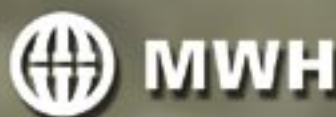


March 2004



Elsinore Valley Municipal Water District

Coldwater Basin Recharge Feasibility Study

Final Report

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APPENDIX C – COST ESTIMATES

Executive Summary

The purpose of this groundwater recharge feasibility study is to evaluate the feasibility of developing a pilot recharge program and ultimately, a long-term groundwater storage program in the Coldwater Basin. The primary goal of the long-term groundwater recharge project is to increase the reliability and sustainability of groundwater resources in the Coldwater Basin, now and in the future.

To achieve this goal, the project objective is to evaluate the feasibility of a recharge program that would enhance and manage groundwater supplies through conjunctive use activities. Conjunctive use is the process of storing water in the groundwater basin during periods when additional water supplies are available and extracting the water in periods when supplemental water supplies are not available. The recharge feasibility study includes a compilation of hydrogeologic data needed to estimate the basin yield and evaluate the long-term storage potential in the basin through conjunctive use.

STUDY AREA

The study area for this investigation is the Coldwater Basin watershed, which consists of the Coldwater groundwater basin and its tributary surface drainage area (**Figure ES-1**). The Coldwater Basin is located about 8 miles southeast of the City of Corona within the Temescal Valley southwest of Interstate 15. The watershed area is approximately 10,740 acres, of which about 1,680 acres makes up the groundwater basin. The remaining portions of the Coldwater Basin consist of the surrounding highlands of the Santa Ana Mountains and associated streams and canyons. Major surface water drainages include Coldwater, Anderson, Bixby, Mayhew, and Brown Canyons, which surround the western and southern boundaries of the groundwater basin.

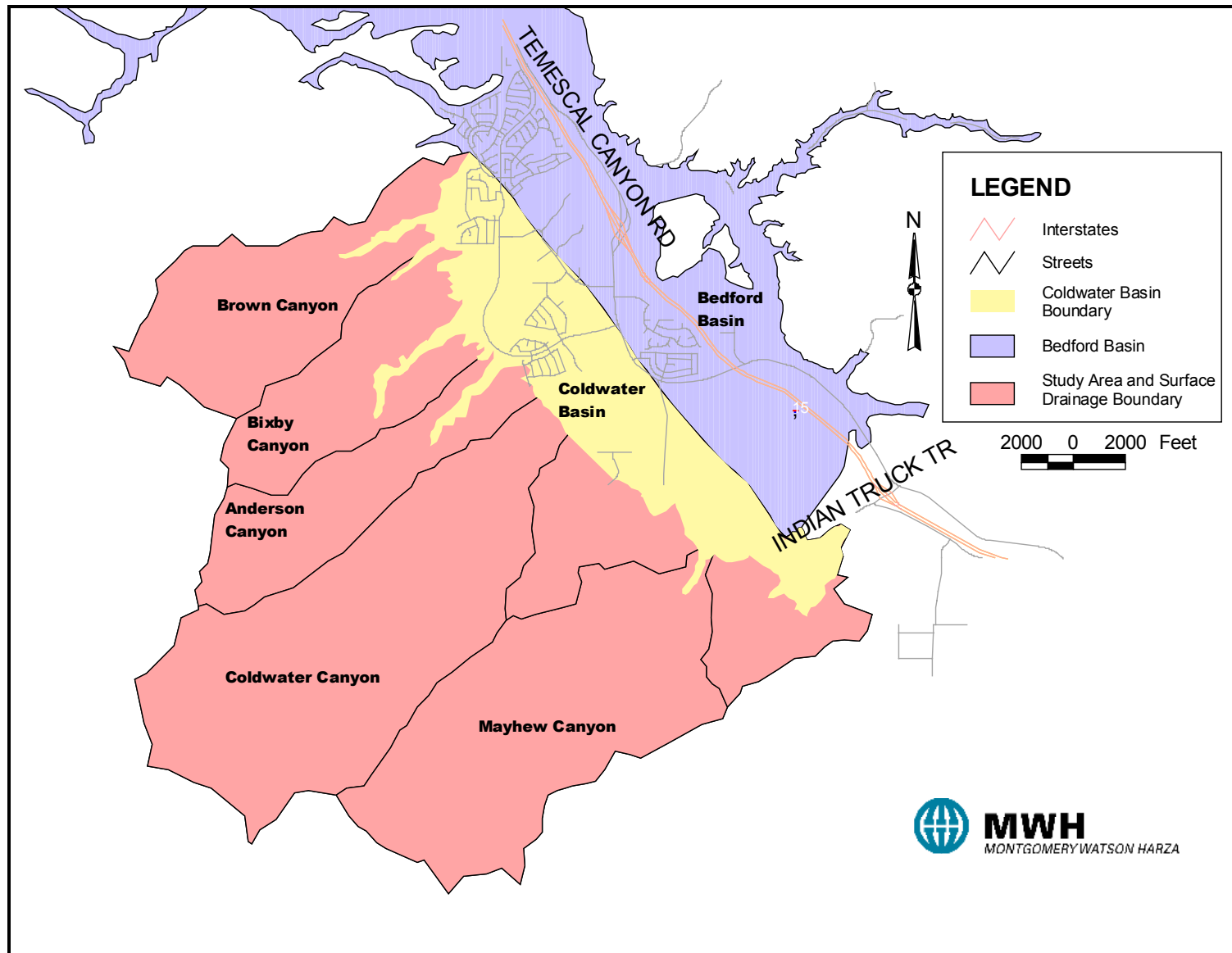
HYDROGEOLOGIC SETTING

The Coldwater Basin lies within a down-dropped block between the North Glen Ivy and South Glen Ivy faults, which are associated with the right lateral strike-slip-dominated Elsinore Fault Zone (EFZ). The EFZ extends approximately 200 km from Baja California north to the Corona area. The Coldwater Basin is surrounded by the metamorphic, volcanic and granitic basement rocks of the Santa Ana Mountains to the south and west, and the Bedford groundwater basin, which is located to the north and east and is separated from the Coldwater Basin by the North Glen Ivy fault. MWH has reviewed and compiled available data to evaluate the geometry and update the hydrogeologic conceptual model for the Coldwater Basin. Based upon the data compiled as part of this report, the Coldwater Basin watershed contains the following stratigraphic units:

- Alluvium
- Bedford Canyon Formation
- Volcanic rocks and
- Granitic basement rocks

Only the alluvium produces significant groundwater resources.

**Figure ES-1
Study Area**



Based upon the data compiled as part of this study, there do not appear to be any significant confining layers within the alluvium except in the northwestern portion of the basin where there is substantial clay. As shown in **Figure ES-2**, groundwater appears to flow toward the pumping depression near the center of the basin. Currently, water levels are generally declining throughout the basin. However, historical records indicate that the basin is very responsive to changes in operational and climatic conditions. Recharge to the alluvium occurs along the margins of the basin through Mayhew, Coldwater, Anderson, Bixby and Brown Canyons. Faults within the basin appear to be complete barriers to subsurface flow except where gravel pits cross the faults.

Table ES-1 provides an average groundwater budget for the base period from 1977 to 2000. Comparing total inflows to total outflows shows an average groundwater deficit of approximately 500 acre-ft/yr over the 23-year period of review.

Table ES-1
Summary of Estimated Water Budget – 1977-2000

Component	Average 1977-2000 (acre-ft/yr)
Inflows	
Precipitation and Applied Water	1,700
Surface Diversions	2,200
Returns from Gravel Washing	1,000
Subsurface Inflow	1,800
Total Average Inflow	6,700
Outflows	
Groundwater Pumpage	6,100
Evaporation from Gravel Pits	200
Losses from Gravel Operations	700
Subsurface Outflow	200
Total Average Outflow	7,200
Net Surplus or Deficit	-500

Figure ES-3 shows the estimated water in storage during the base period. The total basin storage volume is estimated to be approximately 74,800 acre-ft based upon a specific yield ranging from 7 to 9 percent. The estimated groundwater in storage in September 2000 is estimated to be approximately 41,600 acre-ft (about 55 percent full). The estimated cumulative loss in storage in the Coldwater Basin between 1977 and 2000 is approximately 10,000 acre-ft.

Figure ES-2
Cross Section A-A'

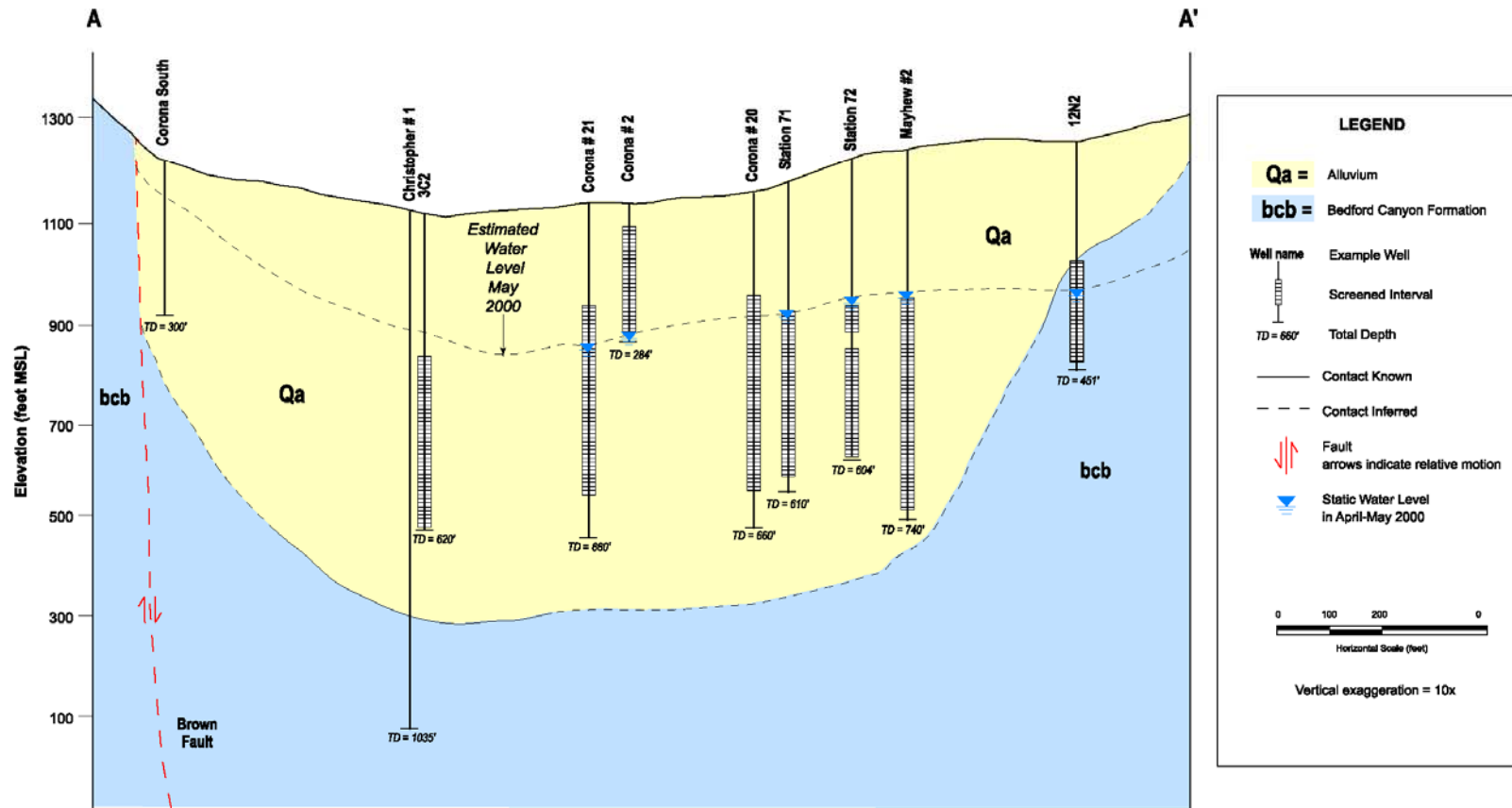
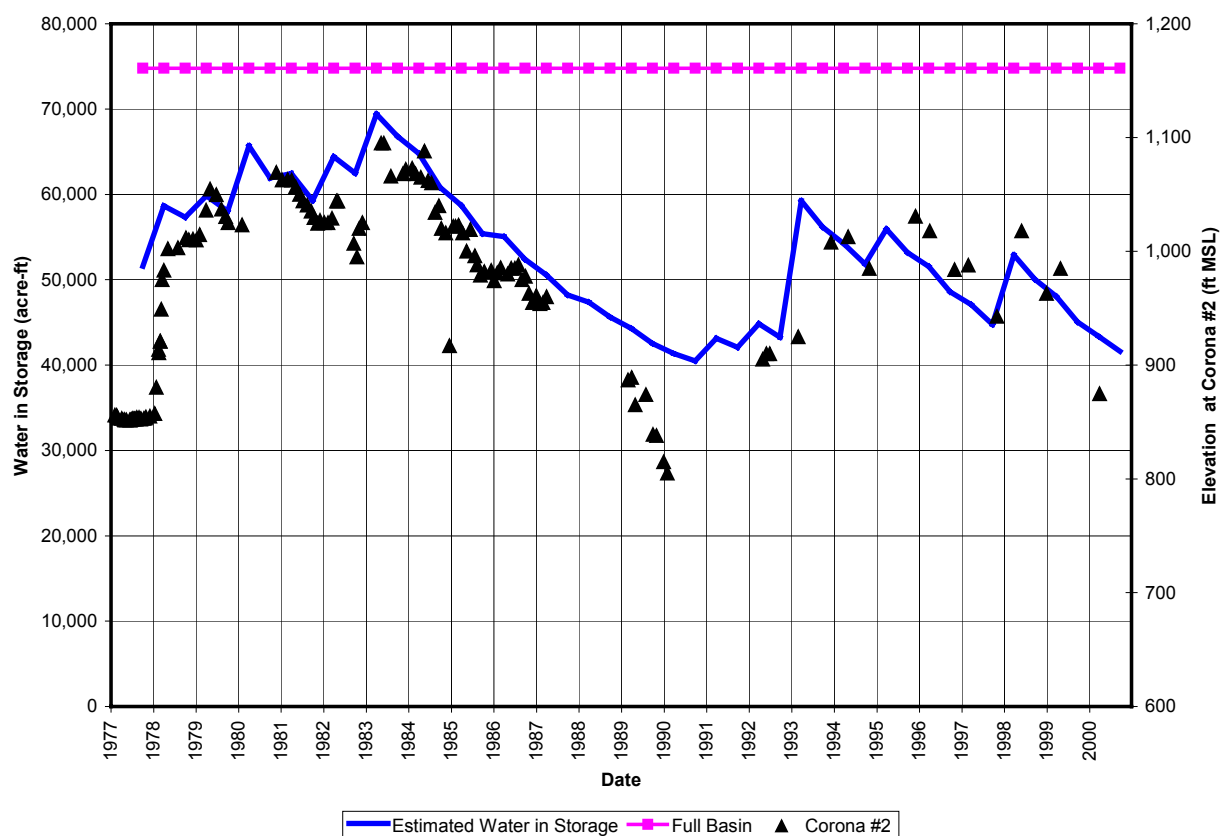


Figure ES-3
Estimated Water in Storage – 1977-2000



GROUNDWATER MODEL

Based upon the hydrogeologic conceptual model, a single layer numerical groundwater flow model was constructed and calibrated to evaluate conjunctive use alternatives. The model was calibrated using static and pumping water level information from seven wells in the Coldwater Basin. Calibration is generally good throughout the basin, with the best calibration near the City of Corona's and the District's wells. The model is most sensitive to net recharge and least sensitive to changes in hydraulic conductivity.

PROJECT ALTERNATIVES

Based upon a review of the hydrogeologic setting of the Elsinore Basin, discussions with District staff and field reconnaissance, three project alternatives (including baseline) have been identified. These include:

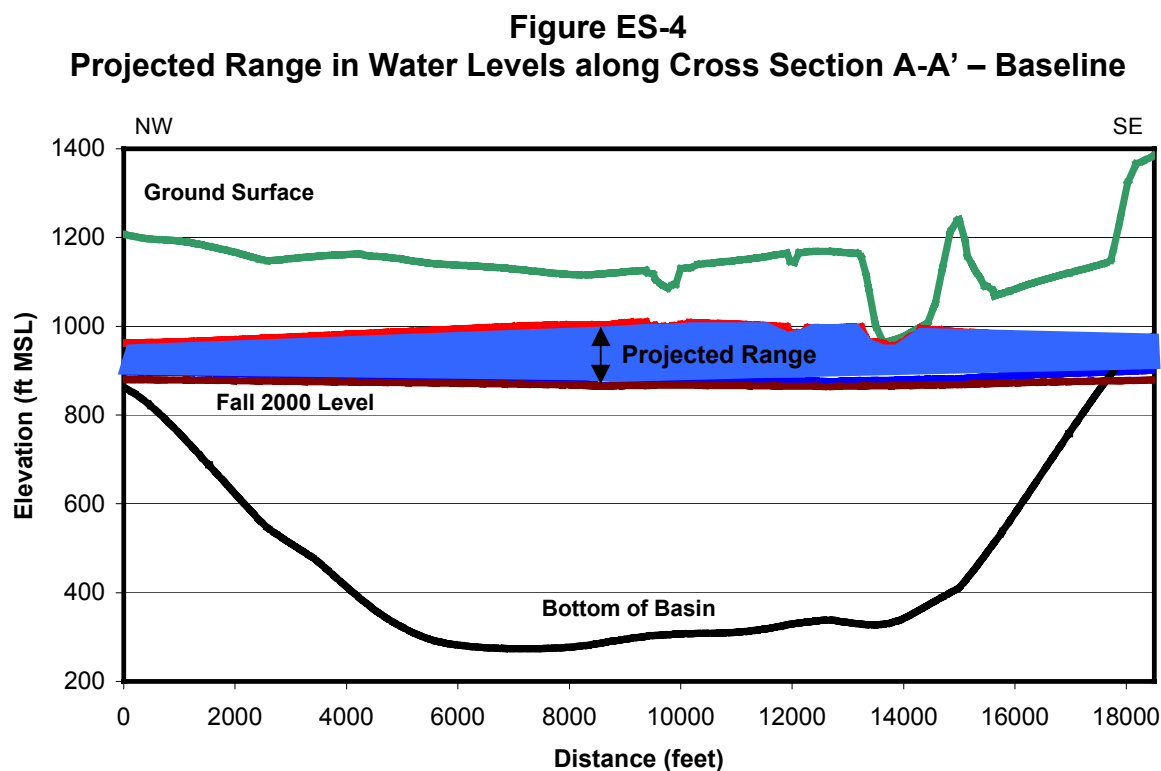
- Baseline – Continuation of current conditions
- Alternative 1 – Dual purpose wells and recharge basins
- Alternative 2 – Gravel pit storage

Each alternative is described below. A summary of each alternative is provided in **Table ES-2**.

Baseline

The baseline alternative includes the continuation of current pumping conditions. The continuation of the current pumping scenario of higher pumping during wet years and lower pumping dry years would maintain a sustainable water balance. Average extractions are projected to be about 5,300 acre-ft/yr. The dry period yield (i.e. the amount of pumping during a 6-month dry period) under baseline conditions would be about 2,100 acre-ft.

Figure ES-4 shows the projected range in water levels under the baseline alternative. Water levels are projected to range from about 870 feet MSL to 1,010 feet MSL. Water levels in the vicinity of the gravel pits would remain below the level of the pits. Because of the existing well capacity, the basin is projected to range from about 50 percent to 70 percent full under baseline conditions. This scenario would not significantly impact the operation of the basin or result in significant environmental issues.



Alternative 1

Alternative 1 includes the construction of two new dual purpose injection and extraction wells, conversion of three existing wells to dual purpose and groundwater recharge in the existing Coldwater Canyon recharge ponds. Imported water from the Temescal Valley Pipeline (TVP) would deliver imported water for recharge.

Table ES-2
Summary of Project Alternatives

Parameters	Baseline	Alternative 1	Alternative 2
Technical Feasibility	Feasible	Feasible	Feasible
Project Components and New Facilities	- Continue existing operation - No new facilities	2 new dual purpose wells 3 converted wells - Rehabilitation of existing recharge basins - Pipelines from TVP to new facilities	- Surface storage in gravel pits 2 new dual purpose wells - Pipelines from TVP to new facilities
Operational Yield (Average Pumping)	5,300 acre-ft/yr	8,200 acre-ft/yr	9,500 acre-ft/yr
Dry Period Yield	2,100 acre-ft	5,700 acre-ft	6,100 acre-ft
Water Levels in Gravel Pits	Below bottom of pits	As much as 160 feet above bottom of pit (in Chandler Pit)	As much as 200 feet above bottom of pit (in Chandler Pit)
Range in Storage	39,000-53,000 acre-ft	30,000-60,000 acre-ft	33,000-60,000 acre-ft
Range in Water Level	870 – 1,010 feet MSL	800 – 1,100 feet MSL	820 – 1,120 feet MSL

This alternative results in a sustainable water balance with an average pumping of 8,200 acre-ft/yr. The average dry period yield of Alternative 1 would be about 5,700 acre-ft per 6-month period.

Figure ES-5 shows the projected range in water levels under Alternative 1. Water levels are projected to range from about 800 feet MSL to 1,100 feet MSL. The basin is projected to operate in a range from about 40 percent to 80 percent full. This alternative would result in higher water levels in the gravel pits. This could be a potentially significant environmental impact with respect to slope stability, land use and potential loss in mineral resources.

Alternative 2

Alternative 2 appears feasible for the Coldwater Basin. Alternative 2 includes the construction of two new extraction wells and surface spreading of imported water from the TVP in the gravel pits. This alternative results in a sustainable water balance with average pumping of about 9,500 acre-ft/yr. The average dry period yield of Alternative 2 would be about 6,100 acre-ft per 6-month period. Alternative 2 provides the most additional yield of the three alternatives.

Figure ES-5
Projected Range in Water Levels along Cross Section A-A' – Alternative 1

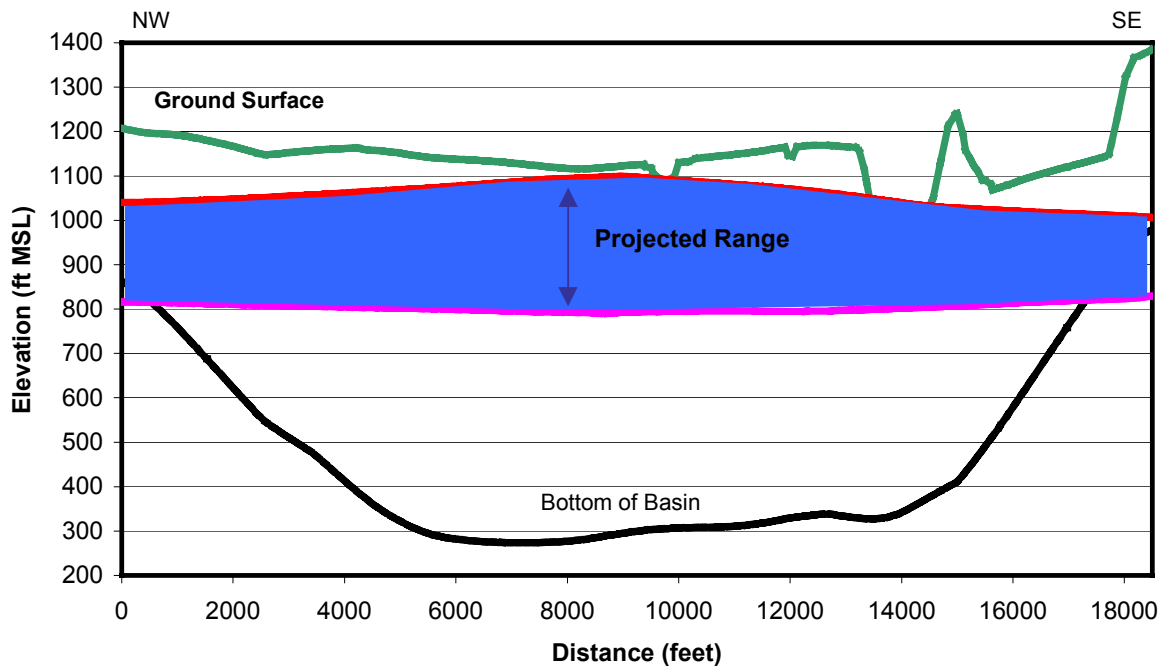
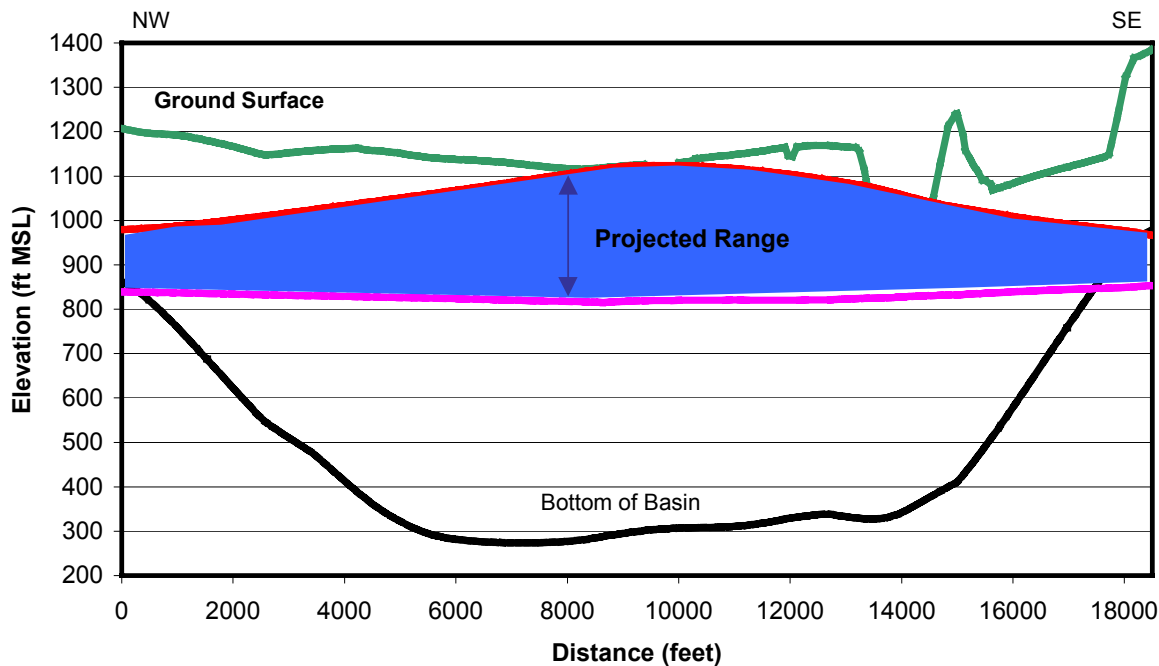


Figure ES-6 shows the projected range in water levels under Alternative 2.

