offset the mitigation requirements from recycled water recharge. The water quality monitoring program includes all basins that are currently used for recharge and other basins that have been improved in the Chino Basin Facilities Improvement Program described below in Section 6.2.

6.1 Storm Water Recharge Calculations for 2000/01 through 2003/04

Chino Basin Water Conservation District (CBWCD) has installed integrated pressure transducers/data loggers in the Montclair Basins No. 1 through No. 4, Brooks Street Basin, Turner Basin No. 1, and the Grove Basin. The locations of these basins are shown in Figure 6-1. These instruments collect quasi-continuous water-level monitoring data in these basins. This water level data and other information make it possible to estimate:

- basin inflows by source type
  - storm water discharge
  - dry-weather discharge
  - imported water discharge
- outflows consisting of
  - groundwater recharge
  - evaporation
  - discharge by source type
- storage of water by source type

6.1.1 Methodology to Estimate Inflow and Recharge

The recharge that occurs in a spreading basin, at any time, can be estimated by solving the continuity equation:

$$\Delta S = I - O \qquad (1)$$

Where:

ΔS	is the change in storage in a basin
I	is the inflow into a basin
O	is outflow from a basin

This equation can be expanded and solved for a recharge basin with multiple inflows and outflows. Substituting individual inflow and outflow terms in Equation 1 yields:

$$S_{t+1} - S_t = (QI_{t,t+1} - QO_{t,t+1}) * \Delta t + (R_{t,t+1} - P_{t,t+1} - E_{t,t+1}) * A_{t,t+1} * \Delta t \qquad (2)$$

Where:

S_t	is the storage in the basin at time *t*
S_{t+1}	is the storage in the basin at time *t+1*
$QI_{t,t+1}$	is the rate of runoff into the basin during the period *t* to *t+1*
$QO_{t,t+1}$	is the rate of outflow from the basin during the period *t* to *t+1*
$R_{t,t+1}$	is the rate of precipitation that falls on the basin during the period *t* to *t+1*
$P_{t,t+1}$	is the rate of percolation from the basin during the period *t* to *t+1*
$E_{t,t+1}$	is the rate of evaporation from the water surface in the basin during the period *t* to *t+1*
Δt	duration of the time period *t* to *t+1*
$A_{t,t+1}$	average surface area of the water surface in the basin during the period *t* to *t+1*

The continuity equation was solved at 60-minute time steps for each day that water was observed in the spreading basins. These calculations resulted in the hourly estimates of inflow by source type, outflow by source type—including the volume of water recharged and the percolation rate, and the volume of water in storage by type. These calculations are based on the following measurements and assumptions:

Water Levels in the Basin. Water-level data for the recharge basins were provided by CBWCD. Water levels were measured with integrated pressure transducers/data loggers that were set to take readings every 60 minutes. CBWCD staff downloaded these data on a monthly basis. Water-level time history plots are provided in Appendix D.

Daily Rainfall and Evaporation. Daily rainfall ($R_{t,t+1}$) and evaporation ($E_{t,t+1}$) rates were estimated from the nearest rainfall gauging stations and Puddingstone Reservoir, respectively. The following rainfall gauging stations were used:

- 1335Auto Ontario Fire Station #3
- 1347 Monte Vista County Water District
- 1075B Guasti Park
- 1019B Upland - Water Facilities Authority
- 1137 Montclair Fire Department

Average rainfall in the urban watersheds tributary to these basins is about 16 inches per year. In contrast, the rainfall in the area in year 2001/02 was about 5.3 inches and the rainfall in 2002/03 was about 16.3 inches (based on rainfall gauges 1335 and 1347).

Basin Geometry. The storage in the basin at a specific time is estimated from the relationship between basin water level and storage (S_t). The area of inundation, or "wetted" area, ($A_{t,t+1}$) is necessary to determine the percolation rate and to compute evaporation from stored water. Elevation-area-volume rating curves were developed for each basin from topographic information provided by CBWCD.

History of Outlet Works Operations and Discharge out of Basins. Some of the basins have operable outlet works, which include gates that can be closed, opened partially, or opened completely. To calculate outflow, the time histories of gate settings must be known. CBWCD provided these time histories. WEI developed elevation-outflow curves for each basin containing an operable outlet works. Outflow from a basin was estimated from the time history of measured basin water levels, the outlet gate setting, and the appropriate elevation-outflow curve.

Percolation and Evaporation Rates. Percolation rates ($P_{t,t+1}$) are only estimable when the gates of an operable outlet works are closed and runoff into the basin is negligible. When this occurs, there is no inflow and the only outflows are evaporation and recharge. Evaporation is accounted for by multiplying the daily evaporation rate ($E_{t,t+1}$) from Puddingstone Reservoir by the water-surface area ($A_{t,t+1}$) of the basin in question. The water-surface area ($A_{t,t+1}$) can be calculated from the water-surface elevation and elevation-area-volume rating curves. The percolation rate is then:

$$P_{t,t+1} = Rech_{t,t+1} / [A_{t,t+1} * \Delta t] = [S_t - S_{t+1} - E_{t,t+1} * A_{t,t+1} * \Delta t] / A_{t,t+1} / \Delta t \quad (3)$$

which can be approximated as:

$$P_{t,t+1} = \Delta WL_{t+1} / \Delta t - E_{t,t+1} \quad (4)$$

The percolation rate, as described above, is the rate at which water actually enters the soil during a short period. Its magnitude depends on many factors, including the water-level in the basin, duration of inundation, debris content of prior storm water inflows, and other conditions in the basin. To estimate the percolation rate, the water-level time history was divided to small time steps (about 6 hours) and the rate of water-level drop was calculated during each time step, as shown in Figure 6-2, with Brooks Basin data. The length of the time step was based upon the characteristics of the change in water level, which should be constant during the time-step period. Then the estimated rate of water-level change was plotted against the average water level during the time step, as shown in Figure 6-3. Note that in Figure 6-3, there are five distinctive percolation rate-elevation relationships. They are named as Fill 1 through Fill 5. They correspond to five different fill periods or fill events in the Brooks Basin. Note that the percolation rates shown on the negative y-axis by convention as they are based on falling water levels. For example, the percolation rate for the Fill 1period is about -0.92 ft/day when water level is 10 ft, which means that the water level in the basin declined about 0.92 ft/day during the first fill event when the water level in the basin was 10 feet. Review of the data in Figure 6-3, for the Brooks Basin, indicates that the percolation rate changes over time and varies with water level. The percolation rate-elevation relationship for each fill event is used to estimate the recharge of each fill event. The fill event recharge estimates are aggregated to obtain an annual recharge estimate.

The water-level time history and the percolation-elevation charts for the Brooks, Montclair, and Turner Basins are provided in Appendix D. Similar charts for Grove Basin can be found in *Grove Basin Monitoring Program Technical Memorandum 2002-2004* (WEI, 2004b).

Estimates of Basin Inflow. Given all the information developed above, the basin inflow hydrographs can be estimated from Equation 2. The inflow hydrograph for the Montclair Basins includes storm water and State Water Project water released from the Metropolitan Foothill Feeder. The storm flow into the Montclair Basins is estimated by subtracting the State Water Project water inflow to the Montclair basins from the total inflow hydrograph developed from Equation 2. Figure 6-4 illustrates the State Water Project water inflow hydrograph for the Montclair Basins for fiscal years 2001/02 and 2002/03.

6.1.2 Recharge Estimates

Table 6-1 summarizes the recharge estimates by basin and source water type for years 2000/01, 2001/02 and 2002/03. During fiscal year 2000/01, Watermaster diverted 6,490 acre-ft of State Water Project water to the Montclair Basins. About 6,464 acre-ft of this water was estimated to have recharged the groundwater basin and about 26 acre-ft was estimated to have evaporated. During fiscal year 2001/02, Watermaster diverted 6,502 acre-ft of State Water Project water to the Montclair Basins. About 6,482 acre-ft of this water was estimated to have recharged the groundwater basin and about 20 acre-ft was estimated to have evaporated. During fiscal year 2002/03, Watermaster diverted about 8,492 acre-ft of imported water into the Montclair Basins; further, about 8,354 acre-ft percolated into the groundwater basin, about 40 acre-ft evaporated, and about 47 acre-ft was lost downstream. Total storm-water recharge in the Montclair Basins was about: 2,890 acre-ft in fiscal 2000/01; 773 acre-ft in fiscal year 2001/02; in fiscal year 2002/03, storm-water recharge increased to about 1,328 acre-ft.

For the Brooks Street Basin, storm-water recharge was about: 667 acre-ft in fiscal 2000/01; 104 acre-ft in fiscal year 2001/02; and 676 acre-ft in fiscal year 2002/03.

For Turner No. 1 Basin storm water recharge was at least: 22 acre-ft in fiscal 2000/01; 10 acre-ft in fiscal 2001/02; unknown in fiscal year 2002/03 due to instrument failure.

For Grove Basin, storm-water recharge was about: 76 acre-ft in fiscal year 2001/02; and 264 acre-ft in fiscal year 2002/03.

6.1.3 Recommendations for Future Basin Percolation Monitoring

Starting in 2005/06, water level and inflow monitoring will be through a SCADA system that includes these and the other recharge basins that were improved in the CBFIP. The San Sevaine Basins are not included in the SCADA system even though they are used by the Watermaster for supplemental water recharge. The San Sevaine Basins should either be included in the SCADA system in the near future or the Watermaster should install water level sensors in these basins.

For the remainder of 2004/05 the following recommendations have been made and sent to CBWCD for their consideration:

- As mentioned above, instrument failure at all basins result in a total loss of data for the instrumented basins. In 2000/01, CBWCD set the water level sampling rate at 30 minutes and for 2001/02 and 2002/03 CBWCD set the sampling rate at 60 minutes. Respectfully, the water level sampling rate should be no greater than 15 minutes. This will allow for more accurate inflow and outflow computations. The data should be downloaded and reviewed after each significant storm and at least monthly. If this were done prior to and during 2003/04, it is very likely that some or all the water level and temperature data would have been retrieved.
- Some of the basins are equipped with controllable inlets and/or outlets. Accurate records regarding the opening and closing of controllable inlets and/or outlets are essential to the accuracy of outflow and recharge calculations. WEI recommends that CBWCD develop a consistent procedure for reading and recording outlet and inlet gate settings.
- The reference elevation of the pressure transducers needs to be reestablished every time they are removed for maintenance or relocated. If they are relocated then they need to be surveyed.

6.2 The Chino Basin Facilities Improvement Project

The IEUA and the Watermaster completed the Phase II Recharge Master Plan development in August 2001 and began facility designs in December 2001. Subsequently, the IEUA began construction of recharge improvements most of which were complete in the Fall of 2004 with the remaining work to be completed by June 2005. Figure 6-1 shows the basins included in the CBFIP. Table 6-2 summarizes the improvements at each basin. The cost of these improvements is about $44 million.

6.3 Baseline Estimates of Storm Water Recharge and New Yield from the CBFIP

Table 6-3 lists the recharge/storm water retention basins that are currently used or will be used for storm and supplemental water recharge purposes; and estimates of average annual storm water recharge for July 1, 2000 basin conditions and operations. Table 6-3 also contains the expected average annual recharge estimates for these basins based on Watermaster modeling studies (WEI, 2003) that incorporate most of the facility improvements included in the CBFIP. Improvements not included are the pump stations and force mains used to move supplemental and some storm water from San Sevaine Creek to Banana, RP3 and Declez Basins.

The supplemental water recharge capacity of the entire system of recharge basins is lower than anticipated during the Phase II Recharge Master Plan (Black and Veatch, 2001). The supplemental water recharge capacity was estimated to range between about 82,000 to 122,000 acre-ft/yr in the Recharge Master Plan. The current expected supplemental water recharge capacity is about 60,000 acre-ft/yr. The major reason for the reduced capacity is the deferment in the use of the College Heights and Upland Basins pending the results of hydrogeological and geotechnical investigations; and the deletion of the Etiwanda Spreading Grounds and Etiwanda Conservation Ponds from the CBFIP. This supplemental water recharge capacity is less than the estimated required future capacity of 63,000 acre-ft/yr required in the future.

The expected increase in stormwater recharge is about 12,000 acre-ft/yr with a total expected recharge capacity between 17,000 and 18,000 acre-ft/yr.

6.4 Storm Water Recharge Quality

Watermaster staff has been systematically collecting and analyzing surface water samples from 21 recharge basins in Chino Basin since November 1997. About 350 water quality samples from the basins were collected and analyzed from November 1997 to September 2004. The sampling frequency for each of the recharge basins over the last four wet seasons is shown graphically in Figure 6-5. Watermaster staff collects from one to four samples in each basin, depending on basin configuration and water elevation. These samples are volumetrically composited at the analytical laboratory to provide an estimate of the average water quality recharged at a given point in time at each of the basins. The vertical gridlines in Figure 6-5 represent 2-week intervals from November 1st through April 30th for each wet season.

The basins recharge water from several sources, including:

- urban dry weather flow;
- urban stormwater;

- San Gabriel Mountain stormwater;
- State Project Water;
- GE Flatiron Plant remediation water; and
- IEUA recycled water.

Table 6-4 summarizes the average TDS and nitrate-nitrogen concentrations collected from the basins. Also included in Table 6-4 is a semi-quantitative assessment of the source of recharge water; major and minor components of source waters listed in the above bullets are given in the table. Basins that recharge mostly urban stormwater have excellent water quality. For example, Brooks Basin had an average TDS of 58 mg/L and an average nitrate-nitrogen of 0.6 mg/L. Table 6-4 was developed from data derived from Watermaster's water quality database. In addition to TDS and nitrate, the surface water grab samples are also analyzed for the following constituents:

- Ammonia -N
- Anion sum
- Bicarbonate
- Boron
- Calcium
- Cation sum
- Chloride
- Color
- Electrical Conductivity
- Fluoride
- Hydroxide
- Magnesium
- MBAS
- Nitrate-N
- Nitrite-N
- Odor
- pH
- Potassium
- Sodium
- Sulfate
- Total Alkalinity
- Total Dissolved Solids
- Total Hardness
- Total Organic Carbon and Dissolved Organic Carbon
- Total Phosphorus

This database can be queried in future studies to determine the state of the basin's recharge water quality for any constituent listed above.

Table 6-1
Estimated Groundwater Recharge during Fiscal Years 2000/01 through 2002/03

(acre-ft)

	Montclair Basins	Brooks Basin	Turner 1 Basin	Grove Basin
Fiscal Year 2000/01 - Imported Water				
Inflow	6,490			
Evaporation	26			
Percolation	6,464	667		
Outflow1				
Outflow2				
Fiscal Year 2000/01 - Storm Runoff				
Inflow				
Evaporation				
Percolation	2,890			
Outflow1				
Outflow2				
Fiscal Year 2001/02 - Imported Water				
Inflow	6,502			
Evaporation	19			
Percolation	6,482			
Outflow1	0			
Outflow2				
Fiscal Year 2001/02 - Storm Runoff				
Inflow		106	11	270
Evaporation	9	2	1	5
Percolation	773	104	10	76
Outflow1	-	-	-	190
Outflow2				
Fiscal Year 2002/03 - Imported Water				
Inflow				
Evaporation	40			
Percolation	8,354			
Outflow1	47			
Outflow2				
Fiscal Year 2002/03 - Storm Runoff				
Inflow		689		882
Evaporation	23	13		22
Percolation	1,328	676		264
Outflow1	600	-		581
Outflow2				

Table 6-2
Improvements at Recharge Basins Included in the Chino Basin Facilities Improvement Project

Recharge Basins	New or Existing	Grading				Hydraulics			New MWDSC Turnout	SCADA	Other Significant Improvement
		Enlarge	Internal Berms	Optimize Bottoms	Other Minor	New Inlet	New Outlet	Rubber Dams			
Management Zone 1											
Brooks Street Basin	Existing				X	X	X			X	
College Heights Basins[2]	New	X		X	X	X	X	X		X	
Montclair Basin 1	Existing									X	
Montclair Basin 2	Existing									X	
Montclair Basin 3	Existing									X	
Montclair Basin 4	Existing									X	
Seventh and Eighth Street Basins	Existing		X	X	X		X		X	X	
Upland Basin[2]	Existing						X			X	
Management Zone 2											
Ely Basins	Existing		X	X	X				X	X	
Hickory Basin	Existing		X	X	X		X	X	X	X	Pump Station and Force Main to Banana Basin
Lower Day Basin	Existing		X	X	X	X		X	X	X	
San Sevaine No. 1	Existing										
San Sevaine No. 2	Existing										
San Sevaine No. 3	Existing										
San Sevaine No.'s 4 and 5	Existing										
Turner Basins No. 1 and 2	Existing		X	X	X	X		X		X	
Turner Basins No. 3 and 4	Existing		X	X	X	X				X	
Victoria Basin	Existing		X	X	X	X	X			X	
Management Zone 3											
Banana Basin	Existing				X		X			X	
Jurupa Basin	Existing				X						Pump Station and Force Main to RP3 Ponds
Declez Basin	Existing		X	X	X		X			X	
IEUA RP3 Ponds	New	X	X	X	X	X	X	X		X	

Table 6-3

New Storm Water Recharge and Supplemental Water Estimates at Each Basin[1]

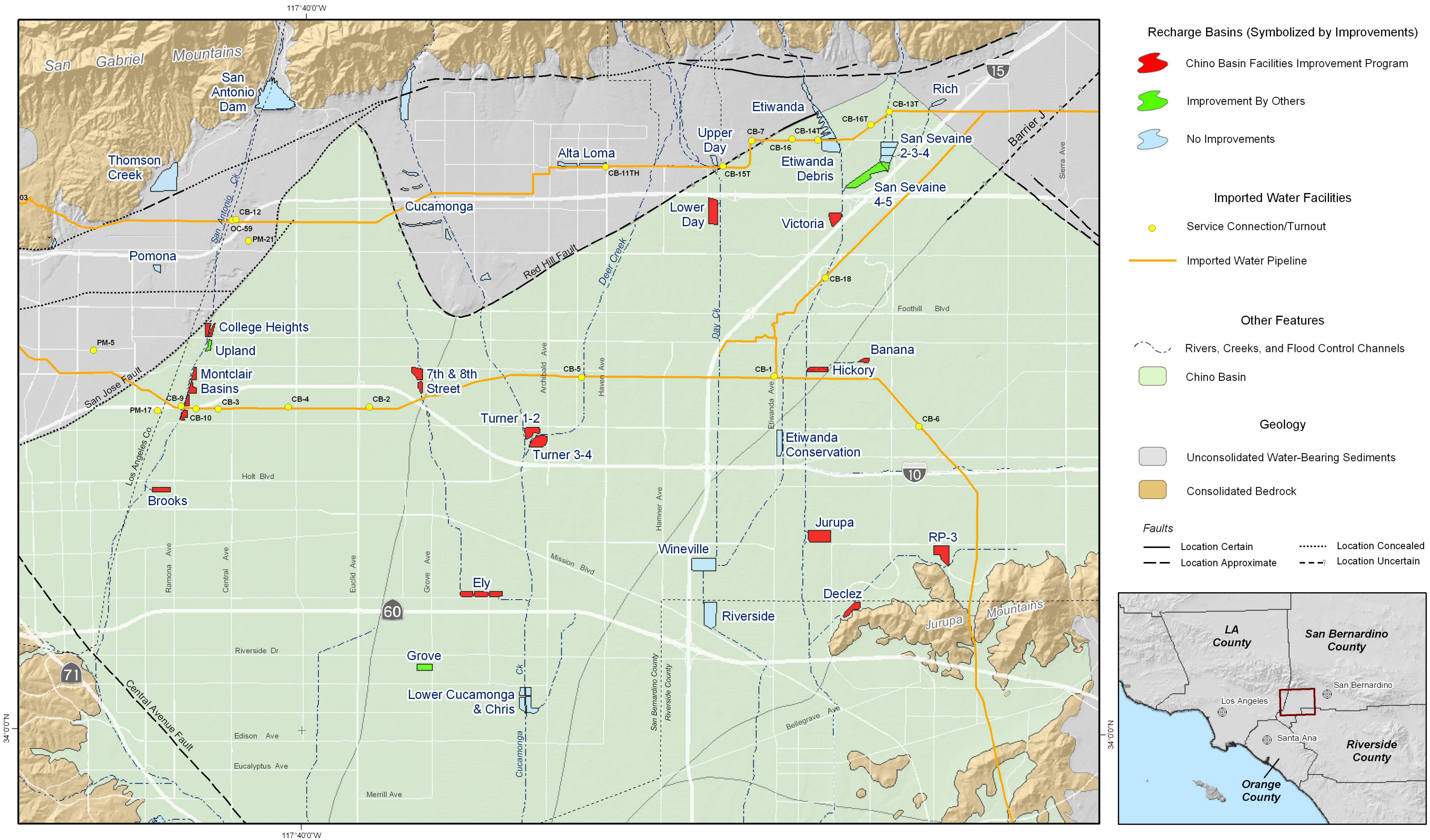
Basin	Phase 2 Recharge Master Plan Estimates of Storm Water Conservation (acre-ft/yr)			Revised Estimates Based on CBFIP Designs and Improved Model (acre-ft/yr)			Supplemental Water: Operational Plan (1=on, 0=off)												Supplemental Water: Utilization	Supplemental Water: Supplemental Water Recharge Capacity (acre-ft/yr)		Recycled Water Recharge Capacity[4]
	Pre-Project Estimate	Post-Project Estimate with Ultimate Land Use	Increase	Pre-Project Estimate with 1993 Land Use	Post-Project Estimate with Ultimate Land Use	Increase	J	F	M	A	M	J	J	A	S	O	N	D		Current Estimate	Future Capacity	
Brooks Street Basin	850	1,800	950	1,260	1,710	450	1	1	1	1	1	0	0	0	0	1	1	1	70%	0	3,724	1,044
College Heights Basins[2]	0	100	100	0	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0
Montclair Basin 1	350	350	0	260	340	80	1	1	1	1	1	0	0	0	0	1	1	1	70%	2,331	2,331	603
Montclair Basin 2	780	780	0	320	370	50	1	1	1	1	1	0	0	0	0	1	1	1	70%	3,682	3,682	933
Montclair Basin 3	370	370	0	160	160	0	1	1	1	1	1	0	0	0	0	1	1	1	70%	1,317	1,317	329
Montclair Basin 4	440	440	0	220	250	30	1	1	1	1	1	0	0	0	0	1	1	1	70%	1,697	1,697	432
Seventh and Eighth Street Basins	0	1,550	1,550	0	1,020	1,020	1	1	1	1	1	0	0	0	0	1	1	1	70%	0	2,196	804
Upland Basin[2]	760	1,000	240	500	580	80	0	0	0	0	0	0	0	0	0	0	0	0	0%	0	0	0
Subtotal Management Zone 1	3,550	6,390	2,840	2,720	4,480	1,760														9,027	14,947	4,144
Ely Basins	1,000	2,800	1,800	1,870	1,570	-300	1	1	1	1	1	0	0	0	0	1	1	1	70%	0	3,167	792
Etiwanda spreading area (joint use of Etiwanda debris basin)	0	1,635	1,635	0	0	0	1	1	1	1	1	0	0	0	0	1	1	1	70%	0	0	0
Hickory Basin	0	840	840	0	780	780	1	1	1	1	1	0	0	0	0	1	1	1	70%	0	4,395	1,294
Lower Day Basin	0	500	500	0	2,180	2,180	1	1	1	1	1	0	0	0	0	1	1	1	70%	0	2,027	1,052
San Sevaine No. 1	610	820	210	200	930	730	1	1	1	1	1	0	0	0	0	1	1	1	70%	8,310	8,310	2,260
San Sevaine No. 2	20	20	0	20	110	90	1	1	1	1	1	0	0	0	0	1	1	1	70%	1,723	1,723	453
San Sevaine No. 3	380	640	260	380	770	390	1	1	1	1	1	0	0	0	0	1	1	1	70%	3,673	3,673	1,016
San Sevaine No.'s 4 and 5	60	500	440	150	630	480	1	1	1	1	1	0	0	0	0	1	1	1	70%	4,771	4,771	1,313
Turner Basins No. 1 and 2	200	860	660	160	1,240	1,080	1	1	1	1	1	0	0	0	0	1	1	1	70%	0	1,098	544
Turner Basins No. 3 and 4	0	1,800	1,800	0	640	640	1	1	1	1	1	0	0	0	0	1	1	1	70%	0	937	394
Victoria Basin	240	940	700	30	2,090	2,060	1	1	1	1	1	0	0	0	0	1	1	1	70%	0	2,365	1,106
Subtotal Management Zone 2	2,510	11,355	8,845	2,810	10,940	8,130														18,477	32,465	7,087
Banana Basin	0	800	800	0	410	410	1	1	1	1	1	0	0	0	0	1	1	1	70%	0	2,196	651
Declez Basin	0	260	260	0	80	80	1	1	1	1	1	0	0	0	0	1	1	1	70%	0	3,547	907
Etiwanda Conservation Ponds[3]	0	1,060	1,060	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70%	0	0	0
IEUA RP3 Ponds	0	1,700	1,700	0	1,330	1,330 0	1	1	1	1	1	0	0	0	0	1	1	1	70%	0	6,562	1,973
Subtotal Management Zone 3	0	3,820	3,820	0	1,820	1,820														0	12,304	10,618
Totals	6,060	21,565	15,505	5,530	17,240	11,710														27,505	59,717	21,849

1 -- Recharge Basins not optimized for storm water recharge; actual recharge performance may be greater.
2 -- College Heights and Upland Basins will not be used for supplemental water recharge for the near future, pending resolution of geotechnical issues.
3 -- Etiwanda Conservation Ponds will not be used for recharge of either storm or supplemental water for the near future due to issues with the land owner.
4 -- Assumes that recycled water would be no more than 20 percent of the combined supplemental and storm water recharge.

Table 6-4
Average Water Quality in Surface Water Samples Collected from Recharge Basins in Chino Basin
Samples Collected from November 1997 to August 2004

Basin	Nitrate-N (mg/L)	Nitrate-N (# samples)	TDS (mg/L)	TDS (# samples)	Water Source a	Water Source b	Water Source c	Water Source d	Water Source e	Water Source f
15th Street	0.5	2	45	2	❍	●				
Banana	0.7	7	84	9	❍	●				
Brooks	0.6	21	58	21	❍	●				
Chris	1.3	6	143	7	●	●				
Church	1.2	8	159	8	●	●				
College Heights	1.0	1	47	1		●				
Declez	3.2	17	236	18	●					
Ely 1	2.1	8	113	8	❍	●			❍	
Ely 3	1.0	16	69	17	❍	●				❍
Etiwanda	2.3	1	170	1			●			
Grove	0.7	42	195	45	❍	●				
Hickory	0.8	16	102	17	❍	●				
Lower Cuca. West	0.5	1	215	1	❍	●				
Lower Day	0.5	9	70	9	❍	●	●			
Montclair 1	0.9	15	128	15	❍	●		●		
Montclair 2	0.8	13	90	13	❍	●		●		
Montclair 3	0.7	15	72	16	❍	●		●		
Montclair 4	0.8	18	76	18	❍	●		●		
Riverside	1.1	12	125	12	❍	●				
San Sevaine 1	0.9	20	120	21	❍	●	●			
San Sevaine 5	0.6	19	112	20	❍	●	●			
Turner #1	0.9	9	192	9	❍	●				
Turner #5	3.1	12	167	12	❍	●				
Upland	0.8	7	117	7	❍	●				
Victoria	0.8	22	107	23	❍	●				
Wineville	1.4	21	171	22	❍	●				

● major component of source water
❍ minor component of source water
a urban dry weather flow
b urban stormwater
c San Gabriel Mountain stormwater
d State Project Water
e GE Flatiron Plant remediation water
f IEUA recycled water



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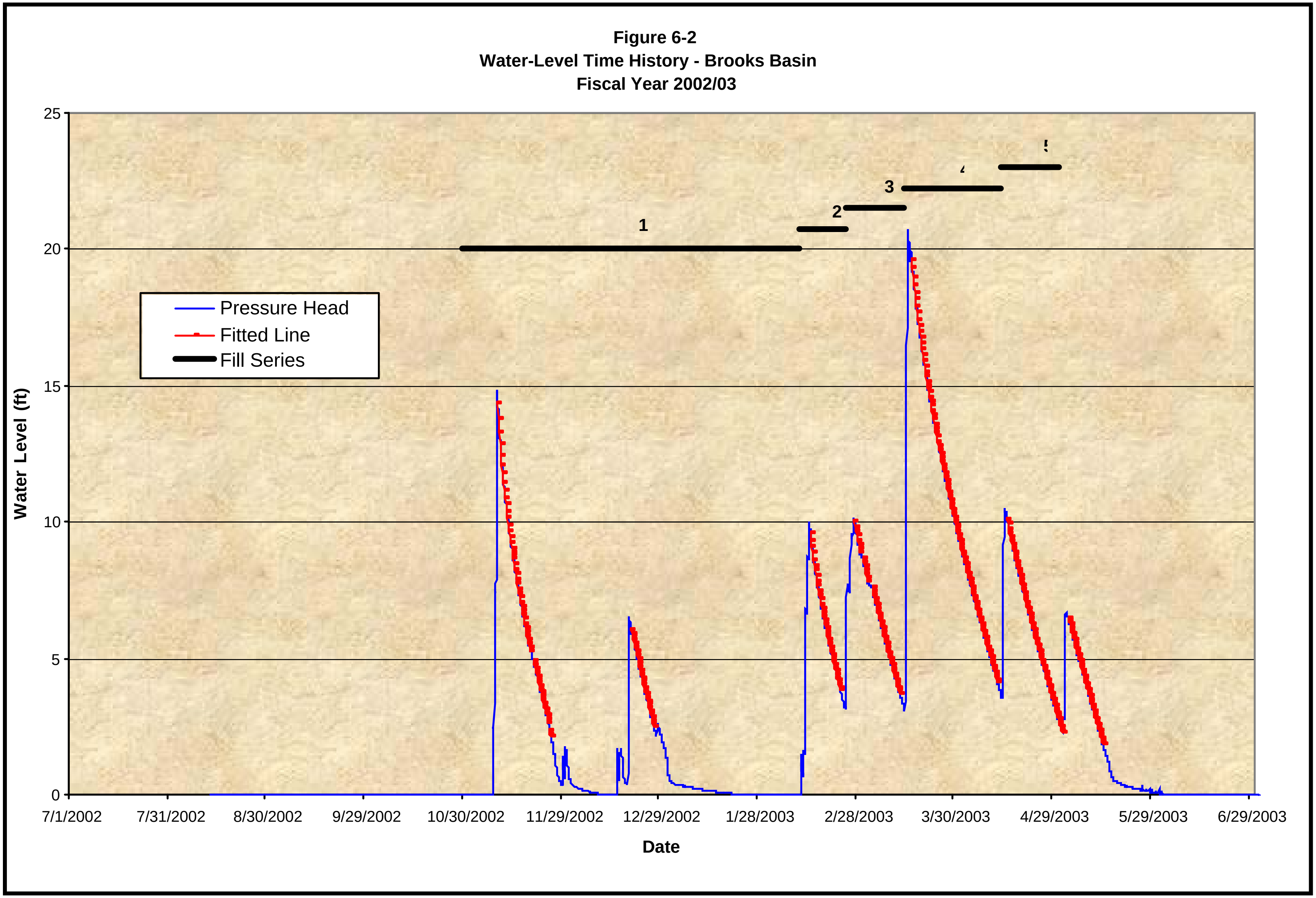
State of the Basin Report -- 2004
Recharge Basin Monitoring

Groundwater Recharge and Imported Water Facilities

Figure 6-1



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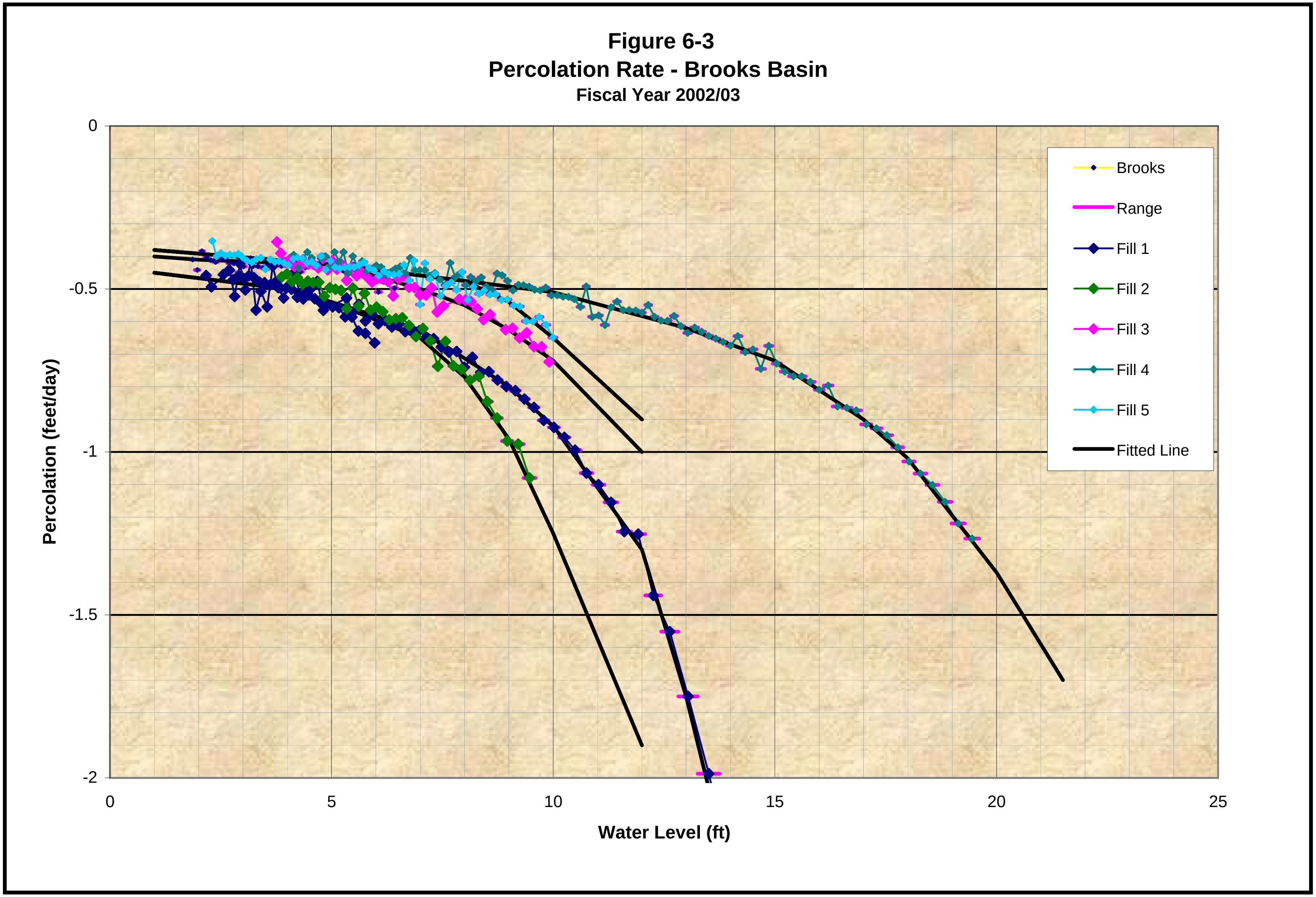

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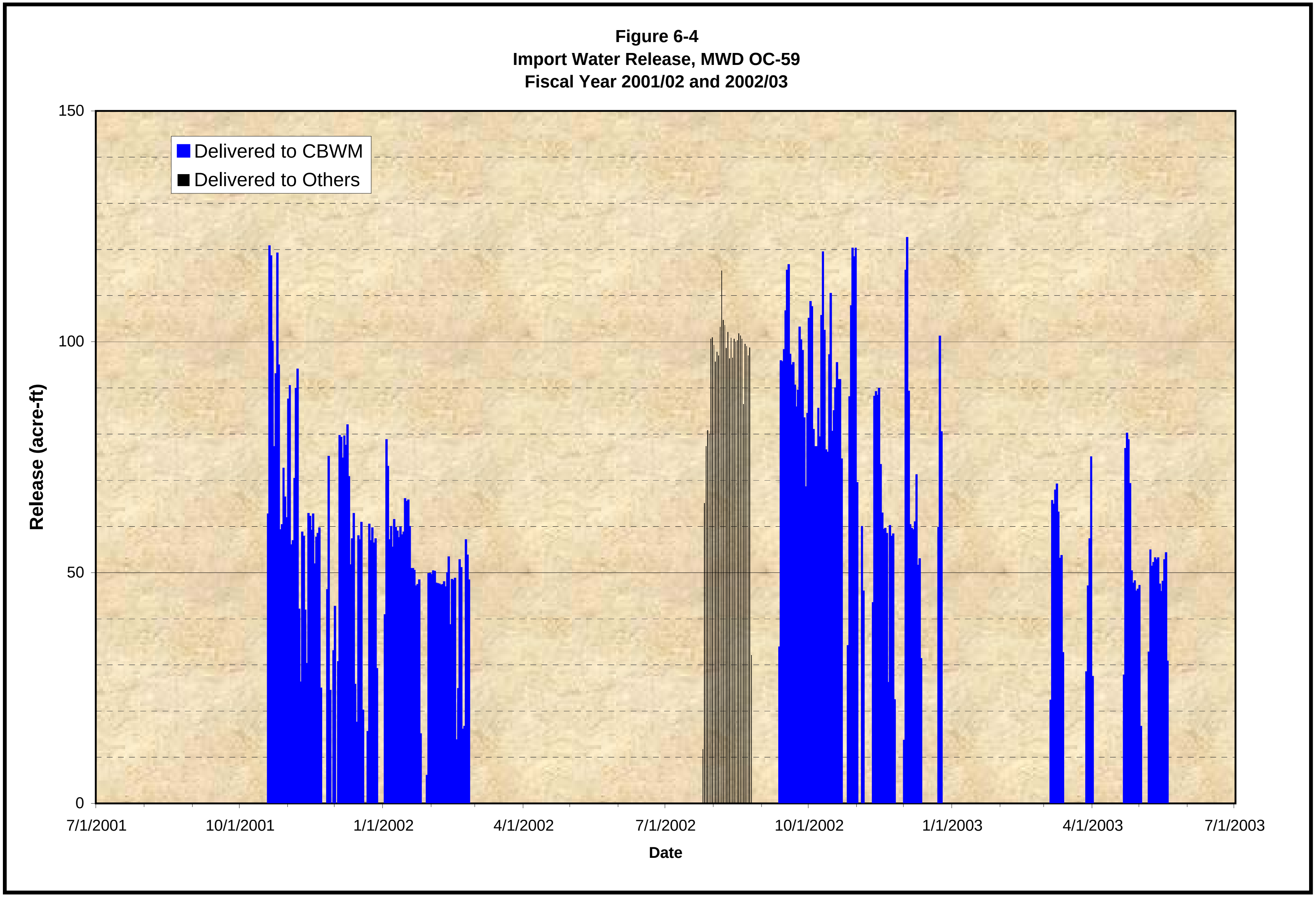

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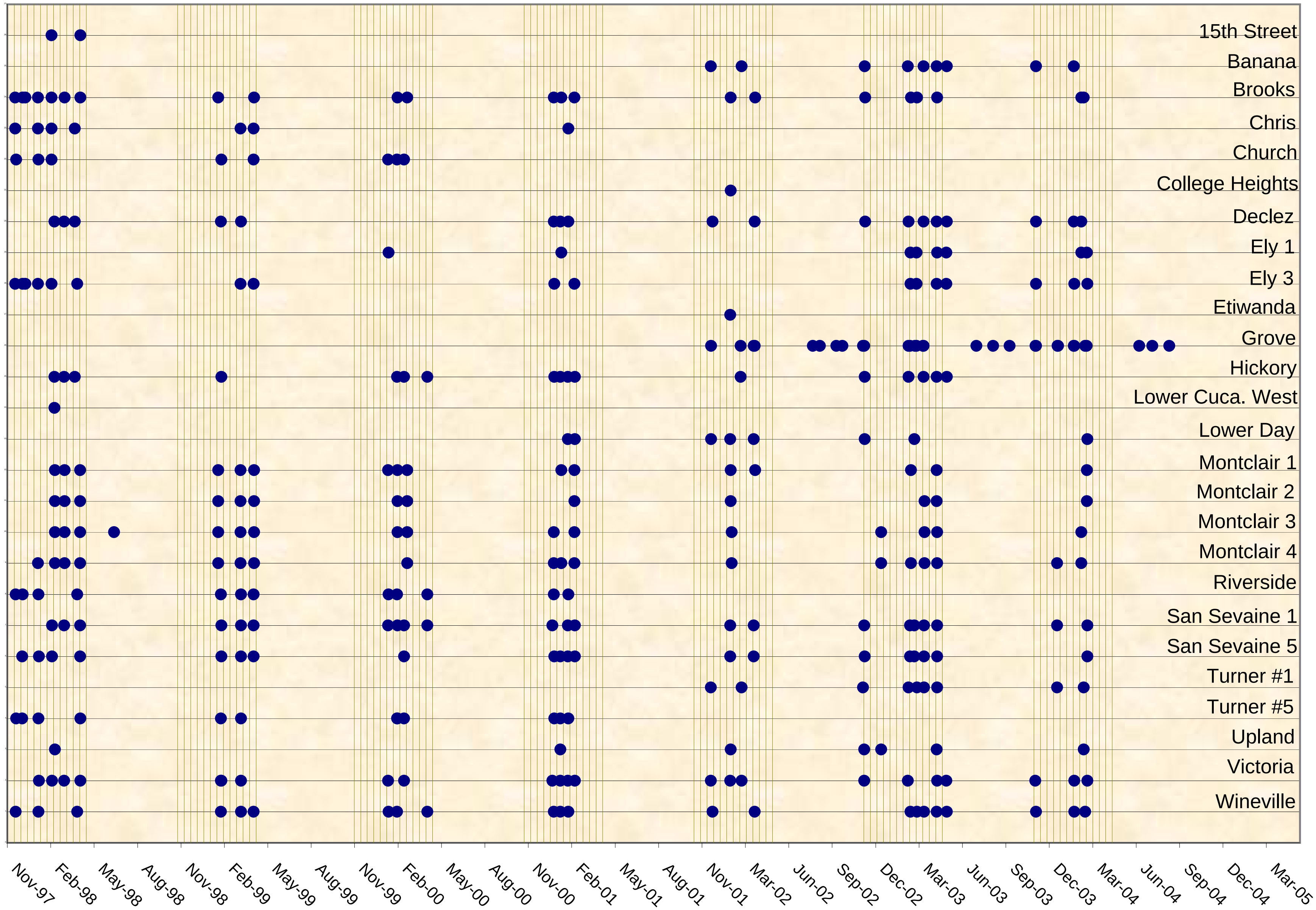
Figure 6-5
Surface Water Sampling Frequency for Recharge Basins in Chino Basin



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7. BASIN PLAN UPDATE FOR THE CHINO BASIN

7.1 Background

The TIN/TDS Task Force was formed in the mid 1990s to perform certain investigations that would lead to the establishment of new nitrate-nitrogen and total dissolved solids (TDS) objectives for groundwater basins in the Santa Ana River Watershed. The Regional Water Quality Control Board (RWQCB), Chino Basin Watermaster, water-recycling agencies, and many other entities participated in the Task Force. The RWQCB used the reports and other information developed by the Task Force to amend the Water Quality Control Plan for the Santa Ana River Watershed (Basin Plan). The Task Force initially proposed nitrate and TDS objectives based on a statistical analysis of well water quality data for the period 1954 to 1973 with the resulting well statistics volumetrically averaged to yield a new statistic for each water body. The basis for this approach is State Water Resources Control Board (SWRCB) Executive Order 68-16. The operating concept from Executive Order 68-16 is:

> "1. Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies."

The TIN/TDS Task Force published a report entitled *TIN/TDS Study – Phase 2A, Final Technical Memorandum* (WEI, 2000). The proposed antidegradation objectives and associated water bodies for the Chino Basin were:

Management Zone	Proposed TDS Objective (mg L)	Nitrate-N Objective (mg L)
Chino 1	293	4.9
Chino 2	255	2.9
Chino 3	262	3.5
Chino 4	730	10.0
Chino 5	650	4.2
Cucamonga	210	2.4

The management zones for the proposed objectives are identical to the management zones adopted by Watermaster in the OBMP and are shown in *Figure 3-12* of the *TIN/TDS Study – Phase 2A, Final Technical Memorandum*, and are shown in Figure 1-1 herein. The Task Force demonstrated with a similar statistical procedure that the current (1997) ambient TDS and nitrate concentrations exceed these objectives – that is, there is no assimilative capacity in any of these management zones for TDS or nitrate.

These objectives would, from a practical standpoint, make the large-scale use of recycled water very difficult and potentially impractical in the Chino Basin. However, the OBMP anticipates the use of about 26,000 acre-ft/yr of recycled water for direct use by 2025 and about 20,000-30,000 acre-ft/yr for recharge in 2025. Recycled water is a critical resource that the OBMP stakeholders are counting on to implement the OBMP. If the antidegradation objectives were adopted, Watermaster, the parties to the Judgment, and IEUA, would have substantial mitigation obligations for the use of recycled water.

7.2 Watermaster's Proposal for TDS and TIN Water Quality Objectives

In December 2002, Watermaster and IEUA proposed to the RWQCB to develop new TDS and nitrate objectives based on criteria contained in California Water Code Section 13241. Section 13241 states:

> "Each regional board shall establish such water quality objectives in water quality control plans as in its judgment will ensure the reasonable protection of beneficial uses and the prevention of nuisance; however, it is recognized that it may be possible for the quality of water to be changed to some degree without unreasonably affecting beneficial uses. Factors to be considered by a regional board in establishing water quality objectives shall include, but not necessarily be limited to, all of the following:
>
> a) Past, present, and probable future beneficial uses of water.
> b) Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto.
> c) Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area.
> d) Economic considerations.
> e) The need for developing housing within the region.
> f) The need to develop and use recycled water."

The Task Force modified the southern boundaries of Management Zones 1, 2, and 3, the northern end of the Temescal Management Zone, and the western boundary of Chino Basin Management Zone 5 to accommodate a new management zone that it calls the Prado Basin Management Zone. Watermaster and IEUA proposed that the remaining area in the Chino Basin be divided into the *Chino North*, *Chino East*, and *Chino South* Management Zones instead of the five management zones presented in the *TIN/TDS Study – Phase 2A, Final Technical Memorandum* (WEI, 2000a) and the OBMP (WEI, 1999). The boundary for the Cucamonga Management Zone would remain unchanged. Figure 7-1 shows the proposed management zones. *Chino North* would consist of the remaining parts of Management Zones 1, 2 and 3. *Chino East* consists of Management Zone 4 and *Chino South* consists of Management Zone 5. Watermaster and IEUA proposed that the TDS and nitrate objectives for Chino and Cucamonga management zones be:

Management Zone	TDS (mg L)		Nitrate-N (mg L)	
	Objective	Current	Objective	Current
Chino North	420	300	5.0	7.4
Chino East	730	760	10.0	13.3
Chino South	680	720	4.2	8.8
Cucamonga	380	260	5.0	4.4

The *current* estimate listed above is an estimate of the volume-weighted quality in 1997. It is consistent with, and uses the same data and computational methods as the current ambient concentrations listed in the *TIN/TDS Study – Phase 2A, Final Technical Memorandum* (WEI, 2000a). The proposed TDS objectives for *Chino North* and *Cucamonga* are based on the long-term projection of the average TDS concentration in these management zones with the recycling program included in the OBMP. The proposed nitrate objective is based on values that can accommodate planned recycled water recharge in *Chino North* and *Cucamonga* without impairing beneficial uses in either management zone. The TDS and nitrate objectives for *Chino East* and *Chino South* are based on antidegradation objectives for the Chino 4 and 5 management zones. The proposed objectives for *Chino North* and *Chino South* have been adjusted slightly to account for the new Prado Basin Management Zone. Watermaster and IEUA made specific commitments to back up this proposal (see Commitments below). The Watermaster and IEUA proposal was evaluated using Water Code Section 13241 and one other criterion described below.

7.2.1 S13241 (a) Past, Present, and Probable Future Beneficial Uses of Water.

The beneficial uses in the 1995 Basin Plan for the Chino Basin subbasins I, II and III are:

> MUN – waters used for community, military, municipal, or individual water systems. These uses include, but are not limited to, drinking water supply.
>
> AGR – waters used for farming, horticulture or ranching. These uses may include, but are not limited to, irrigation, stock watering, and support of vegetation for range grazing.
>
> IND – waters used for industrial activities that do not depend primarily on water quality. These uses include, but are not limited to, mining, cooling water supply, conveyance, gravel washing, fire protection and oil well repressurization.
>
> PROC – waters are used for industrial activities that depend primarily on water quality. These uses include, but are not limited to, process water supply, and all uses of water related to product manufacturing and food preparation.

The use impairment threshold concentrations for TDS and TIN for these beneficial uses as listed or inferred from the current basin plan are:

Beneficial Use	TDS Threshold (mg L)	TIN Threshold (mg L-N)
MUN	500	10
AGR	700	>10
IND	nl	nl
PROC	nl	nl

The "nl" listed above means that the basin plan is silent as to the impairment threshold concentration for these uses. For the AGR use, the basin plan states that 700 mg/L is the beneficial use threshold for irrigation. The basin plan is silent regarding the TIN impairment threshold for the AGR use, however it is reasonable to assume that this impairment threshold is significantly greater than 10 mg/L – thus it is shown above as >10 mg/L. With the exception of TDS in *Chino South*, the proposed TDS and TIN objectives are protective of these beneficial uses. The protection of the MUN use in *Chino South* with regard to TDS is described below.

7.2.2 S13241 (b) Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto.

TDS. Watermaster conducted a reconnaissance-level investigation to estimate the future TDS concentrations in *Chino North* and *Cucamonga* Management Zones. A *continuously-stirred reactor model* (CSRM) was developed to estimate the future TDS concentrations.

In a CSRM, fluid particles enter the reactor and are instantaneously dispersed throughout the reactor volume. The fluid particles leave the reactor in proportion to their statistical population. This approximation is used to study lakes and reservoirs with continuous inputs and outputs (see, for example, *Water Quality: Characteristics, Modeling and Modification,* by Tchobanoglous and Schroeder, 1987). The extension of this approach to a groundwater basin is somewhat tenuous and at best provides a first-order approximation of the time scale of TDS degradation. In words, the approach is as follows:

- Estimate the volume and volume averaged TDS concentration of the subject management zone at the start of the simulation period (initial condition).

For each time step do the following:

- Estimate the inflow and outflow volumes
- Estimate change in storage
- Estimate the TDS concentration for each inflow component
- Assume TDS in outflow is equal to the TDS concentration at the end of the previous time step
- Estimate the TDS mass in the reactor
- Estimate the TDS concentration in the reactor at the end of the time step

The initial condition for the management zones was based on the 1997 estimates from the Phase 2A report. The inflows consist of deep percolation of precipitation, deep percolation of applied water, natural and artificial recharge of storm waters, artificial recharge of supplemental water, and subsurface inflows from adjacent groundwater basins. With the exception of deep percolation of applied water, the inflow terms are independent of groundwater outflow terms, and are calculated or assumed values. The deep percolation of applied water is closely related to the total water demand and is derived from the portion of the water demand used to satisfy irrigation uses. It is calculated as follows:

$$AW_{t\ to\ t+1} = TD_{t\ to\ t+1} * FNS$$
$$DPAW_{t\ to\ t+1} = AW_{t\ to\ t+1} * (1.0\text{-}IEFF)$$

Where:

$AW_{t\ to\ t+1}$	is the applied water
$TD_{t\ to\ t+1}$	is total demand
FNS	is the fraction of total demand that does not enter the sewer system
$DPAW_{t\ to\ t+1}$	is the deep percolation of applied water
IEFF	is the irrigation efficiency or the fraction of water consumed by the vegetation served by the applied water.

Total demands and groundwater pumping are derived from the OBMP implementation plan in the Peace Agreement. The fraction of total demand that does not enter the sewer system is based on historical data from IEUA and future estimates from planning documents. Irrigation efficiency was assumed to be 75 percent. The planning documents used to derive total demands, fraction not sewered, and irrigation efficiency are: the Chino Basin Watermaster Optimum Basin Management Program Phase 1 Report (WEI, 1999), Peace Agreement (CBWM, 2000), and the Final Draft, Hydrologic Study of the Cucamonga Groundwater Basin (CDM, 1999).

The water volume and TDS mass balance for a groundwater basin (reactor) is simply:

Inflow – Outflow = Change in Storage

For TDS, an explicit finite-difference approximation is used and is:

$$\Sigma [I_{j,t\ to\ t+1} * C_{j,t}] - \Sigma [O_{k,t\ to\ t+1} * CGW_t] = VGW_{t+1}*CGW_{t+1} - VGW_t*CGW_t$$

Where:

$I_{j,t\ to\ t+1}$	is the j[th] inflow during the period t to t+1
$C_{j,t}$	is the TDS concentration for the j[th] inflow during the period t to t+1
$O_{k,t\ to\ t+1}$	is the k[th] outflow from the groundwater basin during the period t to t+1
VGW_{t+1}	is the volume of groundwater in storage at t+1
CGW_{t+1}	is the TDS concentration of groundwater at t+*1*

The TDS mass balanced is solved for CGW_{t+1} after the hydrologic or water volume mass balance is solved. The following water resources management cases were analyzed:

Case 1 100 Percent of the Replenishment Water in Chino Basin is State Project Water, Non Potable Supply is State Project Water, and No TDS Controls on Water Supply to Maintain Recycled Water below 550 mg/L. No Supplemental Water Recharge in the *Cucamonga* Management Zone.

Case 2 100 Percent of the Replenishment Water in Chino Basin is State Project Water, Non Potable Supply is State Project Water, and TDS Controls on Water Supply to Maintain Recycled Water below 550 mg/L. No Supplemental Water Recharge in the *Cucamonga* Management Zone.

Case 3 100 Percent of the Replenishment Water in Chino Basin is State Project Water, Non Potable Supply is Recycled Water, and TDS Controls on Water Supply to Maintain Recycled Water below 550 mg/L. Supplemental Water Recharge in the Cucamonga Basin consists of 5,000 acre-ft/yr of State Project Water.

Case 4 50 Percent of the Replenishment Water is State Project Water and 50 Percent is Recycled Water, Non Potable Supply is Recycled Water, and TDS Controls on Water Supply to Maintain Recycled Water below 550 mg/L. Supplemental Water Recharge in the *Cucamonga* Management Zone consists of 2,500 acre-ft/yr of State Project Water and 2,500 acre-ft/yr of Recycled Water. Case 4 represents the OBMP with additional desalting.

Each case consists of a 100-year water supply plan and an associated water and salt balance. Detailed tables were prepared that present these water supply plans for the municipal pumpers and associated water and salt balances. For Cases 2 through 4, the TDS concentration in the *Chino North* groundwater supply is equal to either the TDS concentration in the management zone or a fixed lesser value. The latter occurring when the TDS in the composite supply needs to be reduced to ensure that the TDS in recycled water is less than its permit limit. The results are summarized below:

- The Case 1 TDS projection corresponds to increasing water demands and the desalting program in the Chino Basin OBMP but excludes recycled water use. At year 2100, the average TDS concentration in groundwater will be about 470 mg/L for *Chino North* and about 430 mg/L for *Cucamonga*. This is not a feasible case because recycled water produced will exceed the permit level of 550 mg/L.
- Case 2 is identical to Case 1 except that additional desalting has been added to ensure that recycled water produced in the Chino Basin meets a TDS limitation of 550 mg/L. At year 2100, the average TDS concentration will be about 430 mg/L in *Chino North* and about 420 mg/L in *Cucamonga* – a decrease of 40 and 10 mg/L, respectively.
- Case 3 is identical to Case 2 except that the non-potable water delivered for direct use in *Chino North* and *Cucamonga* management zones is assumed to be recycled water. At year 2100, the average TDS concentration in groundwater will be about 445 mg/L for *Chino North* and about 420 mg/L for *Cucamonga* – an increase over Case 2 of 15 mg/L for *Chino North* and no change for *Cucamonga*. The increase in TDS concentration in *Chino North* over the next 100 years from the direct use of recycled water is about 15 mg/L.
- Case 4 is identical to Case 3 except that half of the replenishment water recharged in *Chino North* is assumed to be recycled water (22,000 acre-ft of recycled water recharge). Similarly for *Cucamonga*, half of the supplemental water recharge is assumed to be recycled water (2,500 acre-ft of recycled water). At year 2100, the average TDS concentration in groundwater will be about 475 mg/L in *Chino North* and about 440 mg/L in *Cucamonga* – an increase over Case 3 of 30 mg/L and 20 mg/L for *Chino North* and *Cucamonga*, respectively. The increase in TDS in *Chino North* and *Cucamonga* management zones over the next 100 years from the recharge of recycled water is about 30 mg/L and 20 mg/L, respectively. Case 4 represents the OBMP with additional desalting to ensure that the TDS concentration in recycled water is less than 550 mg/L.

Figures 7-2 and 7-3 graphically compare the TDS projections for each case for *Chino North* and *Cucamonga*, respectively.

The TDS concentration in imported water was assumed to be 290 mg/L in the preceding discussion. There may be times in the future when the TDS concentration will be much higher. Article 19 of the State Water Project contract provides that DWR "*shall take all reasonable measures*" such that the TDS concentration will not exceed 440 mg/L as a monthly average nor exceed the ten-year average of 220 mg/L. The long-term average TDS concentration of State Project water delivered to Metropolitan from DWR is about 290 mg/L or 70 mg/L above the ten-year average contract objective. The monthly average TDS levels in State Project water have exceeded the 440 mg/L objective twice and have exceeded 400 mg/L 19 times in 27 years (Metropolitan, 1999). There is a concern at Watermaster, based on the actions of other Regional Boards in California that setting the TDS objectives in Chino Basin based on the anti-degradation approach will eventually result in mitigation of the recharge of State Project water when its concentration exceeds the objective. This mitigation will have no practical or economic benefit. Watermaster and IEUA asserted to the RWQCB that the TDS objective should be set high enough to recharge State Project water in the basin without mitigation as long as the recharge does not impair beneficial uses of groundwater.

At the October 22, 2002 Task Force meeting, the RWQCB and Task Force members agreed that establishing a TDS objective at 420 mg/L for *Chino North* is sufficient to promote maximum benefit. This TDS objective is based on the Case 4 TDS projection in year 2030. The RWQCB proposed that the TDS objective in *Cucamonga* be 380 mg/L based on the Case 4 TDS projection in year 2030. These TDS objectives allows Watermaster and IEUA the greatest flexibility in conducting supplemental water recharge, and is protective of current and future beneficial uses.

Nitrate. The TIN/TDS Task Force determined that the use protection threshold for nitrate-nitrogen in groundwater was 8 mg/L. Watermaster proposes that the nitrate-nitrogen objectives for the *Chino North* and *Cucamonga* management zones be set at 5 mg/L, which will allow the direct use and recharge of recycled water without mitigation, and still protect the beneficial uses in these management zones.

7.2.3 S13241 (c) Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area.

The controllable factors that affect TDS and nitrate in Chino Basin groundwater include the recharge of storm water, imported water, recycled water, and Santa Ana River discharge. With OBMP implementation: the storm water recharge (TDS ~ 100mg/L and nitrate < 1 mg/L-N) will increase from 5,600 acre-ft/yr to about 17,000 acre-ft/yr, physical recharge capacity for recharge of supplemental water will increase from about 25,000 acre-ft/yr to about 60,000 acre-ft/yr, and groundwater treatment capacity (RO and ion exchange) will increase from about 9,000 acre-ft/yr to about 68,000 acre-ft/yr. Watermaster and IEUA, in implementing of the OBMP, asserted that they were taking extraordinary steps to optimize the management of the Chino Basin area by improving supply reliability and water quality. Setting the TDS and nitrate objectives per the Watermaster and IEUA proposal will reduce the cost of replenishment, which is necessary to ensure that the groundwater treatment systems are economically viable.

7.2.4 S13241 (d) Economic considerations.

There is no assimilative capacity with the TIN/TDS Task Force proposed antidegradation-based TDS and nitrate objectives. Therefore, there will be a mitigation requirement for TDS and nitrate for the recharge and direct reuse of recycled water and the recharge of imported State Project water. From the discussion in *Section 7.2.2 13241 (b) Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto* above, it is clear that the TDS concentration in the Chino Basin will increase regardless of the TDS objective and with or without recycled water use. In 1990, the Santa Ana Watershed Project Authority Basin Plan Upgrade Task Force (SAWPA BPUTF) retained Bill Dendy and Associates to analyze the economic benefits of various management programs including:

- Managing groundwater basins to achieve basin plan objectives for TDS and nitrate
- Managing groundwater basins to maintain current TDS and nitrate concentrations
- Construction of groundwater treatment systems to ensure that groundwater can be put to potable uses.

The results of Dendy's work are contained in the final report *Nitrogen and TDS Studies, Upper Santa Ana Watershed* (James M. Montgomery, 1991). In summary, the SAWPA BPUTF report concluded that the cost of managing groundwater quality to achieve the Basin Plan objectives or to stop degradation were $6.5 billion and $3.2 billion (present worth, 1991 dollars), respectively. The cost of producing potable water through the construction of groundwater treatment plants was more reasonable at about $1.9 billion. The SAWPA BPUTF report concluded that groundwater treatment for potable use was the best solution to manage future TDS and nitrate degradation of groundwater. This occurs because the TDS and nitrate concentrations in agricultural and urban return flows to groundwater are not regulated and the TDS and nitrate concentrations in groundwater will asymptotically approach their volume-weighted concentrations in the recharge.

Simply put, the TIN/TDS Task Force proposed management zones and associated antidegradation objectives will cause the mitigation expenses to occur without tangible benefits to anyone in the watershed. This economic burden will inhibit the maximum use of recycled water and recharge of imported water and reduce the scale of the groundwater treatment projects planned in the OBMP. The cost of replenishment for desalter or other groundwater treatment plants will make the use of these facilities non economical and delay or eliminate their construction thus promoting the expanded use of State Project water. Note that the expansion of Desalter 1 and construction of Desalter 2 would not be economically feasible if they had to bear the cost of full replenishment even with significant funding from Proposition 13.

Adopting the Watermaster and IEUA-proposed TDS and nitrate objectives will lower the cost of OBMP implementation and increase the amount of State Project water available throughout the state – a state wide economic and environmental benefit.