Figure ES-6
Projected Range in Water Levels – Alternative 2



Water levels are projected to range from about 820 feet MSL to 1,120 feet MSL. Like Alternative 1, Alternative 2 is projected to operate in range from about 40 to 80 percent full. This alternative would result in higher water levels in the gravel pits. This could be a potentially significant environmental impact with respect to slope stability, land use and potential loss in mineral resources.

Based upon the feasibility evaluation provided herein, a conjunctive use program appears feasible in the Coldwater Basin.

COST ESTIMATES

Table ES-3 presents the opinion of probable cost estimates for each alternative. Estimates include capital costs, operation and maintenance (O & M) costs and cost of purchasing imported water from the Metropolitan Water District of Southern California (MWDSC) via the TVP.

Table ES-3
Summary of Costs for each Alternative

Item	Unit	Baseline	Alternative 1	Alternative 2
Total Capital Costs	million \$	\$0.00	\$4.05	\$3.35
Annual Costs				
Annual Capital Costs	million \$	\$0.00	\$0.13	\$0.11
Annual O & M Costs	million \$	\$0.35	\$1.50	\$2.24
Total Annual Costs	million \$	\$0.35	\$1.63	\$2.35
Incremental Costs ¹				
Incremental Annual Cost	million \$	--	\$1.28	\$2.00
Incremental Supply	acre-ft	--	2,853	4,168
Annual Water Supply	acre-ft	5,302	8,155	9,470
Cost of Water Used for Recharge	\$/acre-ft	NA	\$300	\$300
Annual Unit Cost of Water	\$/acre-ft	\$66	\$199	\$248
Incremental Unit Cost of Water ²	\$/acre-ft		\$447	\$479

Note: ¹ Incremental costs represent the increased cost over the baseline alternative.

² Imported water is significant portion of incremental cost

Actual unit cost for purchasing water, per acre-ft, ranges from \$300 for treated imported replenishment water to \$499 for tier 2 treated imported water.

Continuation of existing operations under the baseline alternative would not result in additional capital expenditures. O & M costs are projected to average approximately \$0.35 million per year, which results in an average unit cost of approximately \$ 66 per acre-ft.

Alternative 1 is projected to result in capital expenditures of nearly \$4 million. Annual costs are projected to be about \$1.6 million with an annual unit cost of about \$199 per acre-ft. Most of the additional unit cost of Alternative 1 relative to Baseline comes from the cost of imported water. The incremental cost to increase the operational yield of the basin is approximately \$447 per acre-ft. This increment is less than the cost of Tier 2 treated imported water from MWDSC (\$499 per acre-ft).

Alternative 2 is projected to result in capital expenditures of nearly \$3 million. Annual costs are estimated to be about \$2.4 million with an annual unit cost of about \$248 per acre-ft. The incremental cost to increase the operational yield under this alternative is about \$480 per acre-ft, similar to Alternative 1. Although Alternative 2 is the most expensive option, it provides additional dry year reliability. As with Alternative 1, the incremental cost is less than the cost of Tier 2 water.

Cost estimates for Alternative 1 and 2 do not include cost of acquiring land easements. Because Alternative 2 would likely require purchase of land from the gravel pit owners, which would increase the costs presented for this alternative. In addition, cost presented herein include the use of imported water from the TVP as the recharge water source. If a cheaper water source could be delivered to the Coldwater Basin, the cost of Alternatives 1 and 2 would be lower than presented herein.

ENVIRONMENTAL ISSUES

Based on a preliminary review of the existing conditions, the only significant and unavoidable environmental impacts per CEQA are the potential soil stability and land use issues associated with the gravel pits under Alternatives 1 and 2. In the event other impacts are determined to be significant upon further evaluation, they can most likely be mitigated to a less than significant level without substantial interference with program implementation. A soil stability analysis and coordination with the gravel pit owners will need to be performed prior to implementation.

Spreading and injection operations at any of the sites would have the potential to impact the groundwater quality of the Coldwater Basin. Using the gravel pits as recharge basins may increase potential for groundwater contamination because there is no protective soil above the groundwater at certain times of the year. Limiting potential sources of contamination in the vicinity of the pit can reduce the potential for contamination. Imported water from MWDSC's Mills Water Treatment Plant (WTP) is potentially available through the TVP for the recharge program. Currently sources of water recommended for future use meet the Basin Plan Water Quality Objectives, but should water quality not meet the objectives in the future, potential mitigation measures include blending the imported water with higher quality water to conform to the Basin Plan objectives should be considered. Generally, if the source water is of high quality water the impacts to the groundwater basin should be low.

Any water quality issues should be addressed during the pilot study design phase, if the District and the City choose to proceed with project implementation.

RECOMMENDATIONS

MWH recommends a phased implementation approach that incorporates components of each alternative that could be implemented over the long-term. Because the dual purpose wells provide the most flexibility in operation, this component could be implemented first. Because gravel pit storage would involve coordination with gravel pit owners, this component could be implemented after other storage opportunities have proven successful. Specific activities include pilot testing and the construction of project facilities. Each of these items is discussed below. **Table ES-4** presents a summary of the recommendations for each alternative.

Recommendations for Future Study

The following provides recommendations for future studies based upon this feasibility study:

- Perform pilot testing to confirm feasibility of dual purpose injection program

The pilot study should include injection and extraction testing in an existing well south of Trilogy Parkway nearest the TVP. The purpose of this study would be to confirm the injection and extraction potential in this portion of the basin as well as evaluate the effectiveness of the North Glen Ivy fault as a barrier to flow. To evaluate whether injection and extraction is feasible, changes in normal water production may need to be altered. For example, the wells within a couple hundred feet of the injection test well may be required to cease extraction for the duration of the test to determine the effect on the water levels in the area. In the past, the pilot testing was conducted in 30 days. Specific details of the pilot study will be included in the pilot study design phase that will be prepared in coordination with the users of the basin.

- If pilot testing proves successful, convert existing wells (Division Box, Station 22, and Station 26 or other suitable wells) to dual purpose and construct associated pipelines
- Perform additional pilot testing upon completion of conversion

The purpose of the second phase of pilot testing is to confirm that the recharged water can be injected and extracted with limited adverse impacts to other users in the basin. These wells would be used for injection and extraction over a period of about 1 year.

- If pilot testing proves successful, an additional hydrology study will be necessary to evaluate further the feasibility of surface recharge in Coldwater Canyon

A more detailed hydrology study is necessary to evaluate the recharge potential in the Coldwater Canyon recharge basins to quantify the inflows to the basin from this source.

Table ES-4
Summary of Recommendations

Alternative	Feasibility	Future Action or Recommendation
Baseline	Feasible	• Current operation could continue without negative effects
Alternative 1	Feasible	• Proceed with dual purpose well construction and pilot testing • If feasible, proceed with surface recharge program • Perform additional hydrology study in Coldwater Canyon to evaluate surface recharge
Alternative 2	Potentially Feasible	• Proceed forward with pilot testing if implementation of Alternative 1 suggests that additional recharge and storage is necessary

Recommendations for Future Implementation

Based upon the feasibility analysis provided herein, a conjunctive use program is feasible in the Elsinore Basin. However, current operations within the basin could continue without adverse effects. Therefore, MWH recommends that the District and the City of Corona coordinate to implement the future program. MWH recommends the following for future implementation upon completion of pilot testing:

- Convert existing wells to dual purpose
- Construct two new dual purpose wells and associated pipelines northwest of the existing City of Corona's well field and pipeline to surface recharge ponds
- Evaluate gravel pit storage

Each of these projects could be implemented in phases as additional yield and storage potential becomes necessary.

Section 1

Introduction

MWH was retained by the Elsinore Valley Municipal Water District (District) to evaluate the feasibility of groundwater recharge in the Coldwater Basin. This evaluation is one of four inter-related project elements that evaluate groundwater management strategies in the District's service area. Elements I through IV are defined as follows:

- Element I – Elsinore Basin Groundwater Management Plan
- Element II – Coldwater Basin Feasibility Study
- Element III – Elsinore Basin Injection Pilot Project
- Element IV – Elsinore Basin Spreading Feasibility Study

This investigation was funded in part by a groundwater recharge feasibility study grant from the California Department of Water Resources (DWR) pursuant to Proposition 13.

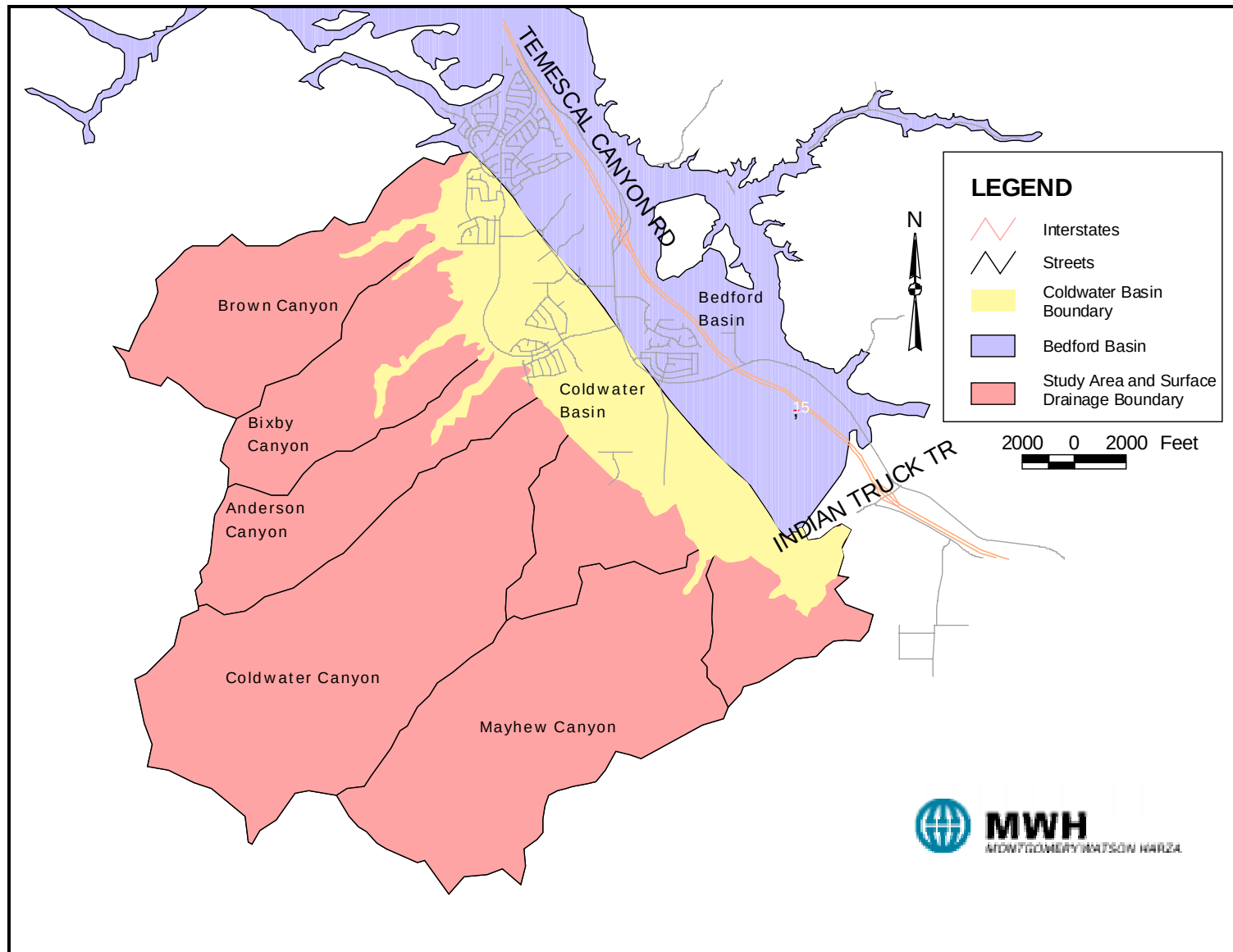
PROJECT BACKGROUND

The study area for this investigation is the Coldwater Basin watershed, which consists of the Coldwater groundwater basin and its tributary surface drainage area (**Figure 1-1**). The Coldwater Basin is located about 8 miles southeast of the City of Corona within the Temescal Valley southwest of Interstate 15. The watershed area is approximately 10,740 acres, of which about 1,680 acres makes up the groundwater basin. The remaining portions of the Coldwater Basin consist of the surrounding highlands of the Santa Ana Mountains and associated streams and canyons. Major surface water drainages include Coldwater, Anderson, Bixby, Mayhew, and Brown Canyons, which surround the western and southern boundaries of the groundwater basin.

For the period between 1991 and 2000, an average of 6,300 acre-ft/yr of groundwater was produced from the groundwater basin. The principal groundwater producers in the basin are the District and the City of Corona, which account for all but about 200 acre-ft/yr of the total average groundwater production in the basin. The remainder of the pumpers in the basin are agricultural users and the gravel pit owners. Approximately one-third of the total basin groundwater extraction during this time period was produced from the District's wells, while two-thirds of the total groundwater production was produced from the City of Corona's wells. All of the groundwater production from the City of Corona's wells is delivered to water users in Corona outside the Coldwater Basin. Therefore, groundwater recharge from return flows is limited. District wells serve agricultural and municipal users within the Coldwater Basin.

The southeastern portion of the Coldwater Basin (about 745 acres) is dominated by gravel pit operations. Gravel mining in the Coldwater Basin began in the early 1970s and continues today. The current depths of the pits are as much as 250 feet, below historical water levels. The continued operation of the gravel pits is a key constraint to the feasibility of recharge in the Coldwater Basin.

**Figure 1-1
Study Area**



Since 1998, groundwater levels within the Coldwater Basin have been declining at a rate of about 50 feet per year throughout the basin. Groundwater levels in many wells are at or below the previous historic low levels of the mid-1970s. Most shallow groundwater wells, particularly in the center of the basin, are currently dry. This water level decline is the result of a combination of an extended period of low rainfall and increased groundwater production in the basin. More groundwater is being extracted each year than is being replenished naturally causing groundwater to be taken from storage. Previous estimates of safe yield for the basin have ranged from 3,100 acre-ft/yr to 5,300 acre-ft/yr (JMM, 1977; GWS, 1991). Groundwater extraction over the past several years has exceeded these estimates. Because the groundwater basin is only 800 feet deep, this supply, if not augmented, will not be available in the future at current extraction rates.

SCOPE OF WORK

The District authorized MWH to complete the scope of work described herein in a contract dated March 28, 2003. This feasibility study includes the work conducted for Element II only and involves the following tasks:

- Task II-1 – Initial data assessment
- Task II-2 – Conceptual hydrogeologic model
- Task II-3 – Numerical groundwater modeling
- Task II-4 – Inventory of potential recharge sites and infiltrometer testing
- Task II-5 – Economic analysis
- Task II-6 – Review of environmental issues
- Task II-7 – Feasibility report and pilot study recommendations
- Task II-8 – Project management

This report summarizes the work performed in this feasibility evaluation.

PROJECT OBJECTIVES

The purpose of this groundwater recharge feasibility study in the Coldwater Groundwater Basin is to evaluate the feasibility of developing a pilot recharge program and ultimately, a long-term groundwater storage program in the Coldwater Basin. The primary goal of the long-term groundwater recharge project is to increase the reliability and sustainability of groundwater resources in the Coldwater Basin, now and in the future.

To achieve this goal, the project objective is to evaluate the feasibility of a recharge program that would enhance and manage groundwater supplies through conjunctive use activities. Conjunctive use is the process of storing water in the groundwater basin during periods when additional water supplies are available and extracting the water in periods when supplemental water supplies are not available. The recharge feasibility study includes a compilation of hydrogeologic data needed to estimate the basin yield and evaluate the long-term storage potential in the basin through conjunctive use.

REPORT OVERVIEW

The Coldwater Basin Recharge Feasibility Study is divided into the following nine sections:

Section 1 is the introduction of the recharge feasibility study and includes background information for the project

Section 2 includes a description of the hydrogeologic setting of the Coldwater Basin and a description of the conceptual model

Section 3 includes the development of a numerical groundwater model

Section 4 includes a description of the potential recharge alternatives

Section 5 includes the economic analysis of the various strategies

Section 6 discusses the environmental, legal, and institutional issues of each strategy

Section 7 selects a preferred recharge strategy and recommends action items to implement a pilot study

Section 2

Hydrogeologic Setting

INTRODUCTION

The Coldwater Basin is water supply for the City of Corona, the District, and other local private groundwater producers. With the assistance of DWR, the District and the City of Corona are evaluating the feasibility of a groundwater recharge program for the basin. The development of a detailed understanding of the groundwater basin is an important step in this evaluation. This section summarizes the development of the hydrogeologic conceptual model for the Coldwater Basin. This section includes a summary of:

- Previous work
- Data collection efforts
- Geology and structure
- Groundwater flow
- Groundwater quality and
- Preliminary groundwater budget

This section documents the data assessment process for the Coldwater Basin Recharge Feasibility Study. It describes the types of information gathered, the information sources that are used, and the organization of information. Most of the collected information is compiled in a geographic information system (GIS) using *ArcView 3.2*[®].

The groundwater GIS has made it possible to organize and store all pertinent information into one database. By centrally locating the information gathered, it is readily available for future investigators to gain a better understanding of the groundwater basin.

Compilation of all available data within an organized system, such as a GIS, is essential for the development of a valid hydrogeologic conceptual model. In addition, the GIS is the main source of input data for the numerical groundwater flow model that will be developed for the Coldwater Basin. The groundwater GIS is one of the deliverables of this project. It provides the District and the City of Corona with detailed information on the Coldwater Basin and the wells located within it.

BACKGROUND

The following section provides a brief background to the recharge feasibility study for the Coldwater Basin. This includes a brief discussion of previous hydrogeologic conceptual models prepared for the basin and a description of the data collected for this project.

PREVIOUS WORK

In 1977, MWH (formerly James M. Montgomery, Consulting Engineers, Inc - JMM), under contract with City of Corona, provided a comprehensive review of the hydrogeology of the Coldwater Basin. This report provided a review of available basin data at the time, including annual basin inflows and outflows, well hydrographs of groundwater levels and groundwater quality. Based upon these data, JMM estimated the annual long-term basin yield for the Coldwater Basin.

Ground Water Systems Inc. (1991) performed a similar analysis to evaluate the impact of the Mountain Cove Ltd. Project, a proposed 776-acre residential and golf course development within the Coldwater Basin. This evaluation included a general description of the hydrogeology of the basin largely based upon the 1977 JMM study and a more detailed hydrology and flood control study in the vicinity of Coldwater Canyon. In addition, this report provided detailed cross-sections of the Coldwater Basin identifying the geology and fault boundaries.

DATA COLLECTION

To augment data already collected as part of previous work, MWH compiled and input various data into the GIS including:

- Wells (logs, diameter, production, water level, screen depth, etc.)
- Faults
- Geology and
- Rain stations and stream gauges

MWH compiled a variety of information to evaluate the hydrogeologic characteristics, define the watershed, calculate the water budget, and identify potential surface recharge locations of the Coldwater Basin. The information and data types included:

- Reference reports and other studies
- Base maps
- Boundary maps
- Well information
- Historic water levels
- Production records
- Surface water flows
- Precipitation data
- Water quality information
- Geophysical data

These data were used in this update of the hydrogeologic conceptual model. The remainder of this document presents the current conceptual understanding of the hydrogeology of the Coldwater Basin.

DATA SOURCES

The sources of the information collected are presented by data type and file format in **Table 2-1**. The shapefile format is the standard file format for the GIS. Other file formats that are compatible with ArcView include images (tiff and pdf), AutoCAD drawings (dwg and dxf), and database tables (dbf).