7.2.5 S13241 (e) The need for developing housing within the region; and (f) the need to develop and use recycled water.

The cities and counties in the Chino Basin area have determined a need for housing in the Chino Basin area, and have adopted general and specific plans that show substantial increases in housing in the Chino Basin as the land is converted from agricultural to urban uses. With the exception of the City of Chino, all these plans have been approved and have certified environmental documents. The water supply entities in the basin have responded to the water supply challenge posed by these plans by developing water supply plans that depend heavily on local and supplemental supplies. The OBMP is a watershed-scale program that addresses current and future demands through the development of large-scale recharge, groundwater treatment, regional conveyance, and conjunctive-use programs. The newly enacted Kuell (SB221) and Costa (SB610) bills require extensive documentation and demonstrations of water supply reliability prior to allowing new housing to occur. The direct use and recharge of recycled water are key to demonstrating and achieving reliability, and therefore to meeting the housing needs in the area. Per the OBMP, The demand for supplemental water will increase from about 70,000 acre-ft/yr in 2001 to about 122,000 acre-ft/yr in 2020 (OBMP Peace Agreement, 2000). Supplemental water consists of imported and recycled water. The imported water source is State Project water and is not a reliable source for all of the Basin's supplemental water demand. Recycled water is reliable. The OBMP water supply plan includes an average direct use of recycled water in 2020 of 26,000 acre-ft/yr and recharge of recycled water of about 20,000 to 30,000 acre-ft/yr. Recycled water use in the Chino Basin area is necessary for growth. Setting the TDS and nitrate objectives as proposed by Watermaster and IEUA will maximize the use of recycled water and the capacity of groundwater treatment thereby improving the reliability of water supplies for future growth in the region.

7.3 Water Quality Impacts to the Santa Ana River from Adopting the Watermaster and IEUA Proposed TDS and TIN Objectives.

RWQCB staff expressed a concern that raising TDS objectives in the Chino Basin area will cause degradation in the Santa Ana River and subsequently impact the Orange County Basin. The OBMP will likely improve the TDS and nitrate in the River over what would occur without the OBMP. A fundamental goal of the OBMP is to eliminate groundwater outflow from the basin to the Santa Ana River. The OBMP desalters, other lower basin groundwater treatment programs, and recharge management programs are the management tools available to Watermaster and IEUA to either eliminate groundwater outflow or to control it to de minimus levels.

Watermaster, IEUA, OCWD, and RWQCB staffs worked together to develop a monitoring program to characterize the relationship of the Santa Ana River and the Chino Basin. This monitoring program, referred to as the *Hydraulic Control Monitoring Program* (WEI, 2004a) was completed in 2004. This program is discussed in Section 8 of this State of the Basin Report. Based on the results of this monitoring program Watermaster and IEUA will fine tune groundwater production and recharge in the Basin to maximize yield and prevent outflow.

7.4 Watermaster and IEUA Commitments

The RWQCB required irrevocable commitments that ensure that Watermaster and IEUA will take appropriate actions that are triggered by ambient water quality and other time-certain conditions. These commitments are contained in the 2004 Basin Plan Amendment. Watermaster and IEUA commitments are described below. Failure to meet these commitments will cause the TDS and nitrate objectives to revert back to the antidegradation objectives, and Watermaster and IEUA will be required to mitigate TDS and nitrate loadings to groundwater based on the antidegradation objectives back to 2004.

7.4.1 TDS Effluent Limitation and Salinity Management

IEUA will limit the volume-weighted average TDS concentration in its effluent to less than or equal to 550 mg/L by: using low TDS source water supply for potable uses, selective desalting of either source water and/or recycled water, and minimizing the TDS waste increment. IEUA, Watermaster and the Chino Basin producers will always attempt to serve the lowest TDS supply available for its potable supply.

When necessary, IEUA, Watermaster and the Chino Basin producers will construct desalting facilities to either reduce the TDS concentration in source water and serve this water to its customers, or to reduce the TDS concentration recycled water.

Finally, IEUA and the Chino Basin producers will use best efforts to enact ordinances and development requirements that minimize the TDS waste increment (the average TDS increase that occurs through indoor uses and numerically equal to the average TDS concentration in recycled water minus the average TDS concentration in the source water supply).

7.4.2 TIN Effluent Limitation

IEUA will reduce the TIN concentration in its recycled water such that it will produce a recycled water effluent with a 12-month average TIN of 8 mg/L or less.

7.4.3 Desalter Construction

Watermaster and IEUA will initiate planning for expansion of the Chino Basin desalting program called out in the OBMP in 2004 and have a plan completed and adopted by the Court in 2005.

7.4.4 Maintenance of Hydraulic Control

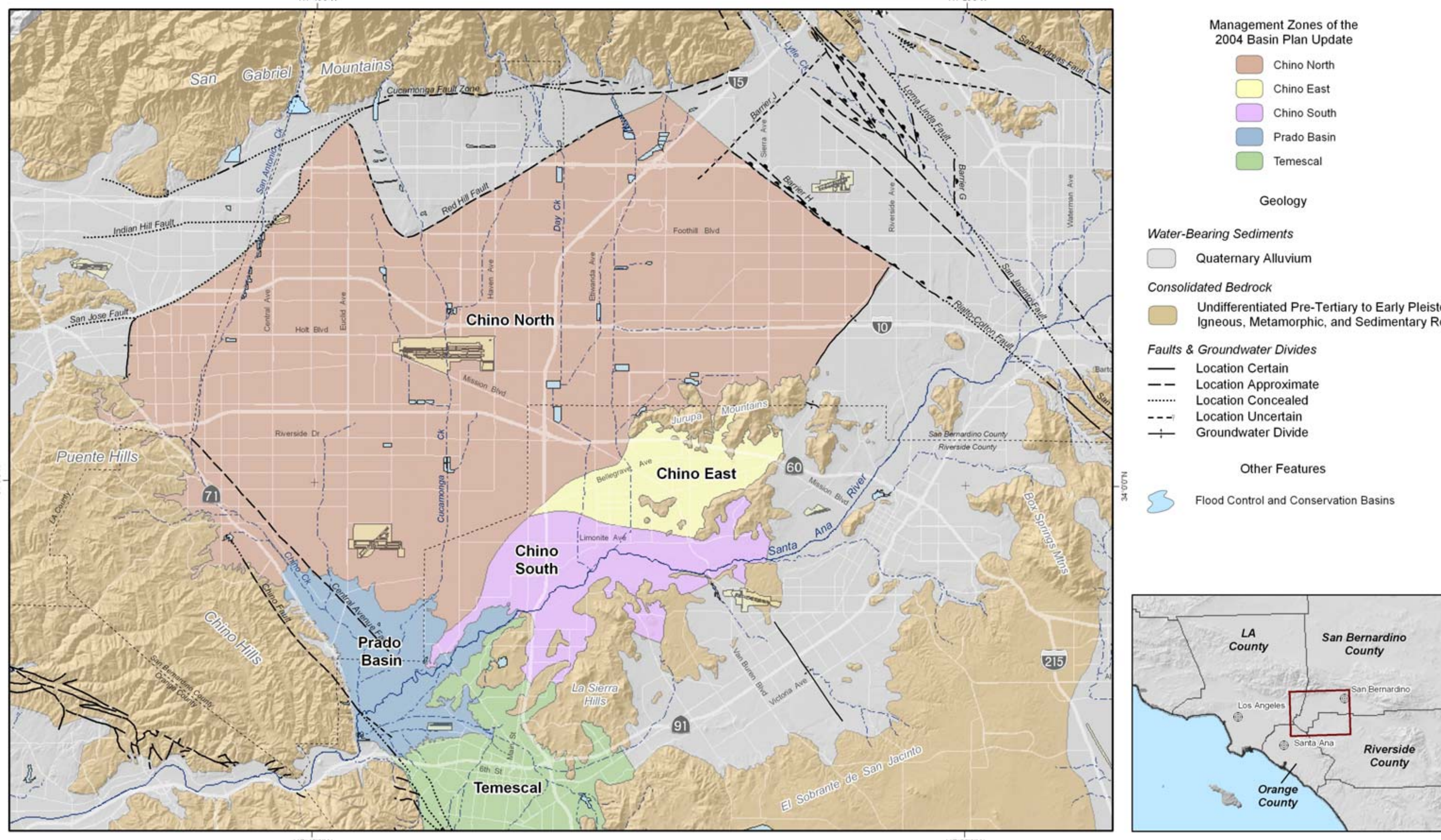
Watermaster and IEUA will monitor conditions in the southern Chino Basin to determine the state of hydraulic control and will modify recharge, production and/or treatment to ensure that hydraulic control is maintained and the effects of temporary losses of hydraulic control are mitigated.

7.4.5 Monitoring

Watermaster and IEUA commit to conducting and funding monitoring activities to enable the determination of ambient TDS and nitrate concentrations in groundwater in the Chino Basin, and to cooperate with the RWQCB in the sharing of monitoring data consistent with IEUA and Watermaster policies.

7.5 Status of Maximum Benefit Proposal and the Basin Plan Amendment

The maximum benefit proposal described above was formally incorporated into the 2004 Basin Plan Amendment and was approved by the Santa Ana Regional Board in February 2004. The State Water Resources Control Board approved this amendment in September 2004 and the Office of Administrative Law gave its approval in December 2004. The amendment was sent to the US Environmental Protection Agency for their review and approval. The EPA review and approval applies to Clean Water Act requirements and from a regulatory perspective will have no practical impact on the TDS and nitrate objectives. The Basin Plan Amendment, as it pertains to managing the Chino Basin, is now in effect.



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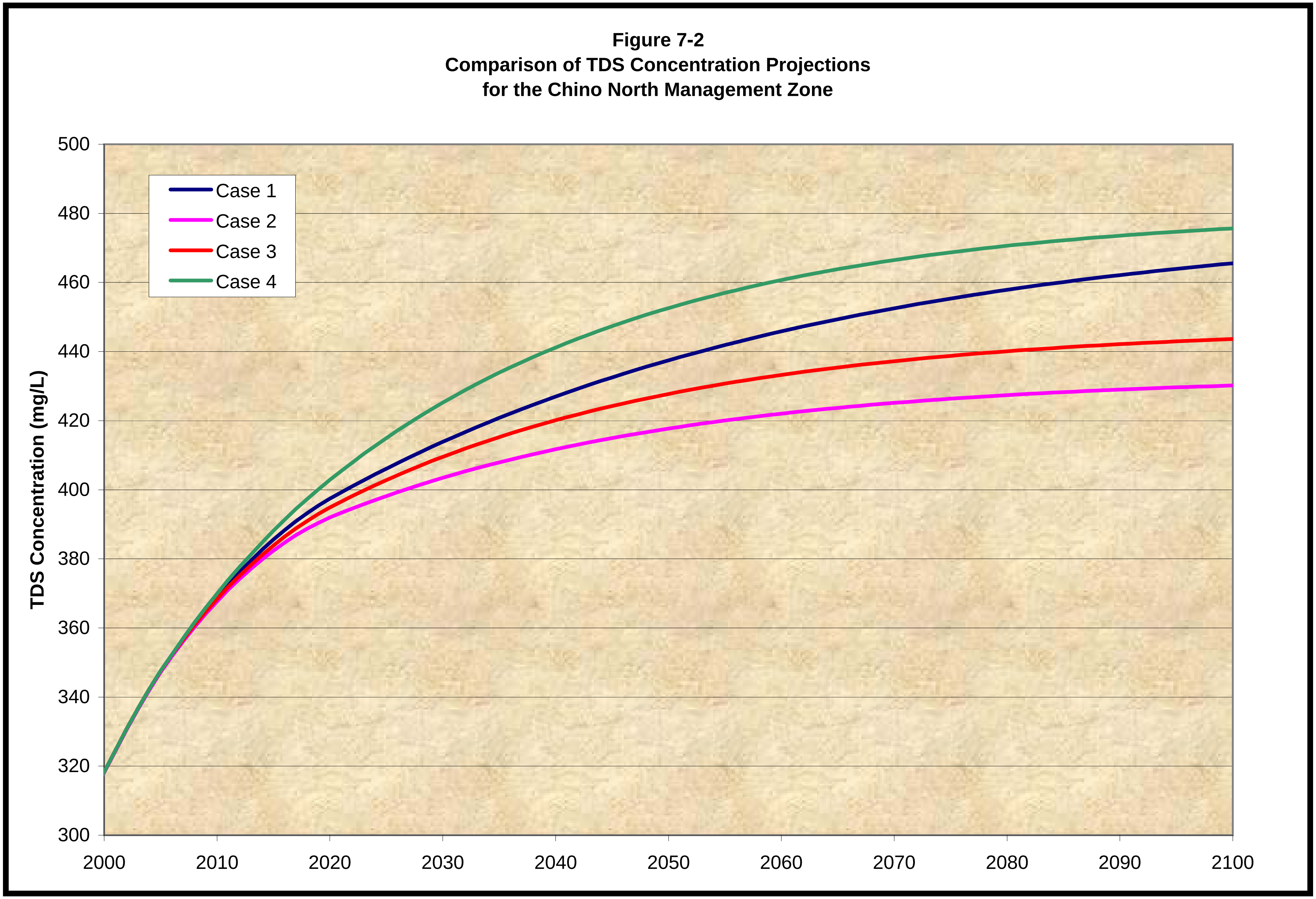
State of the Basin Report -- 2004

Water Quality Control Plan Management Zones

2004 Basin Plan Update

Figure 7-1



Figures 7-2 and 7-3.xls -- 20021017 Figure 7-2
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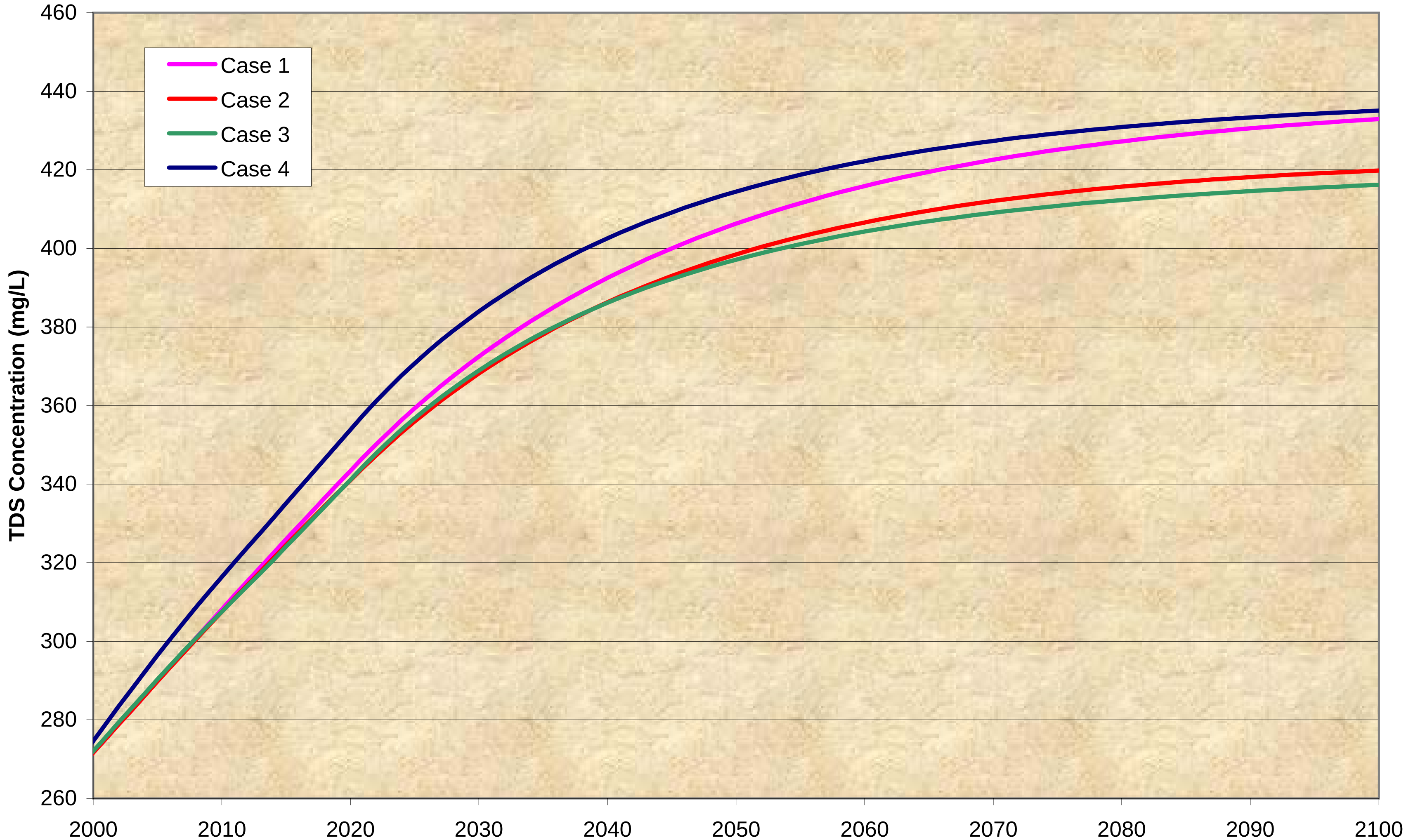
Figure 7-3
Comparison of TDS Concentration Projections
for the Cucamonga Management Zone



8. HYDRAULIC CONTROL MONITORING PROGRAM

8.1 Background

Under virgin conditions (pre- to early-1900s), groundwater flowing in a southerly direction from the northern part of the basin would rise to become surface flow in the southwestern part of the basin, ultimately discharging to the Santa Ana River. Since the onset of pumping and associated regional drawdown of groundwater-levels, this southerly flow of groundwater is thought to be intercepted by agricultural wells, and in the last few years, by desalter wells before rising as surface flow in significant quantities. Past investigations that used groundwater models to simulate flow and water quality have suggested that currently there is little or no discharge of groundwater originating in the upper part of the Chino Basin to the Santa Ana River. These same studies suggest that production in the southern part of the Chino Basin can influence the recharge of Santa Ana River flow in the southern part of the basin – the greater the production, the greater the recharge of Santa Ana River flow. The condition where groundwater is intercepted before discharging to the Santa Ana River is herein referred to as "hydraulic control." Data from existing groundwater-level monitoring programs suggest hydraulic control could be occurring, but are not sufficient to conclude that hydraulic control is actually occurring. The number and location of wells available to monitor groundwater-level and quality are not sufficient to determine conclusively the state of hydraulic control.

As part of the 2004 Basin Plan update, Watermaster and IEUA have proposed that the total dissolved solids (TDS) and nitrate objectives in the Chino North management zone be established based on maximum benefit and not on antidegradation (see Section 7). One of the criteria required by the Regional Water Quality Control Board (RWQCB) that must be satisfied to establish objectives based on maximum benefit is to demonstrate that raising the TDS objective to 420 milligrams per liter (mg/L) and the nitrate-nitrogen objective to 5 mg/L will not adversely impact the quality of the Santa Ana River or downstream beneficial uses. Demonstrating hydraulic control will show that downstream beneficial uses are not impaired by management activities in the Chino North management zone.

This section describes the assessment of hydraulic control of the Chino Basin. Four engineering or scientific showings can be used to corroboratively demonstrate the state of hydraulic control in the southern portion of Chino Basin:

- water chemistry
- hydrologic balance
- piezometric levels
- groundwater modeling

While any individual demonstration may not be adequate to demonstrate complete containment, all four elements can be combined to assess the state of hydraulic control and to optimize the management of the basin to maximize yield and reduce discharge to the Santa Ana River, and subsequent outflow of poor quality groundwater at Prado Dam.

Achievement of hydraulic control, and data to demonstrate this, is important to Watermaster, IEUA, Orange County Water District (OCWD), and the RWQCB. The specific issues of each of the above entities with regard to hydraulic control are:

- **Maximize/maintain basin yield.** Watermaster included yield maximization by hydraulic control in the OBMP. The OBMP Desalter Program currently being implemented is an important element of yield maximization. The desalter wells are located at the down-gradient end of the Chino Basin, near the Santa Ana River. The current desalter capacity of 8 mgd will be expanded to 20 mgd by 2005, and will reach 40 mgd between 2010 and 2015. One objective of the desalter program is to minimize or eliminate groundwater outflow thereby maintaining or increasing yield.
- **Minimize/eliminate loss of stored water.** Watermaster, IEUA, and Chino Basin producers either store or will store supplemental and native water in the basin. These entities want to minimize the loss of stored water from the Chino Basin to protect the investments of the producers and minimize the importation of State Project Water.
- **Protect Santa Ana River water quality.** All entities want to protect the quality and beneficial uses of the Santa Ana River through hydraulic control. Watermaster and IEUA have committed to hydraulic control in recent California Environmental Quality Act (CEQA) documents as a means to protect and prevent significant impacts to Santa Ana River water quality.
- **Protect riparian habitat.** OCWD has invested in the construction and maintenance of riparian habitat in the Prado Basin area and is concerned that Chino Basin pumping patterns that maintain hydraulic control or that depresses groundwater levels in the riparian areas may harm riparian vegetation. Watermaster and IEUA have committed (in recent CEQA documents) to monitoring the effects of hydraulic control and desalter production on riparian vegetation.

8.2 Activities and Accomplishments to Date

Watermaster, IEUA, OCWD, and the RWQCB conducted a series of meetings beginning in Summer 2002 concerning this Hydraulic Control Monitoring Program (HCMP). These agencies are hereafter referred to collectively as the HCMP technical group. The HCMP technical group is implementing the activities described in this report to determine the state of hydraulic control in the lower Chino Basin. The monitoring and analytical activities described herein are phased in and modified over time as necessary to provide management-level decision support information. Once the Basin Plan Amendment is approved by the Office of Administrative Law (OAL), regular meetings will be held and quarterly progress reports will be prepared by Watermaster staff (with dissenting and supporting comments attached by the IEUA and OCWD, as warranted) for submittal to the RWQCB. These progress reports will describe the status of activities (what was scheduled to occur, what occurred, variances to the schedule, and what is expected to occur in the next quarter), data collected during the period, and analysis of the data. At some time in the future, the reporting frequency could be relaxed to once per year, if appropriate. Watermaster and IEUA will use the information produced in this effort to revise basin management activities that may include: expansion/curtailment of recycled water use, increasing/decreasing groundwater production in the southern part of the basin, expansion/reduction of storage programs, and others. The RWQCB will use this information to regulate water-recycling activities conducted by IEUA.

8.2.1 HCMP Work Plan

The HCMP Work Plan was submitted as Draft in July 2003. OCWD commented on the work plan, WEI addressed the comments, and the work plan was published as Final in May 2004. The HCMP Final Work Plan (WEI, 2004a) describes basin-wide geology/hydrogeology and groundwater quality, and discusses the proposed tasks in the HCMP. The individual tasks presented in the work plan can be used to corroboratively demonstrate hydraulic control (or not).

8.2.2 Groundwater Elevation and Water Quality Data

8.2.2.1 Define the Study Area

The area in which monitoring is required (monitoring area) is the portion of the Chino Basin bounded by the Santa Ana River to the south, including the Prado Basin and the area of the desalters' estimated drawdown of five feet or greater (the estimated drawdown of five feet or greater is shown on Figure 4.3-18 in the Draft Subsequent Environmental Impact Report (EIR) for the Chino I Desalter Expansion and Chino II Desalter Project, prepared for the Chino Basin Desalter Authority by Tom Dodson and Associates and RBF Consulting, November 2001). The study area is shown in Figure 8-1.

8.2.2.2 Selection of Key Wells

As part of the work plan development, key wells were selected to characterize groundwater flow and quality in the southern portion of the basin, near the desalter well fields. Watermaster is implementing a key well monitoring program for water level measurements (Figure 8-2). The criteria used to select these wells were:

- Wells in the key well program require a spatial distribution such that water elevation contour maps drawn using data from only these wells are comparable to a map that used data from all wells in the following respects:
  - regional (study area) gradients are comparable, and
  - local pumping depressions are represented by the key well program.
- Wells with construction information (perforated intervals) are selected preferentially over other wells.
- The time history of water level at a well is compared to those at adjacent or nearby wells to determine if there are differences in responses to aquifer stresses over time that may indicate that the adjacent wells are perforated in different aquifer zones, especially on the southwest side of Chino Basin. In that situation, both wells would be retained in the key well program.
- The density of key wells near the desalter well fields would be greater than outlying areas, given that hydraulic gradients are expected to be steeper near the desalter well fields.
- All private wells have access ports for groundwater level sounders and that reference points are marked and well documented.

Key wells were also selected for the water quality monitoring program. The steps taken in determining the key wells (the groundwater quality key wells are shown in Figure 8-3) were:

- The basin was divided into a grid, with each cell being 2000 square meters (m^2).
- For each grid cell, the average TDS and NO_3 values were calculated (using the last five years of available data).
- The water quality of each individual well was examined. Wells most closely matching the average constituent concentrations were chosen as representative. One to two wells in each grid square were retained. Preference was given to wells with the following characteristics:
  - Known construction;
  - Choice as a groundwater level key well;
  - Likelihood of surviving the regional development.
- Basin-wide TDS and NO_3 arithmetic averages were recalculated using just the key wells and compared to the total basin arithmetic averages. New maps were made representing the water quality conditions of the key wells and qualitatively compared to the original basin maps. See Figures 4-2 through 4-7 for locations of wells with maximum concentrations of TDS and NO_3.

The USGS, as part of the National Water-Quality Assessment (NAWQA) Program, installed a series of shallow monitoring wells along Reach 3 of the Santa Ana River. These wells (shown on Figure 8-2) will be incorporated into the groundwater level and quality key well programs. Watermaster staff has equipped these wells with pressure transducers and the wells are being sampled on a monthly basis for the first year. Some of these wells, however, were destroyed by heavy rain storms and flooding in Fall 2004. Watermaster has repaired the three damaged wells at the Horse Staging Area.

8.2.2.3 Collection of Groundwater Samples

Figure 4-1 shows the locations of all the wells with water quality data. The groundwater quality key wells (shown in Figure 8-3) are sampled every two years. Half of the approximate 111 key wells are sampled each year, so that each well is sampled every two years.

The field activities for this project are in general accordance with the guidelines established in California EPA (1994) and US EPA (1998). These protocols are followed to ensure the collection of high-quality and well-documented data.

Groundwater samples are tested for the following analytes:

Analytes	Method	Wells
Major cations: K, Na, Ca, Mg, Fe	EPA 200.7	All
Major anions: Cl, SO_4, NO_2, NO_3	EPA 300.0	All
Apparent Color	SM 2120B	All
ClO_4	EPA 314	All
Hardness	SM 2340B	All

Analytes	Method	Wells
HCO_3, CO_3, OH	EPA 310.1/SM 2320B	All
NH_3	EPA 350.1	All
Odor	SM 2150B	All
P	EPA 365.1	All
pH	EPA 150.1/SM 4500-HB	All
TDS	EPA 160.1/SM 2540C	All
Total Kjeldahl Nitrogen (TKN)	EPA 351.4	All
Turbidity	EPA 180.1	All
VOCs	SM 8260	Wells within or Near the Chino Airport and South of Ontario Airport Plumes

8.2.3 Surface Water Flow and Water Quality Data

Review of Santa Ana River Watermaster reports show that baseflow increases in the Santa Ana River at Prado Dam by about 80 cubic feet per second (cfs) during the winter. Recycled water and other non-tributary discharges to the River cannot account for this change in flow. The increase in baseflow discharge could be caused by a decrease in evapotranspiration by riparian vegetation in Prado Reservoir and near the river, by changes in groundwater management in either or both Chino and Temescal Basins (seasonally reduced groundwater pumping, increased recharge, changes in pumping patterns, *et cetera*) or some combination of all three. An assessment of evapotranspiration will be conducted to determine whether seasonal baseflow changes at Prado can be accounted for by evapotranspiration (Section 8.4).

8.2.3.1 Selection of Surface Water Stations

The surface water stations are listed in Table 8-1 and shown in Figure 8-4. Stations shaded in yellow are active USGS gauging stations and are included in the HCMP, along with the *ad hoc* stations, the recycled water discharge points, and the non-tributary flows.

8.2.3.2 Measurement of Flow at Stations on Routine Basis

Watermaster had contracted with the USGS to conduct the initial gauging measurements. USGS also trained Watermaster staff to conduct the stream flow measurements. Watermaster staff and its consultant conducted a site visit to the *ad hoc* stations to assess their suitability for stream gauging. The *ad hoc* stations are gauged by Watermaster staff every two weeks year-round for at least the first year, weather, and safety permitting. The permanent USGS stations are measured daily using transducers.

8.2.3.3 Grab Surface Water Samples

Watermaster staff collects grab samples at the *ad hoc* stations and at the permanent USGS stations monthly. The samples at the *ad hoc* stations are coordinated with the USGS stream gauging and occur at the same time (every other stream flow measurement).

Concurrent with USGS NAWQA monitoring well sampling, Watermaster staff collect grab samples from the Santa Ana River at stations located approximately 100 meters (310 feet) upgradient of the wells. Initially, at each station one discrete surface water sample was collected at approximately 25, 50, and 75 percent of the distance measured along a transect oriented normal to river flow (a total of 3 discrete samples at each station). The samples for each station were composited in the laboratory for chemical analysis. Analytical results showed no significant difference in the samples collected along the transect. Therefore, all subsequent samples are collected only at 50% or half way across the river.

Surface water samples are tested for the following analytes:

Analytes	Method	Surface Water Stations
Major cations: K, Na, Ca, Mg, Fe	EPA 200.7	All
Major anions: Cl, SO_4, NO_2, NO_3	EPA 300.0	All
Apparent Color	SM 2120B	All
ClO_4	EPA 314	All
Hardness	SM 2340B	All
HCO_3, CO_3, OH	EPA 310.1/SM 2320B	All
NH_3	EPA 350.1	All
Odor	SM 2150B	All
P	EPA 365.1	All
pH	EPA 150.1/SM 4500-HB	All
TDS	EPA 160.1/SM 2540C	All
Total Kjeldahl Nitrogen (TKN)	EPA 351.4	All
Turbidity	EPA 180.1	All

8.2.3.4 Collection of Flow and Surface Water Quality Data from Cooperating Agencies

Data are collected from the permanent USGS stations routinely from the following website: http://nwis.waterdata.usgs.gov/usa/nwis/discharge. Discharge data are collected from the Publicly-Owned Treatment Works (POTW) operators on an on-going basis.

8.2.4 Characterization of Hydraulic Control near the Desalter Well Fields

Watermaster, IEUA, and OCWD concur that the hydrogeology of the lower Chino Basin needs to be better characterized for proper interpretation of groundwater monitoring data. Watermaster staff has recently revised its conceptual model of the entire Chino Basin for the Watermaster-IEUA-MWDSC dry-year yield program and has built a new three-dimensional groundwater model to simulate, among other things, the effect of groundwater storage on basin outflow.

Watermaster has committed to characterizing the state of hydraulic control near the existing and proposed Desalter well fields in the southern Chino Basin. To support this effort, a hydrogeologic characterization investigation was completed in this region (see Section 2.3.3). This investigation resulted in the creation of key well monitoring networks of existing wells for water quality and water levels, and the selection of nine (9) sites for the construction of new, nested monitoring wells. Monitoring of water quality and piezometric head at all wells in these monitoring networks will be critical to the determination of hydraulic control near the Desalter well fields.

The following tasks have been or are being completed to establish and augment the above-mentioned key well monitoring networks.

8.2.4.1 Video Logging of Private Wells South of Desalters

Groundwater levels and groundwater quality data have been collected at existing production wells within the south Chino Basin since 1999 as part of the implementation of the OBMP. Many of these wells are part of the HCMP key well monitoring networks (see Section 8.2.2). However, most of these wells are private and information pertaining to well construction and well screen depths are scarce. In August and October 2003, Watermaster video logged 10 of these wells to verify well screen depths, rendering groundwater data collected at these wells useful for hydrogeologic characterization and determination of hydraulic control. The following wells were video logged:

Well ID	Screened Interval, Approximate (Feet below top of casing)
60051	184 to 260 (perforations not clearly seen)
600197	150 to 325
600221	115 to 267
600331	130 to 327
600612	504 to 859
600637	75 to 81
600668	not able to video log
600699	no perforations observed
3600455	no perforations observed
3601410	107 to 128

8.2.4.2 Nested Monitoring Well Construction

Nine nested monitoring wells are currently being drilled and completed near the desalter well fields as part of the Hydraulic Control Monitoring Program. These wells will be used to help determine the effectiveness of the desalter wells as a hydraulic barrier. Each well will be completed in such a manner as to isolate two or three water-bearing zones encountered at depths ranging from approximately 100 to 600 feet below ground surface (bgs). The wells are designed to allow discrete analyses to be conducted on the individual water-bearing zones. Monitoring well boreholes are being drilled to final diameter in one pass, without the use of pilot boreholes, to approximately 300-600 feet bgs for lithologic logging and geophysical logging purposes.

Two nested monitoring wells are sited along a flow line that passes through the Chino-1 Desalter well field. The objective of these wells is to document the development and existence of a local "trough" or depression in the piezometric surface, for both the shallow and deep aquifer systems, as a result of Desalter pumping. The monitoring wells will be used to better characterize the hydrogeology in this area, including the hydrostratigraphy, the vertical and horizontal piezometric distribution, and the groundwater quality. Subsequent monitoring at these wells and other nearby wells, along with groundwater modeling efforts, will determine if hydraulic control is occurring in the vicinity of the Chino-1 Desalter well field, or will determine how desalter well field production should be changed to ensure hydraulic control.

Seven (7) nested monitoring wells are sited to the west, south, and east of the existing and proposed Desalter well fields. The objective of these wells is to document the development and existence of a regional depression in the piezometric surface, for both the shallow and deep aquifer systems, as a result of Desalter pumping. If the water level data collected from these (and other) monitoring wells depicts a regional Desalter capture zone that draws groundwater from beneath the Santa Ana River and Prado Basin, then it is likely that groundwater is not rising to become surface flow in these areas. The nine nested monitoring well locations are shown in Figures 8-2 and 8-3.

As of January 2005 four monitoring wells have been drilled and completed (MW-2, MW-5, MW-8 and MW-9). MW-2, MW-5 and MW-8 were the first to be installed, as the property owner, Lewis Group, requested construction occur as soon as possible so that delays in site development could be avoided. MW-9 was drilled and completed on Jurupa Unified School District Property to coincide with the winter school recess.

The five remaining wells will be drilled during the first quarter of 2005. These wells will be drilled in the following order: MW-7, MW-3, MW-6, MW-4 and MW-1.

The wells are being constructed in compliance with the latest edition or supplement of: State of California Water Well Standards, Bulletin No. 74-81 dated December 1981 and Bulletin No. 74-90 dated June 1991, local modifications to these Standards, and Sections 13800 through 13806 of the California Water Code.

8.2.4.3 Property Owners and Well Site Access

Current ownership of the monitoring well sites has been determined and the property owners contacted. Stakeholders will negotiate purchase agreements or right of entry agreements with the property owners to obtain long-term access to the sites. The following summarizes the well site property owners:

Well Identification	Property Owner
MW-1	Chino Airport
MW-2	Lewis Group
MW-3	Inland Empire Utilities Agency
MW-4	Orange County Flood Control District
MW-5	Lewis Group
MW-6	Orange County Water District
MW-7	Jurupa Community Services District

Well Identification	Property Owner
MW-8	Lewis Group
MW-9	Jurupa Unified School District

8.2.4.4 Plans and Specifications

Detailed plans and specifications were prepared for the monitoring well construction project. Following the site selection process, draft plans and specifications were completed and submitted to the stakeholders and permitting agencies for review. Review comments were incorporated into the final plans and specifications.

8.2.4.5 Selected Contractor

A bid package containing bidding instructions, contract documents, and the final plans and specifications were prepared and submitted for public bidding. Proposals were evaluated and a well drilling contractor was selected based on qualifications, experience, and best value to the stakeholders. Three bids were received for the well construction and Beylik Drilling, Inc. was selected.

8.3 Results of the Hydraulic Control Monitoring Program

As mentioned previously, four engineering or scientific showings can be used to corroboratively demonstrate whether or not hydraulic control is occurring. The following results present two of the four lines of evidence: hydrologic balance and groundwater modeling.

8.3.1 Estimation of Hydraulic and Hydrologic Balance of the Lower Chino Basin

Two methods were used to evaluate the past and current, hydraulic and hydrologic balance in the lower end of the Chino Basin. The first of these methods is a review of available hydrologic studies that were done in support of the 1969 Judgment in OCWD *vs*. Chino *et al.* and the subsequent Santa Ana River Watermaster reports that are products of the 1969 Judgment. The second approach is based on groundwater model calibration and projection performed by Watermaster. Both of these approaches are independent of each other.

8.3.1.1 Santa Ana River Judgment Accounting

The Santa Ana River was adjudicated in the 1960s and a stipulated judgment was filed in 1969 (OCWD vs. City of Chino, *et al.* Case No. 117628, County of Orange). Since that time, the Santa Ana River Watermaster has compiled annual reports that contain estimates of all significant discharges to the Santa Ana River. Specifically, the Santa Ana Watermaster tabulates these discharges for the River near the Riverside Narrows (actually at the Metropolitan Water District of Southern California [MWDSC], Lower Feeder Crossing) and at below Prado Dam. From these tabulations, the Santa Ana River Watermaster computes the storm water, baseflow, and non-tributary discharges, and determines the obligations of the parties to the Judgment. The Santa Ana River Watermaster began submitting its reports for water year 1970/71 and has compiled annual reports since then (a total of 33).

The discharge data within the Santa Ana River Watermaster annual reports can be used to develop a hydrologic budget for the Santa Ana River between Riverside Narrows and Prado Dam. The demonstration that will be attempted will be to determine if there is a reach-wide net loss in baseflow from the Santa Ana River. Baseflow, as used herein, consists of rising groundwater, recycled water, and other non-tributary discharges to the river. Baseflow is estimated as the difference between total discharge and storm water discharge. Figure 8-5 shows the locations of two USGS gauging stations located near the Narrows and below Prado Dam. Figure 8-5 also shows the location of recycled water facilities that discharge either directly to the Santa Ana River or to tributaries of the Santa Ana River. With the exception of the City of Corona, all discharges are directly to surface water. Historically, Corona has discharged to ponds located along Temescal Creek. After recharge, the recycled water either becomes surface water discharge at Prado or is consumed by riparian vegetation in the Prado area. Beginning in October 1998, Corona began to discharge about 7 million gallons per day (mgd) directly to Temescal Creek and eliminated the use of some of its ponds in the Prado reservoir area where the depth to water was less than 10 feet bgs.

Table 8-2 lists the storm and baseflow discharges for the Santa Ana River coming into the basin at Riverside Narrows, leaving the basin at below Prado dam and the various discharge components in the reach between San Jacinto fault and Prado dam. The Santa Ana Watermaster estimates the storm water component of the hydrograph and subtracts the storm water discharge from the total observed discharge to obtain a trial baseflow. In the 1969 Judgment, baseflow, by definition, consists of the rising groundwater and recycled water discharged to the Santa Ana River from dischargers in the service areas of the San Bernardino Valley Municipal Water District, Inland Empire Utilities Agency, and the Western Municipal Water District. The baseflow and storm flow contributions are plotted in Figures 8-6 and 8-7 for the Santa Ana River at Riverside Narrows and below Prado dam, respectively.

Table 8-2 includes an accounting of the Santa Ana River discharge coming into the Chino Basin at Riverside Narrows and leaving the basin at Prado dam. Note that the subsurface inflow into the Chino Basin at the Riverside Narrows is negligible because the Riverside Narrows is a shallow bedrock narrows that forces groundwater in the Riverside Basin to rise and become surface flow. There is negligible subsurface outflow from Chino Basin under the Santa Ana River because Prado dam has been constructed in a similar bedrock narrows and the dam sits on a grout curtain that was constructed to eliminate underflow. Given these subsurface flow assumptions, the net rising groundwater from the Chino Basin to the Santa Ana River can be calculated from the Santa Ana River Watermaster tabulations using the following equation:

$$Q_{RW} = Q_{BF,\ Prado} - Q_{BF,\ Riverside\ Narrows} - \Sigma Q_{RECi} - \Sigma Q_{ONTDj}$$

where:
Q_{RW} is the net rising water from the Chino Groundwater Basin to the Santa Ana River
$Q_{BF,\ Prado}$ is the baseflow at below Prado Dam
$Q_{BF,\ Riverside\ Narrows}$ is the baseflow at Riverside Narrows
Q_{RECi} is the i^{th} recycled water discharge to the Santa Ana River in the Chino Basin
Q_{ONTDj} is the j^{th} other non-tributary discharge to the Santa Ana River in the Chino Basin

Estimates of the net rising water contribution to surface discharge (column 15) are shown in Table 8-2 for the period 1970/71 to 2002/03. In all but two years (1980/81 and 1982/83), the net rising water is negative which means that the Santa Ana River recharges more baseflow into the Chino Basin than it receives as rising groundwater from the Chino Basin. The net rising groundwater ranges from a high of 20,200 acre-ft/yr to a low of –23,800 acre-ft/yr and averages about –10,600 acre-ft/yr. Over the 1970/71 to 2002/03 period the total rising groundwater was about –351,000 acre-ft. The time history of rising groundwater is presented graphically in Figure 8-8.

Table 8-3 is similar to Table 8-2 except that it shows the accounting at a monthly time step for the reach between Riverside Narrows and Prado dam for the fourteen-year period of 1989/90 through 2002/03. The rising water values are also presented in Table 8-4 and Figure 8-9. Review of Table 8-4 and Figure 8-9 show that the net rising water is almost always negative through the year with some positive values occurring generally in the winter months January through March. Figure 8-10 is a plot of the average net rising water by month for the period 1989/90 through 2002/03 and for 1998/99 through 2002/03. This plot illustrates the average rising water pattern during the year and suggests in the short term that there may be an increasing trend in baseflow losses throughout the year including the January through March period.

Note that some of the Santa Ana River storm water discharges entering the Chino Basin at Riverside Narrows and storm water produced in the Chino Basin also recharge the Chino Basin in the Santa Ana River flood plain and lower tributaries.

In summary, this review of the Santa Ana River Watermaster data shows that the Chino Basin receives more recharge from Santa Ana River baseflow than it yields as rising groundwater to the River. This is a necessary but not sufficient condition to verify hydraulic control.

8.3.1.2 Groundwater Modeling of Current and Future Conditions

WEI developed a new groundwater model (hereafter, the 2003 Watermaster Model) for the Chino Basin in support of the Chino Basin Watermaster, Inland Empire Utility Agency (IEUA), and Metropolitan Water District of Southern California (Metropolitan) Dry-Year Yield (DYY) Program. The 2003 Watermaster Model was used to evaluate the magnitude of groundwater level and storage changes throughout Chino Basin, the change in direction and speed of specific known water quality anomalies, and the storage losses from the DYY Program. This was accomplished by first determining a baseline OBMP scenario, second by simulating the baseline OBMP and DYY scenarios, and third by comparing the model results of the baseline OBMP and DYY scenarios. The planning period used in this analysis consisted of a 25-year period ranging from October 2003 through September 2028. This period corresponds to the 25-year period of the DYY Program.

8.3.1.2.1 Baseline OBMP Scenario

The baseline scenario is based on a modified version of the water supply plan from the OBMP Implementation Plan. The water supply plan from the Implementation Plan contains future groundwater production plans for all producers in the Chino Basin. Black and Veatch modified the water supply plan for the water purveyors that are participating in the DYY Program and WEI used the water supply plan from the Implementation Plan for the remaining producers.

Table 8-5 shows the baseline groundwater production time history. Groundwater production in the Basin ranges from 197,000 acre-ft/yr in 2003/2004 to about 210,000 acre-ft/yr in 2019/2020 and thereafter. Watermaster's replenishment obligation was estimated using the following assumptions pursuant to the Judgment and the Implementation Plan:

- The initial increase in stormwater recharge that is anticipated from the Chino Basin Facilities Improvement Plan is about 12,000 acre-ft/yr with a goal of about 20,000 acre -ft/yr. To be conservative, the increase in stormwater recharge was assumed to be 12,000 acre -ft/yr.
- OBMP desalter capacity is increased from the current level of 8 million gallons per day (mgd) in 2002/2003 to 40 mgd as per the water supply plan from the Implementation Plan. Half of the production from the desalters will come from decreased rising water and new induced recharge from the Santa Ana River.
- The Judgment allows a 5,000 acre -ft/yr overdraft of Chino Basin through 2017.

Table 8-5 contains the replenishment obligation pursuant to the Judgment and the Implementation Plan, which ranges from about 30,000 acre-ft/yr in 2003/2004 to about 34,000 acre-ft/yr in 2019/2020 and is constant thereafter. An analysis of actual recent production in the Chino Basin indicates that the production and replenishment estimated in Table 8-5 may be higher than will actually occur in first few years of the baseline scenario. For consistency with the OBMP planning documents, the production and replenishment estimates in Table 8-5 were used.

The locations and magnitude of recharge shown in Table 8-5 were based on the requirements of the Peace Agreement to balance recharge and discharge in every area and sub-area. This requirement must be met over a period of time, which was assumed herein as a long-term requirement. Thus, in an individual season or year there might not be a balance between recharge and discharge in an area, sub-area, or the Basin.

Balancing recharge and discharge may be critical to the management of the subsidence-prone area in the western part of the Chino Basin. Watermaster is currently involved in an investigation to develop a management program for this subsidence-prone area. Until that management program is developed, it is assumed that Watermaster replenishment and groundwater production would be managed such that groundwater levels would remain near or above current levels. Current groundwater levels were assumed to be the groundwater levels at the end of the calibration period of the 2003 Watermaster Model; the groundwater levels were from Fall 2001. In the rest of the Basin, replenishment would be managed to maximize desalter replenishment from a combination of reduced rising water to the Santa Ana River and increased streambed recharge from the Santa Ana River.

8.3.1.2.2 Hydrologic Balance and Storage

The hydrologic balance for the baseline scenario is shown by management zone (Figure 7-1) in Tables 8-6a through 8-6e. The hydrologic balance includes estimates of groundwater flow between management zones. Of particular interest is the groundwater flow from Chino North, Chino South, and Temescal MZs to the PBMZ and subsequent contributions to rising water at Prado Dam. The subsurface outflow from Chino North MZ to the PBMZ decreased over time by about 5,500 acre-ft/yr. The stream recharge in the Chino South MZ increased about 12,000 acre-ft/yr from whence it flows to the desalter well field. The 2003 Watermaster Model projected that the yield of Chino Basin will increase by about 17,500 acre-ft through the recharge plan described in Table 8-5 and the construction and operation of the desalters.

Table 8-7 lists the inflow components to the PBMZ and includes a reckoning of the volumes of rising water at Prado Dam from the inflowing management zones. These estimates were made by assuming that half of the stream flow recharge in the PBMZ contributes to rising water and that remaining rising water is allocated to the inflowing management zone based on the magnitude of groundwater inflow to the

PBMZ. For the baseline scenario, the average rising water contribution from the Chino North and Chino South MZs is estimated to be about 400 acre-ft/yr and 100 acre-ft/yr, respectively, or about 500 acre-ft/yr from the Chino Basin.

The total storage in the Chino Basin declined monotonically during the baseline scenario from a high of 5,940,000 acre-ft in Fall 2003 to 5,730,000 acre-ft in Fall 2028 – a decline of about 210,000 acre-ft. Figure 8-11 shows the estimated groundwater storage for the Chino Basin during the planning period. The modeling results suggest that the total storage in the Basin appears to be asymptotically approaching a level near 5,700,000 acre-ft. This decline in storage is necessary to induce the recharge of the Santa Ana River.

8.4 On-Going and Recommended Activities

8.4.1 Ancillary Studies

Two additional significant components of the water budget in the lower Chino Basin are groundwater pumping from private well owners and evapotranspiration losses from phreatophytes and riparian vegetation. These two studies are intended to provide additional data to help assess the state of hydraulic control.

8.4.1.1 Groundwater Production

Groundwater production from private wells and from the desalter wells is routinely collected, reviewed, and uploaded into Watermaster's relational database. These data will be used in the computation of hydrologic balance.

8.4.1.2 Vegetation Surveys

Phreatophytes are deep-rooted plants that obtain their water from the water table or the layer of soil just above it, while riparian vegetation refers to flora that are located on the bank of a natural watercourse, such as the Santa Ana River. Riparian woodlands and shrub lands occur in drainages, seepages, and riverine areas where water availability is high and is dominated by winter deciduous trees – willows, cottonwoods, alders, and sycamores. More than 95 percent of the riparian habitat historically occurring in southern California has been lost to agriculture, development, flood control, channel improvements, and other human caused impacts. Giant reed (Arundo donax) and salt cedar (Tamarix spp.) are non-indigenous plants that readily invade riparian channels in southern California, especially in areas that are disturbed. Arundo is very competitive, difficult to control, and generally does not provide either nesting or foraging habitat for native animals. It grows very quickly - up to 2 inches per day, is highly flammable, and re-sprouts rapidly after a fire. Because of these characteristics, once arundo invades a riparian area, it redirects the succession of the community towards pure stands of reed, usually through increasingly frequent fire events. Iverson (1999) states:

Not only does arundo out compete native plants, it uses about three times as much water as they do. There are no specific studies on the evapotranspiration rates of arundo. Horticulture experts, however, estimate arundo evaporates water at approximately the same rate as rice. This means that every acre of arundo uses about 5.62 acre-feet of water per year. Native species use only about two thirds this amount, 1.87 acre-feet per year. The water lost to evapotranspiration is water that would otherwise be available for groundwater recharge and ultimately drinking water supplies.

A GIS process termed "change detection" will be employed to monitor the riparian community in Prado Basin. The data utilized in change detection analysis includes (1) vegetation data collected by a botanist with a GPS receiver at various key locations in the field and (2) multi-spectral satellite imagery that covers the area of interest. These two data sets are then combined in a GIS environment to provide a map of the extent and health of the various vegetation types for a particular point in time. Same data sets from future times can be compared to the original data set to produce a map of vegetation change over the period of comparison.

These surveys will be repeated every three years for at least 15 years. This record of riparian vegetation surveys will not only allow for an accounting of water consumption, but will allow the interested parties to assess the potential impacts to the health of the riparian community from basin management activities.

8.4.2 Groundwater Monitoring

Once the nine nested monitoring wells are installed, they will be monitored as part of the HCMP along with the existing desalter wells and nearby agricultural wells. The new monitoring wells will be equipped with dedicated pressure transducers with integrated data loggers and water quality monitoring probes. Piezometric level measurements and limited water quality data will be recorded in the new monitoring wells on a continuous basis. Piezometric level data will be recorded daily in the desalter wells and every two weeks in nearby agricultural wells. The new monitoring wells also will be equipped with dedicated sampling pumps to facilitate the collection of water quality samples. The new monitoring wells will be sampled quarterly and the samples will be analyzed at a State-certified laboratory for Title 22 compliance and other analytes.

8.4.3 Recommended Activities

An estimate of hydrologic balance of surface and groundwater would be accomplished by conducting sampling events at a regular frequency at key locations on the Santa Ana River, its tributaries, points of non-tributary discharge and at wells in the lower Basin. The purpose of monitoring water chemistry in surface and groundwater is to determine if groundwater from the Chino Basin is discharging as rising groundwater to the Santa Ana River. The general water chemistry of Chino Basin groundwater is different from the Santa Ana River. Native groundwater in the Chino Basin typically has a calcium-bicarbonate water character, while the Santa Ana River reflects the influence of tertiary wastewater in the baseflow of the river and has more sodium-chloride-sulfate character. The dry-weather discharge of the Santa Ana River in the Basin consists of rising groundwater from the Riverside Basin, recycled water discharged by publicly-owned treatment works (POTWs), and rising groundwater from the Temescal and Chino Basins. From time to time, other waters are discharged to the Santa Ana River, including Arlington Desalter water, SWP water, and groundwater pumped from the San Bernardino area.

These discharges will be identified and their chemistries will be characterized using Piper diagrams and a modification of the Piper method for time histories known as Water Character Index (WCI). WCI is a parameter that can be used to generally characterize water in terms of rations of major cations and anions. WCI is a unitless parameter that provides a numerical estimation of water character. WCI is used to assess the ionic distribution of constituents in a water sample. WCI is analogous to a trilinear or Piper diagram, which is a graphical means of displaying the ratios of the principal ionic constituents in water (Piper, 1944; Watson and Burnett, 1995). The utility of the WCI method, compared with a Stiff or Piper/trilinear diagram, is that many data points can be plotted as time histories for a given well or surface water station. The points can also be plotted to show aerial and spatial distributions of water character.

In addition to general water chemistry, Watermaster's database of groundwater quality along with new field data in the southern Chino Basin area will be queried to see if there are other naturally occurring or introduced constituents that can potentially be used as a tracer to determine if Basin groundwater is discharging to the Santa Ana River.

Table 8-1
Surface Water Monitoring Stations for the HCMP

USGS Gauging Stations					
Status	Number	Site Name	From	To	Approximate Count
Non	11066440	Santa Ana R A Mission Blvd at Riverside CA	2/1/1971	9/30/1982	4019
Active	11066460	Santa Ana R A MWD Crossing CA	3/9/1970	Present	11529
Non	11066478	Riverside WQCP Weir No 1 CA	10/2/1972	10/28/1981	3179
Non	11066479	Riverside WQCP Weir No 2 CA	10/1/1972	10/7/1981	3201
Non	11066480	Riverside Water Quality Control Plant CA	10/1/1965	9/30/1981	5844
Non	11066500	Santa Ana R A Riverside Narrows Nr Arlington CA	10/1/1928	9/30/1973	16436
Non	11066550	Sheehan D A Rn Nr Arlington CA	10/1/1963	9/30/1968	1462
Non	11066950	Day C Div Nr Etiwanda CA	10/1/1965	10/22/1970	1201
Non	11067000	Day C Nr Etiwanda CA	10/1/1928	9/30/1972	16071
Non	11067001	Day C Nr Etiwanda CA.+ CN CA	10/1/1950	9/30/1971	7670
Non	11067890	Santa Ana R A Prado Park Nr Corona CA	3/9/1971	9/30/1980	3494
Non	11068000	Santa Ana R A Auburndale Br Nr Corona CA	10/1/1960	9/30/1968	1985
Non	11072000	Temescal C Nr Corona CA	10/1/1928	6/30/1980	18901
Active	11072100	Temescal C Above Main St A Corona CA	10/1/1980	Present	7237
Non	11072200	Temescal C A Corona CA	1/1/1968	9/30/1980	2557
Non	11073000	San Antonio C Nr Claremont CA	3/11/1901	9/30/1972	25901
Non	11073001	San Antonio C Nr Claremont + CN CA	3/11/1901	9/30/1972	26027
Non	11073200	San Antonio C Below San Antonio Dam CA	10/1/1962	9/30/1980	6575
Active	11073300	San Antonio C A Riverside Dr Nr Chino CA	12/19/1998	Present	1017
Active	11073360	Chino C A Schaefer Avenue Nr Chino CA	10/1/1969	Present	11688
Non	11073440	Chino C Nr Chino CA	1/1/1968	9/30/1969	639
Non	11073470	Cucamonga C Nr Upland CA	1/1/1929	9/30/1975	17074
Active	11073493	W Br Cucamonga Channel Above Ely Perc Basin A Ontario	10/1/1996	Present	1826
Active	11073495	Cucamonga C Nr Mira Loma CA	2/1/1968	Present	11788
Non	11073500	Chino C Nr Prado CA	1/1/1929	9/30/1940	4291
Active	11074000	Santa Ana R Below Prado Dam CA	10/1/1940	Present	22280
Ad Hoc Gauging Stations					
Status		Site Name			
New		Santa Ana River at Van Buren			
New		Santa Ana River at Etiwanda			
New		Santa Ana River at Hamner			
New		Santa Ana River at River Road			
New		Hole Lake Outflow Channel near Arlington			
Recycled Water Discharge Points					

Table 8-1
Surface Water Monitoring Stations for the HCMP

USGS Gauging Stations					
Status	Number	Site Name	From	To	Approximate Count
		Site Name			
		City of Corona -1			
		City of Corona -2			
		IEUA			
		WRRWP			
		City of Riverside - 1			
		City of Riverside - 2			
		Non-Tributary Flows			
		Site Name			
		Arlington Desalter			
		OC-59 Turnout			
		Bunker Hill Groundwater			

Stations shaded in yellow are active USGS gauging stations and will be included in the HCMP, along with the ad hoc stations, the recycled water discharge points, and the non-tributary flows.

Table 8-2
Estimate of Net Rising Groundwater to the Santa Ana River Between San Bernardino and Prado Dam
(acre-ft/yr)

Year	Santa Ana River at Riverside Narrows								Santa Ana River below Prado Dam								
	(1) Groundwater Discharge from Bunker Hill	(2) Recycled Water Discharges	(3) Non-Tributary Discharges	(4)=(6)-(5) Non-Storm Discharge at Riverside Narrows	(5) Storm Discharge at Riverside Narrows	(6) Total Discharge at Riverside Narrows	(7)=(1) (2) (3) Groundwater Discharge from Bunker Hill Recycled Water Discharge Other Non-Tributary Discharges	(8)=(4)-(7) Net Rising Water Contribution to Surface Discharge	(9) Recycled Water Discharges	(10) Non-Tributary Discharges	(11)=(13)-(12) Non-Storm Discharge at Prado Dam	(12) Storm Discharge into Prado Dam	(13) Total Discharge into Prado Dam	(14)=(4) (9) (10) Non-Storm Discharge at Riverside Narrows Recycled Water Discharge Other Non Tributary Discharges	(15)=(11)-(14) Net Rising Water Contribution to Surface Discharge	(16)=(13)-(6) Gain in Total Flow from Riverside Narrows to Prado Dam	(17)=(12)-(5) Gain in Storm Water Discharge between Riverside Narrows and Prado Dam
1970 - 71	0	22,650	0	35,681	7,051	42,732	22,650	13,031	21,810	0	38,402	13,462	51,864	57,491	(19,089)	9,132	6,411
1971 - 72	0	20,650	0	35,161	6,096	41,257	20,650	14,511	28,980	0	40,416	11,327	51,743	64,141	(23,725)	10,486	5,231
1972 - 73	0	23,460	11,617	17,582	15,466	33,048	35,077	(17,495)	32,780	0	49,472	28,485	77,957	50,362	(890)	44,909	13,019
1973 - 74	0	22,530	0	17,203	8,291	25,494	22,530	(5,327)	36,830	63,035	107,784	19,543	127,327	117,068	(9,284)	101,833	11,252
1974 - 75	0	21,050	0	16,771	4,199	20,970	21,050	(4,279)	40,600	27,939	81,742	11,655	93,397	85,310	(3,568)	72,427	7,456
1975 - 76	0	22,030	0	18,350	9,277	27,627	22,030	(3,680)	42,680	60,170	106,797	13,793	120,590	121,200	(14,403)	92,963	4,516
1976 - 77	0	23,240	0	19,474	5,397	24,871	23,240	(3,766)	41,800	8,350	57,603	14,675	72,278	69,624	(12,021)	47,407	9,278
1977 - 78	0	24,780	0	23,100	159,400	182,500	24,780	(1,680)	44,220	1,466	60,707	194,349	255,056	68,786	(8,079)	72,556	34,949
1978 - 79	200	25,940	0	27,208	20,708	47,916	26,140	1,068	46,570	9,897	82,572	62,646	145,218	83,675	(1,103)	97,302	41,938
1979 - 80	1,000	27,540	0	25,805	228,528	254,333	28,540	(2,735)	48,200	23,820	90,921	445,253	536,174	97,825	(6,904)	281,841	216,725
1980 - 81	3,000	27,850	0	18,915	15,783	34,698	30,850	(11,935)	52,300	0	91,377	26,923	118,300	71,215	20,162	83,602	11,140
1981 - 82	6,500	30,590	0	31,715	51,335	83,050	37,090	(5,375)	55,990	0	81,883	61,819	143,702	87,705	(5,822)	60,652	10,484
1982 - 83	11,000	31,380	0	55,884	224,103	279,987	42,380	13,504	55,960	7,720	120,566	306,519	427,085	119,564	1,002	147,098	82,416
1983 - 84	14,000	29,610	0	55,403	27,684	83,087	43,610	11,793	57,190	12,550	122,116	55,825	177,941	125,143	(3,027)	94,854	28,141
1984 - 85	12,000	31,170	0	63,968	15,145	79,113	43,170	20,798	63,440	3,883	125,358	37,889	163,247	131,291	(5,933)	84,134	22,744
1985 - 86	8,000	33,450	0	64,631	34,969	99,600	41,450	23,181	65,620	1,836	127,550	70,158	197,708	132,087	(4,537)	98,108	35,189
1986 - 87	5,000	36,330	0	57,965	20,128	78,093	41,330	16,635	68,670	0	120,182	23,343	143,525	126,635	(6,453)	65,432	3,215
1987 - 88	3,000	39,160	0	53,526	26,521	80,047	42,160	11,366	77,500	5,679	130,117	42,714	172,831	136,705	(6,588)	92,784	16,193
1988 - 89	1,700	39,470	0	50,330	12,387	62,717	41,170	9,160	85,260	6,582	126,488	33,171	159,659	142,172	(15,684)	96,942	20,784
1989 - 90	1,000	40,420	0	51,500	7,000	58,500	41,420	10,080	82,840	1,020	120,503	24,314	144,817	135,360	(14,857)	86,317	17,314
1990 - 91	500	39,530	394	43,710	30,815	74,525	40,424	3,286	84,230	8,052	119,911	75,275	195,186	135,992	(16,081)	120,661	44,460
1991 - 92	100	37,080	0	38,610	33,158	71,768	37,180	1,430	89,360	8,033	115,551	82,729	198,280	136,003	(20,452)	126,512	49,571
1992 - 93	0	38,220	0	39,714	227,670	267,384	38,220	1,494	95,570	5,273	133,438	438,563	572,001	140,557	(7,119)	304,617	210,893
1993 - 94	0	36,170	144	29,639	15,838	45,477	36,314	(6,675)	90,180	5,424	117,075	41,622	158,697	125,243	(8,168)	113,220	25,784
1994 - 95	0	38,650	2,206	45,632	199,985	245,617	40,856	4,776	95,020	18,945	144,619	284,651	429,270	159,597	(14,978)	183,653	84,666
1995 - 96	0	43,660	1,470	53,935	29,321	83,256	45,130	8,805	95,270	25,137	158,468	58,692	217,160	174,342	(15,874)	133,904	29,371
1996 - 97	0	49,960	2,762	63,285	43,995	107,280	52,722	10,563	93,760	48,473	187,911	61,783	249,694	205,518	(17,607)	142,414	17,788
1997 - 98	0	56,746	1,342	64,147	150,228	214,375	58,088	6,059	104,774	6,665	162,029	300,604	462,633	175,586	(13,557)	248,258	150,376
1998 - 99	0	54,111	0	70,912	5,382	76,294	54,111	16,801	109,300	2,684	161,321	23,673	184,994	182,896	(21,575)	108,700	18,291
1999 - 0	0	52,404	0	61,260	14,312	75,572	52,404	8,856	108,221	19,945	168,214	40,269	208,483	189,426	(21,212)	132,911	25,957
2000 - 1	0	57,753	2,760	62,366	15,725	78,091	60,513	1,853	110,852	10,686	167,305	54,621	221,926	183,904	(16,599)	143,835	38,896
2001 - 2	0	52,465	9,410	65,845	2,999	68,844	61,875	3,970	105,454	9,053	164,353	10,615	174,968	180,352	(15,999)	106,124	7,616
2002 - 3	0	53,612	3,664	59,089	33,077	92,166	57,276	1,813	111,752	8,570	158,347	97,810	256,157	179,411	(21,064)	163,991	64,733
Total	67,000	1,183,661	35,769	1,438,316	1,701,973	3,140,289	1,286,430	151,886	2,342,983	410,887	3,841,098	3,068,770	6,909,868	4,192,186	(351,088)	3,769,579	1,366,797
Average	2,030	35,869	1,084	43,585	51,575	95,160	38,983	4,603	70,999	12,451	116,397	92,993	209,390	127,036	(10,639)	114,230	41,418
Standard Dev	3,871	11,487	2,636	17,734	72,569	74,549	12,136	9,385	27,552	16,350	39,476	121,028	131,702	42,983	8,787	65,694	53,546
Coef of Var	191%	32%	243%	41%	141%	78%	31%	204%	39%	131%	34%	130%	63%	34%	-83%	58%	129%
Median	0	36,170	0	45,632	20,128	76,294	40,856	3,970	68,670	7,720	120,503	42,714	174,968	131,291	(12,021)	98,108	22,744
Max	14,000	57,753	11,617	70,912	228,528	279,987	61,875	23,181	111,752	63,035	187,911	445,253	572,001	205,518	20,162	304,617	216,725
Min	0	20,650	0	16,771	2,999	20,970	20,650	(17,495)	21,810	0	38,402	10,615	51,743	50,362	(23,725)	9,132	3,215