Table 2-1
Data Sources

Data Type	Data Description	Data Source	Data Format
Base Maps	Streets and Freeways	EVMWD	Shapefile
	Aerial Photography	EVMWD	Shapefile
	Water Bodies	EVMWD	Shapefile
	Ground Elevation Contours	USGS ¹	Shapefile
Boundary Maps	District Service Area	EVMWD	Shapefile
	Groundwater Basins	EVMWD	Shapefile
	Coldwater Watershed	EVMWD	Shapefile
	Townships, Ranges & Sections	EVMWD	Shapefile
Well Information	See Table 2 for details	Various ²	Shapefile, Excel
Historical Water Levels	Monthly Data 1956-2001 ⁶	EVMWD, City of Corona	Excel
Production Records	Monthly Data 1947-2001 ⁶	EVMWD, City of Corona SAWPA, SWRCB ³	Excel
Land Use	Yearly Data 2002	Riverside County FCD ⁴	Excel
Precipitation Data	Monthly Data 1905-1999	Riverside County FCD	Excel
Water Quality Data	Monthly Data 1984-2002 ⁶	DHS ⁵	Excel
Geophysical Data	Geologic Formations	USGS (digitized by MWH)	Shapefile
	Faults	EVMWD, USGS	Shapefile

1-Drawn and digitized from United States Geological Survey (USGS) contour data

2-State Division of Oil & Gas, EVMWD and the City of Corona

3-State Water Resources Control Board

4-Flood Control District

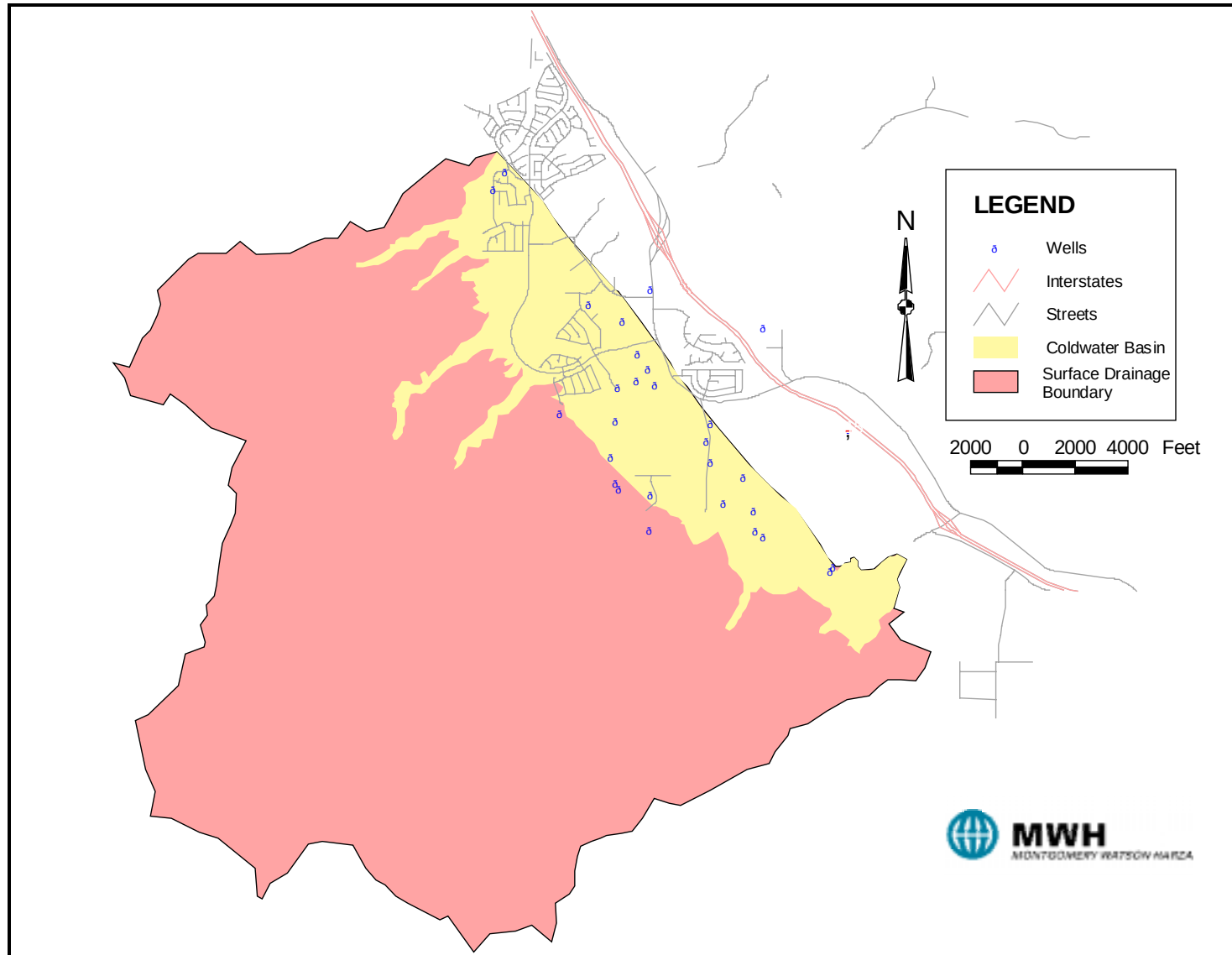
5-Department of Health Services

6-Sporadic Data

Many data sources were used to gather information on the groundwater wells within the basin. MWH reviewed nearly 30 wells in the area, which varied in characteristics such as well status, depth, production rates, screened intervals, and ownership. **Figure 2-1** shows the locations of wells from the GIS. The level of information per well log varied greatly. Detailed information from these wells was used to:

- Obtain an understanding of the stratigraphy
- Obtain estimates on the aquifer depth and thickness
- Obtain an understanding on the variation in water levels over time
- Determine the groundwater flow direction
- Determine the location and rates of the main pumping agencies
- Prepare a conceptual hydrogeologic model

Figure 2-1
Wells in Coldwater Basin



Section 2 – Hydrogeologic Setting

Because the information on wells is critical to the basin feasibility study, well data assessment has been extensive, using as many data sources as possible. The well information gathered and the respective sources are listed in **Table 2-2**. All of the information presented in this table is combined in one shapefile.

Table 2-2
Well Data Information

Data Type	Data Source
State Well Number	SAWPA, Well Logs, APN ³ , Township/Range/Section ³ .
Well Name	EVMWD, SAWPA, Division of Oil & Gas, MWH ¹
Location	EVMWD, SAWPA, Division of Oil & Gas, MWH ¹
Basin	Compiled by MWH
Owner	From DWR well log
Address	From DWR well log
Type	SAWPA Database, MWH ¹ , Oil & Gas, DWR Well Logs
Use	SAWPA Database, MWH ¹ , Oil & Gas, DWR Well Logs
Status	Compiled by MWH
Date	From DWR well log
Casing Diameter	From DWR well log
Boring Depth	From DWR well log
Well Depth	From DWR well log
Top Screen	From DWR well log
Bottom Screen	From DWR well log
Screen Length	From DWR well log
Transmissivity	DWR well logs, SAWPA and EVMWD pumping records
Storativity	DWR well logs, SAWPA and EVMWD pumping records
Availability of well log	EVMWD, SAWPA, Division of Oil & Gas, MWH ¹
Availability of geology log	Compiled by MWH
Availability of geophysical log	Compiled by MWH
Water quality data	EVMWD
Water level data	SAWPA and EVMWD
X coordinate	Obtained from GIS calculation
Y coordinate	Obtained from GIS calculation
GS Elevation	USGS, Survey information

1 – MWH (formerly JMM) 1977

2 – Department of Water Resources

3 – State Well Numbers are not complete, as some do not contain a Track Number. Based on the Assessor's Parcel Number (APN) and location description, only the Township, Range, and Section designations could be identified for some wells.

DATA ORGANIZATION

The majority of the information were organized in the groundwater GIS. Information that could not be included in the GIS was organized separately. The data organization in the groundwater GIS is discussed below. The information that was not included in the groundwater GIS is described in a later section.

Groundwater GIS

The groundwater GIS is developed within *ArcView* 3.2, a product of the Environmental Systems Research Institute (ESRI). A GIS is a combination of a database program and a graphical interface that displays the information on geographic maps. GIS allows the user to gather and organize information, and also visualize, explore, query, and analyze data geographically.

The groundwater GIS includes all the information presented in Table 2-1 and Table 2-2 with the exception of data in Excel format. The groundwater GIS is created in the NAD83, Zone V, California coordinates system. All information added in the future should be in this coordinate system to obtain the same projection of information.

The GIS is used for the following purposes:

- Data Collection and Organization
- Geographic Mapping
- Information Analyses
- Calculations
- Provide Input data for the Numerical Model

Information not included in the GIS

Information not included in the GIS are the Excel data, which includes time series data, such as the historic water levels, production records, precipitation data, and water quality data. This information is used to analyze trends of water levels and water quality, and to calculate the water budget. The GIS contains two rainfall stations but the historical data are stored in Excel spreadsheets. Historical rainfall data are available for two rainfall stations, the Santiago Peak Station #202 and the Warm Springs, Temescal Canyon Wash, Station #075.

GEOLOGY AND STRUCTURE

The following section describes the geologic setting, stratigraphy and structure of the Coldwater Basin.

Geologic Setting

The Coldwater Basin lies within a down-dropped block between the North Glen Ivy and South Glen Ivy faults, which are associated with the right lateral strike-slip-dominated Elsinore Fault Zone (EFZ). The EFZ extends approximately 200 km from Baja California north to the Corona area. The Coldwater Basin is surrounded by the metamorphic, volcanic and granitic basement

Section 2 – Hydrogeologic Setting

rocks of the Santa Ana Mountains to the south and west, and the Bedford groundwater basin, which is located to the north and east and is separated from the Coldwater Basin by the North Glen Ivy fault.

Stratigraphy

The following provides a brief description of the geology and stratigraphy found within the Coldwater Basin watershed. The units are described from top to bottom. **Figure 2-2** shows a general stratigraphic column for the area. **Figure 2-3** presents a geologic map of the area.

Figure 2-2
Stratigraphy in the Coldwater Basin

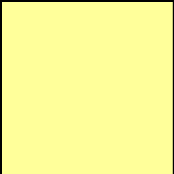
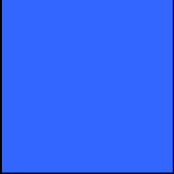
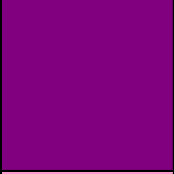
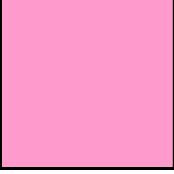
Formation	Symbol	Graphic	Description
Alluvium	Qa		Interfingering alluvial fan gravels, sands and clays
			Artesian flowing groundwater conditions have occurred historically
Bedford Canyon Formation	bcb		Blue to black slate and sandstone
			Limited groundwater production except in fractures
Volcanic Rocks	Kv		Basaltic andesite to rhyolite volcanics
			Limited groundwater production except in fractures
Undifferentiated Basement	bct		Granitic basement rocks
			Limited groundwater production except in fractures

Figure 2-3
Geologic Map of the Coldwater Basin

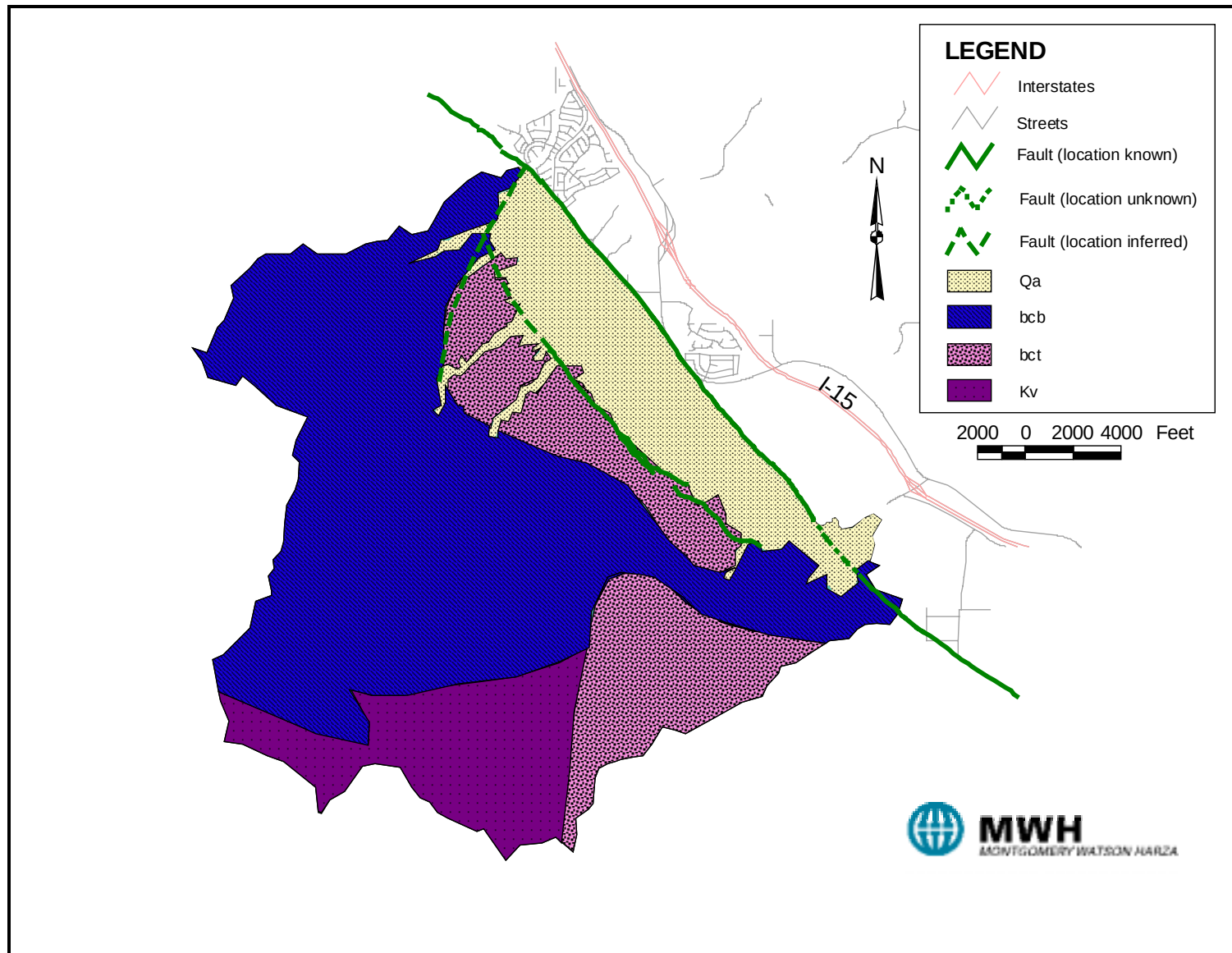
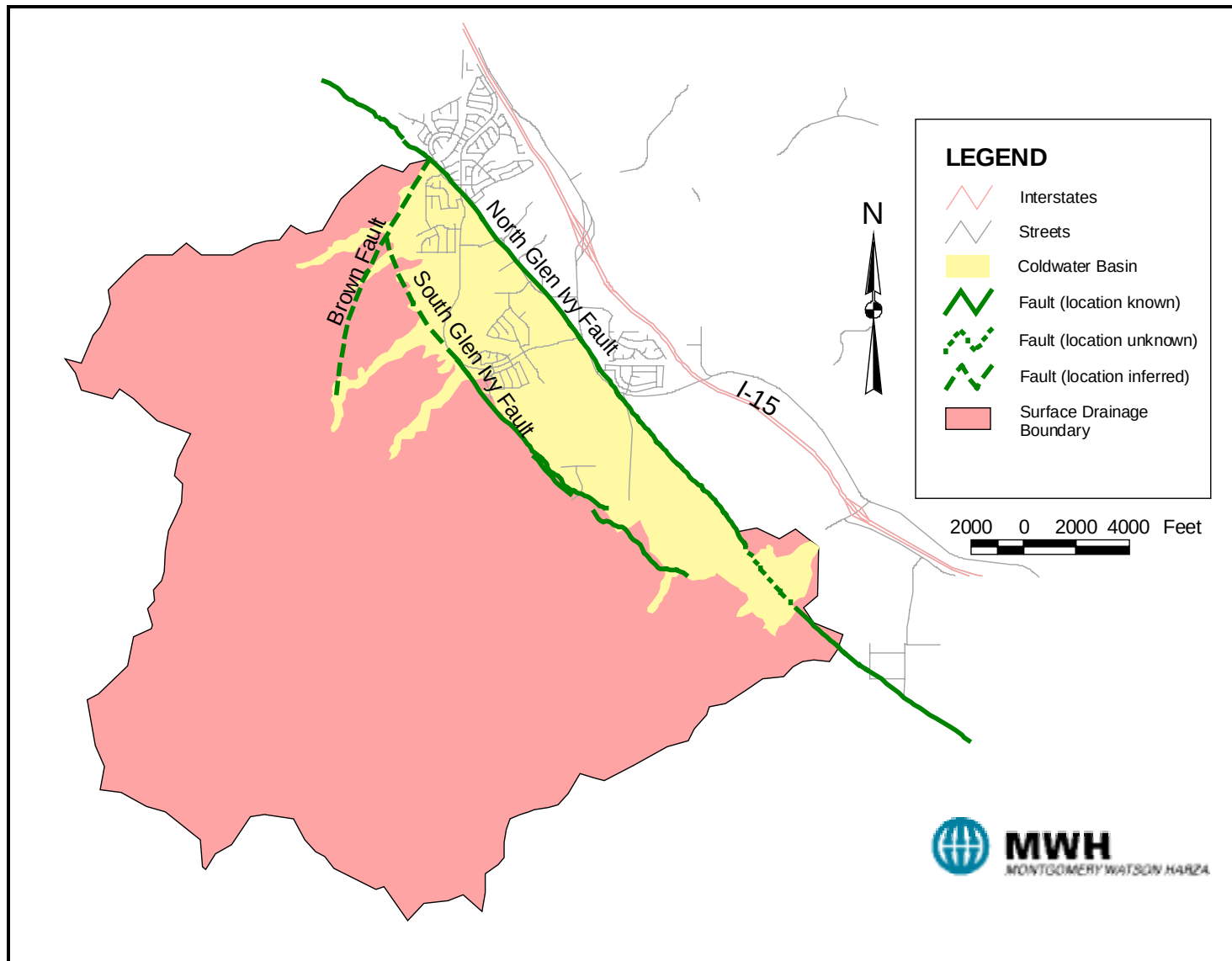


Figure 2-4
Fault Map of the Coldwater Basin



Note: Faults depicted on this map are shown to define hydrogeologic structure. No interpretations of fault activity are made or inferred.

Alluvium

The alluvium (Qa) is the youngest of the formations within the Coldwater Basin watershed ranging from Pleistocene (older) to Holocene (recent) in age. It consists of unconsolidated alluvial fan deposits of interfingering gravel, sand, silt and clay resulting from streams originating in the adjacent highlands. The Recent alluvium is about 800 feet thick in the center of the basin. In general, the alluvium contains more clay in the northwestern portion of the basin and contains more gravel along the margins and in the central portion of the basin.

Bedford Canyon Formation

The Bedford Canyon Formation (bcb) is characterized by metasedimentary basement rocks including blue to black slate alternating with layers of fine-grained metamorphic sandstones of Jurassic age. Groundwater in the Bedford Canyon Formation is limited to the weathered zones at shallow depths and generally does not produce significant groundwater supplies. The Bedford Canyon Formation is found in the upland areas of the watershed.

Volcanic Rocks

The volcanic rocks (kv) in the Coldwater Basin watershed range from basaltic andesite to rhyolites of Jurassic to Cretaceous age (USGS, Santa Ana Quadrangle, 1999). These rocks do not generally produce significant groundwater except in fractures and are found in the highlands in the southwestern watershed boundary. These rocks are not believed to occur within the groundwater basin.

Undifferentiated Basement Rocks

The basement rocks (bct) in the Coldwater Basin are characterized by igneous granites, tonalites, and gabbros of Cretaceous age ((USGS – Santa Ana Quadrangle, 1999).). These rocks do not generally produce significant groundwater except in fractures, and are found at the surface in the highlands surrounding the basin. In the groundwater basin area itself, depth to bedrock ranges from about 100 feet to more than 800 feet in the center of the basin.

Structure and Faults

As discussed previously, the Coldwater Basin is a structural graben, a down-dropped block, between two branches of the Glen Ivy fault. The basin is composed mostly of unconsolidated alluvium ranging in depths from a few feet near the southeastern boundary to more than 800 feet near the center of the basin. The following section provides a brief discussion of the structure in the Coldwater Basin as it relates to groundwater flow in the basin. Faults described in this section are defined in terms of hydrogeologic structure and groundwater flow. No interpretations of fault activity are made or inferred.

The South Glen Ivy fault separates the igneous and metamorphic rock of the Santa Ana Mountains from the alluvial-filled basin (see **Figure 2-4**). Basin sediment along the fault is believed to be up to 100 feet thick where the primary canyons cross the fault, allowing surface water from the adjacent highlands to enter the basin. Other than in these areas, the South Glen

Ivy fault appears to be a barrier to groundwater flow. Vertical offset along the fault appears to be more than 700 feet well logs in the area.

The North Glen Ivy fault defines the northern boundary of the Coldwater Basin with the Bedford Basin. Sag ponds can be found along the margin, which seems to suggest that this fault is a barrier to flow (JMM, 1977). Historically, groundwater levels have been 75 to 100 feet higher on the Bedford Basin side of the fault (JMM, 1977). In the shallow portions of the fault, the barrier to flow may be less complete and it is possible that water may flow into the Bedford Basin when groundwater levels are at or near the ground surface (artesian flowing conditions are present) in the Coldwater Basin. The vertical offset along the fault appears to be about 300 feet.

The unnamed fault along Brown Canyon (herein referred to as the Brown fault) also appears to provide a barrier to subsurface inflow. Vertical offset with the Bedford Canyon Formation along the fault ranges from 100 to 300 feet.

A drainage divide and bedrock outcrop defines the Coldwater Basin boundary to the southeast. Since the non-water bearing Bedford Canyon Formation (bcb) comprises the entire southwestern edge of the Coldwater Basin, it is reasonable to assume little to no subsurface flow occurs across these boundaries.

Conceptual Hydrogeologic Sections

To provide an illustrative description of the conceptual hydrogeology of the Coldwater Basin, two hydrostratigraphic cross sections of the basin were prepared. Information presented on the cross sections was developed from data compiled from driller's logs, geophysical logs, water level data and interpretation developed during the course of this investigation. The locations of these sections are provided in **Figure 2-5**.

Cross Section A-A'

Cross Section A-A' (shown as **Figure 2-6**) extends approximately 4.4 miles across the length of the basin parallel to the Interstate 15 Freeway. The alluvium (shown as Qa on the section), where most of the groundwater occurs in the basin, ranges in thickness from about 250 feet in the northwest to less than 100 feet in the southeast part of the section. The depth of the alluvial section is about 800 feet in the middle of the basin. Underlying the alluvium in the central portion of the basin is the Bedford Canyon Formation (shown as bcb on the section) and undifferentiated granitic basement rock (bct), which is believed to underlie the Bedford Canyon Formation. No wells in the center of the basin are screened in these non-water bearing formations.

The southeastern edge of the basin is defined by a surface drainage and groundwater divide resulting from uplifted non-water bearing rocks of the Bedford Canyon and underlying basement rocks. Well 05S06W12N02, located in the southeast end of the basin is actually screened entirely within the Bedford Canyon Formation. This well produces less than 25 gpm. It is therefore, valid to assume that little or no groundwater leaves the basin to the southeast.

Figure 2-5
Location of Geologic Cross Sections

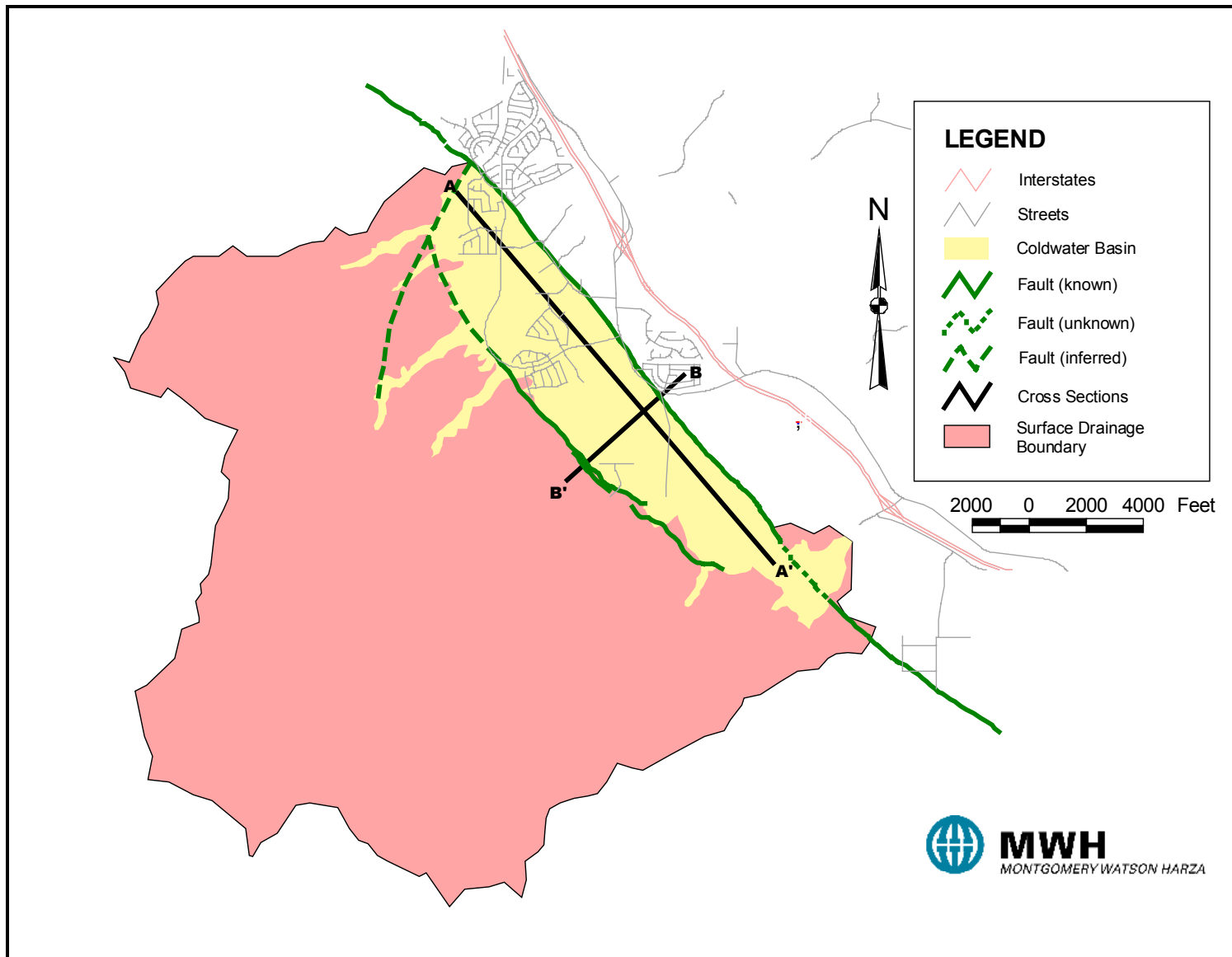
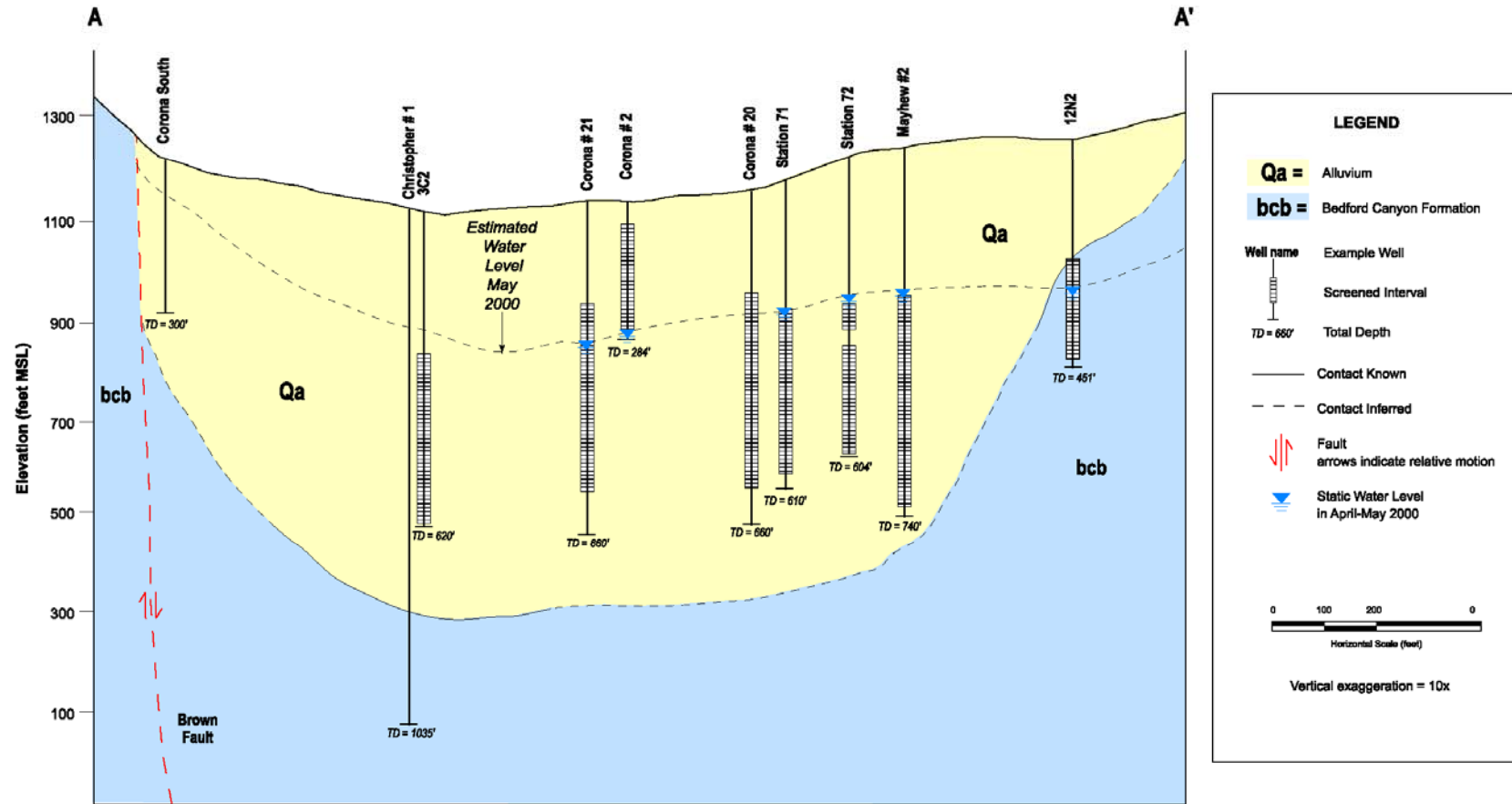


Figure 2-6
Cross Section A-A'



As shown in this section, groundwater generally flows from the edges of the basin where natural recharge occurs toward the City of Corona's wells (#2, #3, and #21), which is the location of most of the groundwater production in the basin. The average groundwater gradient across this section is approximately 0.012, roughly following the ground surface elevation.

Cross Section B-B'

Cross Section B-B' (shown as **Figure 2-7**) extends about 4,000 feet from southwest to northeast between Coldwater and Mayhew Canyons. This section shows the major faults in the Coldwater Basin, the North and South Glen Ivy faults. Bedrock faulting in the area largely controls depth to bedrock and the resultant alluvial thickness. Alluvial thickness increases toward the center of the basin away from the faults.

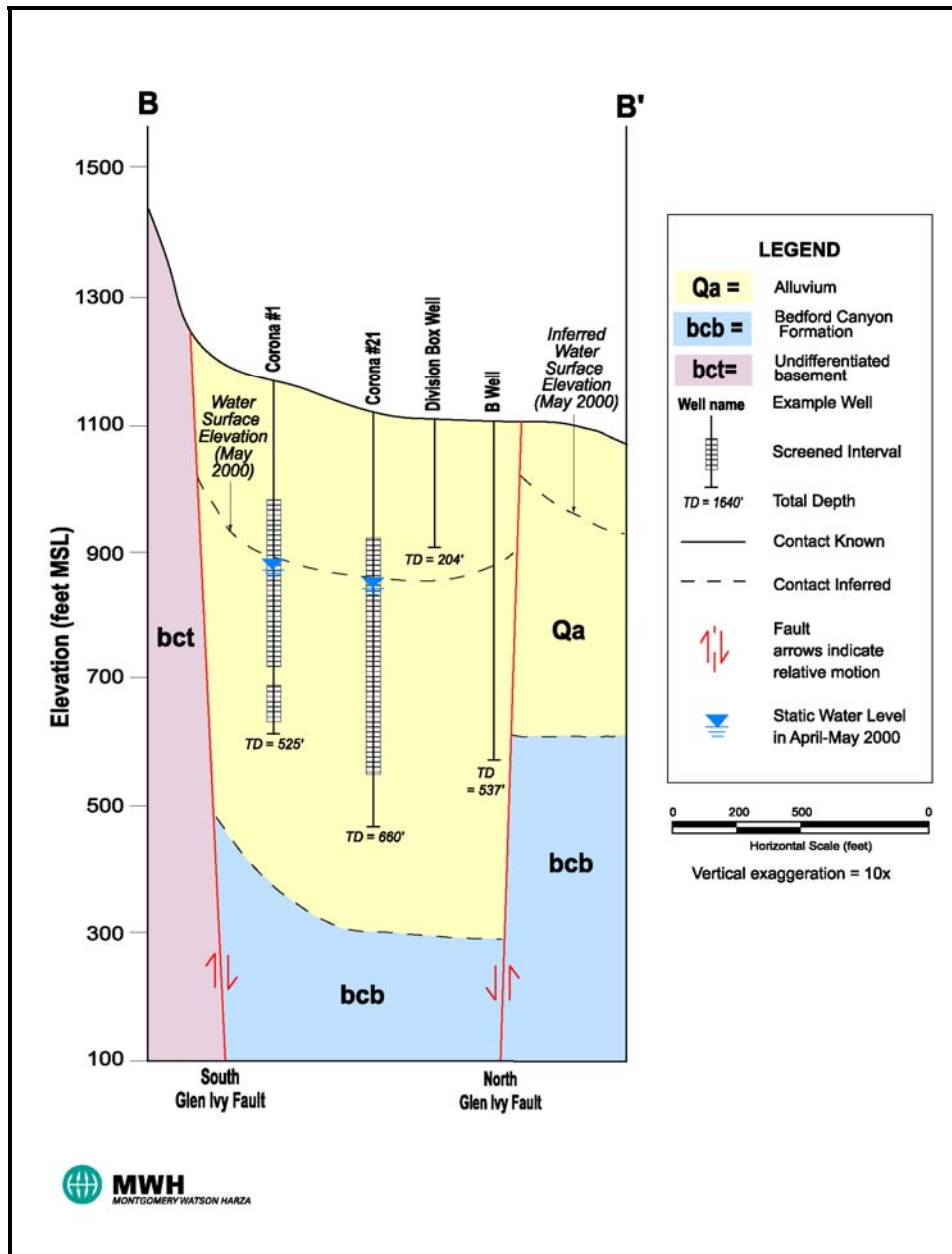
Granitic bedrock, which was uplifted at least 700 feet by the South Glen Ivy fault, is encountered along most of the southern boundary of the Coldwater Basin. As discussed previously, the Bedford Canyon Formation is believed to underlie the alluvium in the middle of the basin and was likely removed by erosion along the mountain front. The North Glen Ivy fault appears to offset the Bedford Canyon Formation and the overlying alluvial section by about 300 feet.

As shown in this section, groundwater generally flows from the canyons toward the pumping depression near the City of Corona's wells. Artesian flowing conditions currently occur in wells on the upthrown side of the South Glen Ivy fault along the mountain front. Groundwater levels are offset about 100 feet across the North Glen Ivy fault, which suggests that this fault provides a barrier to flow in and/or out of the basin. It is possible that when the basin is full (i.e. water elevations are higher than about 1,050 feet MSL), water could flow into the downgradient Bedford Basin. However, in general, it is reasonable to assume that the North Glen Ivy fault provides a complete barrier to flow (JMM, 1977).

AQUIFER CHARACTERISTICS

Direct field measurements of transmissivity and horizontal hydraulic conductivity are not available for the Coldwater Basin. To establish a reasonable range of transmissivity for the principal water-bearing units, all available specific capacity data, and related parameters were compiled. Specific capacity data (pumping rate/drawdown) were compiled from the driller's logs and water level data provided by EVMWD. Although specific capacity is a relative measure of the transmissivity of the aquifer, each specific capacity measurement was evaluated with caution because specific capacity is often affected by partial penetration of the aquifer, well losses, hydrogeologic boundaries, and pumping time. The transmissivity of an unconfined aquifer can be approximated by multiplying the specific capacity by a constant of approximately 1,500 divided by the well efficiency (Logan, 1964). Based on available information, most wells only partially penetrate the aquifer. Therefore, aquifer-specific transmissivities that are calculated from specific capacity data should be considered a lower limit.

Figure 2-7
Cross Section B-B'



Section 2 – Hydrogeologic Setting

Table 2-3 summarizes the aquifer characteristics based upon specific capacity data compiled from DWR, well logs and pumping data throughout the basin. Transmissivity estimates range from approximately 400 gpd/ft in well 05S06W12N02, which is screened entirely within the Bedford Canyon Formation to about 540,000 gpd/ft in Well #21, which is consistent with a general fine sand to gravel lithology.

Table 2-3
Summary of Aquifer Characteristics

Well Name	State Well Number	Well Depth	Screened Interval (fbgs)	Transmissivity ¹ (gpd/ft)
Well #1	05S06W03Q01	548	176-444 460-532	95,000
Well #2	05S06W03J04	284	40-264	80,000
Well #3	05S06W03K01	543	100-530	85,000
Well #20	05S06W11D01	600	200-580	100,000
Well #21	05S06W03J05	600	200-580	540,000 ²
Station 71	05S06W11C01	600	239-588	25,000-62,000
Station 72	05S06W11F02	596	NA	16,000
Mayhew #2	05S06W10B01	740	300-730	117,000
05S06W03C02	05S06W03C02	616	290-617	18,000
05S06W10J01	05S06W10J01	NA	NA	4,000
05S06W12N02	05S06W12N02	451	235-440	400

Note:

- 1 Calculated from specific capacity data assuming $T = \text{specific capacity} \times 1,500 / \text{well efficiency}$ (assumed 75 percent if no data were available) rounded to nearest 1,000.
- 2 Data obtained from incomplete well log information, which may overestimate transmissivity.

No *in-situ* measurements of horizontal hydraulic conductivity are available, so hydraulic conductivity estimates are made from transmissivity. Hydraulic conductivity is defined by the following equation:

$$T/b = k$$

where:

T = transmissivity

b = saturated aquifer thickness and

k = hydraulic conductivity

Based upon the transmissivity estimates presented in **Table 2-3**, horizontal hydraulic conductivity ranges from about 0.3 ft/day in well 05S06W12N02 (where bedrock occurs) to

about 190 ft/day in the central portion of the basin. This range in hydraulic conductivity is consistent with a fine sand to gravel, which is present throughout the Coldwater Basin.

No direct measurements are available for vertical hydraulic conductivity of hydrogeologic units in the basin. In most cases, the vertical hydraulic conductivity is expected to be much less (in some cases orders of magnitude) than the horizontal hydraulic conductivity. Even within relatively homogenous sand and gravel aquifers, horizontal hydraulic conductivity will generally exceed vertical hydraulic conductivity by 2 to 20 times (Todd, 1980). If silts and clays are present, this contrast will be even greater. The amount of silt and clay in most areas of the Coldwater Basin is limited.

GROUNDWATER LEVELS

The following section describes the historical and recent groundwater flow conditions for the Coldwater Basin.

Historical Groundwater Levels

To better understand the behavior of the groundwater basin, it is also important to evaluate the historical groundwater levels. The following section describes the historical groundwater levels in the Coldwater Basin. A summary of water levels in selected wells in the Coldwater Basin is presented in **Figure 2-8** and **Figure 2-9**. In general, historical water levels are highly variable and appear to correspond with changes in annual rainfall and/or groundwater production. In 2002, groundwater levels are nearing the historic lows of the mid-1970s with water levels dropping more than 100 feet in most wells since 1998. During the wet periods of the mid-1980s, artesian flowing groundwater conditions (measured static groundwater levels were above the ground surface) were observed in the Corona #1 well. As groundwater levels dropped throughout the basin and the gravel pit operations expanded closer to Corona #1, the water levels became more similar to the other City wells. Groundwater levels have since dropped nearly 300 feet in this well. Other wells including Corona #2, Station 22 and Division Box have gone dry.

General Groundwater Flow

A summary of groundwater elevations for April-May 2000 is provided in **Table 2-4**. This time period represents the most recent time period for which there is a relatively complete dataset. In general, groundwater flows from the basin margins into the center of the basin near the City of Corona's wells as shown in Figure 2-6 and Figure 2-7. Limited groundwater data are available along the basin margins. Therefore, the groundwater contours are inferred in these areas.

Figure 2-8
Historical Water Levels of Select EVMWD Wells in the Coldwater Basin

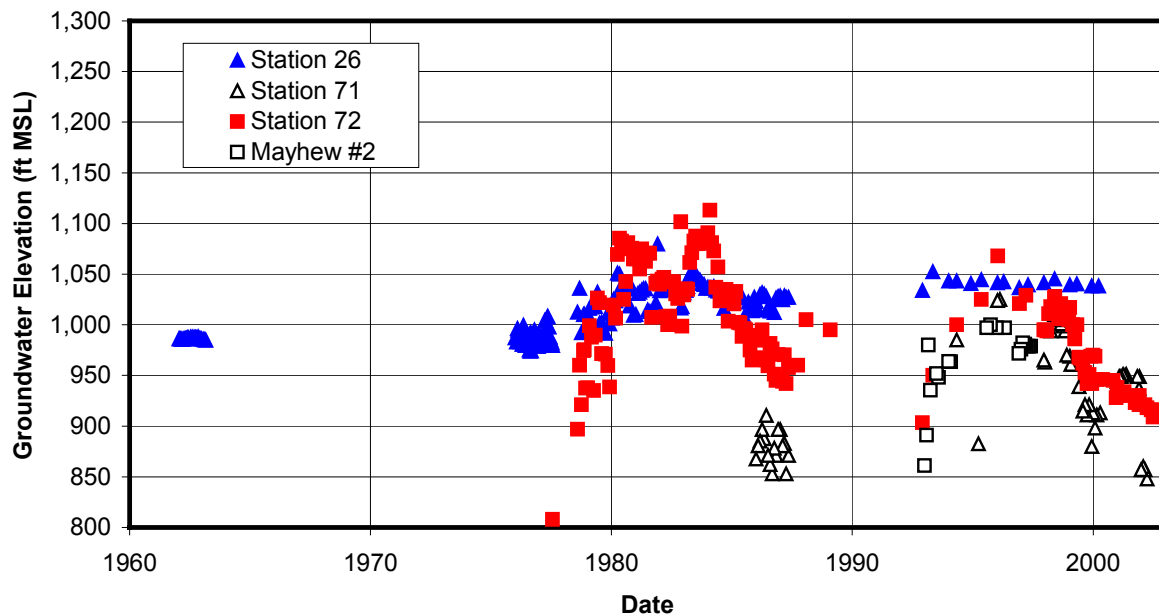


Figure 2-9
Historical Water Levels of Select City of Corona Wells in the Coldwater Basin

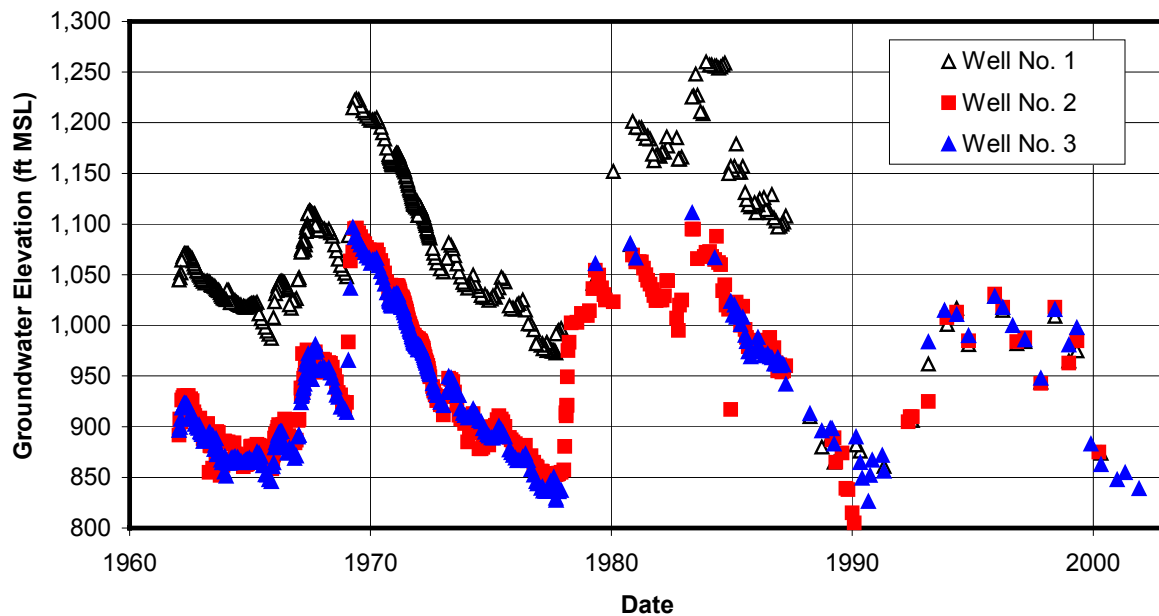


Table 2-4
Summary of Groundwater Elevations (April-May 2000)

Well Name	SWL Elevation (ft MSL)
Well No. 1	873.88
Well No. 2	874.84
Well No. 3	854.7
Well No. 21	844
Station 22	Dry (<910)
Station 26	1038.35
Station 71	913
Station 72	946
Mayhew Well	955
12N2	955
New Sump	986.5
Division Box	Dry (< 899)

GROUNDWATER BUDGET

A groundwater budget analysis is the quantification and reconciliation of the inflow and outflow components of the groundwater regime in the study area. The purpose of this analysis is to characterize the major contributions to groundwater flow and evaluate the relative importance of each inflow and outflow component in the hydrologic behavior of the basin. Historical variations in the various components of flow, as well as potential variations of groundwater in storage, can be used to evaluate a representative range of flow conditions in the basin. Typical components of groundwater inflows and outflows for a groundwater budget analysis are listed below:

Inflows

- Infiltration from direct precipitation
- Surface water infiltration
- Infiltration from deep percolation of applied water
- Infiltration from septic tanks
- Underflow into basin

Outflows

- Evapotranspiration
- Groundwater pumping
- Flow to surface water
- Subsurface outflow
- Evaporation from gravel pits

Each of these potential components of inflow and outflow as they pertain to the Coldwater Basin are discussed in more detail in the following sections.

Inflows

The following are the major inflow components to the Coldwater Groundwater Basin:

- Recharge from precipitation – rainfall directly on the watershed
- Infiltration from land use – groundwater recharge from application of water for irrigation
- Underflow into basin

Recharge from Precipitation

Recharge from precipitation is the most significant inflow to the Coldwater Basin. As shown in **Figure 2-10**, precipitation varies according to geography and topography in the watershed. Annual average precipitation ranges from approximately 15 inches per year in the northeastern portion of the watershed to as much as 30 inches per year in the southern portion of the watershed near Santiago Peak. The following section quantifies the historical annual average precipitation volume and the amount of this precipitation that infiltrates into the groundwater basin. The following equation calculates the amount of precipitation recharge:

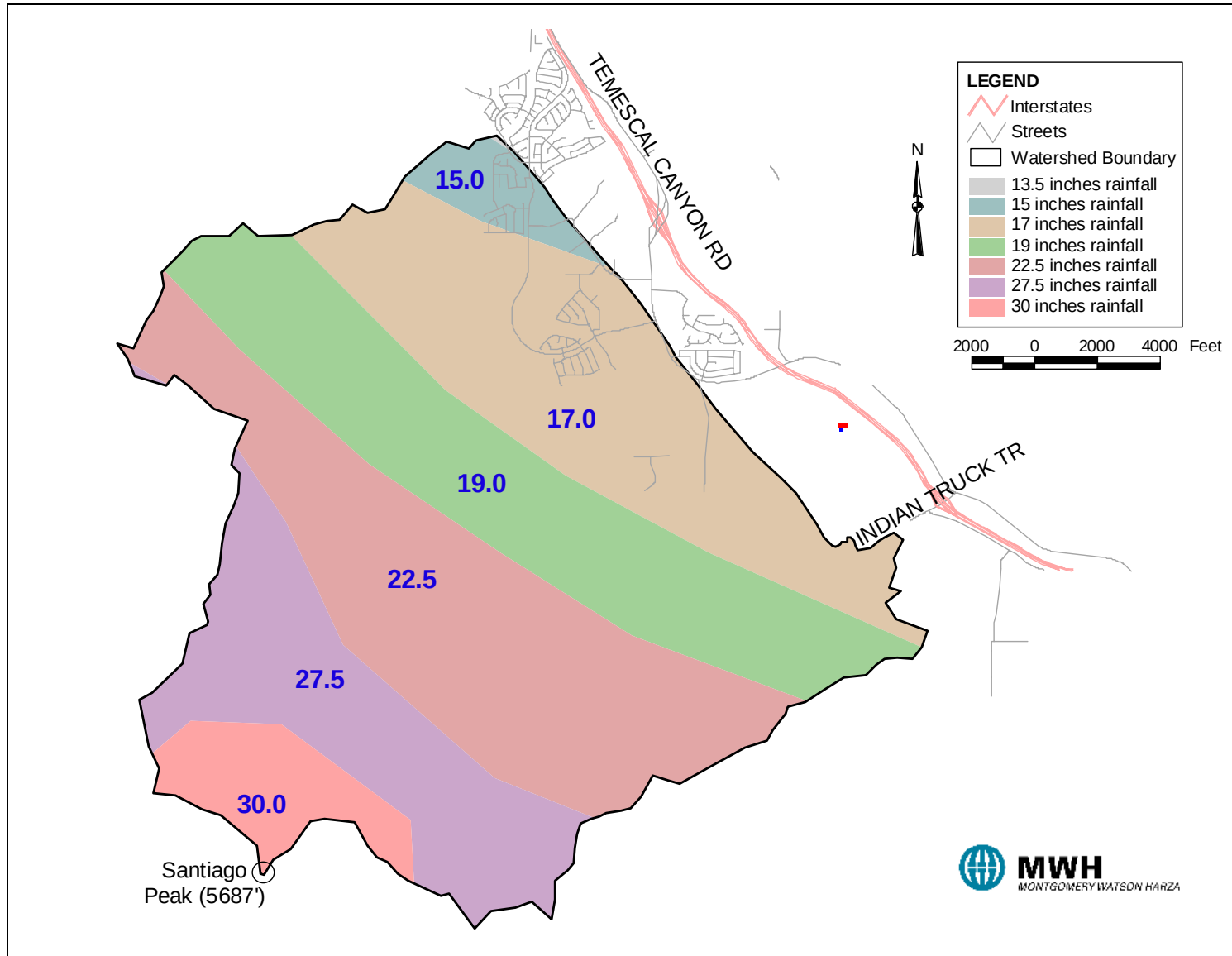
$$\text{Precipitation Recharge} = \text{Total Precipitation} - \text{Runoff} - \text{Evapotranspiration}$$

In the preparation of a groundwater budget, a representative time period (base period), during which inflows and outflows are approximately equal and that approximates current conditions must be selected. When pumping data and groundwater usage is not stable, precipitation is often used to select the representative time period. **Figure 2-11** shows the annual precipitation and cumulative departure from mean precipitation at Station 202 located in the northern part of the Coldwater watershed. Average annual precipitation at this rain gauge since 1905 is approximately 17.4 inches.