Source -- "Groundwater Discharge from Bunker Hill" abstracted from Table 6 of draft report *Hydrology, Description of Computer Models, and Evaluation of Selected Water-Management Alternatives in the San Bernardino Area, California* (USGS, 1997), the rest of the data from the *Annual Reports of the Santa Ana River Watermaster.*

Table 8-3

Tabulation of Monthly Time Histories for Discharge Components of the Santa Ana River Between Riverside Narrows and Prado Dam -- 1989/90 to 1999/00

(acre-ft/mo)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13) =sum of (5) to (12)	(14) =(18)-(13)-(4)	(15) =(16)-(13)-(2)	(16)	(17)	(18)
Month/Yr	Riverside Narrows Discharge			Non-Tributary Reach Discharges									Reach Gains or Losses		Outflow at Prado		
	Baseflow[1]	Storm Discharge	Total	Riverside WRP	IEUA WRP's	WR WRP	Corona WRP	Arlington Desalter	Lake Elsinore	Exchange Water	State Project Water	Subtotal Non-Tributary Discharges	Total Discharge	Baseflow Discharge	Baseflow[1]	Storm Discharge	Total
10/89	4,064	242	4,306	2,768	3,374	0	762	0	0	0	0	6,903	(1,065)	(1,188)	9,779	365	10,144
11/89	4,592	198	4,790	2,768	3,374	0	762	0	0	0	0	6,903	(618)	(954)	10,541	534	11,075
12/89	4,982	0	4,982	2,768	3,374	0	762	0	0	0	0	6,903	427	87	11,972	340	12,312
1/90	5,217	1,910	7,127	2,768	3,374	0	762	0	0	0	0	6,903	2,958	350	12,470	4,518	16,988
2/90	4,611	3,055	7,666	2,768	3,374	0	762	0	0	0	0	6,903	11,821	(321)	11,193	15,197	26,390
3/90	4,988	391	5,379	2,768	3,374	0	762	0	0	0	0	6,903	8	(89)	11,802	488	12,290
4/90	4,647	863	5,510	2,768	3,374	0	762	0	0	0	0	6,903	(806)	(1,016)	10,534	1,073	11,607
5/90	4,628	317	4,945	2,768	3,374	0	762	0	0	0	0	6,903	(314)	(1,548)	9,983	1,551	11,534
6/90	3,935	24	3,959	2,768	3,374	0	762	0	0	0	0	6,903	(2,127)	(2,351)	8,487	248	8,735
7/90	3,171	0	3,171	2,768	3,374	0	762	139	0	0	0	7,042	(2,444)	(2,444)	7,769	0	7,769
8/90	3,507	0	3,507	2,768	3,374	0	762	605	0	0	0	7,508	(2,720)	(2,720)	8,295	0	8,295
9/90	3,158	0	3,158	2,768	3,374	0	762	276	0	0	0	7,179	(2,659)	(2,659)	7,678	0	7,678
10/90	3,372	0	3,372	2,682	3,578	0	759	606	0	0	0	7,625	(1,948)	(1,976)	9,021	28	9,049
11/90	3,108	218	3,326	2,682	3,578	0	759	505	0	0	0	7,524	(600)	(962)	9,670	580	10,250
12/90	4,493	0	4,493	2,682	3,578	0	759	373	0	0	0	7,392	(595)	(595)	11,290	0	11,290
1/91	4,227	1,527	5,754	2,682	3,578	0	759	529	0	0	0	7,548	3,818	306	12,081	5,039	17,120
2/91	4,588	6,502	11,090	2,682	3,578	0	759	402	0	0	0	7,421	4,848	(1,015)	10,994	12,365	23,359
3/91	4,715	22,038	26,753	2,682	3,578	0	759	0	0	0	0	7,019	34,099	(377)	11,357	56,514	67,871
4/91	4,675	530	5,205	2,682	3,578	0	759	101	0	0	0	7,120	(1,048)	(1,199)	10,596	681	11,277
5/91	3,374	0	3,374	2,682	3,578	0	759	518	0	623	0	8,160	(477)	(527)	11,007	50	11,057
6/91	3,782	0	3,782	2,682	3,578	0	759	454	0	443	0	7,916	(1,705)	(1,705)	9,993	0	9,993
7/91	2,658	0	2,658	2,682	3,578	0	759	503	0	845	0	8,367	(2,171)	(2,171)	8,854	0	8,854
8/91	2,404	0	2,404	2,682	3,578	0	759	476	0	676	0	8,171	(2,778)	(2,778)	7,797	0	7,797
9/91	2,319	0	2,319	2,682	3,578	0	759	428	0	550	0	7,997	(3,047)	(3,065)	7,251	18	7,269
10/91	2,595	239	2,834	2,722	3,974	0	751	417	0	851	0	8,715	(3,625)	(3,997)	7,313	611	7,924
11/91	3,135	23	3,158	2,722	3,974	0	751	165	0	1,369	0	8,981	(2,024)	(2,001)	10,115	0	10,115
12/91	3,699	1,043	4,742	2,722	3,974	0	751	580	0	1,860	0	9,887	666	(1,097)	12,489	2,806	15,295
1/92	3,575	2,719	6,294	2,722	3,974	0	751	224	0	0	0	7,671	5,493	(273)	10,973	8,485	19,458
2/92	3,364	17,712	21,076	2,722	3,974	0	751	176	0	210	0	7,833	19,475	(677)	10,520	37,864	48,384
3/92	3,789	10,754	14,543	2,722	3,974	0	751	199	0	147	0	7,793	20,186	(151)	11,431	31,091	42,522
4/92	3,699	514	4,213	2,722	3,974	0	751	0	0	0	0	7,447	(278)	(1,182)	9,964	1,418	11,382
5/92	3,602	79	3,681	2,722	3,974	0	751	0	0	0	0	7,447	(688)	(895)	10,154	286	10,440
6/92	2,999	0	2,999	2,722	3,974	0	751	172	0	0	0	7,619	(2,317)	(2,317)	8,301	0	8,301
7/92	3,206	73	3,279	2,722	3,974	0	751	487	0	0	0	7,934	(2,715)	(2,811)	8,329	169	8,498
8/92	2,537	0	2,537	2,722	3,974	0	751	584	0	0	0	8,031	(2,609)	(2,609)	7,959	0	7,959
9/92	2,412	0	2,412	2,722	3,974	0	751	544	0	48	0	8,039	(2,450)	(2,450)	8,001	0	8,001
10/92	2,488	656	3,144	2,842	4,323	0	800	545	0	908	0	9,417	(860)	(2,025)	9,880	1,821	11,701
11/92	2,927	161	3,088	2,842	4,323	0	800	530	0	0	0	8,494	(1,287)	(1,579)	9,842	453	10,295
12/92	3,462	11,049	14,511	2,842	4,323	0	800	237	0	0	0	8,201	11,719	(299)	11,364	23,067	34,431
1/93	3,746	109,300	113,046	2,842	4,323	0	800	66	0	0	0	8,030	99,042	1,089	12,865	207,253	220,118
2/93	3,806	42,579	46,385	2,842	4,323	0	800	0	0	0	0	7,964	92,572	374	12,144	134,777	146,921
3/93	4,658	29,646	34,304	2,842	4,323	0	800	0	0	0	0	7,964	11,531	1,151	13,773	40,026	53,799
4/93	4,481	19,757	24,238	2,842	4,323	0	800	0	0	0	0	7,964	(424)	928	13,373	18,405	31,778
5/93	4,046	11,197	15,243	2,842	4,323	0	800	0	0	0	0	7,964	(2,211)	1,543	13,553	7,443	20,996
6/93	3,240	3,327	6,567	2,842	4,323	0	800	0	0	0	0	7,964	725	(1,266)	9,938	5,318	15,256
7/93	2,721	0	2,721	2,842	4,323	0	800	603	0	221	0	8,788	(979)	(979)	10,530	0	10,530
8/93	1,991	0	1,991	2,842	4,323	0	800	605	0	869	0	9,438	(2,676)	(2,676)	8,753	0	8,753
9/93	2,144	0	2,144	2,842	4,323	0	800	325	0	364	0	8,653	(3,375)	(3,375)	7,422	0	7,422
10/93	2,404	0	2,404	2,720	4,146	0	649	245	0	0	0	7,760	(806)	(1,367)	8,797	561	9,358
11/93	1,852	280	2,132	2,720	4,146	0	649	434	0	0	0	7,949	1,517	(319)	9,482	2,116	11,598
12/93	2,232	1,122	3,354	2,720	4,146	0	649	450	0	0	0	7,965	2,927	455	10,652	3,594	14,246
1/94	3,103	689	3,792	2,720	4,146	0	649	557	0	0	0	8,072	2,003	1,017	12,192	1,675	13,867
2/94	2,807	6,335	9,142	2,720	4,146	0	649	142	0	0	0	7,657	11,977	222	10,686	18,090	28,776
3/94	3,014	5,981	8,995	2,720	4,146	0	649	306	0	0	0	7,821	7,367	1,093	11,928	12,255	24,183
4/94	2,983	786	3,769	2,720	4,146	0	649	561	0	483	0	8,559	1,688	(145)	11,397	2,619	14,016
5/94	2,659	645	3,304	2,720	4,146	0	649	551	0	379	0	8,445	282	215	11,319	712	12,031
6/94	2,216	0	2,216	2,720	4,146	0	649	545	0	0	0	8,060	(1,969)	(1,969)	8,307	0	8,307
7/94	2,208	0	2,208	2,720	4,146	0	649	0	0	0	0	7,515	(2,203)	(2,203)	7,520	0	7,520
8/94	2,132	0	2,132	2,720	4,146	0	649	232	0	0	0	7,747	(2,746)	(2,746)	7,133	0	7,133
9/94	2,029	0	2,029	2,720	4,146	0	649	548	0	137	0	8,200	(2,567)	(2,567)	7,662	0	7,662
10/94	3,434	384	3,818	2,829	4,478	0	612	546	0	0	253	8,717	(1,596)	(1,917)	10,234	705	10,939
11/94	4,399	917	5,316	2,829	4,478	0	612	512	0	0	2,062	10,492	(2,435)	(2,458)	12,433	940	13,373
12/94	4,292	1,966	6,258	2,829	4,478	0	612	143	0	0	732	8,793	(1,192)	(877)	12,208	1,651	13,859
1/95	3,812	46,772	50,584	2,829	4,478	0	612	0	48	0	0	7,966	48,292	(51)	11,727	95,115	106,842
2/95	3,395	16,698	20,093	2,829	4,478	0	612	0	1,280	0	0	9,198	4,595	(97)	12,496	21,390	33,886
3/95	4,505	106,555	111,060	2,829	4,478	0	612	0	6,908	0	0	14,826	16,550	483	19,814	122,622	142,436
4/95	4,451	12,438	16,889	2,829	4,478	0	612	0	3,624	0	0	11,542	8,933	(9)	15,984	21,380	37,364
5/95	4,365	9,331	13,696	2,829	4,478	0	612	0	2,072	0	0	9,990	1,327	(433)	13,922	11,091	25,013
6/95	3,867	4,686	8,553	2,829	4,478	0	612	0	464	0	0	8,382	3,379	(1,464)	10,785	9,529	20,314
7/95	3,363	227	3,590	2,829	4,478	0	612	0	301	0	0	8,219	(3,870)	(3,862)	7,720	219	7,939
8/95	3,078	0	3,078	2,829	4,478	0	612	0	0	0	0	7,918	(2,398)	(2,398)	8,598	0	8,598
9/95	2,671	11	2,682	2,829	4,478	0	612	0	0	0	0	7,918	(1,893)	(1,891)	8,698	9	8,707
10/95	3,495	0	3,495	2,830	4,455	0	654	0	0	0	0	7,939	(1,693)	(1,693)	9,741	0	9,741
11/95	3,539	0	3,539	2,830	4,455	0	654	0	0	0	0	7,939	(668)	(668)	10,810	0	10,810
12/95	3,726	60	3,786	2,830	4,455	0	654	379	0	0	0	8,318	1,622	332	12,376	1,350	13,726

Table 8-3

Tabulation of Monthly Time Histories for Discharge Components of the Santa Ana River Between Riverside Narrows and Prado Dam -- 1989/90 to 1999/00

(acre-ft/mo)

(1) Month/Yr	(2) Riverside Narrows Discharge: Baseflow[1]	(3) Riverside Narrows Discharge: Storm Discharge	(4) Riverside Narrows Discharge: Total	(5) Non-Tributary Reach Discharges: Riverside WRP	(6) IEUA WRP's	(7) WR WRP	(8) Corona WRP	(9) Arlington Desalter	(10) Lake Elsinore	(11) Exchange Water	(12) State Project Water	(13) =sum of (5) to (12) Subtotal Non-Tributary Discharges	(14) =(18)-(13)-(4) Reach Gains or Losses: Total Discharge	(15) =(16)-(13)-(2) Reach Gains or Losses: Baseflow Discharge	(16) Outflow at Prado: Baseflow[1]	(17) Outflow at Prado: Storm Discharge	(18) Outflow at Prado: Total
1/96	4,031	3,921	7,952	2,830	4,455	0	654	446	0	0	0	8,385	1,113	658	13,074	4,376	17,450
2/96	3,651	18,421	22,072	2,830	4,455	0	654	285	0	0	0	8,224	21,830	1,244	13,119	39,007	52,126
3/96	5,013	6,278	11,291	2,830	4,455	0	654	80	0	0	0	8,019	4,359	(483)	12,549	11,120	23,669
4/96	5,280	641	5,921	2,830	4,455	0	654	526	0	0	3,376	11,841	230	(1,968)	15,153	2,839	17,992
5/96	5,839	0	5,839	2,830	4,455	0	654	549	0	0	6,039	14,527	(1,382)	(1,382)	18,984	0	18,984
6/96	5,435	0	5,435	2,830	4,455	0	654	506	0	0	5,626	14,071	(3,003)	(3,003)	16,503	0	16,503
7/96	4,925	0	4,925	2,830	4,455	0	654	517	0	0	5,768	14,224	(3,662)	(3,662)	15,487	0	15,487
8/96	4,324	0	4,324	2,830	4,455	0	654	409	0	0	84	8,432	(2,462)	(2,462)	10,294	0	10,294
9/96	4,677	0	4,677	2,830	4,455	0	654	547	0	0	0	8,486	(2,785)	(2,785)	10,378	0	10,378
10/96	5,601	835	6,436	2,853	4,540	0	420	505	0	0	0	8,318	(1,689)	(1,905)	12,014	1,051	13,065
11/96	6,090	5,658	11,748	2,853	4,540	0	420	536	0	0	0	8,349	717	(1,782)	12,657	8,157	20,814
12/96	5,679	3,733	9,412	2,853	4,540	0	420	565	0	0	0	8,378	6,041	(333)	13,724	10,107	23,831
1/97	5,609	31,438	37,047	2,853	4,540	0	420	561	0	0	0	8,374	7,667	727	14,710	38,378	53,088
2/97	5,221	1,384	6,605	2,853	4,540	0	420	506	0	0	0	8,319	1,035	(392)	13,148	2,811	15,959
3/97	6,044	5	6,049	2,853	4,540	0	420	519	0	0	0	8,332	603	380	14,756	228	14,984
4/97	5,970	0	5,970	2,853	4,540	0	420	518	0	0	1,311	9,642	(1,321)	(1,321)	14,291	0	14,291
5/97	5,109	0	5,109	2,853	4,540	0	420	499	0	0	5,934	14,246	(1,542)	(1,542)	17,813	0	17,813
6/97	4,830	30	4,860	2,853	4,540	0	420	493	0	0	5,894	14,200	(1,951)	(2,112)	16,918	191	17,109
7/97	4,602	0	4,602	2,853	4,540	0	420	474	0	0	6,220	14,507	(3,033)	(3,033)	16,076	0	16,076
8/97	4,300	0	4,300	2,853	4,540	0	420	510	0	0	11,397	19,720	(3,515)	(3,515)	20,505	0	20,505
9/97	4,229	912	5,141	2,853	4,540	0	420	464	0	0	11,565	19,842	(2,826)	(2,773)	21,298	859	22,157
10/97	4,604	888	5,492	2,952	4,931	0	727	499	0	0	2,304	11,412	(2,377)	(2,193)	13,823	704	14,527
11/97	4,864	1,798	6,662	2,952	4,931	0	727	456	0	0	0	9,065	909	(1,993)	11,936	4,700	16,636
12/97	5,108	6,700	11,808	2,952	4,931	0	727	115	0	0	0	8,724	7,280	(1,152)	12,680	15,132	27,812
1/98	5,129	6,984	12,113	2,952	4,931	0	727	0	0	0	0	8,609	8,489	(318)	13,420	15,791	29,211
2/98	5,045	68,843	73,888	2,952	4,931	0	727	0	0	0	0	8,609	97,226	(115)	13,539	166,184	179,723
3/98	5,939	10,675	16,614	2,952	4,931	0	727	0	1,087	0	0	9,696	13,557	(98)	15,537	24,330	39,867
4/98	5,774	14,001	19,775	2,952	4,931	244	727	0	603	0	0	9,456	2,745	(231)	14,999	16,977	31,976
5/98	5,870	28,867	34,737	2,952	4,931	244	727	0	0	0	0	8,853	15,222	(169)	14,554	44,258	58,812
6/98	5,445	7,237	12,682	2,952	4,931	244	727	0	0	0	0	8,853	434	(1,603)	12,695	9,274	21,969
7/98	5,632	229	5,861	2,952	4,931	244	727	84	0	0	486	9,423	(1,492)	(1,715)	13,340	452	13,792
8/98	5,592	2,068	7,660	2,952	4,931	244	727	361	0	0	228	9,442	(2,788)	(2,145)	12,889	1,425	14,314
9/98	5,145	1,938	7,083	2,952	4,931	244	727	443	0	0	0	9,296	(2,386)	(1,825)	12,616	1,377	13,993
10/98	5,553	276	5,829	2,904	4,853	383	969	271	0	0	0	9,379	(1,261)	(1,491)	13,442	506	13,948
11/98	5,879	224	6,103	2,904	4,853	383	969	0	0	0	0	9,108	469	(1,980)	13,007	2,673	15,680
12/98	6,051	320	6,371	2,904	4,853	383	969	0	0	0	0	9,108	988	(992)	14,167	2,300	16,467
1/99	6,123	1,218	7,341	2,904	4,853	383	969	28	0	0	0	9,136	3,885	23	15,282	5,080	20,362
2/99	5,820	785	6,605	2,904	4,853	383	969	347	0	0	0	9,455	955	(1,380)	13,895	3,120	17,015
3/99	6,236	313	6,549	2,904	4,853	383	969	329	0	0	0	9,437	563	104	15,778	772	16,550
4/99	6,006	1,412	7,418	2,904	4,853	383	969	274	0	0	0	9,382	2,600	(752)	14,637	4,764	19,401
5/99	6,014	8	6,022	2,904	4,853	383	969	93	0	0	0	9,201	576	(1,711)	13,504	2,295	15,799
6/99	6,409	194	6,603	2,904	4,853	383	969	121	0	0	0	9,229	(2,638)	(3,447)	12,191	1,003	13,194
7/99	5,577	631	6,208	2,904	4,853	383	969	433	0	0	0	9,541	(2,471)	(3,000)	12,119	1,160	13,279
8/99	5,758	0	5,758	2,904	4,853	383	969	370	0	0	0	9,478	(3,561)	(3,561)	11,675	0	11,675
9/99	5,486	0	5,486	2,904	4,853	383	969	417	0	0	0	9,525	(3,387)	(3,387)	11,625	0	11,625
10/99	5,042	0	5,042	2,950	4,775	198	1,096	441	0	0	5,827	15,286	(3,159)	(3,159)	17,169	0	17,169
11/99	4,832	16	4,848	2,950	4,775	198	1,096	348	0	0	0	9,366	(1,831)	(1,965)	12,233	150	12,383
12/99	5,270	14	5,284	2,950	4,775	198	1,096	494	0	0	2,935	12,447	(1,127)	(1,224)	16,493	111	16,604
1/00	5,379	607	5,986	2,950	4,775	198	1,096	425	0	0	3,750	13,193	1,013	(407)	18,165	2,027	20,192
2/00	5,068	7,674	12,742	2,950	4,775	198	1,096	382	0	0	2,057	11,457	15,824	(838)	15,687	24,336	40,023
3/00	5,863	4,239	10,102	2,950	4,775	198	1,096	277	0	0	0	9,295	4,197	(950)	14,208	9,386	23,594
4/00	6,288	1,729	8,017	2,950	4,775	198	1,096	497	0	0	0	9,515	1,251	(914)	14,889	3,894	18,783
5/00	5,215	0	5,215	2,950	4,775	198	1,096	444	0	0	0	9,462	(1,283)	(1,283)	13,394	0	13,394
6/00	4,867	0	4,867	2,950	4,775	198	1,096	485	0	0	0	9,503	(2,172)	(2,172)	12,198	0	12,198
7/00	4,491	0	4,491	2,950	4,775	198	1,096	529	0	0	0	9,547	(2,510)	(2,510)	11,528	0	11,528
8/00	4,366	0	4,366	2,950	4,775	198	1,096	537	0	0	0	9,555	(2,710)	(2,710)	11,211	0	11,211
9/00	4,580	34	4,614	2,950	4,775	198	1,096	516	0	0	0	9,534	(2,745)	(3,075)	11,039	364	11,403
10/00	5,696	153	5,849	2,972	4,990	184	1,092	489	0	0	2,106	11,833	(991)	(2,053)	15,476	1,215	16,691
11/00	5,931	4	5,935	2,972	4,990	184	1,092	517	0	0	3,888	13,643	(984)	(1,162)	18,412	182	18,594
12/00	6,188	0	6,188	2,972	4,990	184	1,092	537	0	0	0	9,775	(533)	(723)	15,240	190	15,430
1/01	5,571	5,205	10,776	2,972	4,990	184	1,092	183	0	0	0	9,421	8,063	(849)	14,143	14,117	28,260
2/01	5,079	7,024	12,103	2,972	4,990	184	1,092	117	0	0	0	9,355	22,736	(781)	13,653	30,541	44,194
3/01	5,806	1,931	7,737	2,972	4,990	184	1,092	88	0	0	0	9,326	3,753	1,160	16,292	4,524	20,816
4/01	5,479	1,358	6,837	2,972	4,990	184	1,092	553	0	0	0	9,791	1,420	(863)	14,407	3,641	18,048
5/01	4,701	0	4,701	2,972	4,990	184	1,092	585	0	0	0	9,823	(997)	(997)	13,527	0	13,527
6/01	4,542	0	4,542	2,972	4,990	184	1,092	527	0	0	0	9,765	(2,394)	(2,394)	11,913	0	11,913
7/01	4,423	50	4,473	2,972	4,990	184	1,092	343	0	0	0	9,581	(2,486)	(2,647)	11,357	211	11,568
8/01	4,485	0	4,485	2,972	4,990	184	1,092	306	0	0	0	9,544	(2,957)	(2,957)	11,072	0	11,072
9/01	4,465	0	4,465	2,972	4,990	184	1,092	447	0	0	0	9,685	(2,337)	(2,337)	11,813	0	11,813
10/01	5,008	0	5,008	2,966	4,593	198	1,032	548	0	0	0	9,336	(870)	(870)	13,474	0	13,474
11/01	5,389	2,037	7,426	2,966	4,593	198	1,032	570	0	0	0	9,358	899	(689)	14,058	3,625	17,683
12/01	5,989	382	6,371	2,966	4,593	198	1,032	581	0	0	0	9,369	2,216	133	15,491	2,465	17,956
1/02	5,980	90	6,070	2,966	4,593	198	1,032	498	0	0	0	9,286	1,268	(2)	15,264	1,360	16,624
2/02	4,876	3	4,879	2,966	4,593	198	1,032	379	0	0	0	9,167	(281)	(612)	13,431	334	13,765
3/02	5,944	383	6,327	2,966	4,593	198	1,032	515	0	0	0	9,303	1,295	(52)	15,195	1,730	16,925

Table 8-3
Tabulation of Monthly Time Histories for Discharge Components of the Santa Ana River Between Riverside Narrows and Prado Dam -- 1989/90 to 1999/00

(acre-ft/mo)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13) =sum of (5) to (12)	(14) =(18)-(13)-(4)	(15) =(16)-(13)-(2)	(16)	(17)	(18)
Month/Yr	Riverside Narrows Discharge			Non-Tributary Reach Discharges									Reach Gains or Losses		Outflow at Prado		
	Baseflow[1]	Storm Discharge	Total	Riverside WRP	IEUA WRP's	WR WRP	Corona WRP	Arlington Desalter	Lake Elsinore	Exchange Water	State Project Water	Subtotal Non-Tributary Discharges	Total Discharge	Baseflow Discharge	Baseflow[1]	Storm Discharge	Total
4/02	6,416	104	6,520	2,966	4,593	198	1,032	551	0	0	0	9,339	246	(585)	15,170	935	16,105
5/02	6,819	0	6,819	2,966	4,593	198	1,032	560	0	0	0	9,348	(1,726)	(1,892)	14,275	166	14,441
6/02	5,490	0	5,490	2,966	4,593	198	1,032	521	0	0	0	9,309	(2,472)	(2,472)	12,327	0	12,327
7/02	5,050	0	5,050	2,966	4,593	198	1,032	521	0	0	441	9,750	(3,126)	(3,126)	11,674	0	11,674
8/02	4,570	0	4,570	2,966	4,593	198	1,032	438	0	0	2,412	11,638	(2,603)	(2,603)	13,605	0	13,605
9/02	4,314	0	4,314	2,966	4,593	198	1,032	518	0	0	0	9,306	(3,231)	(3,231)	10,389	0	10,389
10/02	4,485	0	4,485	3,025	5,085	201	1,002	542	0	0	0	9,855	(1,892)	(1,892)	12,448	0	12,448
11/02	4,724	3,682	8,406	3,025	5,085	201	1,002	522	0	0	0	9,835	1,963	(2,793)	11,766	8,438	20,204
12/02	4,887	4,168	9,055	3,025	5,085	201	1,002	482	0	0	0	9,795	8,085	(1,227)	13,455	13,480	26,935
1/03	4,994	52	5,046	3,025	5,085	201	1,002	435	0	0	0	9,748	(907)	(914)	13,828	59	13,887
2/03	4,729	11,974	16,703	3,025	5,085	201	1,002	455	0	0	0	9,768	19,685	(1,030)	13,467	32,689	46,156
3/03	5,304	10,264	15,568	3,025	5,085	201	1,002	456	5	0	0	9,774	21,972	33	15,111	32,203	47,314
4/03	5,042	2,646	7,688	3,025	5,085	201	1,002	468	1,165	0	0	10,946	3,738	(2,015)	13,973	8,399	22,372
5/03	4,999	291	5,290	3,025	5,085	201	1,002	82	854	0	0	10,249	1,062	(1,051)	14,197	2,404	16,601
6/03	5,018	0	5,018	3,025	5,085	201	1,002	0	0	0	0	9,313	(1,519)	(1,519)	12,812	0	12,812
7/03	5,008	0	5,008	3,025	5,085	201	1,002	156	0	0	0	9,469	(1,606)	(1,744)	12,733	138	12,871
8/03	5,119	0	5,119	3,025	5,085	201	1,002	632	0	0	667	10,612	(3,622)	(3,622)	12,109	0	12,109
9/03	4,780	0	4,780	3,025	5,085	201	1,002	652	0	0	997	10,962	(3,294)	(3,294)	12,448	0	12,448
Average	4,462	4,818	9,281	2,858	4,435	92	809	323	110	65	562	9,254	3,336	(1,341)	12,375	9,495	21,871
Standard Deviation	1,165	14,367	14,419	104	500	123	195	222	641	240	1,785	2,057	14,437	1,244	2,743	26,710	27,246
Coefficient of Variation	26%	298%	155%	4%	11%	134%	24%	69%	585%	367%	318%	22%	433%	-93%	22%	281%	125%
Max	6,819	109,300	113,046	3,025	5,085	383	1,096	652	6,908	1,860	11,565	19,842	99,042	1,543	21,298	207,253	220,118
Min	1,852	0	1,991	2,682	3,374	0	420	0	0	0	0	6,903	(3,870)	(3,997)	7,133	0	7,133

Source -- Raw data obtained from the Annual Reports of the Santa Ana Watermaster

1 -- Baseflow, as used herein, is the difference between total discharge as measured at USGS gaging stations, and storm water discharge as estimated by the Santa Ana River Watermaster

Table 8-4
Monthly Distribution of Gains ( ) and Losses (-) to Baseflow in the Santa Ana River Between the Riverside Narrows and Prado Dam

(acre-ft/mo)