The cumulative departure from mean, which represents the cumulative difference between the annual precipitation and the historical average precipitation, is also shown on this figure. An upward (positive) indicates a wet period while a downward (negative) slope indicates a dry period. The cumulative departure from mean curve shows that in the first half of the century the number of years above and below the average was fairly constant. The first thirty years of record were slightly drier than average followed by an eight year wet period. The second half of the century was characterized by a long cycle of dry years followed by above average rainfall. Most notable is the period from the mid-1940s to the mid-1960s was characterized by a 20-year dry period. Since the late 1970s rainfall has been above normal.

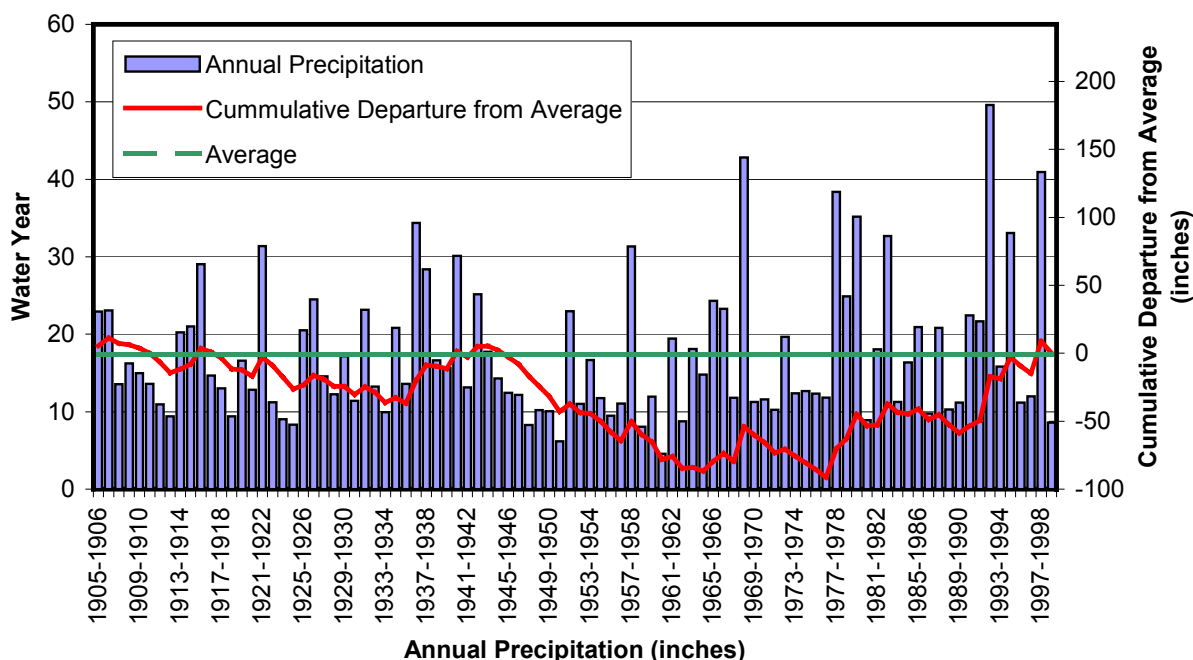
The base period for the groundwater budget selected for this study is from October 1977 to September 2000. This 23-year period includes wet and dry periods and has average annual precipitation of approximately 21.2 inches per year. The period average is 22 percent higher than the average for the 95 years of historical data.

Figure 2-10
Isohyetal Map of Coldwater Watershed



Source: Riverside County Flood Control and Water Conservation District, Isohyetal Map of Average Annual Precipitation.

Figure 2-11
Historical Annual Precipitation
Riverside Flood Control District – Station 202



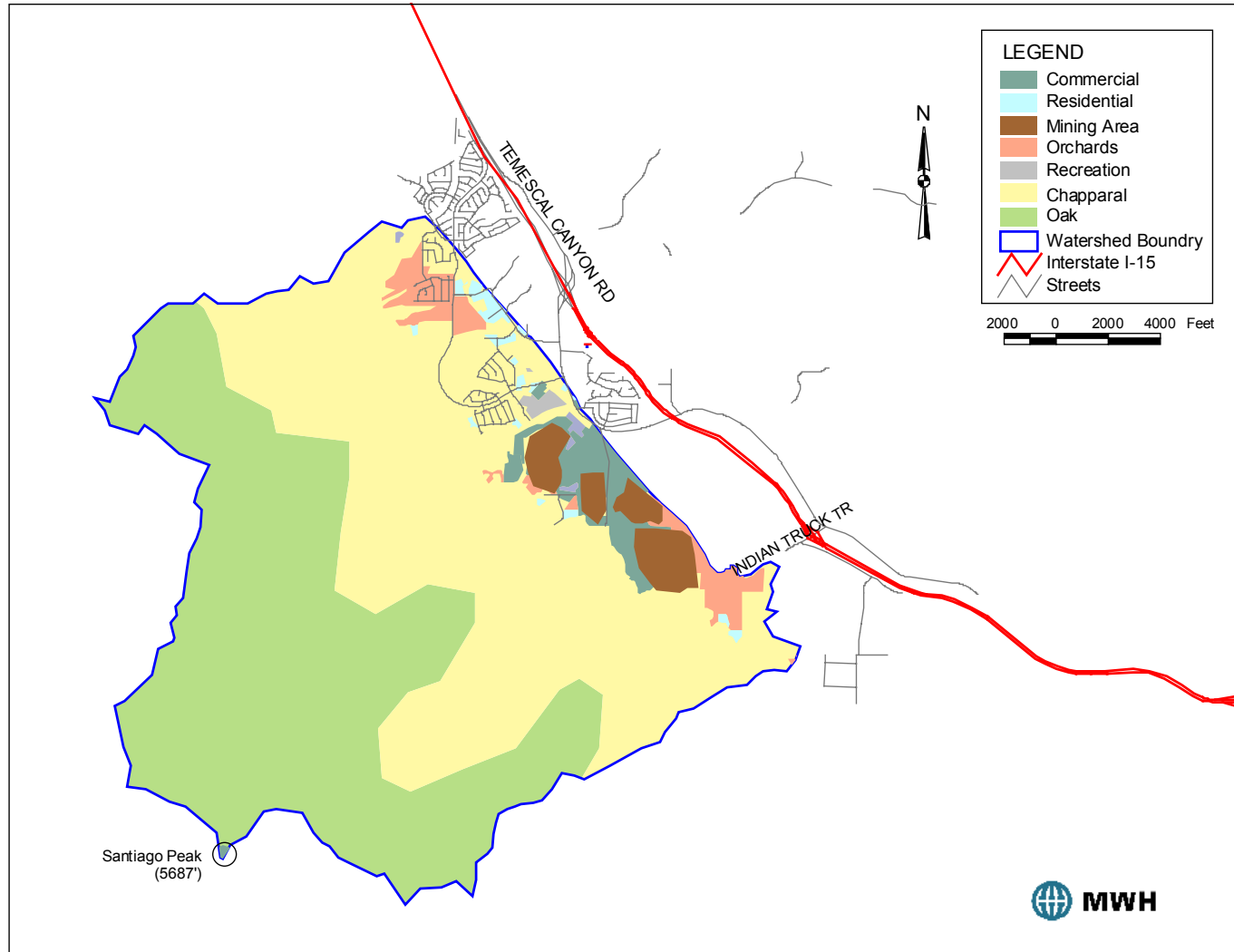
Because the methods for determining the runoff coefficients and associated infiltration rates in the open space areas and the urban areas are different, each component will be discussed separately. Runoff and evapotranspiration estimates for each category are presented below.

Recharge from Precipitation on Open Areas

Figure 2-12 shows the distribution of land use in the Coldwater watershed. Because the Mountain Cove Development was not constructed during the base period, this development has not been included in the land use estimates for the historical base period. The majority of the watershed is open space, approximately 10,060 acres. MWH used the methodology described in the Riverside County Flood Control District Hydrology Manual (Riverside County Flood Control District, 1978) to estimate runoff coefficients based upon various vegetation types, soil types, and rainfall intensity. As shown in Figure 2-12, the vegetation cover in the open areas within the Coldwater watershed is approximately 50 percent chaparral and 50 percent canyon live oak (Information Center for the Environment, UC Davis).

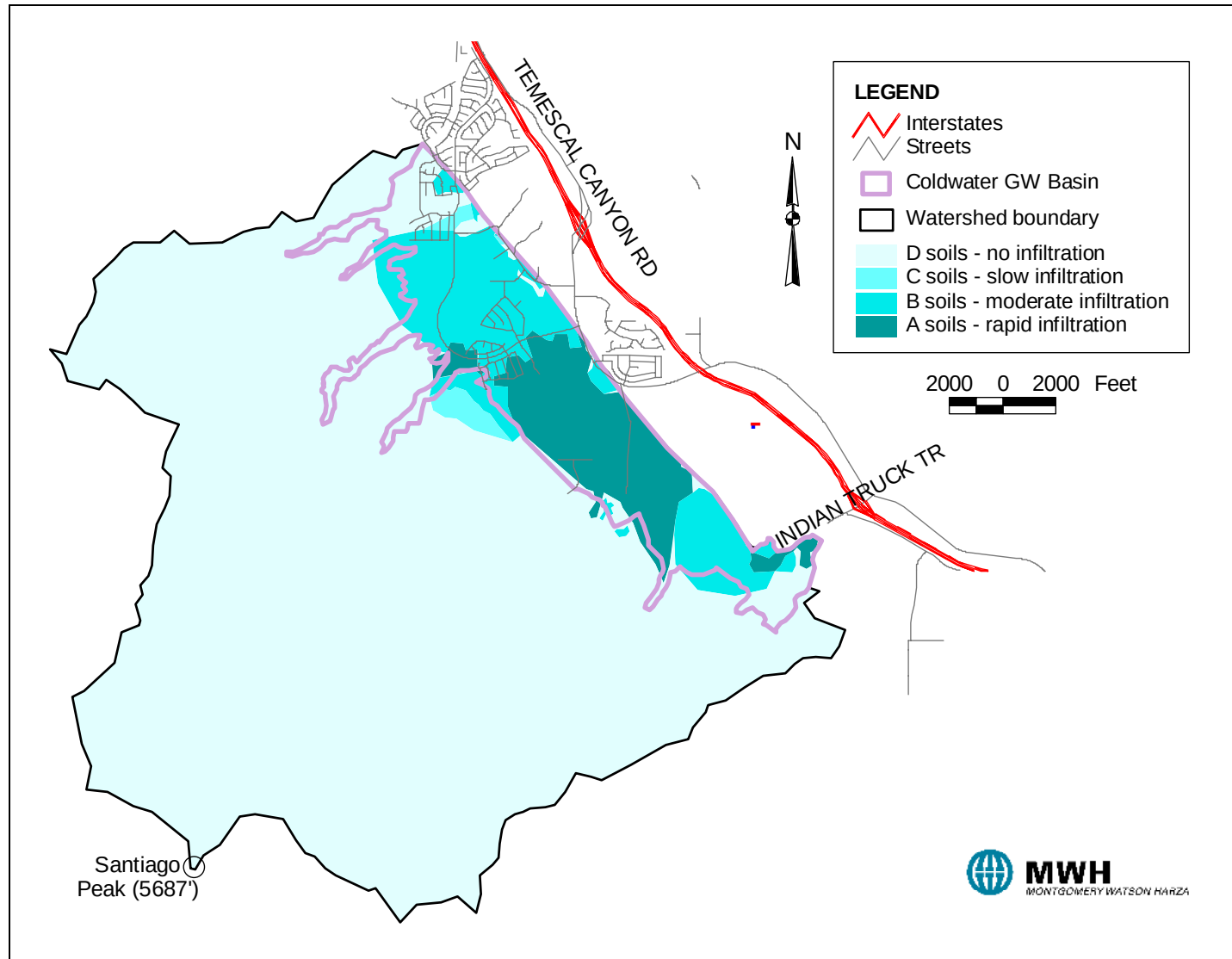
MWH estimated runoff coefficients for each subwatershed based on the soil types and vegetative cover. **Figure 2-13** shows the soil types in the Coldwater watershed and the location of the groundwater basin. A large portion of the watershed is characterized by bedrock with little to no infiltration except in fractures.

Figure 2-12
Vegetation Distributions in the Coldwater Watershed



Source: Information Center for the Environment, UC Davis

Figure 2-13
Coldwater Basin Soil Types



Source: Hydrologic Soils Group Maps, Riverside County Hydrology Manual

Section 2 – Hydrogeologic Setting

The valley areas in the north and east portions of the watershed are characterized by soil types A and B with high infiltration rates. An antecedent moisture condition (AMC) value of I was used to determine the runoff coefficients because most storms occur under dry ambient conditions. Runoff coefficients used for the analysis of open areas ranged from 0.32 to 0.40.

MWH estimated the evapotranspiration within the open space according to the method described by the Department of Water Resources (2000). These estimates are provided in **Table 2-5**. With this method, the evapotranspiration is estimated by multiplying the reference evapotranspiration for the area by a landscape coefficient (K_L) for the specific plant. According to the Riverside County Water Budget Formula (2001), the reference annual evapotranspiration value for the Elsinore area is 55 inches. This reference evapotranspiration is assumed to be valid for the Coldwater area.

Table 2-5
Evapotranspiration Constants for Coldwater Basin

Plant	Water Needs Category	K_L	Evapotranspiration (inches per year)
Chamise Chaparral	Very Low	0.15	8.3
Canyon Live Oak	Low	0.25	13.8

Recharge from Precipitation in Urban Areas

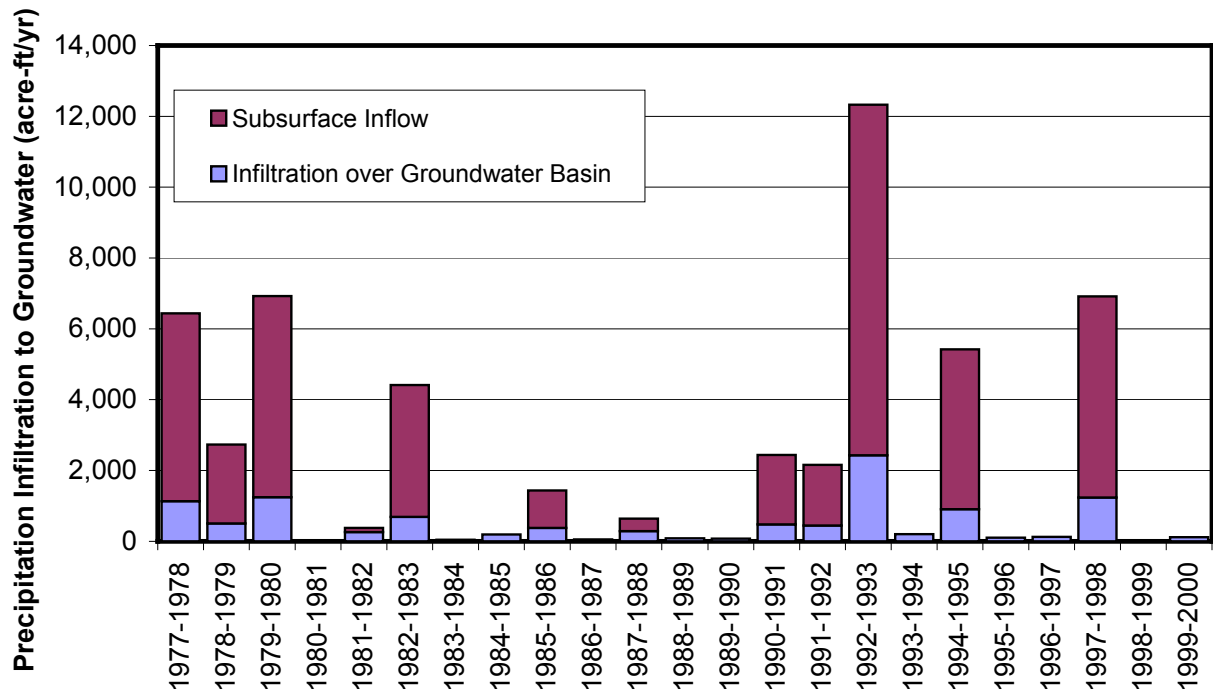
Urban area makes up only a small fraction of the total watershed area and contributes a similarly small portion of the groundwater recharge. Figure 2-12 shows where the urban areas are located in the watershed based upon year 2000 land use. The types of urban land use include residential, commercial, and industrial. The total acreage of the residential area is approximately 150 acres while the total acreage of the commercial and industrial areas are 80 acres. Commercial and industrial land uses are typically highly impervious. MWH estimated the fate of precipitation on the urban areas in the Coldwater Basin by creating a runoff coefficient for the urban areas of each subwatershed. Land use data was used to make a weighted average percent imperviousness for each subwatershed. A runoff coefficient was calculated from percent imperviousness. Runoff coefficients varied from 0.26 to 0.69 in urban areas. Runoff was calculated by multiplying the precipitation over the subwatershed by the runoff coefficient. Evapotranspiration from the pervious areas of the watershed was subtracted from the non-runoff water and the remainder, if any, was considered as groundwater infiltration.

Infiltration in Gravel Pits from Precipitation

Based upon year 2000 land use, approximately 450 acres of the Coldwater Basin consists of gravel pit operations. Precipitation can more easily recharge the groundwater in these areas because these areas do not generate significant runoff.

Figure 2-14 presents estimated total infiltration due to precipitation from 1990 to 2000. The average inflow during this time period was approximately 4,750 acre-ft/yr. It is important to note that significant infiltration only occurs during infrequent, wet years. Dry years have little to no infiltration as most precipitation evaporates or restores soil moisture, which is later lost to evapotranspiration (ET).

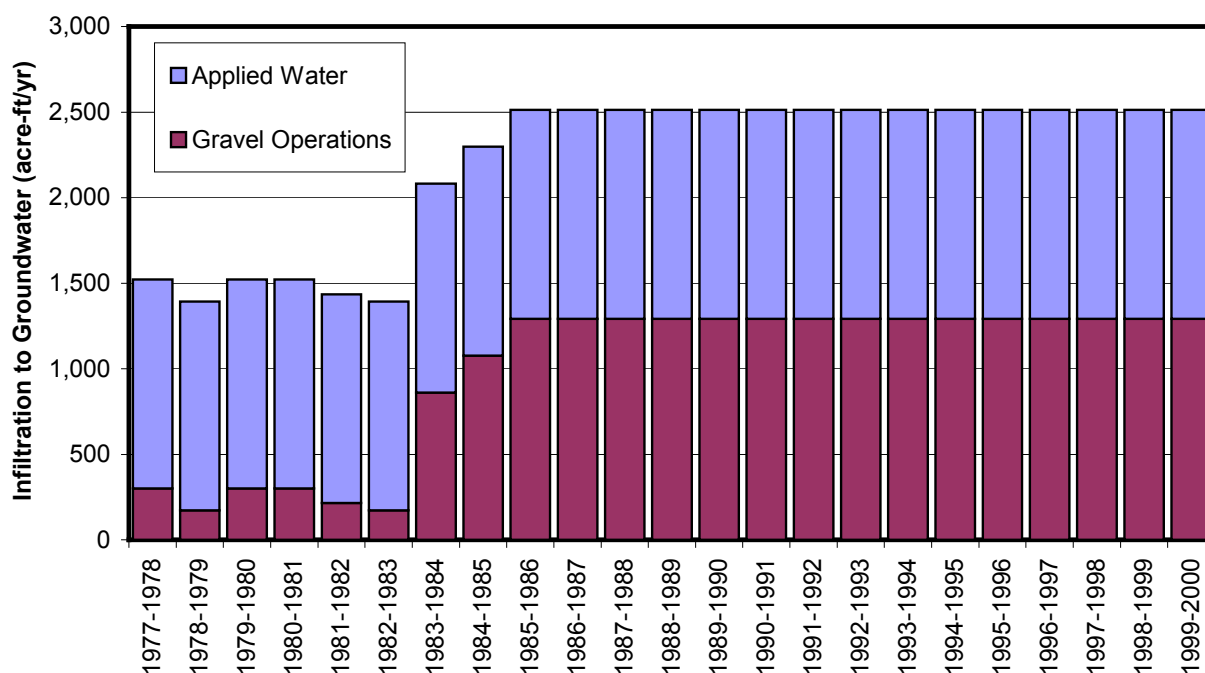
Figure 2-14
Estimated Groundwater Recharge from Precipitation – 1977-2000



Recharge through Use

Groundwater recharge also occurs from applied water for irrigation and return flows from gravel washing activities. **Figure 2-15** summaries the recharge through use for the period from 1977 to 2000.

Figure 2-15
Estimated Recharge Through Use – 1977-2000



Applied Water

Water is applied to both urban landscaping and agriculture. A significant amount of this applied water returns to the groundwater. Based upon water production and usage data from the Elsinore Basin (a similar basin), approximately 39 percent of the urban water demand (approximately 560 acre-ft/yr in the Coldwater Basin) is used for outdoor needs such as landscape irrigation (Montgomery Watson, 2001). Assuming an irrigation efficiency of approximately 75 percent, an average of approximately 50 acre-ft/yr enters the groundwater basin from applied water in urban areas.

The Coldwater watershed has approximately 360 acres of orchards and vineyards. When irrigation efficiency and losses to leaching and evapotranspiration are removed, 1.3 acre-feet per acre are expected to return to groundwater. An average of approximately 1,150 acre-ft/yr is returned to the Coldwater basin from agricultural irrigation annually. The remainder of the annual applied water comes from urban irrigation.

Septic Systems

According to the septic system data provided by the District, septic systems within the Coldwater Basin watershed exist at the Glen Ivy Hot Springs and the Emissaries of Divine Light (EDL). The impact of the two septic systems on water quality is expected to be minor.

The Regional Water Quality Control Board (RWQCB) issued a Waste Discharge Permit (Order No. R8-2004-0003) for the Glen Ivy Hot Springs, Inc on March 17, 2004. Glen Ivy Hot Springs,

Inc. leases 17.25 acres of land from the EDL that owns a total of 80 acres. The waste discharge permit is for the discharge of untreated wastewater from the resort's recreational pools and water features to Coldwater Canton Creek. The maximum daily concentration limits for the constituents identified in the permit are as follows: total suspended solids – 75 mg/L, total dissolved solids – 500 mg/L, and chlorine residual – 0.1 mg/L.

In a letter dated December 15, 2003, the RWQCB provided the EDL and Glen Ivy Hot Springs, Inc. a waiver for subsurface disposal systems based on the existing and proposed disposal systems and an agreement between the two entities. The waiver is to be reviewed if conditions stated in the agreement or waiver letter change or in five years. An estimated peak discharge of 16,000 gallons per day was used to determine the minimum lot size requirement for new developments proposing the use of on-site septic-tank subsurface leaching/percolation systems.

Gravel Pit Operations

Water is added to the basin through gravel washing operations in the basin. Prior to 1989 all of the gravel pits currently in production had started operations. After 1989, not all current pits were in operation. Returns from gravel washing range from about 200 acre-ft/yr in 1977 to about 1,300 acre-ft/yr after 1989 with an average of about 1,000 acre-ft/yr. (Law/Crandall, 1993)

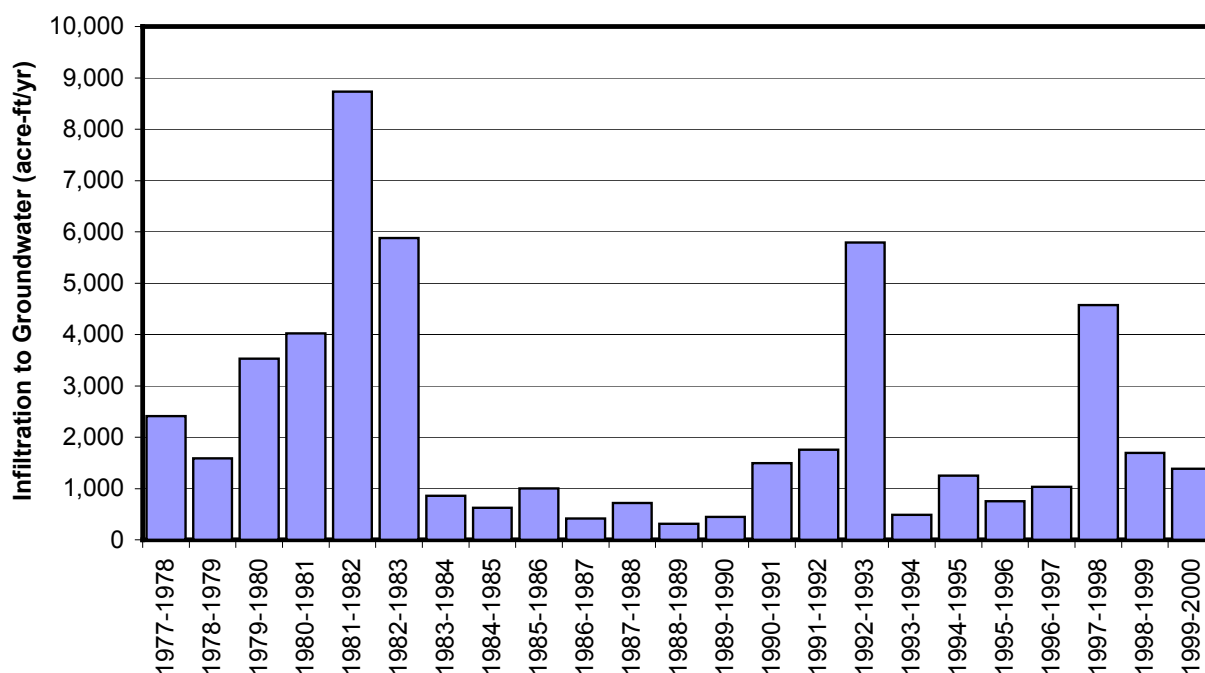
Summary

As shown in Figure 2-15, the estimated recharge through use ranges from about 1,400 acre-ft/yr to as much as 2,500 acre-ft/yr between 1977 and 2000. The average is approximately 2,200 acre-ft/yr.

Infiltration of Surface Runoff

The District currently diverts water from Mayhew Canyon to the gravel pits and agricultural users in the east end of the Coldwater Basin. The City of Corona currently diverts water from Coldwater into recharge basins located near Well No. 3. An average of 1,200 acre-ft/yr is infiltrated from these two canyons, ranging from about 200 acre-ft/yr to 8,700 acre-ft/yr, depending upon hydrologic conditions.

Figure 2-16
Diversion of Surface Runoff – 1977-2000



Subsurface Inflow

As discussed previously, the Coldwater Basin is essentially closed to underflow from outside the basin. Therefore, there is no subsurface inflow except as described above.

Outflows

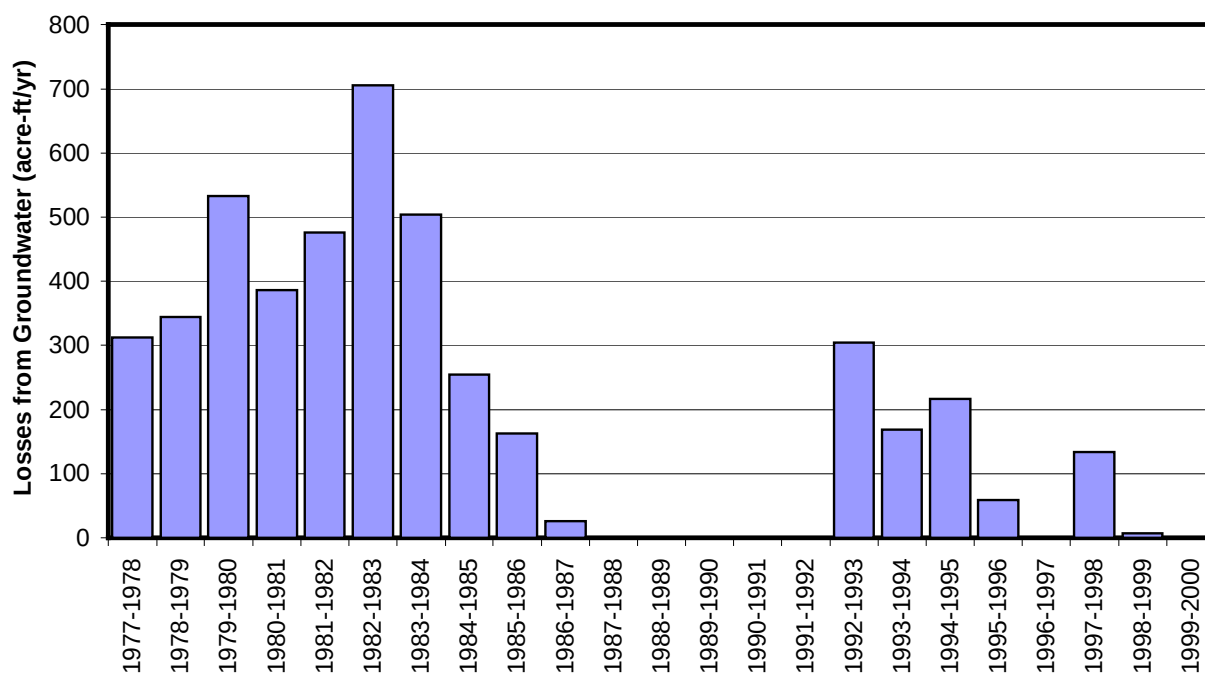
The following are the major outflow components to the Coldwater Basin:

- Evapotranspiration – the loss of groundwater from soil and transpiration by plants
- Groundwater pumping – groundwater extraction by wells in the basin
- Flow to Surface Water – flow from the groundwater basin to surface water
- Underflow – subsurface outflow from the basin

Evapotranspiration

A portion of the groundwater is lost to evaporation in the gravel pits as shown in **Figure 2-17**. The groundwater model (described in Section 3 of this report) has been used to estimate the evaporation from the gravel pits. MWH estimates that this accounts for an average of approximately 200 acre-ft/yr. Because groundwater levels are generally substantially below the ground surface, it is unlikely that groundwater is currently lost to phreatophyte plant evapotranspiration. Therefore, this outflow is zero.

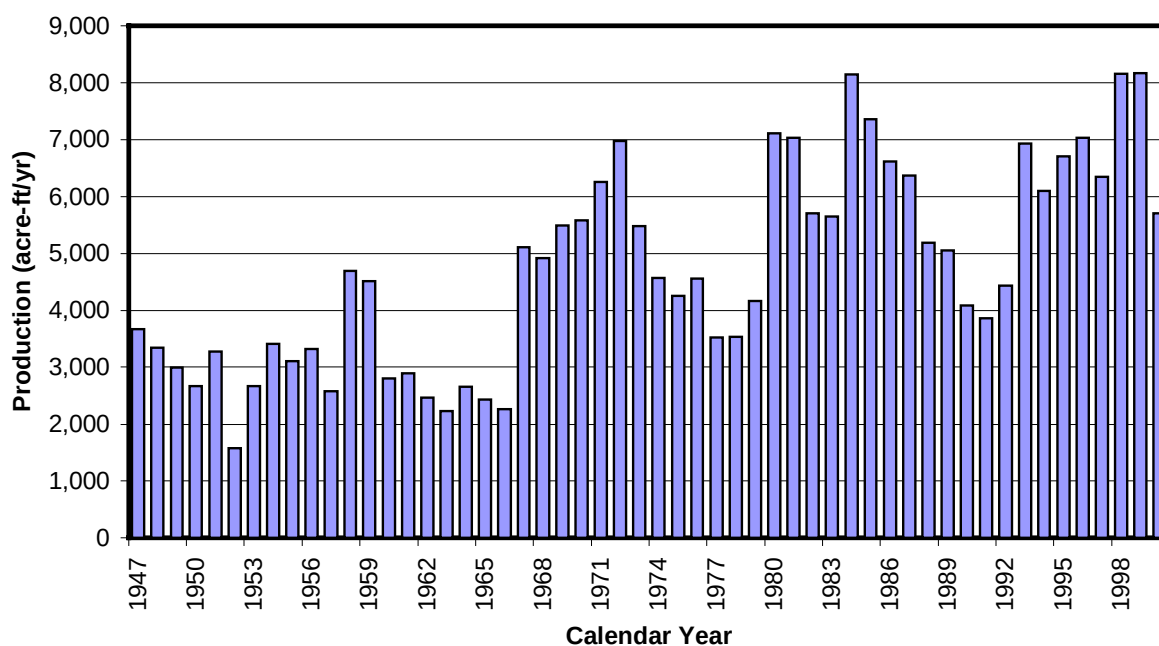
Figure 2-17
Estimated Losses Due to Evaporation in Gravel Pits – 1977-2000



Groundwater Pumping

Historical pumping data are summarized in **Figure 2-18**. Historical pumping has ranged from about 1,500 acre-ft/yr to more than 8,100 acre-ft/yr. In general, groundwater pumping in the basin has increased over the past few years, which is reflected in the declining groundwater levels since 1998 as discussed previously. The average pumping during the base period was about 6,100 acre-ft/yr.

Figure 2-18
Historical Groundwater Pumping in the Coldwater Basin



Other Outflows

Other outflows include losses from gravel operations and losses across the North Glen Ivy fault. Each outflow is discussed in more detail below.

Losses from Gravel Operations

Losses occur when the sand and gravel from the gravel pits, which contains groundwater used for washing, is transported from the Coldwater Basin. The estimated losses from gravel operations are provided in **Figure 2-19**. Losses range from about 300 acre-ft/yr to more than 900 acre-ft/yr (Law/Crandall, 1993). The average losses are approximately 700 acre-ft/yr (Law/Crandall, 1993). MWH has assumed that the losses from gravel operations have remained constant since 1989.

Losses Across Faults

As discussed previously, the North Glen Ivy fault generally provides a barrier to flow except in the area where the fault crosses a gravel pit. At these locations, water can flow into the Bedford Basin. The groundwater model has been used to estimate the outflow across the fault. Estimated outflow across the fault from 1977 to 2000 is provided in **Figure 2-20**. The outflow ranges from 0 acre-ft/yr when water levels are low to more than 600 acre-ft/yr when water levels are high. The average is approximately 200 acre-ft/yr. **Figure 2-21** shows the location of the Glen Ivy Fault with respect to the gravel pits.

Figure 2-19
Estimated Losses from Gravel Operations – 1977-2000

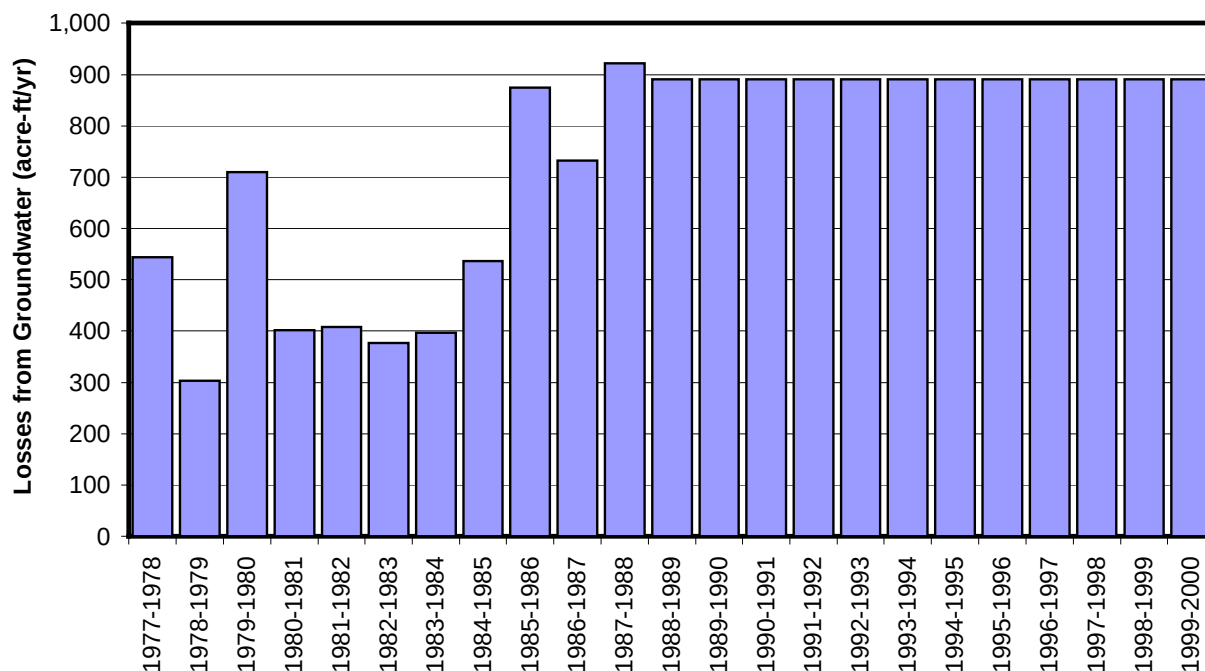


Figure 2-20
Estimated Losses Across North Glen Ivy Fault – 1977-2000

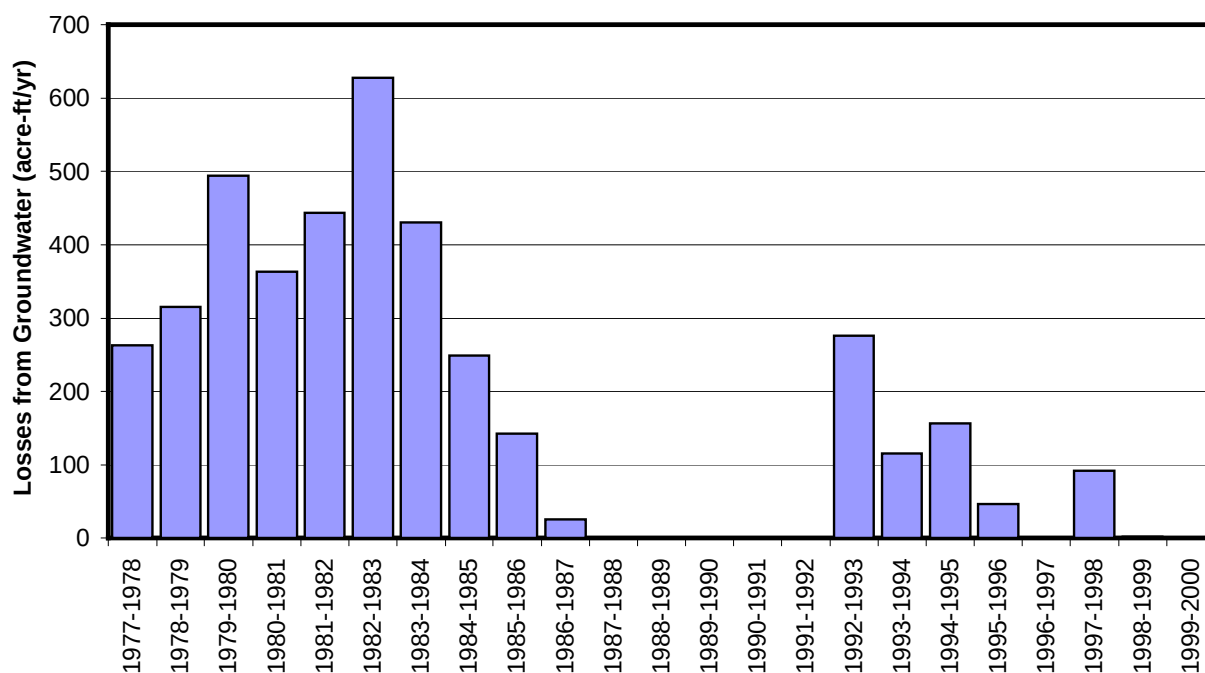
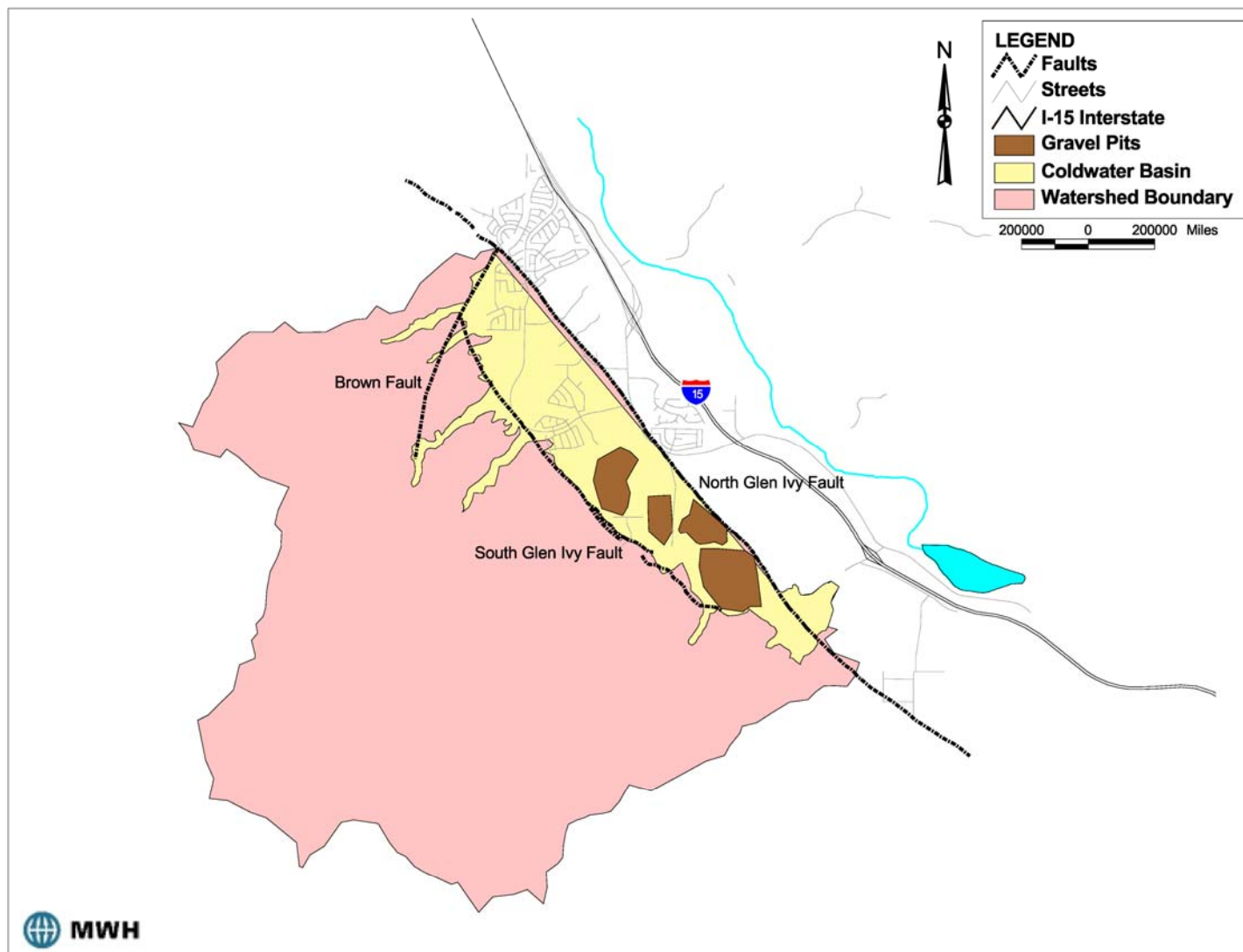


Figure 2-21
Fault Locations near Gravel Pits



Water Budget Summary

Table 2-6 provides an average groundwater budget for the base period from 1977 to 2000. Comparing total inflows to total outflows shows an average groundwater deficit of approximately 500 acre-feet per year over the 23-year period of review. **Figure 2-22** shows estimated annual inflows and outflows over the period.

Table 2-6
Summary of Estimated Water Budget – 1977-2000

Component	Average 1977-2000 (acre-ft/yr)
Inflows	
Precipitation and Applied Water	1,700
Surface Diversions	2,200
Returns from Gravel Washing	1,000
Subsurface Inflow	1,800
Total Average Inflow	6,700
Outflows	
Groundwater Pumpage	6,100
Evaporation from Gravel Pits	200
Losses from Gravel Operations	700
Subsurface Outflow	200
Total Average Outflow	7,200
Net Surplus or Deficit	-500

Figure 2-23 shows the estimated water in storage during the base period. The total basin storage volume is estimated to be approximately 74,800 acre-ft based upon a specific yield ranging from 7 to 9 percent. The estimated groundwater in storage in September 2000 is estimated to be approximately 41,600 acre-ft (about 55 percent full). The estimated cumulative loss in storage in the Coldwater Basin between 1977 and 2000 is approximately 10,000 acre-ft. **Figure 2-23** also shows water levels in the City of Corona's Well #2. Water levels in this well, which is located in the central portion of the basin, appear to trend relatively well with changes in groundwater storage. Like groundwater storage, water levels are at or near historic lows in the basin.

Figure 2-22
Total Estimated Inflows and Outflows to Groundwater Basin

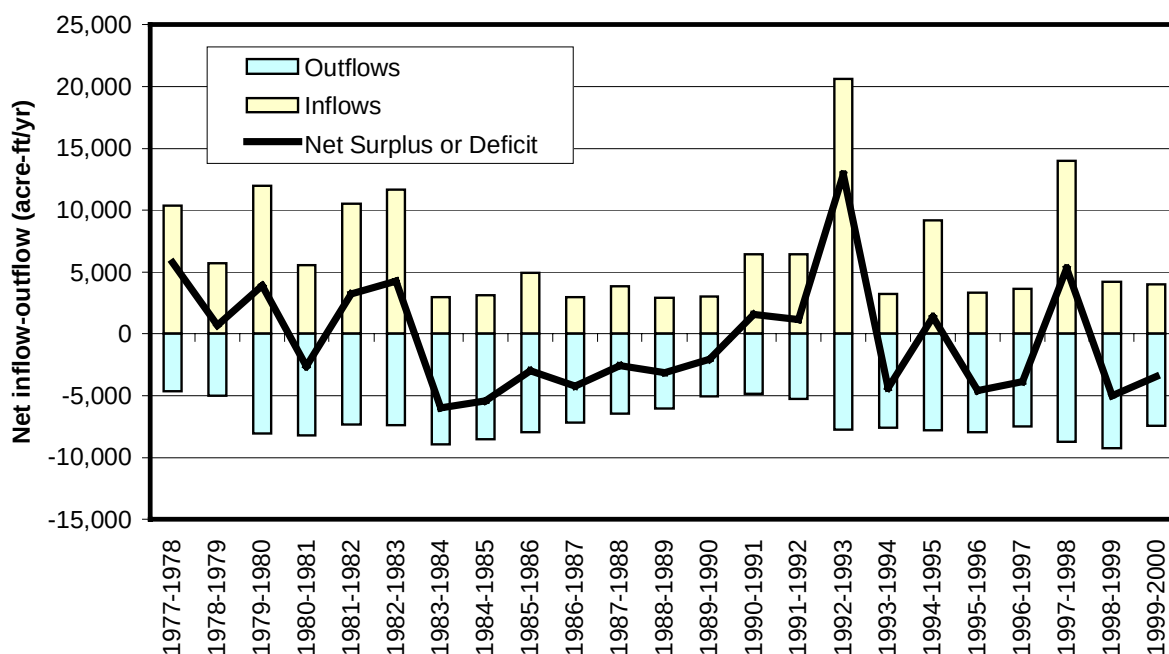
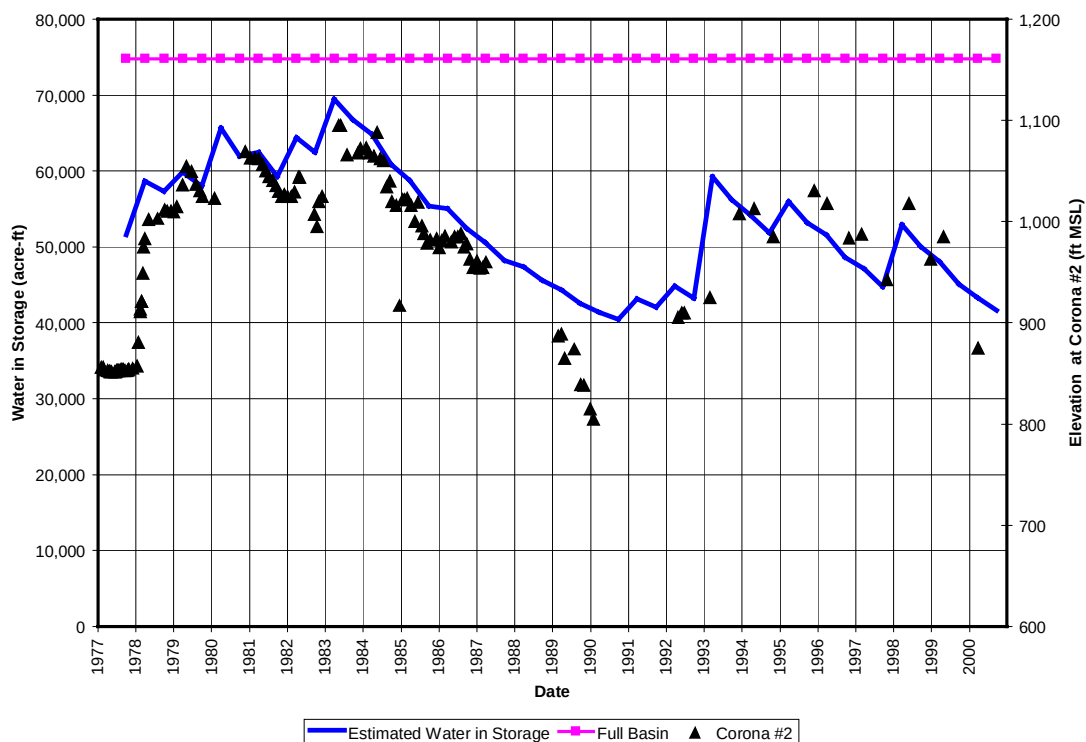