Month	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Average	Standard Deviation	Coeficient of Variation	Maximum	Minimum
October	-1,188	-1,976	-3,997	-2,025	-1,367	-1,917	-1,693	-1,905	-2,193	-1,491	-3,159	-2,053	-870	-1,892	-1,980	789	40%	-870	-3,997
November	-954	-962	-2,001	-1,579	-319	-2,458	-668	-1,782	-1,993	-1,980	-1,965	-1,162	-689	-2,793	-1,522	737	48%	-319	-2,793
December	87	-595	-1,097	-299	455	-877	332	-333	-1,152	-992	-1,224	-723	133	-1,227	-537	600	112%	455	-1,227
January	350	306	-273	1,089	1,017	-51	658	727	-318	23	-407	-849	-2	-914	97	630	651%	1,089	-914
February	-321	-1,015	-677	374	222	-97	1,244	-392	-115	-1,380	-838	-781	-612	-1,030	-387	683	176%	1,244	-1,380
March	-89	-377	-151	1,151	1,093	483	-483	380	-98	104	-950	1,160	-52	33	157	634	403%	1,160	-950
April	-1,016	-1,199	-1,182	928	-145	-9	-1,968	-1,321	-231	-752	-914	-863	-585	-2,015	-805	779	97%	928	-2,015
May	-1,548	-527	-895	1,543	215	-433	-1,382	-1,542	-169	-1,711	-1,283	-997	-1,892	-1,051	-834	917	110%	1,543	-1,892
June	-2,351	-1,705	-2,317	-1,266	-1,969	-1,464	-3,003	-2,112	-1,603	-3,447	-2,172	-2,394	-2,472	-1,519	-2,128	609	29%	-1,266	-3,447
July	-2,444	-2,171	-2,811	-979	-2,203	-3,862	-3,662	-3,033	-1,715	-3,000	-2,510	-2,647	-3,126	-1,744	-2,565	779	30%	-979	-3,862
August	-2,720	-2,778	-2,609	-2,676	-2,746	-2,398	-2,462	-3,515	-2,145	-3,561	-2,710	-2,957	-2,603	-3,622	-2,822	447	16%	-2,145	-3,622
September	-2,659	-3,065	-2,450	-3,375	-2,567	-1,891	-2,785	-2,773	-1,825	-3,387	-3,075	-2,337	-3,231	-3,294	-2,765	513	19%	-1,825	-3,387
Total	-14,857	-16,066	-20,456	-7,116	-8,314	-14,978	-15,874	-17,605	-13,559	-21,574	-21,212	-16,599	-15,999	-21,064	-16,091	4,411	27%	-7,116	-21,574
Average	-1,238	-1,339	-1,705	-593	-693	-1,248	-1,323	-1,467	-1,130	-1,798	-1,768	-1,383	-1,333	-1,755	-1,341				
Max	350	306	-151	1,543	1,093	483	1,244	727	-98	104	-407	1,160	133	33	466				
Min	-2,720	-3,065	-3,997	-3,375	-2,746	-3,862	-3,662	-3,515	-2,193	-3,561	-3,159	-2,957	-3,231	-3,622	-3,262				

Source -- Basic data from the Santa Ana River Watermaster Annual Reports

Table 8-5
Total Chino Basin Production, Watermaster Replenishment Requirement and Replenishment Plan that Balances Recharge and Discharge for Baseline Scenario

(1) Fiscal Year	(2) Production	(3) Operating Yield	(4) New Stormwater	(5) SAR Inflow	(6) = (2) - (3) - (4) - (5) Replenishment Obligation	(7)	(8)	(9)	(10)	(11)	(12) = Σ(7) to (11)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20) = Σ(13) to (18	(21) = (12) + (20)
						Supplemental Water Recharge Plan														
						MZ1 Recharge Basins						MZ2 and MZ3 Recharge Basins								Total
						MZ1 Goal	Montclair 1-4 0.25	Upland 0.15	College Hts 0.15	Brooks 0.15	Subtotal	San Sevaine 0.25	Victoria	Banana + Hickory	Etiwanda Cons	Etiwanda Perc	RP3 0.05	Declez	Subtotal	
2004	196,577	145,000	12,000	9,989	29,588	20,712	20,712	0	0	0	20,712	8,876	0	0	0	0	0	0	8,876	29,588
2005	197,542	145,000	12,000	10,710	29,832	20,882	7,458	4,475	4,475	4,475	20,882	7,458	0	0	0	0	1,492	0	8,949	29,832
2006	195,715	145,000	12,000	10,888	27,827	19,479	6,957	4,174	4,174	4,174	19,479	6,957	0	0	0	0	1,391	0	8,348	27,827
2007	197,912	145,000	12,000	13,053	27,858	19,501	6,965	4,179	4,179	4,179	19,501	6,965	0	0	0	0	1,393	0	8,358	27,858
2008	196,068	145,000	12,000	13,231	25,837	18,086	6,459	3,876	3,876	3,876	18,086	6,459	0	0	0	0	1,292	0	7,751	25,837
2009	194,245	145,000	12,000	13,408	23,837	16,686	5,959	3,576	3,576	3,576	16,686	5,959	0	0	0	0	1,192	0	7,151	23,837
2010	206,871	145,000	12,000	20,744	29,127	20,389	7,282	4,369	4,369	4,369	20,389	7,282	0	0	0	0	1,456	0	8,738	29,127
2011	207,484	145,000	12,000	21,130	29,355	20,548	7,339	4,403	4,403	4,403	20,548	7,339	0	0	0	0	1,468	0	8,806	29,355
2012	208,089	145,000	12,000	21,515	29,574	20,702	7,393	4,436	4,436	4,436	20,702	7,393	0	0	0	0	1,479	0	8,872	29,574
2013	208,704	145,000	12,000	21,900	29,804	20,863	7,451	4,471	4,471	4,471	20,863	7,451	0	0	0	0	1,490	0	8,941	29,804
2014	209,311	145,000	12,000	22,285	30,026	21,018	7,507	4,504	4,504	4,504	21,018	7,507	0	0	0	0	1,501	0	9,008	30,026
2015	209,917	145,000	12,000	22,670	30,247	21,173	7,562	4,537	4,537	4,537	21,173	7,562	0	0	0	0	1,512	0	9,074	30,247
2016	210,015	145,000	12,000	23,057	29,958	20,971	7,490	4,494	4,494	4,494	20,971	7,490	0	0	0	0	1,498	0	8,987	29,958
2017	210,126	145,000	12,000	23,443	29,683	20,778	7,421	4,452	4,452	4,452	20,778	7,421	0	0	0	0	1,484	0	8,905	29,683
2018	210,229	140,000	12,000	23,830	34,399	24,079	8,600	5,160	5,160	5,160	24,079	8,600	0	0	0	0	1,720	0	10,320	34,399
2019	210,328	140,000	12,000	24,216	34,112	23,879	8,528	5,117	5,117	5,117	23,879	8,528	0	0	0	0	1,706	0	10,234	34,112
2020	210,423	140,000	12,000	24,602	33,821	23,675	8,455	5,073	5,073	5,073	23,675	8,455	0	0	0	0	1,691	0	10,146	33,821
2021	210,427	140,000	12,000	24,602	33,825	23,677	8,456	5,074	5,074	5,074	23,677	8,456	0	0	0	0	1,691	0	10,147	33,825
2022	210,427	140,000	12,000	24,602	33,825	23,677	8,456	5,074	5,074	5,074	23,677	8,456	0	0	0	0	1,691	0	10,147	33,825
2023	210,427	140,000	12,000	24,602	33,825	23,677	8,456	5,074	5,074	5,074	23,677	8,456	0	0	0	0	1,691	0	10,147	33,825
2024	210,423	140,000	12,000	24,602	33,821	23,675	8,455	5,073	5,073	5,073	23,675	8,455	0	0	0	0	1,691	0	10,146	33,821
2025	210,427	140,000	12,000	24,602	33,825	23,677	8,456	5,074	5,074	5,074	23,677	8,456	0	0	0	0	1,691	0	10,147	33,825
2026	210,427	140,000	12,000	24,602	33,825	23,677	8,456	5,074	5,074	5,074	23,677	8,456	0	0	0	0	1,691	0	10,147	33,825
2027	210,427	140,000	12,000	24,602	33,825	23,677	8,456	5,074	5,074	5,074	23,677	8,456	0	0	0	0	1,691	0	10,147	33,825
2028	210,423	140,000	12,000	24,602	33,821	23,675	8,455	5,073	5,073	5,073	23,675	8,455	0	0	0	0	1,691	0	10,146	33,821

Note -- recharge allocated to facilities that are assured of being on line in 2004

Table 8-6a
Estimated Hydrologic Budget for the Chino Basin by RWQCB Management Zone – Chino North, Baseline Period 2004/05 to 2028/29

(acre-ft)

Period	Inflow										Outflows							Inflow-Outflow
		Inter-basin Flow			Deep Percolation			Artificial Recharge		Subtotal Inflows	Pumping	Inter-basin Flow			ET	Rising Groundwater	Subtotal Outflow	
	Boundary Inflow	Chino South	Chino East	PBMZ	Precipitation	Applied Water	Stream Recharge	Storm	Imported and Recycled Water			Chino South	Chino East	PBMZ				
1	16,711	6,137	403	0	58,235	35,299	191	20,409	29,588	166,974	174,680	0	32	8,440	68	0	183,220	-16,246
2	16,711	7,081	124	0	57,224	36,634	339	20,409	29,832	168,353	174,330	0	134	7,865	68	0	182,397	-14,043
3	16,711	7,649	123	0	56,212	37,969	373	20,409	27,827	167,273	172,710	0	97	7,432	68	0	180,307	-13,034
4	16,711	8,400	86	0	55,200	39,303	377	20,409	27,858	168,345	175,270	0	314	7,014	68	0	182,667	-14,322
5	16,711	8,810	141	0	54,188	40,638	383	20,409	25,837	167,117	172,660	0	105	6,724	68	0	179,558	-12,440
6	16,711	8,997	511	0	53,176	41,973	384	20,409	23,837	165,999	170,440	0	0	6,567	68	0	177,075	-11,077
7	16,711	10,762	850	0	52,164	43,308	387	20,409	29,127	173,718	180,830	0	0	4,434	68	0	185,333	-11,614
8	16,711	12,287	960	0	51,153	44,643	391	20,409	29,355	175,907	181,590	0	0	3,117	68	0	184,776	-8,869
9	16,711	12,917	1,002	0	50,141	45,977	395	20,409	29,574	177,126	182,110	0	0	2,632	68	0	184,810	-7,684
10	16,711	13,103	976	0	49,129	47,312	396	20,409	29,804	177,841	182,450	0	0	2,351	68	0	184,869	-7,028
11	16,711	13,293	1,017	0	48,117	48,647	399	20,409	30,026	178,619	183,160	0	0	2,201	68	0	185,429	-6,810
12	16,711	13,398	1,043	0	47,105	49,982	402	20,409	30,247	179,297	183,910	0	0	2,124	68	0	186,102	-6,805
13	16,711	13,450	1,062	0	46,094	51,317	407	20,409	29,958	179,407	184,240	0	0	2,128	68	0	186,436	-7,029
14	16,711	13,398	1,110	0	45,082	52,651	408	20,409	29,683	179,451	184,590	0	0	2,154	68	0	186,813	-7,362
15	16,711	13,352	1,262	0	44,070	53,986	410	20,409	34,399	184,599	184,930	0	0	2,228	68	0	187,226	-2,627
16	16,711	13,259	1,253	0	43,058	55,321	413	20,409	34,112	184,536	185,260	0	0	2,337	68	0	187,666	-3,129
17	16,711	13,150	1,230	0	42,046	56,656	417	20,409	33,821	184,440	185,580	0	0	2,493	68	0	188,142	-3,701
18	16,711	12,987	1,212	0	42,046	56,656	415	20,409	33,825	184,261	185,590	0	0	2,618	68	0	188,277	-4,016
19	16,711	12,895	1,153	0	42,046	56,656	415	20,409	33,825	184,109	185,590	0	0	2,719	68	0	188,377	-4,268
20	16,711	12,880	855	0	42,046	56,656	415	20,409	33,825	183,797	186,430	0	0	2,793	68	0	189,291	-5,494
21	16,711	12,945	834	0	42,046	56,656	417	20,409	33,821	183,839	186,060	0	0	2,853	68	0	188,981	-5,142
22	16,711	12,808	1,231	0	42,046	56,656	415	20,409	33,825	184,101	185,600	0	0	2,858	68	0	188,527	-4,426
23	16,711	12,807	1,258	0	42,046	56,656	415	20,409	33,825	184,127	185,600	0	0	2,881	68	0	188,549	-4,422
24	16,711	12,790	1,271	0	42,046	56,656	415	20,409	33,825	184,123	185,600	0	0	2,899	68	0	188,567	-4,444
25	16,711	12,792	1,287	0	42,046	56,656	417	20,409	33,821	184,139	185,590	0	0	2,933	68	0	188,592	-4,453
Total	417,775	292,347	22,254	0	1,188,764	1,234,864	9,796	510,225	775,474	4,451,499	4,544,800	0	682	94,794	1,711	0	4,641,986	-190,487
Average	16,711	11,694	890	0	47,551	49,395	392	20,409	31,019	178,060	181,792	0	27	3,792	68	0	185,679	-7,619
Maximum	16,711	13,450	1,287	0	58,235	56,656	417	20,409	34,399	184,599	186,430	0	314	8,440	68	0	189,291	-2,627
Minimum	16,711	6,137	86	0	42,046	35,299	191	20,409	23,837	165,999	170,440	0	0	2,124	68	0	177,075	-16,246

Table 8-6b
Estimated Hydrologic Budget for the Chino Basin by RWQCB Management Zone – Chino East, Baseline Period 2004/05 to 2028/29

(acre-ft)

Period	Inflow										Outflows						Inflow-Outflow
		Inter-basin Flow		Deep Percolation			Artificial Recharge			Subtotal Inflows	Pumping	Inter-basin Flow		ET	Rising Groundwater	Subtotal Outflow	
	Boundary Inflow	Chino North	Chino South	Precipitation	Applied Water	Stream Recharge	Storm	State Project	Recycled			Chino North	Chino South				
1	887	32	1,902	1,139	1,247	0	0	0	0	5,207	6,260	403	0	0	0	6,663	-1,456
2	887	134	2,594	1,126	1,274	0	0	0	0	6,014	6,539	124	0	0	0	6,663	-649
3	887	97	2,972	1,112	1,300	0	0	0	0	6,368	6,579	123	0	0	0	6,702	-334
4	887	314	3,509	1,099	1,327	0	0	0	0	7,136	7,570	86	0	0	0	7,656	-520
5	887	105	3,739	1,085	1,353	0	0	0	0	7,170	7,230	141	0	0	0	7,371	-202
6	887	0	3,632	1,072	1,380	0	0	0	0	6,971	6,523	511	0	0	0	7,034	-63
7	887	0	3,554	1,058	1,406	0	0	0	0	6,906	5,980	850	0	0	0	6,830	76
8	887	0	3,534	1,045	1,433	0	0	0	0	6,899	6,018	960	0	0	0	6,978	-79
9	887	0	3,620	1,031	1,460	0	0	0	0	6,998	6,057	1,002	0	0	0	7,059	-61
10	887	0	3,676	1,018	1,486	0	0	0	0	7,067	6,094	976	0	0	0	7,070	-3
11	887	0	3,751	1,004	1,513	0	0	0	0	7,154	6,133	1,017	0	0	0	7,150	5
12	887	0	3,816	991	1,539	0	0	0	0	7,233	6,171	1,043	0	0	0	7,214	19
13	887	0	3,869	977	1,566	0	0	0	0	7,299	6,195	1,062	0	0	0	7,257	43
14	887	0	3,839	964	1,592	0	0	0	0	7,282	6,030	1,110	0	0	0	7,140	143
15	887	0	3,664	951	1,619	0	0	0	0	7,120	5,682	1,262	0	0	0	6,944	176
16	887	0	3,618	937	1,645	0	0	0	0	7,087	5,697	1,253	0	0	0	6,950	137
17	887	0	3,591	924	1,672	0	0	0	0	7,074	5,712	1,230	0	0	0	6,942	132
18	887	0	3,559	924	1,672	0	0	0	0	7,041	5,712	1,212	0	0	0	6,924	117
19	887	0	3,603	924	1,672	0	0	0	0	7,085	5,909	1,153	0	0	0	7,062	23
20	887	0	3,949	924	1,672	0	0	0	0	7,431	6,703	855	0	0	0	7,558	-127
21	887	0	4,172	924	1,672	0	0	0	0	7,654	6,732	834	0	0	0	7,566	88
22	887	0	3,702	924	1,672	0	0	0	0	7,184	5,712	1,231	0	0	0	6,943	241
23	887	0	3,639	924	1,672	0	0	0	0	7,121	5,712	1,258	0	0	0	6,970	151
24	887	0	3,612	924	1,672	0	0	0	0	7,094	5,712	1,271	0	0	0	6,983	111
25	887	0	3,609	924	1,672	0	0	0	0	7,091	5,712	1,287	0	0	0	6,999	92
Total	22,176	682	88,723	24,922	38,185	0	0	0	0	174,687	154,373	22,254	0	0	0	176,627	-1,940
Average	887	27	3,549	997	1,527	0	0	0	0	6,987	6,175	890	0	0	0	7,065	-78
Maximum	887	314	4,172	1,139	1,672	0	0	0	0	7,654	7,570	1,287	0	0	0	7,656	241
Minimum	887	0	1,902	924	1,247	0	0	0	0	5,207	5,682	86	0	0	0	6,663	-1,456

Table 8-6c
Estimated Hydrologic Budget for the Chino Basin by RWQCB Management Zone – Chino South Baseline Period 2004/05 to 2028/29

(acre-ft)

Period	Inflows											Outflows							Inflow-Outflow
		Inter-basin Flow			Deep Percolation		Stream	Artificial Recharge			Subtotal	Pumping	Inter-basin Flow			ET	Rising	Subtotal	
	Boundary	Chino North	PBMZ	Chino East	Precipitation	Applied Water	Recharge	Storm	State Project	Recycled	Inflows		Chino North	PBMZ	Chino East		Groundwater	Outflow	
1	125	0	0	0	2,836	2,670	16,094	0	0	0	21,725	7,658	6,137	2,638	1,902	6,434	794	25,563	-3,838
2	125	0	0	0	2,793	2,707	18,928	0	0	0	24,553	7,640	7,081	2,522	2,594	6,427	244	26,508	-1,955
3	125	0	0	0	2,749	2,744	20,418	0	0	0	26,036	7,473	7,649	2,456	2,972	6,427	74	27,050	-1,014
4	125	0	0	0	2,706	2,781	21,573	0	0	0	27,185	7,686	8,400	2,408	3,509	6,427	29	28,459	-1,273
5	125	0	0	0	2,663	2,819	22,656	0	0	0	28,262	7,519	8,810	2,374	3,739	6,434	21	28,896	-634
6	125	0	0	0	2,619	2,856	22,921	0	0	0	28,521	7,352	8,997	2,352	3,632	6,427	20	28,780	-259
7	125	0	0	0	2,576	2,893	25,303	0	0	0	30,897	10,390	10,762	2,036	3,554	6,427	20	33,189	-2,292
8	125	0	0	0	2,533	2,930	27,638	0	0	0	33,226	10,287	12,287	1,796	3,534	6,427	20	34,351	-1,125
9	125	0	0	0	2,489	2,968	28,677	0	0	0	34,259	10,184	12,917	1,726	3,620	6,434	21	34,901	-642
10	125	0	0	0	2,446	3,005	29,047	0	0	0	34,623	10,081	13,103	1,686	3,676	6,427	20	34,994	-371
11	125	0	0	0	2,403	3,042	29,253	0	0	0	34,823	9,977	13,293	1,669	3,751	6,427	20	35,137	-314
12	125	0	0	0	2,359	3,079	29,369	0	0	0	34,933	9,875	13,398	1,661	3,816	6,427	21	35,197	-264
13	125	0	0	0	2,316	3,117	29,430	0	0	0	34,988	9,724	13,450	1,666	3,869	6,434	21	35,164	-176
14	125	0	0	0	2,273	3,154	29,279	0	0	0	34,831	9,573	13,398	1,665	3,839	6,427	21	34,923	-92
15	125	0	0	0	2,230	3,191	29,012	0	0	0	34,558	9,423	13,352	1,673	3,664	6,427	22	34,560	-3
16	125	0	0	0	2,186	3,228	28,715	0	0	0	34,255	9,272	13,259	1,685	3,618	6,427	22	34,283	-28
17	125	0	0	0	2,143	3,266	28,500	0	0	0	34,033	9,121	13,150	1,706	3,591	6,434	22	34,024	9
18	125	0	0	0	2,143	3,266	28,226	0	0	0	33,759	9,121	12,987	1,712	3,559	6,427	23	33,828	-69
19	125	0	0	0	2,143	3,266	28,091	0	0	0	33,624	9,121	12,895	1,721	3,603	6,427	23	33,789	-165
20	125	0	0	0	2,143	3,266	28,149	0	0	0	33,682	9,121	12,880	1,726	3,949	6,427	23	34,126	-443
21	125	0	0	0	2,143	3,266	28,561	0	0	0	34,094	9,121	12,945	1,731	4,172	6,434	23	34,425	-331
22	125	0	0	0	2,143	3,266	28,377	0	0	0	33,910	9,121	12,808	1,724	3,702	6,427	23	33,804	106
23	125	0	0	0	2,143	3,266	28,136	0	0	0	33,669	9,121	12,807	1,727	3,639	6,427	24	33,744	-74
24	125	0	0	0	2,143	3,266	28,015	0	0	0	33,548	9,121	12,790	1,728	3,612	6,427	24	33,702	-154
25	125	0	0	0	2,143	3,266	28,009	0	0	0	33,542	9,121	12,792	1,735	3,609	6,434	24	33,715	-172
Total	3,125	0	0	0	59,464	76,574	662,377	0	0	0	801,540	226,203	292,347	47,522	88,723	160,718	1,601	817,113	-15,573
Average	125	0	0	0	2,379	3,063	26,495	0	0	0	32,062	9,048	11,694	1,901	3,549	6,429	64	32,685	-623
Maximum	125	0	0	0	2,836	3,266	29,430	0	0	0	34,988	10,390	13,450	2,638	4,172	6,434	794	35,197	106
Minimum	125	0	0	0	2,143	2,670	16,094	0	0	0	21,725	7,352	6,137	1,661	1,902	6,427	20	25,563	-3,838

Table 8-6d
Estimated Hydrologic Budget for the Chino Basin by RWQCB Management Zone – Prado Basin, Baseline Period 2004/05 to 2028/29

(acre-ft)

Period	Inflow											Outflows							Inflow-Outflow
		Inter-basin Flow			Deep Percolation		Stream Recharge	Artificial Recharge			Subtotal Inflows	Pumping	Inter-basin Flow			ET	Rising Groundwater	Subtotal Outflow	
	Boundary	Chino North	Chino South	Temescal	Precipitation	Applied Water		Storm	State Project	Recycled			Chino North	Chino South	Temescal				
1	0	8,440	2,638	1,360	2,168	1,193	10,759	0	0	4,500	31,058	4,771	0	0	0	16,134	11,232	32,137	-1,079
2	0	7,865	2,522	889	2,138	1,164	11,639	0	0	4,500	30,716	4,657	0	0	0	16,117	10,492	31,266	-550
3	0	7,432	2,456	927	2,107	1,136	12,270	0	0	4,500	30,828	4,542	0	0	0	16,117	10,157	30,816	12
4	0	7,014	2,408	956	2,077	1,107	12,629	0	0	4,500	30,691	4,428	0	0	0	16,117	10,007	30,552	139
5	0	6,724	2,374	964	2,047	1,078	12,861	0	0	4,500	30,547	4,312	0	0	0	16,134	9,904	30,350	198
6	0	6,567	2,352	952	2,016	1,050	12,967	0	0	4,500	30,404	4,198	0	0	0	16,117	9,800	30,115	289
7	0	4,434	2,036	934	1,986	1,021	13,596	0	0	4,500	28,507	4,082	0	0	0	16,117	9,332	29,531	-1,025
8	0	3,117	1,796	920	1,956	992	14,717	0	0	4,500	27,997	3,966	0	0	0	16,117	8,482	28,565	-568
9	0	2,632	1,726	898	1,925	962	15,338	0	0	4,500	27,982	3,849	0	0	0	16,134	8,078	28,061	-80
10	0	2,351	1,686	867	1,895	934	15,591	0	0	4,500	27,823	3,734	0	0	0	16,117	7,843	27,694	129
11	0	2,201	1,669	831	1,864	904	15,761	0	0	4,500	27,731	3,618	0	0	0	16,117	7,742	27,477	255
12	0	2,124	1,661	794	1,834	875	15,864	0	0	4,500	27,652	3,501	0	0	0	16,117	7,704	27,322	330
13	0	2,128	1,666	758	1,804	838	15,941	0	0	4,500	27,635	3,354	0	0	0	16,134	7,749	27,237	398
14	0	2,154	1,665	721	1,773	802	15,921	0	0	4,500	27,536	3,206	0	0	0	16,117	7,780	27,103	433
15	0	2,228	1,673	682	1,743	765	15,909	0	0	4,500	27,499	3,058	0	0	0	16,117	7,865	27,040	458
16	0	2,337	1,685	642	1,713	728	15,878	0	0	4,500	27,483	2,911	0	0	0	16,117	7,973	27,001	482
17	0	2,493	1,706	605	1,682	691	15,861	0	0	4,500	27,538	2,763	0	0	0	16,134	8,134	27,031	507
18	0	2,618	1,712	570	1,682	691	15,776	0	0	4,500	27,549	2,763	0	0	0	16,117	8,221	27,101	448
19	0	2,719	1,721	535	1,682	691	15,757	0	0	4,500	27,605	2,763	0	0	0	16,117	8,300	27,180	425
20	0	2,793	1,726	505	1,682	691	15,751	0	0	4,500	27,647	2,763	0	0	0	16,117	8,358	27,238	409
21	0	2,853	1,731	478	1,682	691	15,780	0	0	4,500	27,714	2,763	0	0	0	16,134	8,431	27,328	386
22	0	2,858	1,724	477	1,682	691	15,767	0	0	4,500	27,699	2,763	0	0	0	16,117	8,426	27,306	393
23	0	2,881	1,727	808	1,682	691	15,703	0	0	4,500	27,991	2,763	0	0	0	16,117	8,449	27,329	662
24	0	2,899	1,728	1,199	1,682	691	15,447	0	0	4,500	28,147	2,763	0	0	0	16,117	8,494	27,374	773
25	0	2,933	1,735	1,489	1,682	691	15,169	0	0	4,500	28,199	2,763	0	0	0	16,134	8,581	27,478	721
Total	0	94,794	47,522	20,761	46,187	21,763	368,652	0	0	112,500	712,179	87,054	0	0	0	403,044	217,534	707,632	4,548
Average	0	3,792	1,901	830	1,847	871	14,746	0	0	4,500	28,487	3,482	0	0	0	16,122	8,701	28,305	182
Maximum	0	8,440	2,638	1,489	2,168	1,193	15,941	0	0	4,500	31,058	4,771	0	0	0	16,134	11,232	32,137	773
Minimum	0	2,124	1,661	477	1,682	691	10,759	0	0	4,500	27,483	2,763	0	0	0	16,117	7,704	27,001	-1,079

Table 8-6e
Estimated Hydrologic Budget for the Chino Basin by RWQCB Management Zone – Temescal, Baseline Period 2004/05 to 2028/29

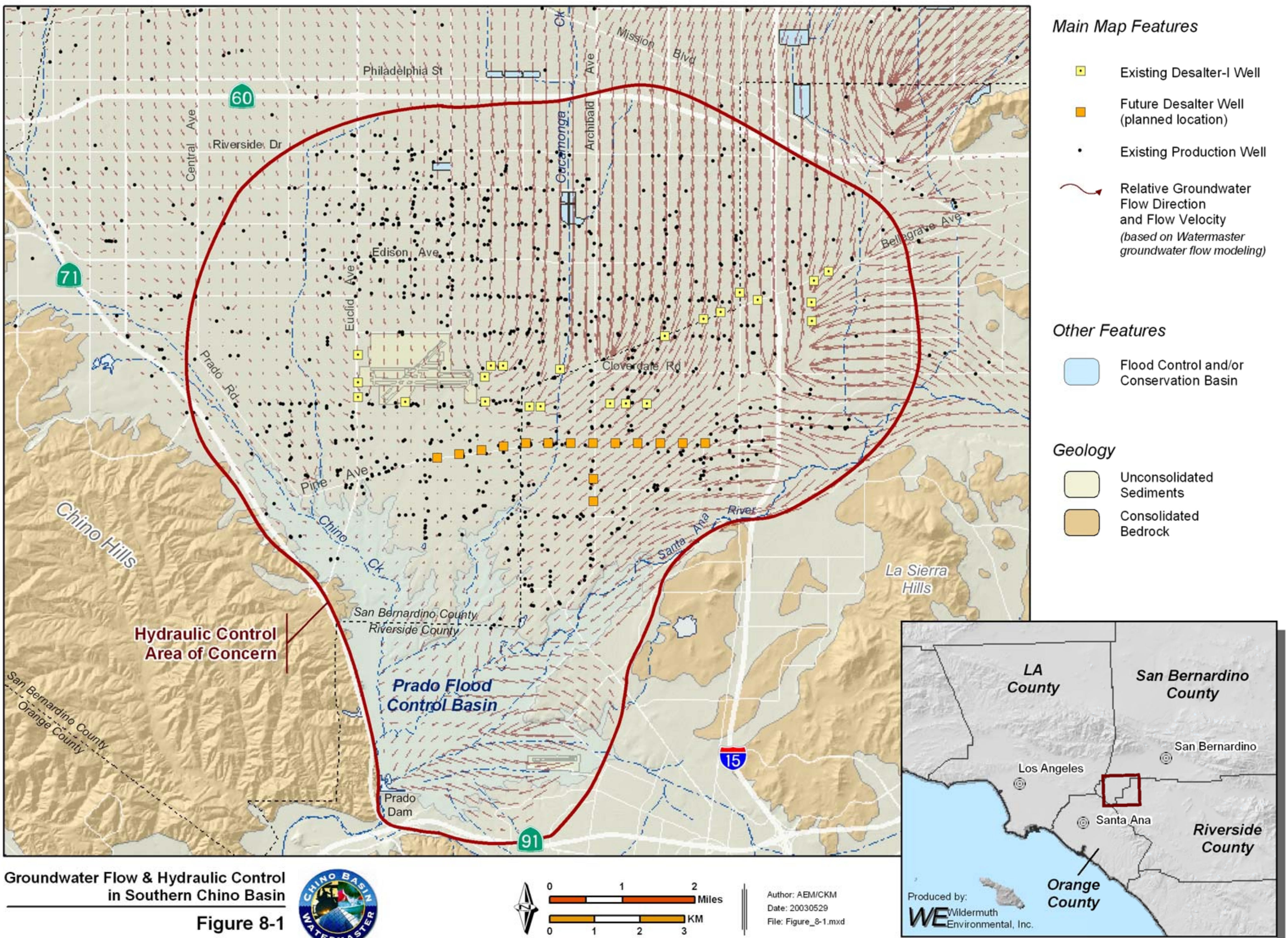
(acre-ft)