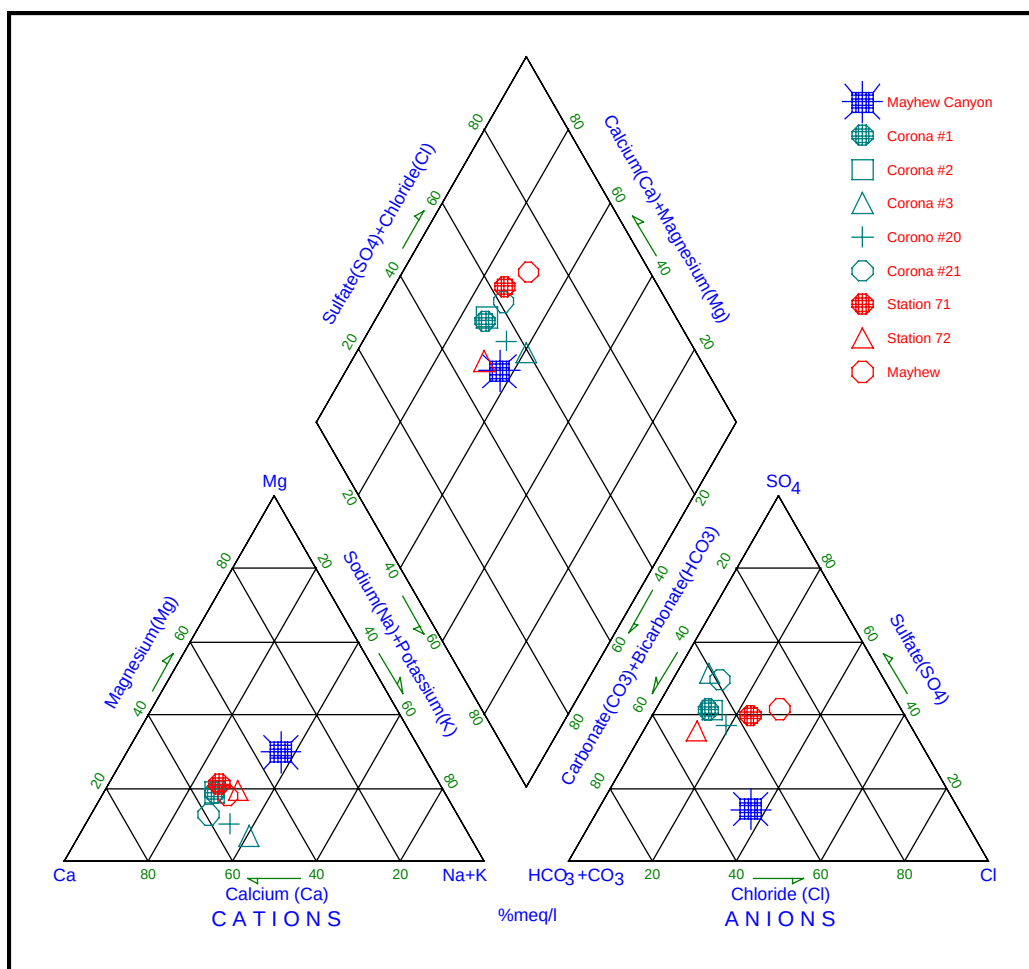
Figure 2-23
Estimated Water in Storage – 1977-2000



GROUNDWATER QUALITY

Piper diagrams are often used to observe differences in general water quality from various sources. A Piper diagram plots various cation and anion concentrations on the same graph as a relative percentage, which allows for identification of water quality similarities and differences among various water sources that may not be detected simply by comparing bulk concentrations. A Piper diagram for wells within the Coldwater Basin is presented in **Figure 2-24**. These data show that most of the municipal wells within the basin have similar overall water quality because they plot closely on this figure. Surface water from Mayhew Canyon has a slightly different character. Water produced from Station 72, which is located immediately downgradient from the gravel pits where runoff from Mayhew Canyon is diverted, appears most similar in quality to surface water during wet periods.

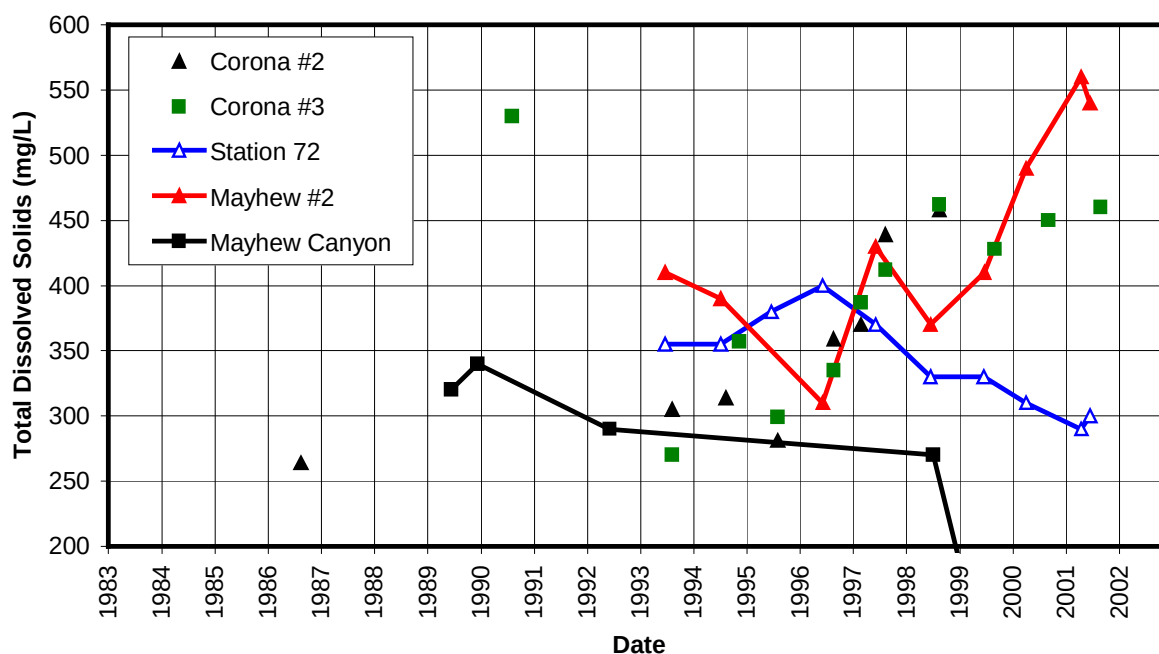
Figure 2-24
Piper Diagram for the Coldwater Basin Wells -2001



Historical total dissolved solids (TDS) concentrations in various wells are presented in **Figure 2-25**. Data for wells Station 72, Mayhew #2 and Mayhew Canyon are connected with lines to

illustrate representative trends that are present in the other data. In general, the groundwater quality within the Coldwater Basin is relatively good. The TDS in most wells is below the secondary standard of 500 mg/L for TDS. However, these data suggest that the TDS of the groundwater basin is generally increasing in most wells except for Station 72 since the early 1990s. The TDS concentrations are generally higher during dry periods and lower during wet periods.

Figure 2-25
Historical Total Dissolved Solids Concentrations in the Coldwater Basin



In general surface water from local runoff has better water quality (< 250 mg/L TDS) than the returns from use (>500 mg/L). Therefore, as the proportion of the water from runoff decreases, the TDS increases.

Similar trends are observed in sulfate and nitrate concentrations, which are summarized in **Figure 2-26** and **Figure 2-27**, respectively. For example, in the Mayhew #2 well, sulfate and nitrate concentrations have more than doubled since 1996. None of the wells exceed applicable MCLs for sulfate or nitrate. However, the increasing trends may lead to potential water quality problems in the future. The elevated nitrate and sulfate concentrations may be a result of historical agricultural activity in the region. As with TDS, the sulfate and nitrate in the Station 72 well, adjacent to the gravel pits where surface runoff is diverted, appear more similar in quality to the surface runoff during wet periods.

Figure 2-26
Historical Sulfate Concentrations in the Coldwater Basin

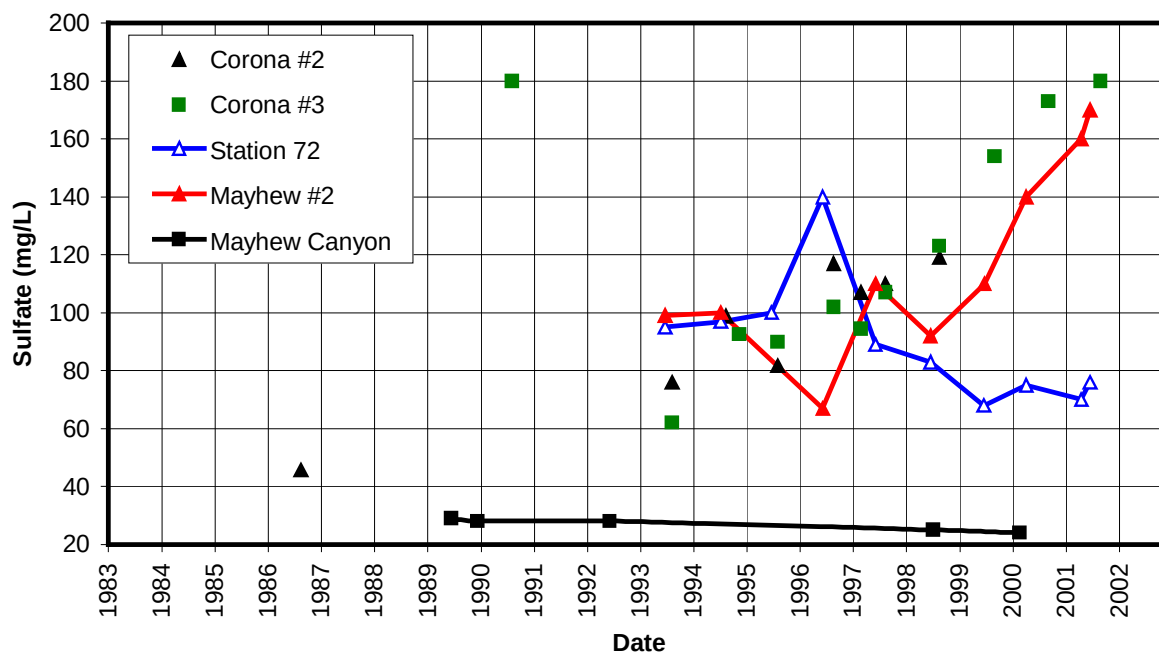
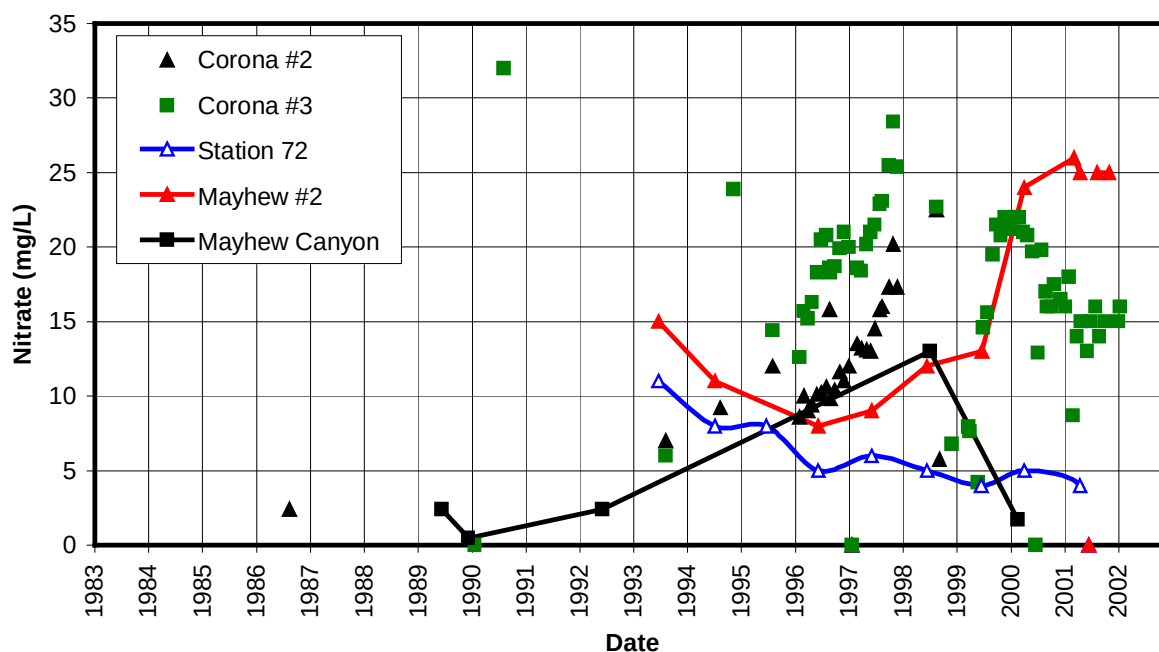


Figure 2-27
Historical Nitrate Concentrations in the Coldwater Basin



SUMMARY

MWH has reviewed and compiled available data to evaluate the geometry and update the hydrogeologic conceptual model for the Coldwater Basin. Two cross sections have been prepared to aid in understanding the complex structure of this basin. Groundwater levels and water quality have also been evaluated in the context of this conceptual understanding. Data compiled as part of this study are consistent with the previous conceptual understanding of the basin.

Based upon the data compiled as part of this report, the Coldwater Basin watershed contains the following stratigraphic units:

- Alluvium
- Bedford Canyon Formation
- Volcanic rocks and
- Granitic basement rocks

Only the alluvium produces significant groundwater resources.

Based upon the data compiled as part of this study, there do not appear to be any significant confining layers within the alluvium except in the northwestern portion of the basin where there is substantial clay. Groundwater appears to flow toward the pumping depression near the City of Corona's wells. Water levels are generally declining throughout the basin. Recharge to the alluvium occurs along the margins of the basin through Mayhew, Coldwater, Anderson, Bixby and Brown Canyons. Faults within the basin appear to be complete barriers to subsurface flow except where gravel pits cross the faults.

In general, groundwater quality was remarkably similar in all the wells. TDS and sulfate concentrations are generally increasing with time, which may impact the ability to use this groundwater basin in future.

MWH evaluated the inflows and outflows of the Elsinore Basin. Based upon these estimates, the average groundwater deficit between 1977 and 2000 was approximately 500 acre-ft/yr. This estimate is generally consistent with the observed decline in groundwater levels during this time period. These data are used in the construction of the groundwater model discussed in Section 3.

Section 3

Groundwater Model

The following section summarizes the attributes of a transient groundwater flow model created to enhance understanding of the groundwater hydrology of the Coldwater Basin and the benefits artificial recharge may offer to the management of groundwater resources within it. This section includes:

- Model layer definition, including thickness and horizontal extent
- Aquifer parameter definition, including vertical and horizontal conductivity and storativity
- Boundary conditions
- Results of model calibration
- Model mass balance output
- Sensitivity analyses results

The flow model will be used as a groundwater resource planning tool to quantitatively evaluate aquifer responses to induced stresses and proposed groundwater use scenarios.

MODEL CONSTRUCTION

In general, a numerical model approximates flow conditions for a groundwater system based upon conceptual model aquifer parameters, groundwater flow conditions, and proximal groundwater quality. Flow model construction and calibration simulations were undertaken using Visual MODFLOW Pro 3.1 (Waterloo Hydrogeologic, 2003), a graphical interface to MODFLOW 2000. Visual MODFLOW Pro is a commercially available, three-dimensional, block-centered, finite difference simulator of groundwater flow. MODFLOW 2000 is an updated version of an industry standard, numerical groundwater model developed by the United States Geological Survey (USGS).

This section describes the model domain, model layer discretization, aquifer parameters, boundary conditions, and hydrologic stresses.

Model Domain

The horizontal model domain, shown in **Figure 3-1**, is an area of approximately 3,840 acres, of which approximately 1,664 acres are comprised of active cells located within the Coldwater groundwater basin. Computational cells in the remaining area lie outside the groundwater basin boundary, and these were assigned inactive status in the model. The model domain is oriented with its principal axis coincident with the longitudinal axis of the basin. The dimensions of the domain are 7,004 feet by 23,710 feet. The horizontal model domain is comprised of a grid of rectangular computational cells. The active cells within the model domain comprise an area approximately 4,000 feet by 21,700 feet.

Figure 3-1
Model Domain and Grid Discretization

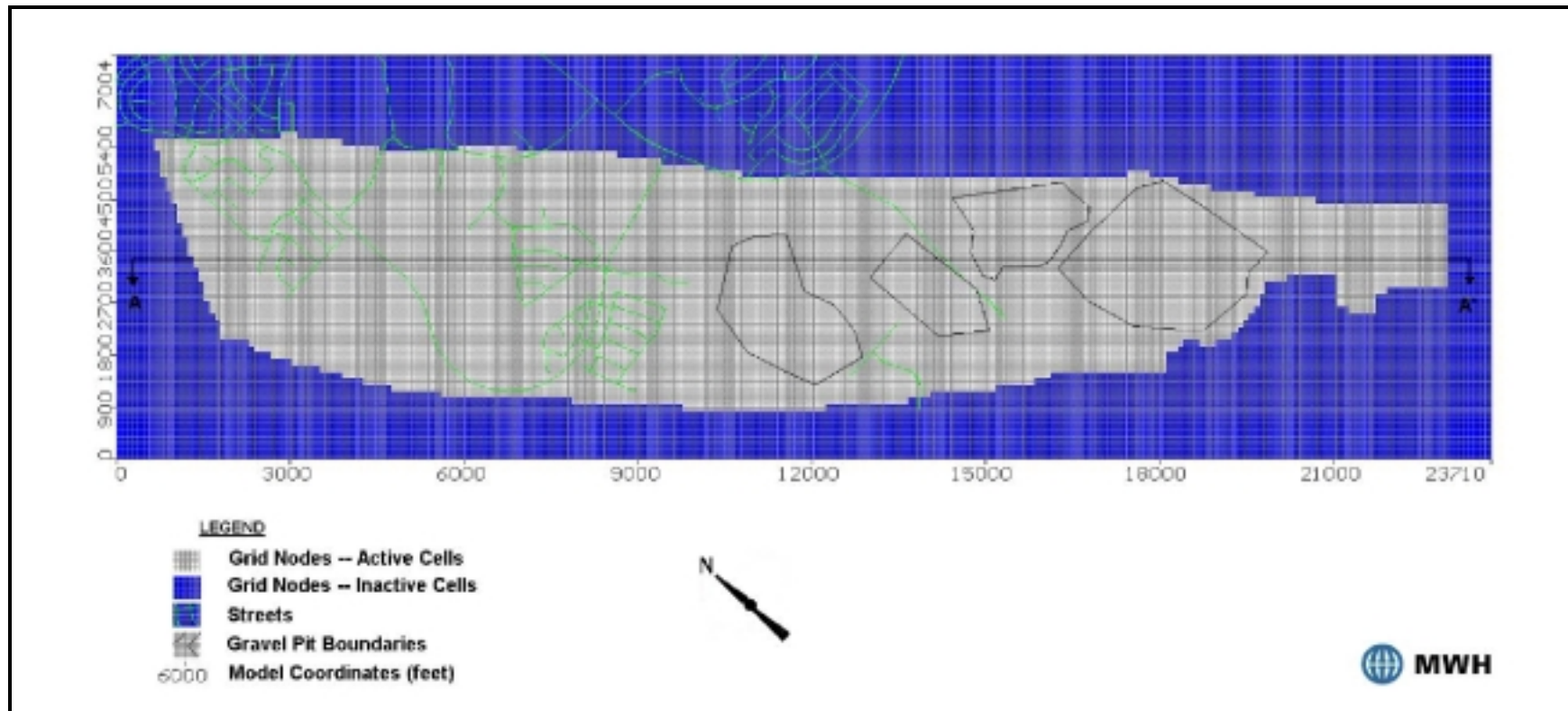
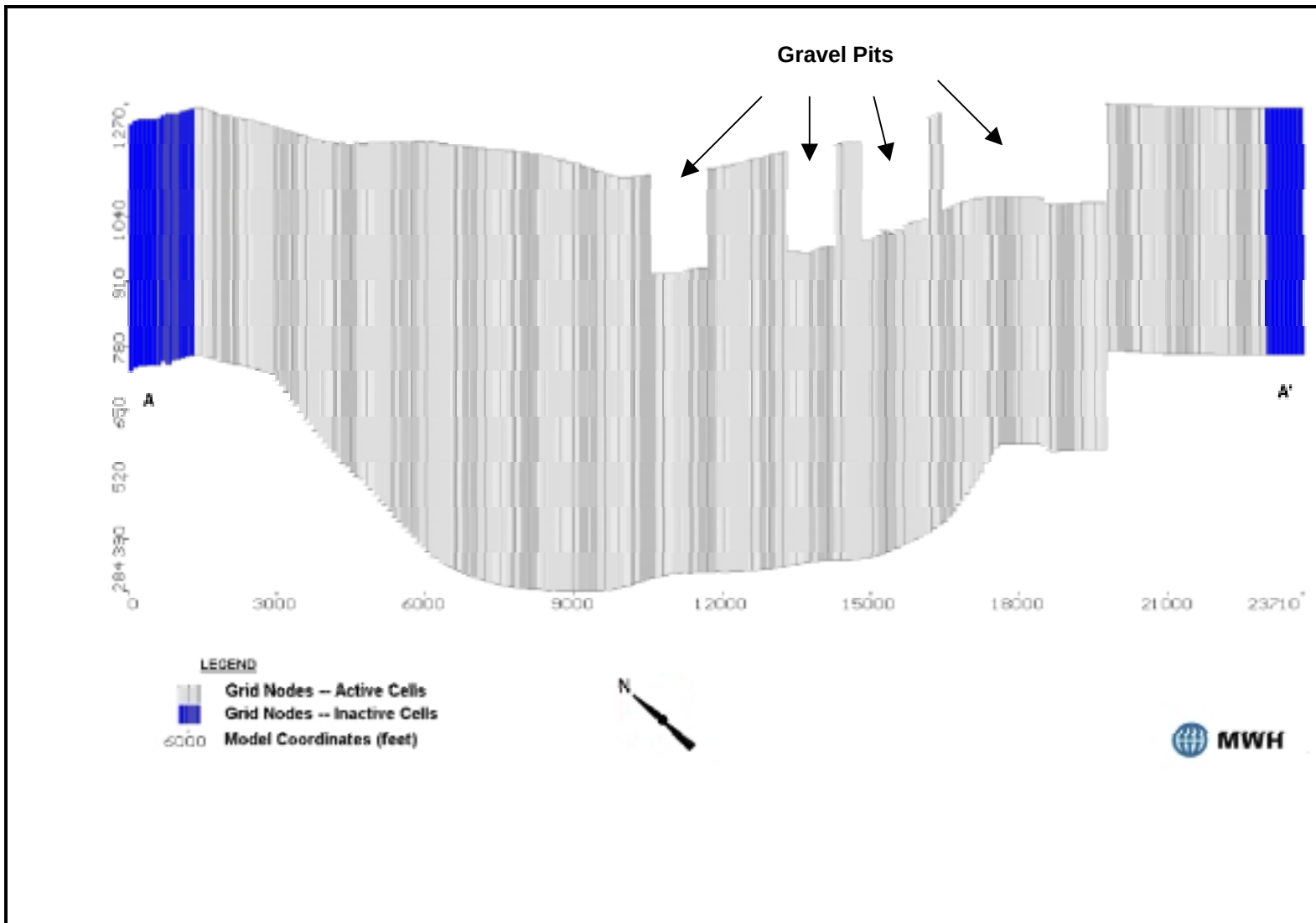


Figure 3-2
Longitudinal Cross Section Through Flow Model



Rectangular grid spacing is uniform, having grid dimensions of approximately 48 by 56 feet. Overall, the model grid is comprised of 109 rows and 487 columns. Vertically, the model is discretized into one layer.