Period	Inflows										Outflows						Inflow-Outflow
	Inter-basin Flow			Deep Percolation		Stream Recharge	Artificial Recharge			Subtotal Inflows	Pumping	Inter-basin Flow		ET	Rising Groundwater	Subtotal Outflow	
	Boundary	PBMZ	Chino South	Precipitation	Applied Water		Storm	State Project	Recycled			PBMZ	Chino South				
1	2,520	0	0	1,902	1,761	1,067	0	0	4,500	11,750	19,346	1,360	0	0	0	20,706	-8,955
2	2,520	0	0	1,869	1,754	1,063	0	0	4,500	11,706	10,458	889	0	0	0	11,347	359
3	2,520	0	0	1,836	1,747	1,063	0	0	4,500	11,666	10,458	927	0	0	0	11,385	280
4	2,520	0	0	1,802	1,740	1,063	0	0	4,500	11,625	10,458	956	0	0	0	11,414	211
5	2,520	0	0	1,769	1,732	1,067	0	0	4,500	11,588	10,458	964	0	0	0	11,422	166
6	2,520	0	0	1,736	1,725	1,063	0	0	4,500	11,544	10,458	952	0	0	0	11,410	134
7	2,520	0	0	1,703	1,718	1,063	0	0	4,500	11,503	10,458	934	0	0	0	11,392	112
8	2,520	0	0	1,669	1,711	1,063	0	0	4,500	11,463	10,458	920	0	0	0	11,378	85
9	2,520	0	0	1,636	1,703	1,067	0	0	4,500	11,426	10,458	898	0	0	0	11,356	70
10	2,520	0	0	1,603	1,696	1,063	0	0	4,500	11,382	10,458	867	0	0	0	11,325	57
11	2,520	0	0	1,570	1,689	1,063	0	0	4,500	11,341	10,458	831	0	0	0	11,289	52
12	2,520	0	0	1,536	1,681	1,063	0	0	4,500	11,301	10,458	794	0	0	0	11,252	49
13	2,520	0	0	1,503	1,674	1,067	0	0	4,500	11,264	10,458	758	0	0	0	11,216	48
14	2,520	0	0	1,470	1,667	1,063	0	0	4,500	11,220	10,458	721	0	0	0	11,179	41
15	2,520	0	0	1,436	1,660	1,063	0	0	4,500	11,179	10,458	682	0	0	0	11,140	40
16	2,520	0	0	1,403	1,652	1,063	0	0	4,500	11,139	10,458	642	0	0	0	11,100	38
17	2,520	0	0	1,370	1,645	1,067	0	0	4,500	11,102	10,458	605	0	0	0	11,063	39
18	2,520	0	0	1,370	1,645	1,067	0	0	4,500	11,102	10,458	570	0	0	0	11,028	74
19	2,520	0	0	1,370	1,645	1,067	0	0	4,500	11,102	10,458	535	0	0	0	10,993	109
20	2,520	0	0	1,370	1,645	1,067	0	0	4,500	11,102	10,458	505	0	0	0	10,963	139
21	2,520	0	0	1,370	1,645	1,067	0	0	4,500	11,102	10,458	478	0	0	0	10,936	166
22	2,520	0	0	1,370	1,645	1,067	0	0	4,500	11,102	9,366	477	0	0	0	9,843	1,259
23	2,520	0	0	1,370	1,645	1,067	0	0	4,500	11,102	7,260	808	0	0	0	8,068	3,034
24	2,520	0	0	1,370	1,645	1,067	0	0	4,500	11,102	7,260	1,199	0	0	0	8,459	2,643
26	2,520	0	0	1,370	1,645	1,067	0	0	4,500	11,102	7,260	1,489	0	0	0	8,749	2,353
Total	63,000	0	0	38,773	42,116	26,627	0	0	112,500	283,016	259,652	20,761	0	0	0	280,413	2,602
Average	2,520	0	0	1,551	1,685	1,065	0	0	4,500	11,321	10,386	830	0	0	0	11,217	104
Maximum	2,520	0	0	1,902	1,761	1,067	0	0	4,500	11,750	19,346	1,489	0	0	0	20,706	3,034
Minimum	2,520	0	0	1,370	1,645	1,063	0	0	4,500	11,102	7,260	477	0	0	0	8,068	-8,955

Table 8-7
Model-Estimated Inflows, Outflows and Rising Water Contributions to the Santa Ana River for the Prado Basin Management Zone
Baseline Scenario 2004/05 to 2028/29

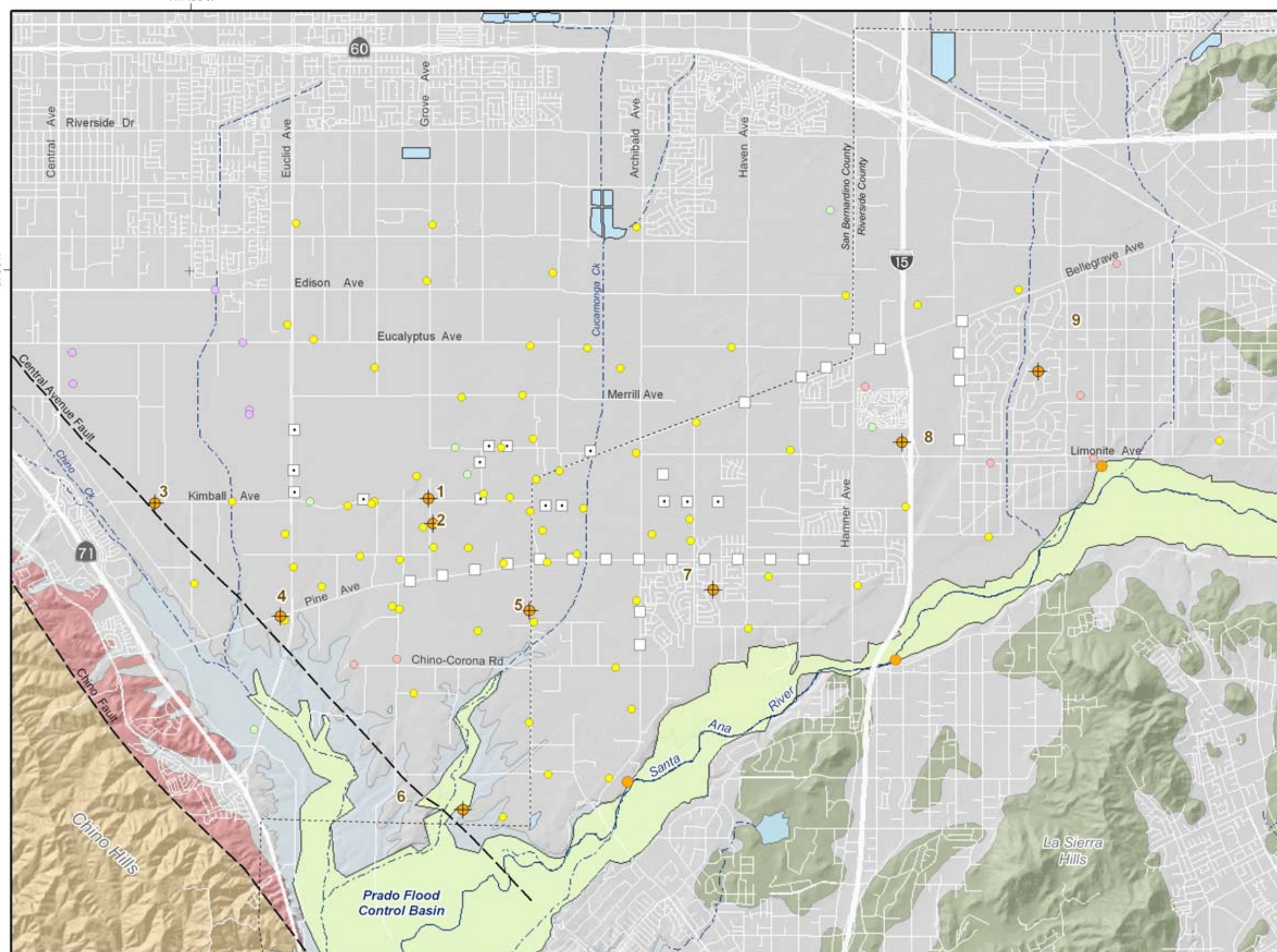
(acre-ft)

Period	Inflow								Outflows				Rising Water Attributed to Inflows from Upgradient Management Zones				
	Inter-basin Flow			Deep Percolation		Stream	ficial Recha	Subtotal	Pumping	Uptake by	Rising	Subtotal					
	Chino North	Chino South	Temescal	Precipitation	Applied Water	Recharge	Recycled	Inflows		Riparian Vegetation	Groundwater	Outflow	Chino North	Chino South	Temescal	PBMZ	Total
1	8,440	2,638	1,360	2,168	1,193	10,759	4,500	31,058	4,771	16,134	11,232	32,137	1,924	601	310	8,397	11,232
2	7,865	2,522	889	2,138	1,164	11,639	4,500	30,716	4,657	16,117	10,492	31,266	1,476	473	167	8,376	10,492
3	7,432	2,456	927	2,107	1,136	12,270	4,500	30,828	4,542	16,117	10,157	30,816	1,211	400	151	8,395	10,157
4	7,014	2,408	956	2,077	1,107	12,629	4,500	30,691	4,428	16,117	10,007	30,552	1,062	365	145	8,435	10,007
5	6,724	2,374	964	2,047	1,078	12,861	4,500	30,547	4,312	16,134	9,904	30,350	968	342	139	8,455	9,904
6	6,567	2,352	952	2,016	1,050	12,967	4,500	30,404	4,198	16,117	9,800	30,115	910	326	132	8,431	9,800
7	4,434	2,036	934	1,986	1,021	13,596	4,500	28,507	4,082	16,117	9,332	29,531	518	238	109	8,468	9,332
8	3,117	1,796	920	1,956	992	14,717	4,500	27,997	3,966	16,117	8,482	28,565	170	98	50	8,164	8,482
9	2,632	1,726	898	1,925	962	15,338	4,500	27,982	3,849	16,134	8,078	28,061	53	35	18	7,972	8,078
10	2,351	1,686	867	1,895	934	15,591	4,500	27,823	3,734	16,117	7,843	27,694	6	4	2	7,831	7,843
11	2,201	1,669	831	1,864	904	15,761	4,500	27,731	3,618	16,117	7,742	27,477	0	0	0	7,742	7,742
12	2,124	1,661	794	1,834	875	15,864	4,500	27,652	3,501	16,117	7,704	27,322	0	0	0	7,704	7,704
13	2,128	1,666	758	1,804	838	15,941	4,500	27,635	3,354	16,134	7,749	27,237	0	0	0	7,749	7,749
14	2,154	1,665	721	1,773	802	15,921	4,500	27,536	3,206	16,117	7,780	27,103	0	0	0	7,780	7,780
15	2,228	1,673	682	1,743	765	15,909	4,500	27,499	3,058	16,117	7,865	27,040	0	0	0	7,865	7,865
16	2,337	1,685	642	1,713	728	15,878	4,500	27,483	2,911	16,117	7,973	27,001	4	3	1	7,965	7,973
17	2,493	1,706	605	1,682	691	15,861	4,500	27,538	2,763	16,134	8,134	27,031	26	18	6	8,084	8,134
18	2,618	1,712	570	1,682	691	15,776	4,500	27,549	2,763	16,117	8,221	27,101	44	29	10	8,138	8,221
19	2,719	1,721	535	1,682	691	15,757	4,500	27,605	2,763	16,117	8,300	27,180	58	37	11	8,194	8,300
20	2,793	1,726	505	1,682	691	15,751	4,500	27,647	2,763	16,117	8,358	27,238	68	42	12	8,235	8,358
21	2,853	1,731	478	1,682	691	15,780	4,500	27,714	2,763	16,134	8,431	27,328	78	47	13	8,293	8,431
22	2,858	1,724	477	1,682	691	15,767	4,500	27,699	2,763	16,117	8,426	27,306	78	47	13	8,287	8,426
23	2,881	1,727	808	1,682	691	15,703	4,500	27,991	2,763	16,117	8,449	27,329	85	51	24	8,288	8,449
24	2,899	1,728	1,199	1,682	691	15,447	4,500	28,147	2,763	16,117	8,494	27,374	109	65	45	8,274	8,494
25	2,933	1,735	1,489	1,682	691	15,169	4,500	28,199	2,763	16,134	8,581	27,478	142	84	72	8,283	8,581
Total	94,794	47,522	20,761	46,187	21,763	368,652	112,500	712,179	87,054	403,044	217,534	707,632	8,991	3,305	1,431	203,808	217,534
Average	3,792	1,901	830	1,847	871	14,746	4,500	28,487	3,482	16,122	8,701	28,305	360	132	57	8,152	8,701
Maximum	8,440	2,638	1,489	2,168	1,193	15,941	4,500	31,058	4,771	16,134	11,232	32,137	1,924	601	310	8,468	11,232
Minimum	2,124	1,661	477	1,682	691	10,759	4,500	27,483	2,763	16,117	7,704	27,001	0	0	0	7,704	7,704



Groundwater Flow & Hydraulic Control in Southern Chino Basin

Figure 8-1



Proposed HCMP Nested Monitoring Well

HCMP Key Well -- Water Level Monitoring

- Agricultural Pool
- Overlying Non-Ag Pool
- Appropriative Pool
- State of California Well
- USGS NAWQA Monitoring Well

Other Features

- Chino-1 Desalter Well (Existing)
- Chino Desalter Well (Proposed)
- Phreatophytes

Geology

Water-Bearing Sediments

- Quaternary Alluvium

Consolidated Bedrock

- Plio-Pleistocene Sedimentary Rocks
- Cretaceous to Miocene Sedimentary Rocks
- Pre-Tertiary Igneous and Metamorphic Rocks

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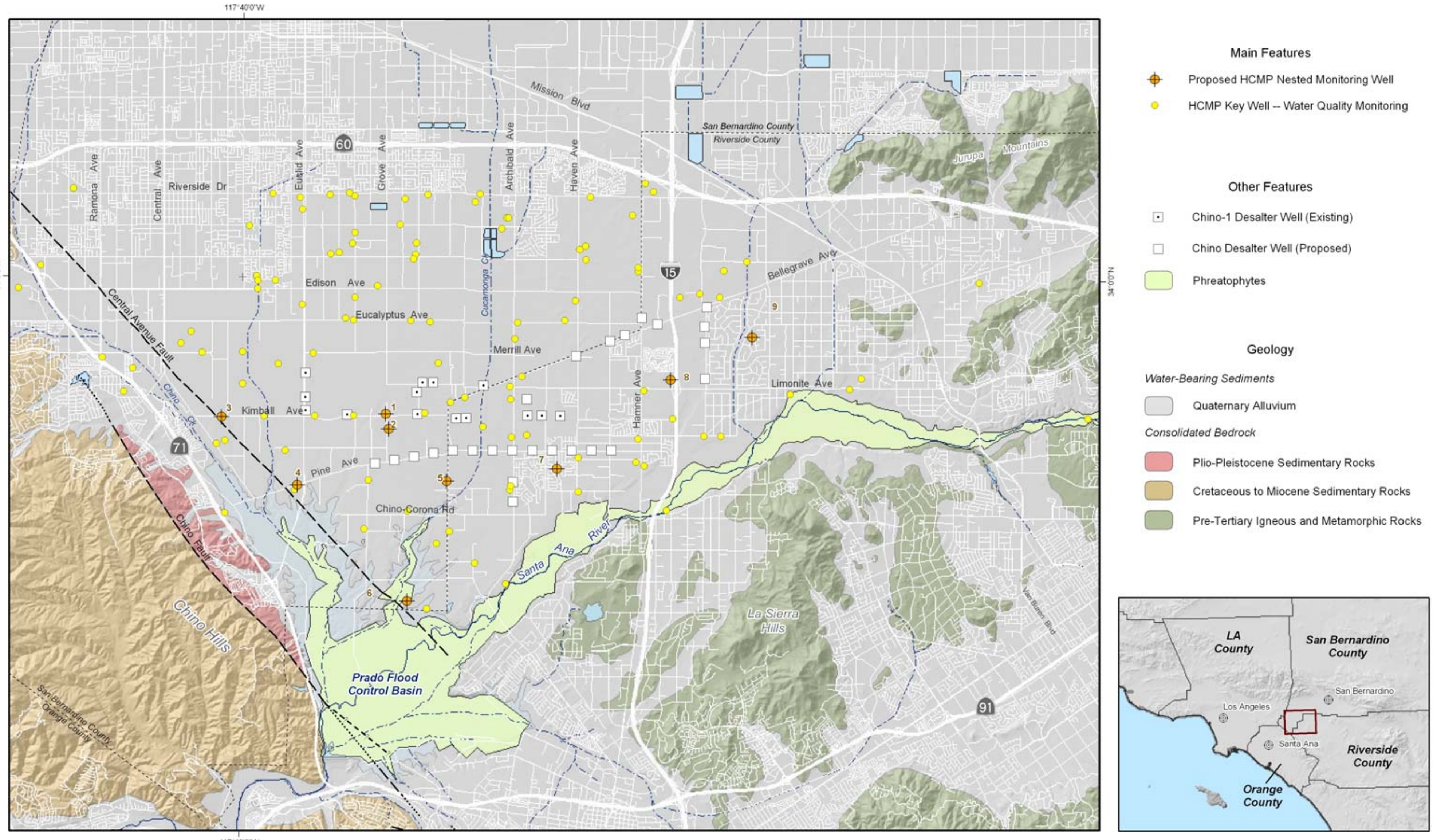
0 1 2 Miles
0 2 4 KM

State of the Basin Report -- 2004
Hydraulic Control

HCMP Key Well Network

Groundwater Levels

Figure 8-2



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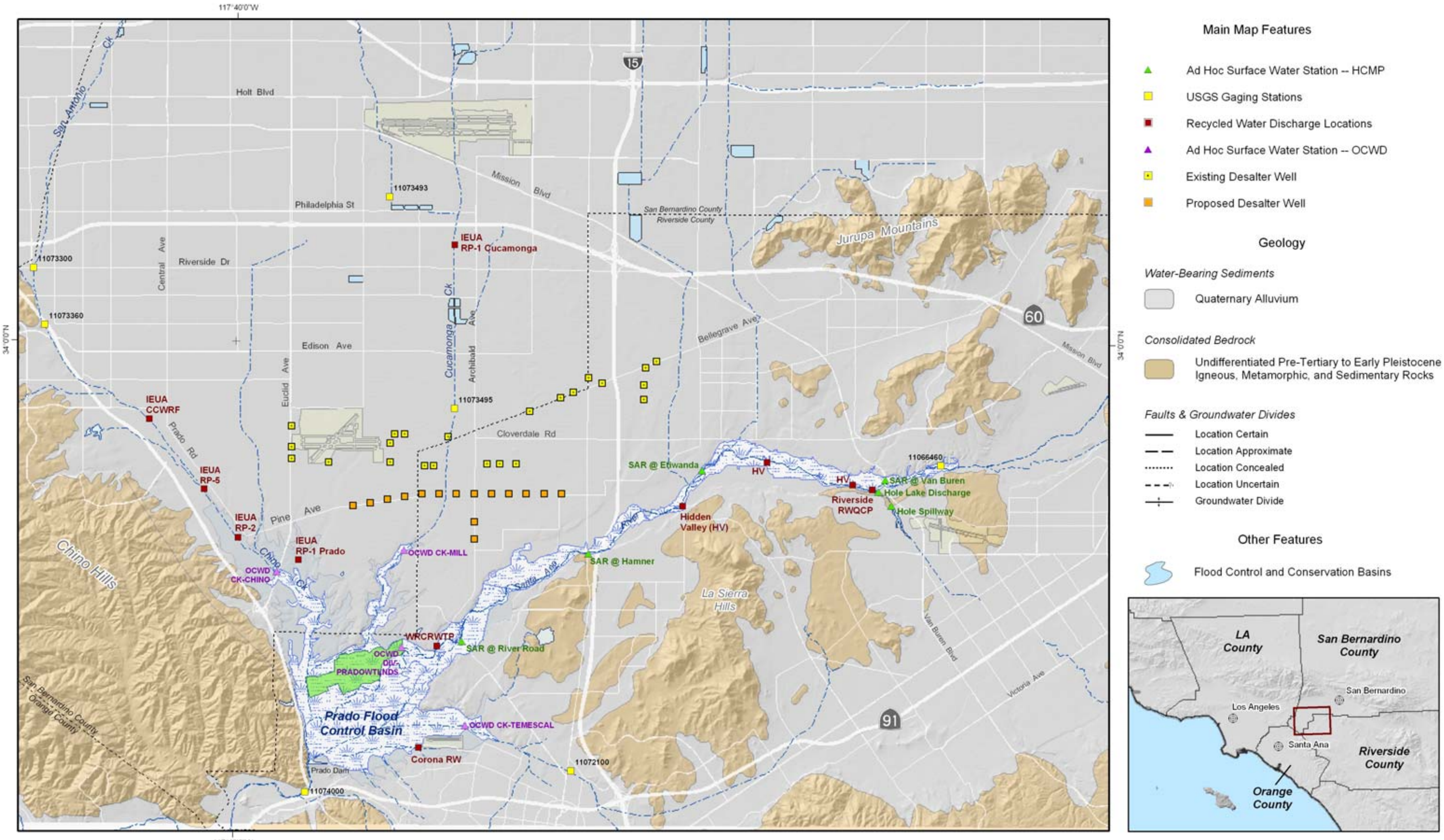
0 1 2 Miles
0 2 4 KM

State of the Basin Report -- 2004
Hydraulic Control

HCMP Key Well Network

Groundwater Quality

Figure 8-3



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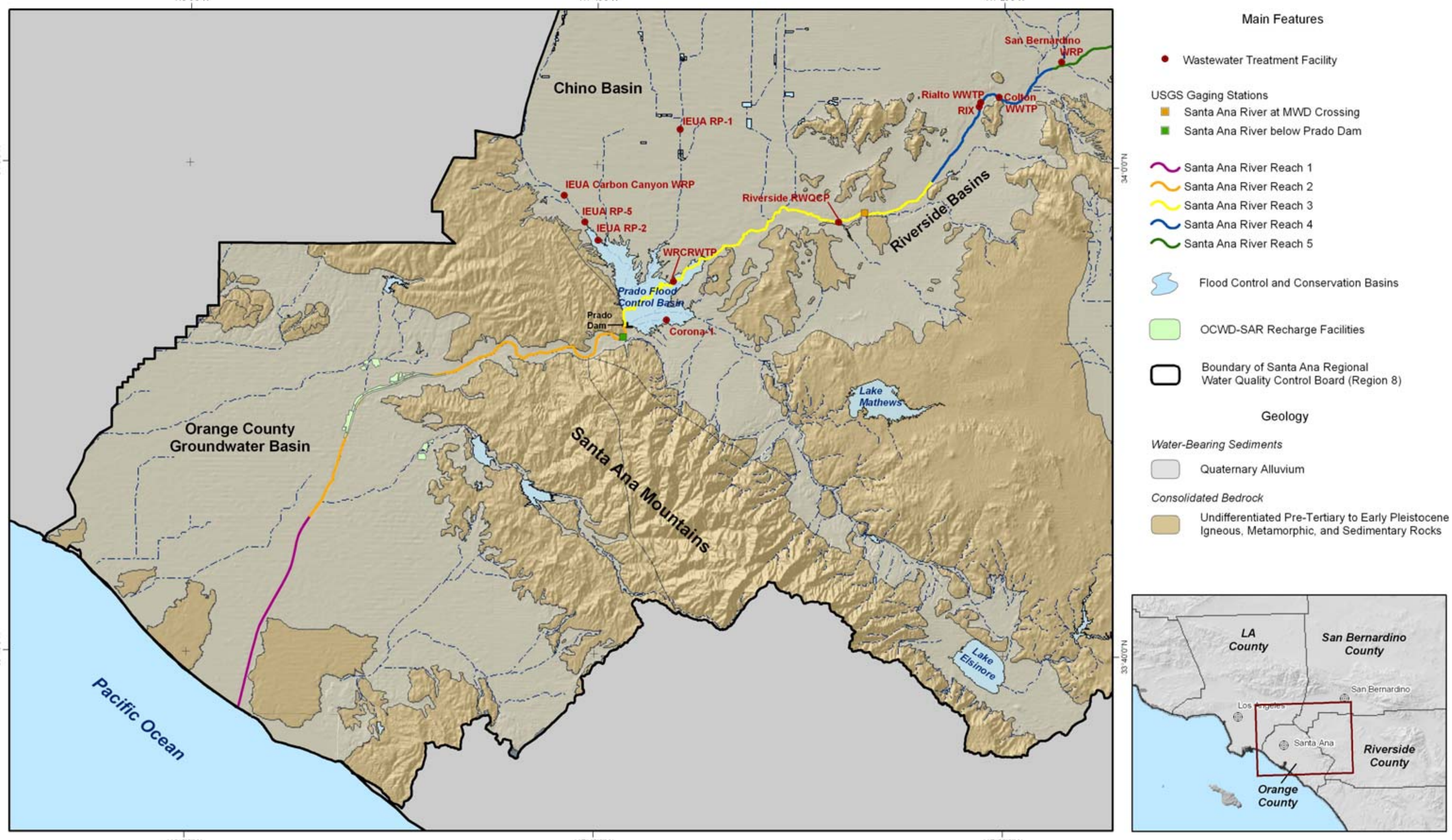
State of the Basin Report -- 2004
Hydraulic Control

Location of Surface Water Stations in the HCMP

Figure 8-4



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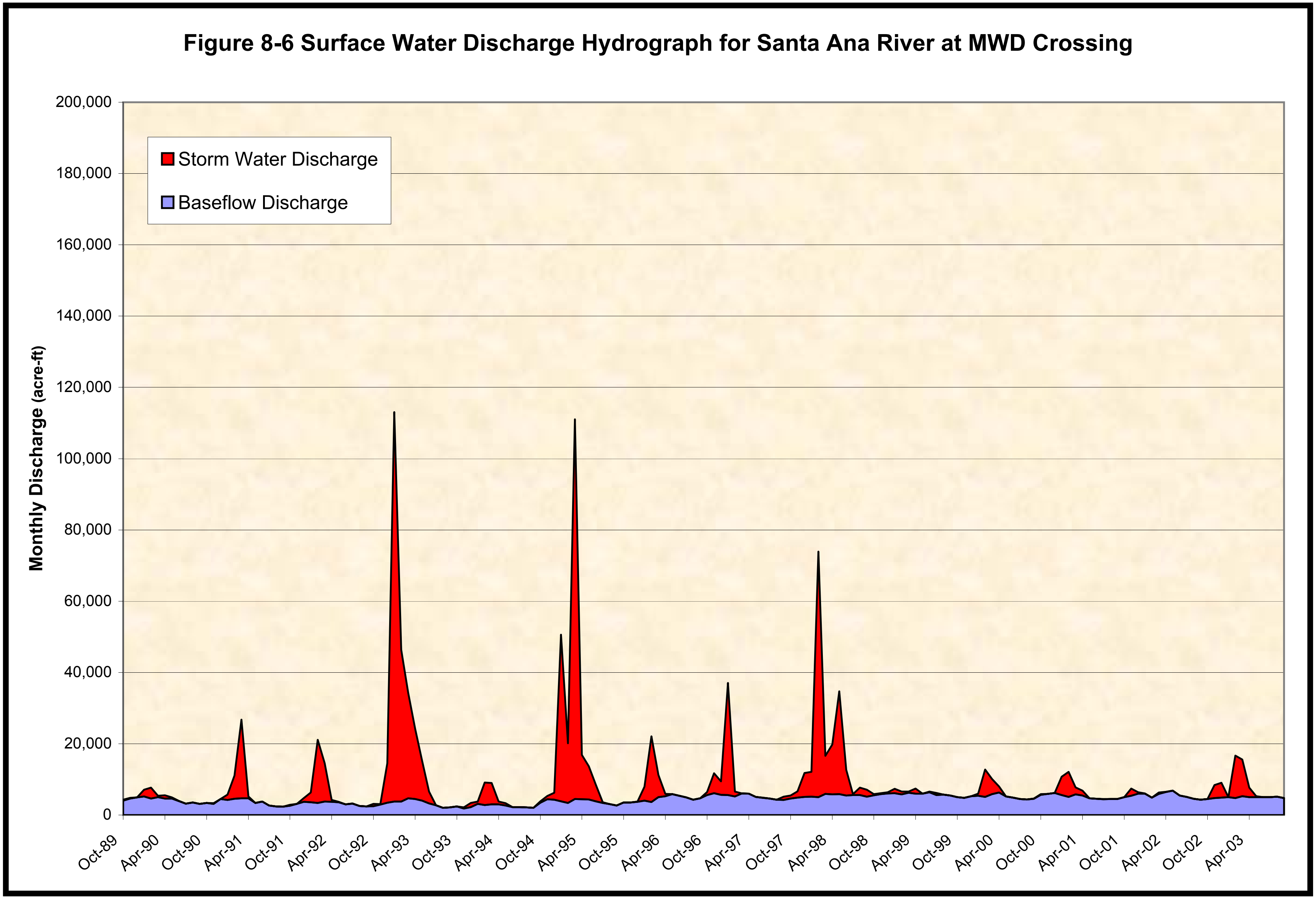
State of the Basin Report -- 2004
Hydraulic Control

Location of Stream Gages and Points of Recycled Water Discharge to the Santa Ana River Watershed

Figure 8-5



Figures_8-6_8-10 -- Fig 8-6 Baseflow and Stor (2)
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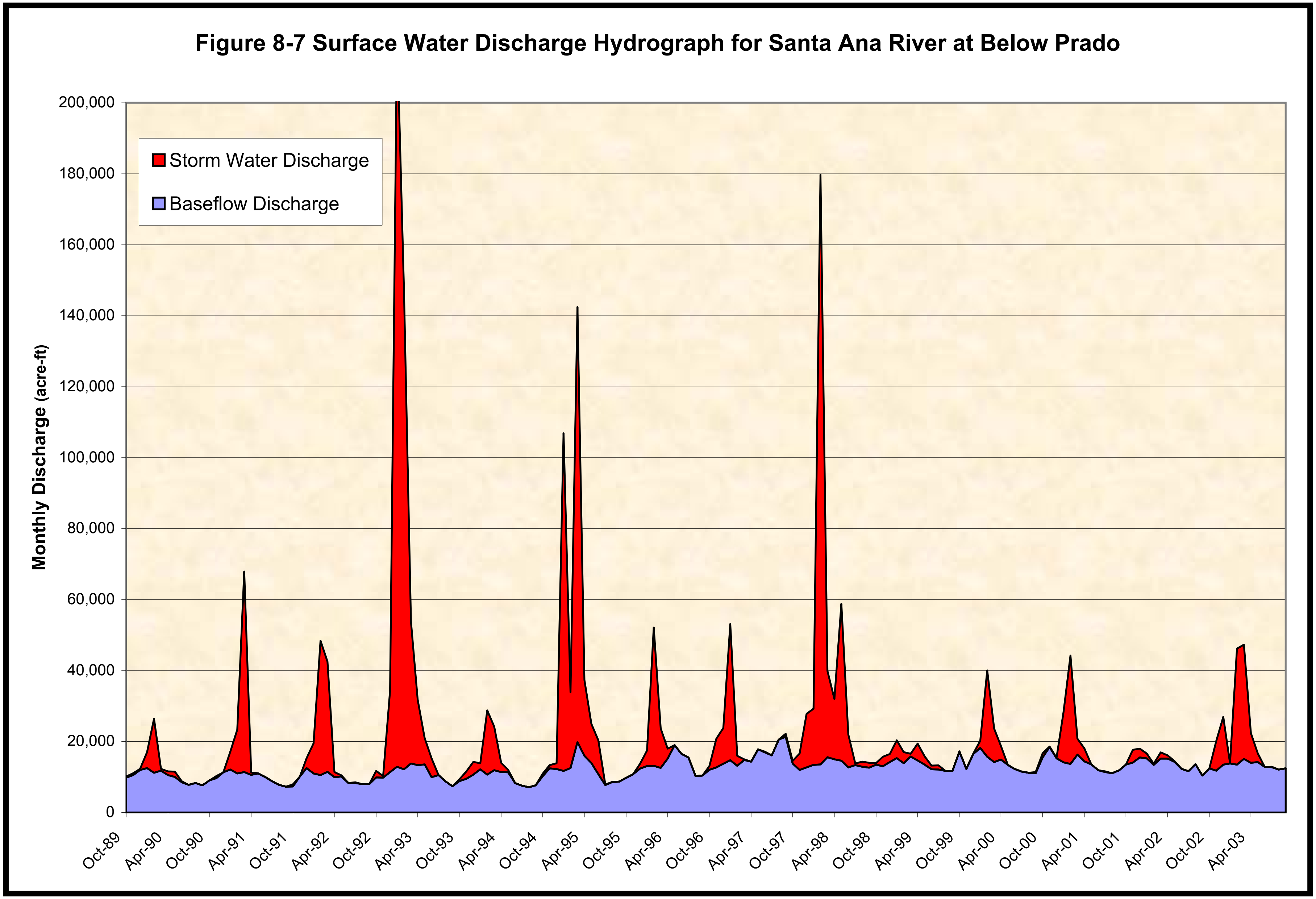
Figure 8-7 Surface Water Discharge Hydrograph for Santa Ana River at Below Prado
Storm Water Discharge
Baseflow Discharge
Monthly Discharge (acre-ft)
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Oct-89
Apr-90
Oct-90
Apr-91
Oct-91
Apr-92
Oct-92
Apr-93
Oct-93
Apr-94
Oct-94
Apr-95
Oct-95
Apr-96
Oct-96
Apr-97
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Apr-02
Oct-02
Apr-03

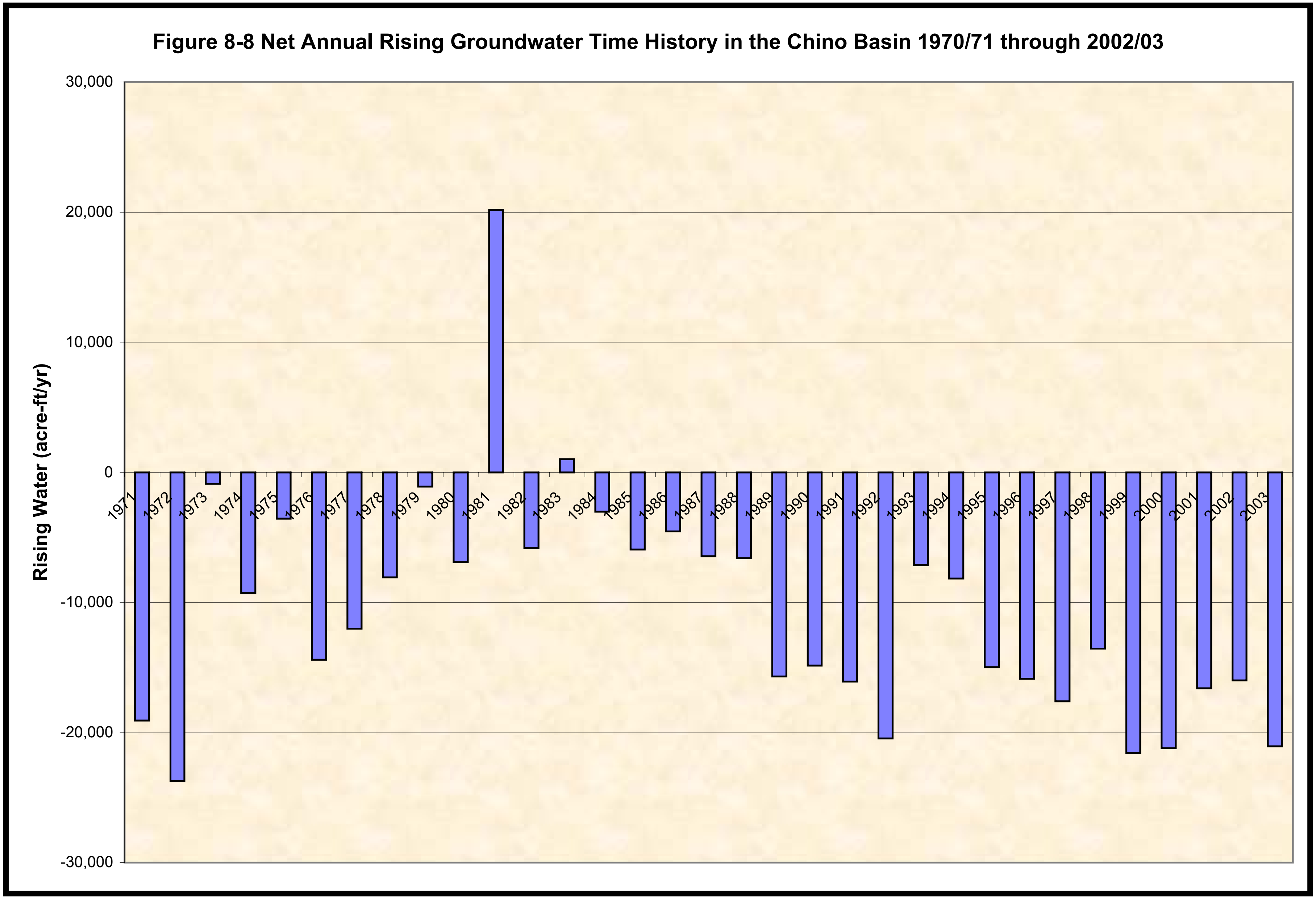

Figure_8-8 -- Fig 8-8
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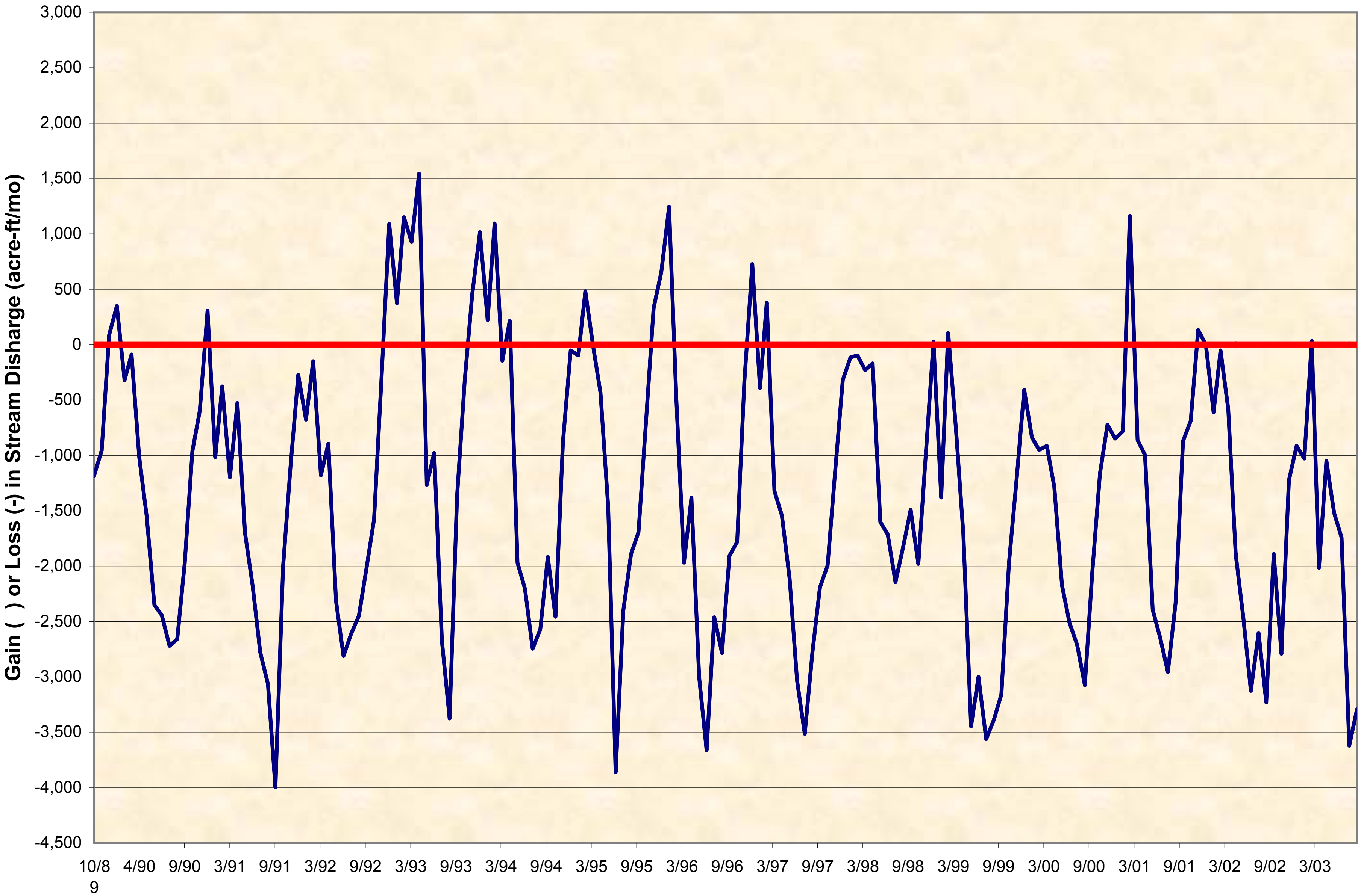
Figure 8-9 Monthly Time History of Baseflow Gains and Losses in the Santa Ana River between Riverside Narrows and Prado Dam -- 1989/90 to 2002/03



Figures_8-6_8-10 -- Fig 8-9 Monthly Time History
1/13/2005

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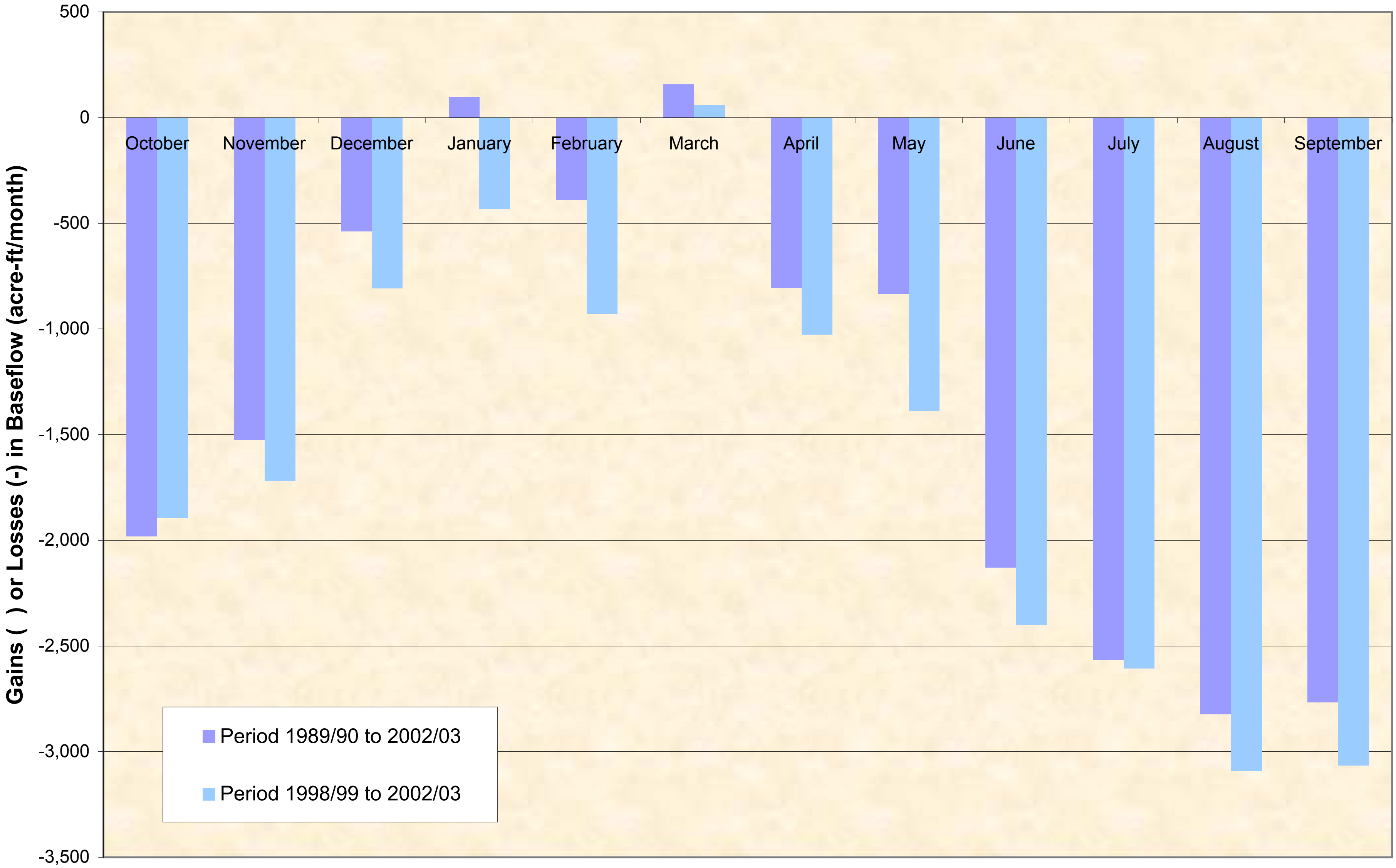
Figure 8-10 Monthly Distribution of Gains and Losses in Santa Ana River Baseflow between Riverside Narrows and Prado Dam -- 1989/90 to 2002/03



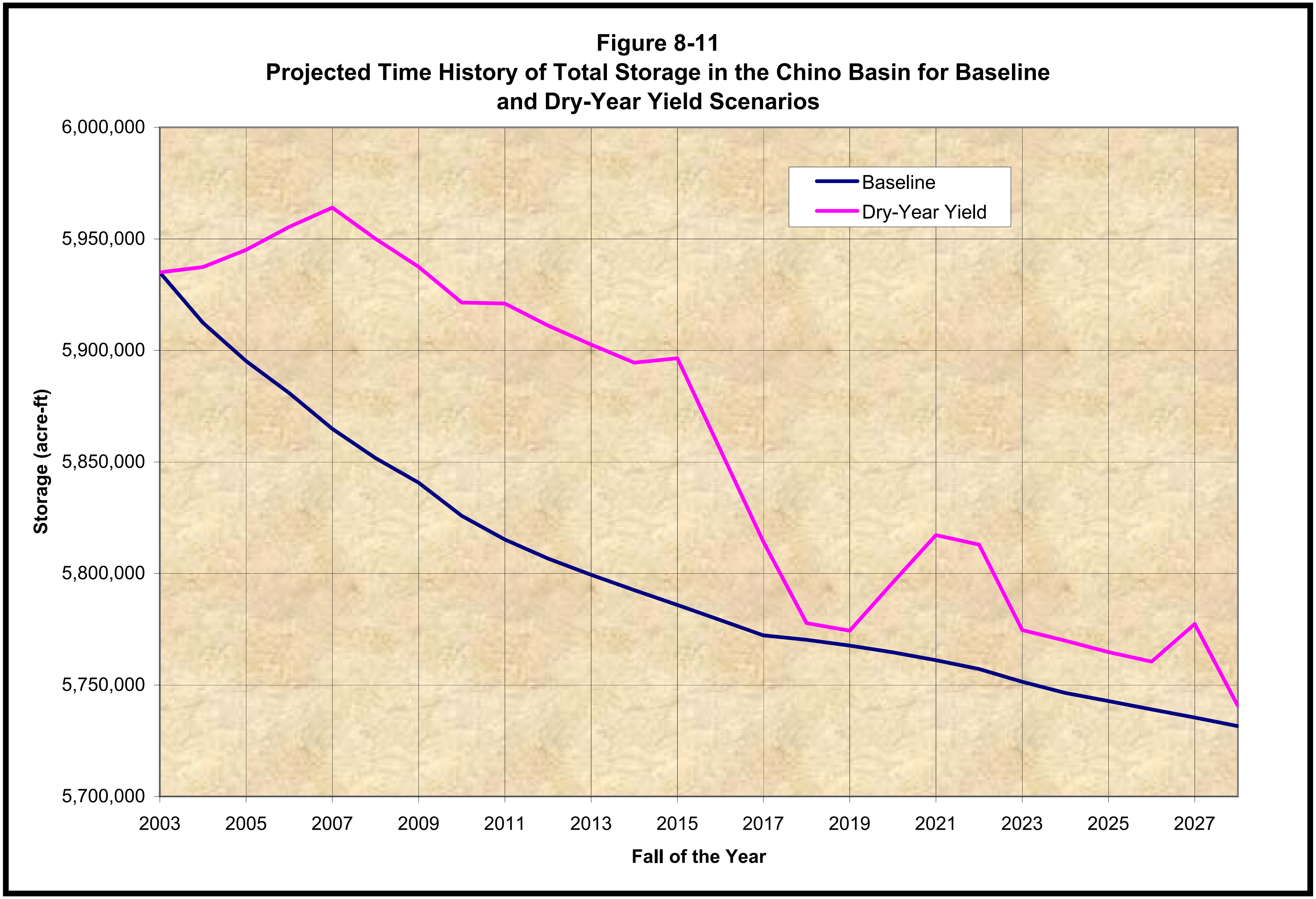


Figure_8-11 -- Figure 8-11
1/13/2005

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9. SUMMARY OF OTHER OBMP ACTIVITIES

9.1 Meter Installation Program

The Watermaster Rules and Regulations require that producers of groundwater in excess of ten (10) acre-feet per year shall install and maintain in good operating condition meters on their well(s). Many Agricultural Pool wells did not have properly functioning in-line meters installed on their discharge pipes when the OBMP was adopted. Watermaster initiated a meter installation program for Agricultural Pool wells without properly functioning in-line meters. As of mid-2004, Watermaster equipped 403 of the 517 existing Agricultural Pool wells with operating in-line meters. The other 114 wells have or will become inactive within 18-24 months because of urban development in the southern portion of Chino Basin.

Watermaster staff reads the meters on Agricultural Pool wells quarterly. A "water duty" method is used to estimate production at agricultural wells that do not have meters.

9.2 Chino Desalter Projects

The Chino I Desalter Expansion and the Chino II Desalter projects primarily consist of the construction of facilities necessary to expand the desalting capacity at the Chino I Desalter by 5 MGD and to generate 10 MGD of product water at the new Chino II Desalter. Both projects began in June 2002 and are estimated to be completed in December 2005.

9.2.1 Chino I Desalter Expansion Facilities

These facilities include the construction of three new wells and one monitoring well, a raw water pipeline from the new extraction wells to the existing raw water pipeline, product water pipelines and pump stations to deliver water to the cities of Ontario and Chino Hills, and a turnout to the City of Chino water system. Other onsite improvements at the Chino I Desalter site are bypass piping, storm drain improvements, SARI flow meter replacement, a sodium hypochlorite station, a volatile organic compound (VOC) treatment system, and an ion exchange treatment facility.

9.2.2 Chino II Desalter Facilities

These facilities include the construction of eight extraction wells and the raw water pipelines to deliver groundwater to the Chino II Desalter facility. The facility itself is being constructed which includes reverse osmosis and ion exchange facilities, product water pipelines and pump stations to deliver the product water to Ontario and the Santa Ana River Water Company, and a brine line pipeline to deliver brine waste to the SARI pipeline.

9.3 Storage and Recovery and DYY Programs

This section will be included in the next draft report.

9.4 Chino Watershed Information System (CWIS)

IEUA and Watermaster maintain information related to local surface water diversion and use, recycled water production and use, groundwater production, recharge of supplemental and storm water, water quality data associated with all forms of water, groundwater level, and monitoring station data independently their own formats and for their own purposes. Each entity uses their data to generate reports at regular frequencies for internal management, internal accounting, and regulatory and planning purposes. The use of different formats for storing and maintaining these data makes the current sharing of these data expensive and leads to errors in the analyses of these data and duplicate efforts in collecting, managing, and storing data. Watermaster and IEUA recognized the issues described above and desired to formalize a data collection and sharing process to minimize the cost of acquiring certain water resources data, to share these data with all interested entities, and to increase the integrity of the data. Watermaster and IEUA are proceeding with the development of the Chino Watershed Information System (CWIS).

At completion in June 2005, the implementation of CWIS will consist of these five main elements:

- CWIS security to allow only permitted users access to information
- IEUA database including data for recycled water, imported water, and supplemental water
- Watermaster database including data for water quality, water level, and water production
- CWIS user interface using an off-the-shelf, web-enabled product called Mapplet.NET by DCSE
- User's guide and documentation

The CWIS security element will define the security and access rules as outlined by both IEUA and Watermaster. The development of the IEUA and Watermaster databases will provide the core elements of CWIS. The Mapplet.NET user interface will provide the seamless access by both IEUA and Watermaster users to CWIS. The user's guide and documentation will facilitate the use of CWIS by end users at both agencies.

Currently, the recycled water data maintained by IEUA can be accessed through an MS-Access based user interface. Imported water data including the ability to collaborate data with MWD bills are currently being implemented. Water quality, level, and production data maintained by Watermaster can be accessed through its own MS-Access based user interface. The ability to exchange water quality data from IEUA's laboratory information management system (LIMS) to CWIS is being tested. The Mapplet.NET user interface has been successfully implemented with more customized data viewing and extraction capabilities developed daily. One of the main features of CWIS will be the ability to enter data securely through web forms which are scheduled to be developed in the coming months.

9.5 Cooperative Efforts and Salt Management

This section will be included in the next draft report.

9.6 Cooperative Agreement between Watermaster and IEUA

This section will be included in the next draft report.

9.7 Balance of Recharge & Discharge

This section will be included in the next draft report.

10. REFERENCES

BDM International. Inc. 1997. Phase II Off-Site Groundwater Investigation Progress Report. General Electric Aircraft Engines. West Coast Operations. Volume I.

Burnham, W.L. 1953. The Geology and Ground Water Conditions of the Etiwanda-Fontana Area, California. Unpublished Master's Thesis, Pomona College. 88 p.

California Department of Health Services. 2002a. California's Experience with Perchlorate in Drinking Water. Press Release. http://www.dhs.cahwnet.gov/ps/ddwem/chemicals/perchl/perchlindex.htm. Last Updated January 11, 2002.

California Department of Health Services. 2002b. Drinking Water Standards - Primary Maximum Contaminant Levels (MCLs) and Lead and Copper Action Levels. http://www.dhs.ca.gov/ps/ddwem/chemicals/MCL/primarymcls.htm. Last Updated February 19, 2002.

California Department of Health Services. 2002c. Perchlorate's Drinking Water Action Level and Regulations. http://www.dhs.ca.gov/ps/ddwem/chemicals/perchl/actionlevel.htm. Last Updated April 29, 2002.

California Department of Water Resources. 1970. Meeting Water Demands in the Chino-Riverside Area, Appendix A: Water Supply. Bulletin No. 104-3, 108 p.

Chino Basin Municipal Water District *v.* City of Chino, *et al.*, San Bernardino Superior Court, No. 164327. January 27, 1978.

Dragun, J. 1988. The Soil Chemistry of Hazardous Materials. Hazardous Materials Control Research Institute. Silver Spring, Maryland.

Durham, D.L. and R.F. Yerkes. 1964. Geology and Oil Resources of the Eastern Puente Hills Area, Southern California: USGS Professional Paper 420-B, 62 p.

Dutcher, L.C. and W.R. Moyle, Jr. 1963. Preliminary Appraisal of the Test-Well Drilling Program in the Bloomington-Colton Area, San Bernardino County, California: USGS Closed-File Report, 15 p.

Dutcher, L.C., and A.A. Garrett. 1963. Geologic and Hydrologic Features of the San Bernardino Area, California, with Special Reference to Underflow Across the San Jacinto Fault: USGS Water Supply Paper 1419, 117 p.

Eckis, R. 1934. Geology and Ground Water Storage Capacity of Valley Fill, South Coastal Basin Investigation: California Department of Public Works, Division of Water Resources Bulletin No. 45, 273 p.

Fife, D.L., Rodgers, D.A., Chase, G.W., Chapman, R.H., and E.C. Sprotte. 1976. Geologic Hazards in Southwestern San Bernardino County, California: California Division of Mines and Geology Special Report 113, 40 p.

Fox, R.C. 1989. Unpublished data from borehole drilling and construction of a municipal well field. Prepared for San Bernardino County Water Works District No. 8. Robert C. Fox Consulting Engineering Geologist. Fullerton, CA.

Fox, R.C. 1990. Euclid Avenue Well Field Investigation. Prepared for San Bernardino County Water Works District No. 8. July 1990.

Freeze R. A. and J. A. Cherry. 1979. Groundwater. Prentice-Hall, Inc. New Jersey.

French, J.J. 1972. Ground-Water Outflow from Chino Basin, Upper Santa Ana Valley, Southern California: USGS Water-Supply Paper 1999-G, 28 p.

GeoLogic Associates. 1997. Engineering Feasibility Study, Upland Landfill, City of Upland. Job No. 9767.

GeoLogic Associates. 1998. Phase II Evaluation Monitoring Program Report, Technical Report and Appendices, Milliken Sanitary Landfill. County of San Bernardino.

GeoLogic Associates. 2002. County of San Bernardino Water Quality Monitoring Report, First Quarter (Winter) 2002 / Annual, Volume I, Santa Ana Region. Prepared for the County of San Bernardino Solid Waste Management Division and the California Regional Water Quality Control Board Santa Ana Region. April 2002.

Geomatrix Consultants, Inc. 1994. Final Report Ground Fissuring Study, California Department of Corrections, California Institution for Men, Chino, California. Project No. 2360. San Francisco, CA.

Geomatrix Consultants, Inc. 1996. Addendum to Work Plan for Phase III Groundwater Assessment, CIM, Chino. Geomatrix Project No.: S2064.04.

Geomatrix Consultants, Inc. 1997. Quarterly Groundwater Monitoring Report, Calendar Quarter October-December 1997. Project No. 1796.09 AH.

Geoscience Support Services, Inc. 2001. Geohydrologic Analysis and Ground Water Flow Model of the Proposed Chino Desalter System Projects Area (Draft). Prepared for the Santa Ana Watershed Project Authority/RBF Consulting. August 31, 2001.

Geoscience Support Services, Inc. 2003. Unpublished data from the drilling and testing of production wells for the expansion of the Chino-1 Desalter.

Gleason, G.B. 1947. South Coastal Basin Investigation, Overdraft on Ground-Water Basins: California Department of Public Works, Division of Water Resources Bulletin 53, 256 p.

Gosling, A.W. 1966. The Patterns of Subsurface Flow in the Bloomington-Colton Area, Upper Santa Ana Valley, California: USGS Open-File Report, 14 p.

Inland Empire Utilities Agency, Dodson and Associates, 2000. Program Environmental Impact Report for the Optimum Basin Management Program. State Clearinghouse Number_______ June 2000.

IT Corporation. 1989. Final Report, Solid Waste Assessment Test, Milliken Sanitary Landfill. San Bernardino County.

James M. Montgomery, Consulting Engineers, Inc. (JMM). 1986. Phase III Groundwater Investigation. Submitted to Kaiser Steel Corporation. March 1986.

James M. Montgomery, Consulting Engineers, Inc. (JMM). 1992. Final Task 5 Memorandum, Chino Basin Conceptual Model.

Johnson, A. I., 1967, Specific yield---compilation of specific yields for various materials: U.S. Geological Survey Water Supply Paper 1662-D, 74 p.

Kleinfelder, Inc. 1993. Geotechnical Investigation, Regional Subsidence and Related Ground Fissuring, City of Chino, California. Project No. 58-3101-01. Diamond Bar, CA.

Kleinfelder, Inc. 1996. Chino Basin Subsidence and Fissuring Study, Chino, California. Project No. 58-5264-02. Diamond Bar, CA.

Kleinfelder, Inc. 1999. Update of Subsidence Map, Chino, California. Project No. 58-9040-01. Diamond Bar, CA.

Kleinfelder, Inc. 2001. Update of Subsidence Map, Chino, California. Project No. 58-9040-01. Diamond Bar, CA.

Larsen, E.S., D.J. Gottfried, H.W. Jaffe, and C.L. Waring. 1958. Lead-alpha ages of the Mesozoic batholiths of western North America: USGS Bull. 1070-B, p. 35-62.

Macler, B. 2000. Drinking Water Standards and Health Advisories Table. USEPA Region IX. February 2000.

MacRostie, W. and A.J. Dolcini. 1959. Santa Ana River Investigation: California Department of Water Resources Bulletin No. 15, 194 p.

Mark J. Wildermuth, Water Resources Engineer. 1991. Phase IV Groundwater Remediation Feasibility Study.

Mark J. Wildermuth, Water Resources Engineers. 1997. Phase 1A Task 2.2 and 2.3 Final Report: Describe Watershed Hydrology and Identify Current TDS and TIN Inflows in the Watershed. September, 1997.

Mendenhall, W. C. 1905. The hydrology of San Bernardino Valley, California: USGS Water-Supply Paper 142, 124 p.

Mendenhall, W. C. 1908. Ground waters and irrigation enterprises in the foothill belt, southern California: USGS Water-Supply Paper 219, p. 39-42, plates III and V.

Metropolitan Water District of Southern California, Camp Dresser & McKee Inc., and James M. Montgomery, Consulting Engineers, Inc. 1988. Draft Environmental Impact Report for the Chino

Basin Groundwater Storage Program. MWDSC Report Number 975. State Clearinghouse Number 8612209. June 1988.

Montgomery Watson and Mark J. Wildermuth Water Resources Engineer. 1994. Final Task 6 Memorandum, Development of Three Dimensional Groundwater Model. March, 1994.

Montgomery Watson. 1995. Chino Basin Water Resources Management Study.

Montgomery Watson. 1999. Summary of Groundwater Production Well Drilling, Construction, Development and Testing Phases I and II (Final). Chino Basin Desalination Program Project. April 1999.

Oak Ridge National Laboratory. 1989. The Installation Restoration Program Toxicology Guide. Prepared for Harry G. Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base. Under DOE Interagency Agreement No. 1891-A076-A1.

Peltzer, G. 1999a. Subsidence Monitoring Project: City of Chino. March 14, 1999.

Peltzer, G. 1999b. Subsidence Monitoring Project: City of Chino. May 9, 1999.

Piper, A. M. 1944. A graphic procedure in the geochemical interpretation of water. Transactions, American Geophysical Union 914-928.

Renner, R. 1999. Study Finding Perchlorate in Fertilizer Rattles Industry. Environmental Science and Technology. Volume 33, Issue 19, pp. 394A to 395A, October 1, 1999.

Santa Ana River Watermaster Reports Numbers 1-30.

United States Geological Survey (USGS). 1999. Land subsidence in the United States / edited by Devin Galloway, David R. Jones, S.E. Ingebritsen. USGS Circular 1182. 175 p.

Urbansky, E. T., T. W. Collette, W. P. Roberge, W. L. Hall, J. M. Skillen, P. F. Kane. 2001 Survey of Fertilizers and Related Materials for Perchlorate (ClO_4^-). Final Report. EPA/600/R-01-047. May 2001.

US EPA. 2001. EPA Announces Arsenic Standard for Drinking Water of 10 Parts per Billion. Dated October 31, 2001.

Watson, I. and A Burnett. 1995. Hydrology: An Environmental Approach. CRC Press. Boca Raton, Florida.

Wildermuth Environmental, Inc. 1999. Optimum Basin Management Program. Phase I Report. Prepared for the Chino Basin Watermaster. August 19, 1999.

Wildermuth Environmental, Inc. 2000a. TIN/TDS Phase 2A: Tasks 1 through 5. TIN/TDS Study of the Santa Ana Watershed. Technical Memorandum. July 2000.

Wildermuth Environmental, Inc. 2000b. TIN/TDS Phase 2A: MS Access Database for TIN/TDS Study of the Santa Ana Watershed. Technical Memorandum. July 2000. Appendix A

Wildermuth Environmental, Inc. 2002. Optimum Basin Management Program, Final Initial State of the Basin Report. Prepared for the Chino Basin Watermaster. October 2002.

Wildermuth Environmental, Inc. 2003. Modeling Report for the Chino Basin Dry-Year Yield Program. Optimum Basin Management Program. Prepared for Chino Basin Watermaster and Inland Empire Utilities Agency under a Subcontract Agreement with Black & Veatch Corp. July 2003.

Wildermuth Environmental, Inc. 2004a. Optimum Basin Management Program. Hydraulic Control Monitoring Program, Final Work Plan. May 2004.

Wildermuth Environmental, Inc. 2004b. Grove Basin Monitoring Program, Technical Memorandum 2002-2004. November 2004.

Woolfenden, L.R., and D. Kadhim. 1997. Geohydrology and Water Chemistry in the Rialto-Colton Basin, San Bernardino County, California: USGS Water-Resources Investigations Report 97-4012, 101 p.