Model Layer Discretization

Vertical discretization of the model reflects the conceptual model of the basin, which was discussed in detail in Section 2. The flow model is comprised of one layer (**Figure 3-2**), with hydraulic characteristics reflecting the alluvial sediments described previously

The single model layer is laterally continuous in the graben defined by the North and South Glen Ivy faults, and the so-called Brown fault at the northwest end of the basin. These faults also define the active model domain. Borehole data suggest that the thickness of the alluvium exceeds 800 feet in the center of the groundwater basin. The base of the flow model in the area between the North and South Glen Ivy faults is the top of the Bedford Canyon Formation (bcb), described as metasedimentary basement rocks, including blue to black slate and interbedded metamorphosed sandstones of Jurassic age. These basement rocks are a no flow boundary at the base of the model.

Aquifer Parameters

Figure 3-3 and **Figure 3-4** show the lateral distribution of hydraulic conductivity and specific yield, respectively, assigned in the model. The color-coded zones correspond to different values of hydraulic conductivity (K) and specific yield within the model. The spatial distribution of hydraulic parameters, as well as the model input values, reflect data gathered from borehole logs, aquifer pumping tests, well specific capacity information, and values estimated from the literature. Other hydraulic characteristics that are assigned to the color-coded zones are summarized in **Table 3-1**.

Table 3-1
Aquifer Property Model Input Parameters

Zone Color	Model Hydraulic Conductivity			Model Specific Yield
	Kx (ft/day)	Ky (ft/day)	Kz (ft/day)	
Blue-green	27-30	27-30	2.7-3.0	6-9 %
Red	30-44	30-44	3.0-4.4	6-9 %
Green	15-22	15-22	1.5-2.2	6-9 %
Blue	11-15	11-15	1.1-1.5	6-9 %
White	8-11	8-11	0.8-1.1	6-9 %

Figure 3-3
Hydraulic Conductivity Distribution

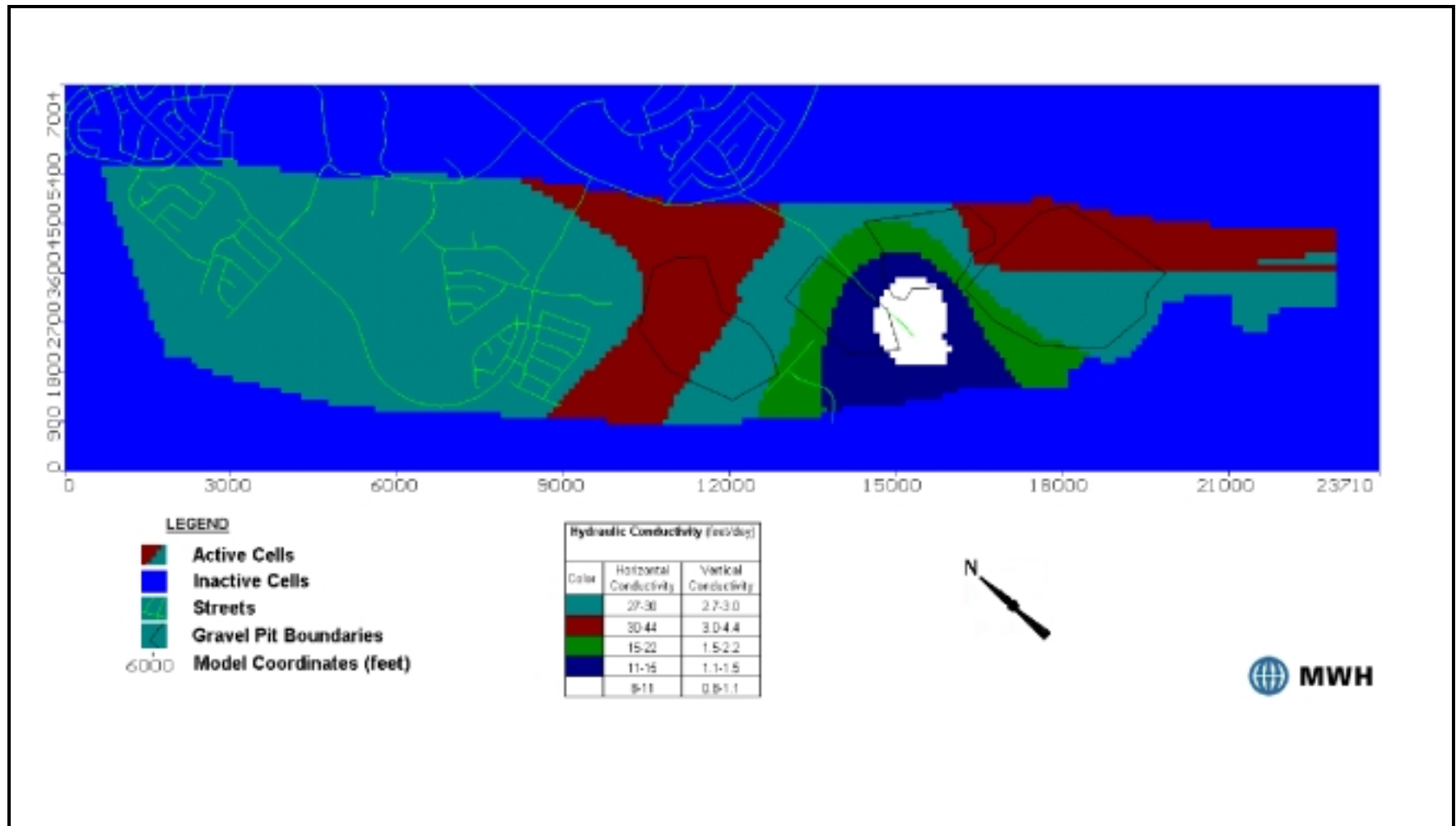
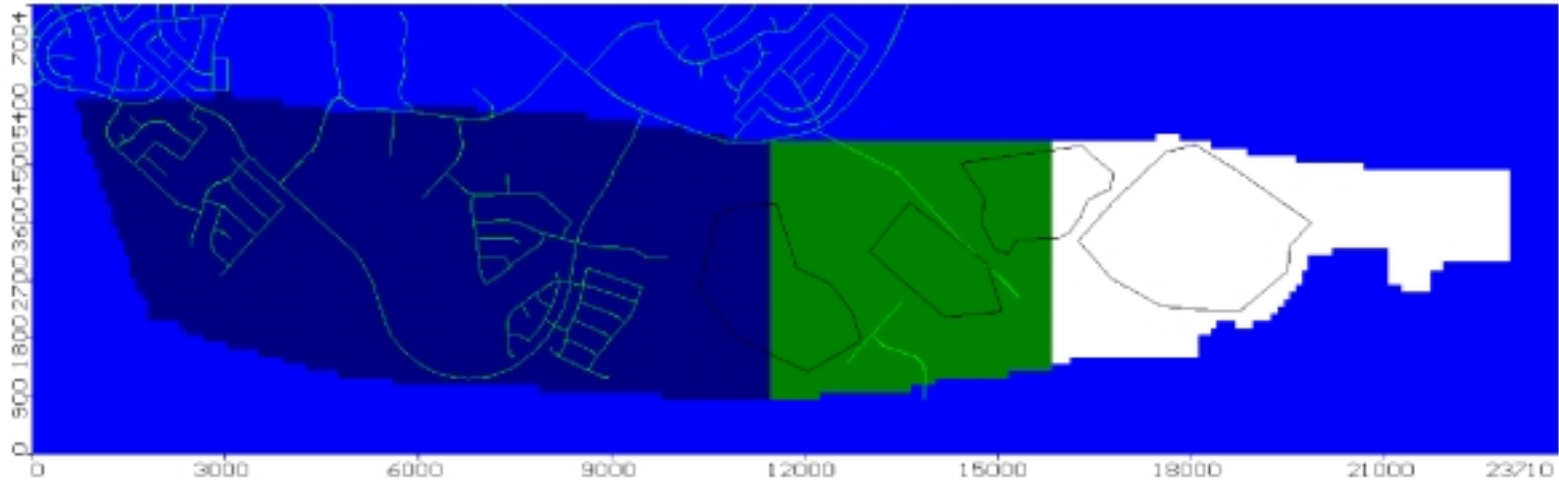


Figure 3-4
Specific Yield Distribution



- LEGEND**
- Active Cells
 - Inactive Cells
 - Streets
 - Gravel Pit Boundaries
 - Model Coordinates (feet)

Specific Yield (%)	
Color	Specific Yield
Dark Blue	6%
Green	8%
White	9%



The model is assigned a horizontal to vertical hydraulic conductivity ($K_H:K_V$) anisotropy ratio of 10:1. Isotropic horizontal hydraulic conductivity values are assumed. Horizontal hydraulic conductivity values are assigned to the zones in the model by krieging points for which data are available. For specific yield, spatially-varying values of 6 percent, 8 percent, and 9 percent are assigned during model calibration.

Figure 3-3 identifies an area of low conductivity near the 15,000-foot north-south location. Definition of the area of lower conductivity was based upon well logs and specific capacity data. After further review of the existing land use in the area of low conductivity, it appears that this area is located within the center of the existing gravel pits.

Boundary Conditions

As summarized in the water budget discussion in Section 2, subsurface inflows of groundwater into the basin are insignificant due to physical boundaries present at the basin perimeter. As a result of the geologic structure, the basin is surrounded and underlain by essentially impermeable rocks.

In the model the physical barriers to groundwater flow are simulated by placing inactive cells in the domain outside the groundwater basin boundary. The basin boundary, therefore, is considered a no-flow boundary. In addition, a no-flow boundary is present at the bottom of the model. No constant-head boundaries were used in the model.

Basin recharge (net of evapotranspiration) in the form of infiltration from precipitation, irrigation return flows, surface runoff from adjacent canyons, inflows to recharge basins, and gravel mining operation return flows were applied as recharge polygons in discrete zones in the active domain of the model. These recharge polygons are shown in **Figure 3-5**. Recharge was applied according to rates obtained from data over a period of 23 years: October 1977 through September 2000. Surface inflows to the basin from adjacent canyons were applied over the same time period in a discrete strip coincident with the trace of the South Glenn Ivy fault, except for those originating from Mayhew Canyon, which were applied at the Sunwest pit.

The MODFLOW Evapotranspiration (ET) Boundary Package was used to simulate evaporative losses from the surface of standing water in the gravel pits. The rate of ET is estimated at 17 inches per year in winter and 38 inches per year in summer. In the model, when the water table is at or above the top of the ground surface (bottom of each pit), evaporation loss from the water table occurs at the maximum rate (input rates). When the elevation of the water table is below the extinction depth (1 foot below the bottom of the pit), ET is negligible. The model does not account for changes in depth or area of gravel pits with time.

Basin losses from the Sunwest pit (formerly owned by Phariss Sand and Gravel) along the North Glenn Ivy fault are simulated in the model using the drain package in MODFLOW. The drain was assigned to a linear group of cells located adjacent to the fault. The drain was assigned an elevation of 936 feet, equal to the estimated bottom of the gravel pit at its deepest point. When hydraulic heads in the drain cells exceed the drain elevation, water flows into the drain and is

removed from the model. When the heads in the drain cells are equal to or less than the drain elevation, no water flows into the drain.

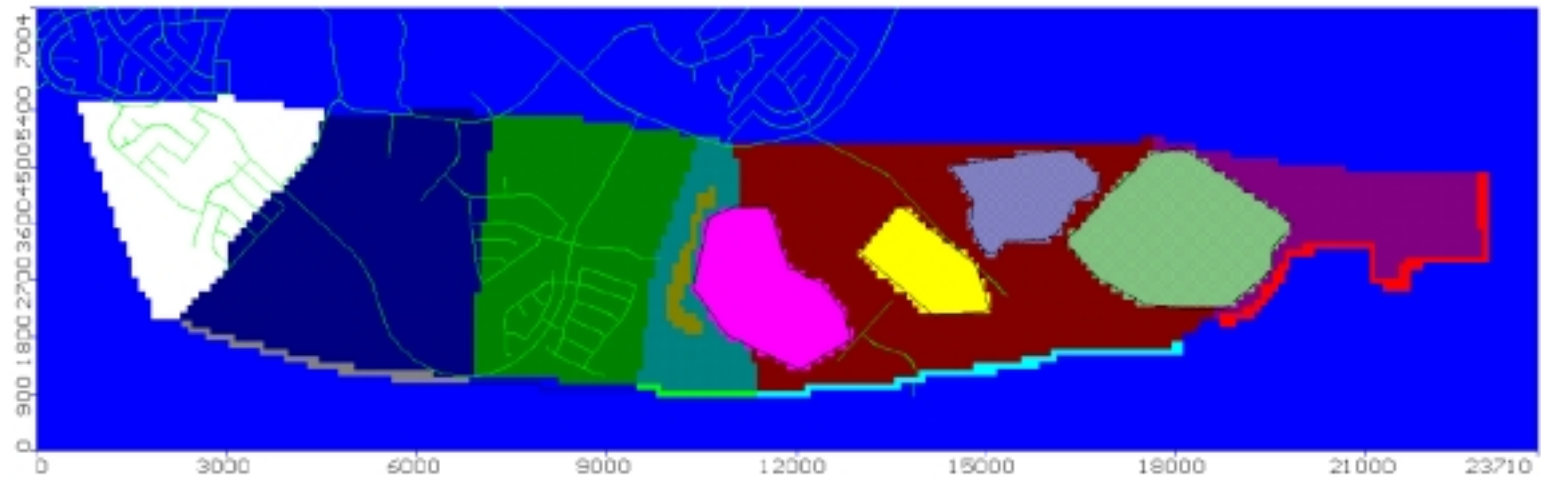
Hydrologic Stresses

Groundwater extraction occurs primarily from municipal wells operated by EVMWD and the City of Corona, as indicated in **Table 3-2** and **Figure 3-6**, and from low capacity private wells. Regional groundwater flow inside the basin is toward the basin center where several EVMWD and City of Corona wells are clustered. Hydraulic heads are typically greater toward the western and eastern ends of the basin and lesser in the central portions of the basin.

Table 3-2
Summary of Wells in Model

Well Identification	Owner	Pumping or Non-Pumping	Model Calibration Water Level Data?
B Well	EVMWD	Non-Pumping	Yes
Corona South	Unknown	Non-Pumping	Yes
Corona #1	City of Corona	Pumping	Yes
Corona #2	City of Corona	Pumping	Yes
Corona #3	City of Corona	Pumping	Yes
Mayhew #2	EVMWD	Pumping	Yes
Division Box Well	EVMWD	Pumping	Yes
Station 71	EVMWD	Pumping	Yes
Station 72	EVMWD	Pumping	Yes
Corona #20	City of Corona	Pumping	No
Corona #21	City of Corona	Pumping	No
Coldwater Aggregates	Coldwater Aggregates	Pumping	No
Mayhew #1	EVMWD	Pumping	No
Station 22	EVMWD	Pumping	No
Station 26	EVMWD	Pumping	No
Warm Springs Well	EVMWD	Pumping	No
33J02	Henry Smith	Pumping	No
33K01	Henry Smith	Pumping	No
33G02	Henry Smith	Pumping	No

Figure 3-5
Recharge (Net) Polygons



LEGEND

- Active Cells
- Inactive Cells
- Streets
- Gravel Pit Boundaries
- Model Coordinates (feet)

Recharge Zone		Recharge Zone	
Color	Recharge Zone	Color	Recharge Zone
	Polygon 1		Anderson Canyon
	Polygon 2		Coldwater Canyon
	Polygon 3		Mar Canyon
	Polygon 4		Terrescal Canyon
	Polygon 5		Gravel Pit #1
	Polygon 6		Gravel Pit #2
	Recharge Basin		Gravel Pit #3
	Bobby Canyon		Gravel Pit #4

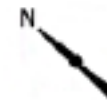
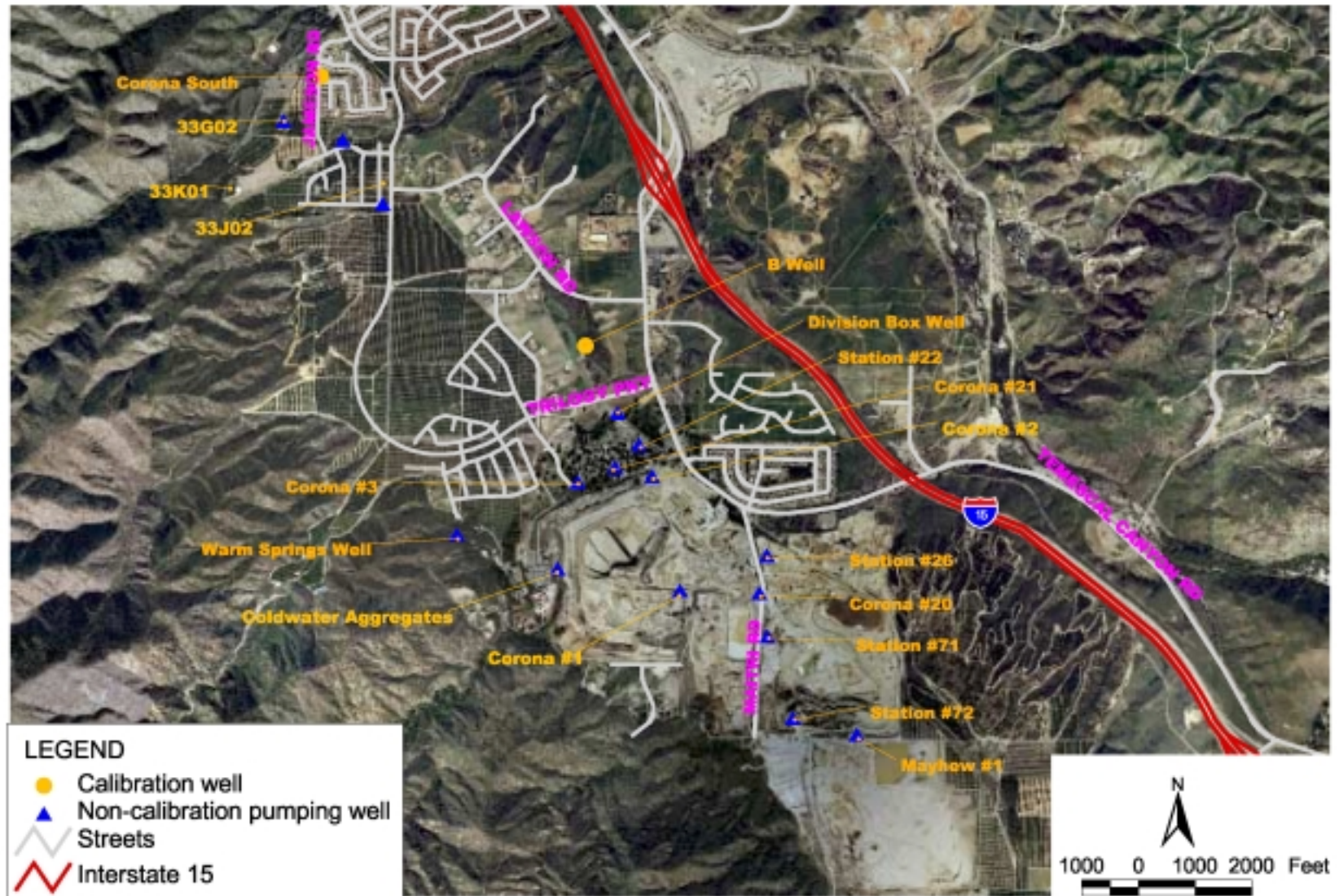


Figure 3-6
Calibration and Pumping Well Location Map



MODEL CALIBRATION

The model described in this section is a transient groundwater flow model because it simulates conditions in the aquifer that change through time. Pumping rates, ET, and net recharge rates are hydrologic stresses that vary temporally in the model over the simulation period.

Within Visual MODFLOW, the user has a choice of five mathematical solvers that can be used to calculate the series of equations developed during solution of the groundwater model flow simulation. For groundwater flow simulations performed during model calibration, the WHS (Waterloo Hydrogeologic Solver) numerical solver was used to calculate simulation results. The WHS is an iterative, bi-conjugate gradient routine that solves the large system of equations using both inner and outer iteration levels. WHS was found to be stable and accurate in its solution of the sets of equations to be solved for the problem posed.

Because of uncertainty in the input data and smoothing effects enacted by numerical grid coarseness, the transient model was considered calibrated if model heads were within approximately 40 feet of the measured static heads for key wells, and if predicted trends in water levels matched the overall observed trends over the calibration period. This criterion is consistent with the uncertainties associated with the historical data available. For example, for early data in particular, it is unknown whether the measured water levels are pumping or static water levels. For purposes of the model, it is assumed that the water levels are static water levels unless otherwise known. In addition, the ground surface elevation in the model at the location of each well was estimated to within 20 feet. Other uncertainties include the fact that natural recharge to the basin is averaged over a 6-month period, returns from gravel pit operations remain constant throughout most of the simulation and the fact that the depth of the gravel pits is assumed to be constant in the model. Given these uncertainties, a 40-foot confidence interval appears reasonable.

Calibration of the model included the following steps:

- Assigning measured heads (October 1977) as initial heads for the 23-year transient simulation
- Assigning values for hydraulic conductivity, specific storage and specific yield
- Input of historical pumping schedules and rates for pumping wells
- Input of observed pumping and static water levels for all observation wells
- Comparing simulated and observed heads at the calibration target wells
- Adjusting hydraulic conductivity, specific yield and drain conductance until a satisfactory fit of calculated to observed head data was attained

Calibration Period

The transient model is calibrated to observed water levels over a 23-year time period, 1977 to 2000. The calibration period is discretized into 46 stress periods of six months duration each. Six-month stress periods are selected because of the relatively long simulation time, data availability, and the climatic six-month wet and dry periods characteristic of this region.

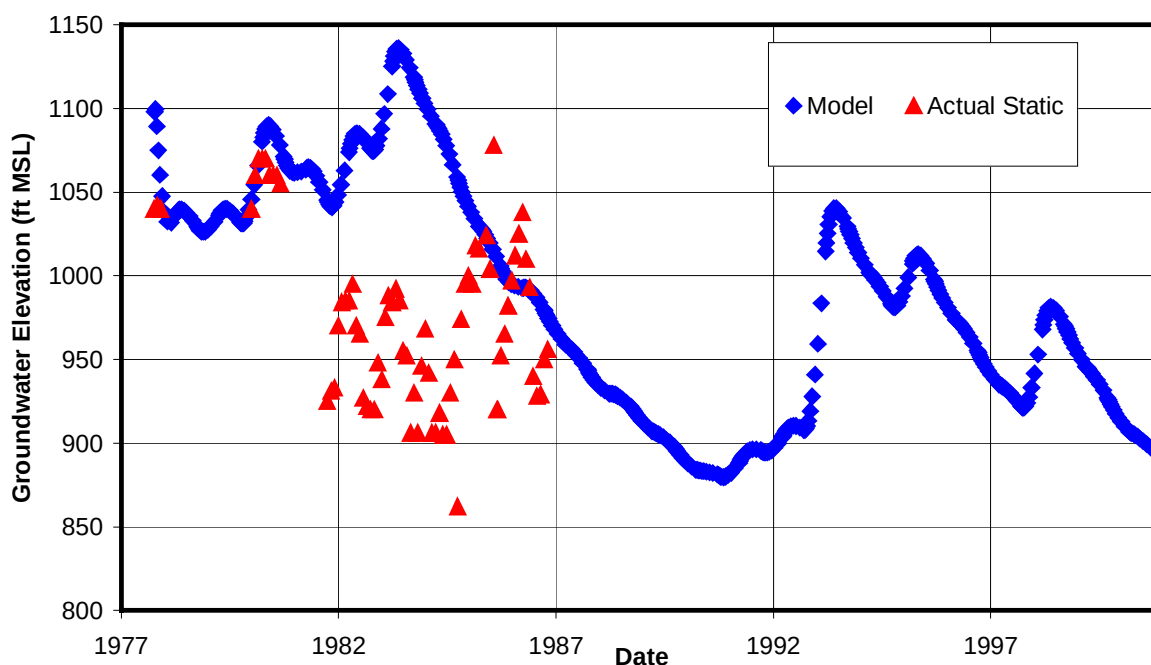
Calibration Wells

Several of the City of Corona and EVMWD municipal wells and private wells, as listed in **Table 3-2**, are used as calibration target wells in the model. Calibration target values consisted of measured water levels under pumping and static conditions. In addition, static water level data collected from the EVMWD B well and Corona South well are used as calibration target values in the model. These wells are not used for groundwater extraction, and therefore, are not included as pumping wells in the model. The locations of wells used for model calibration are shown in **Figure 3-6**.

Results

Figure 3-7 through **Figure 3-14** present flow modeling results for select wells in the basin. The model shows groundwater flow to be predominately directed from the northwest and the southeast toward the center of the basin and the pumping wells, consistent with observed water levels during this time period. A brief summary of calibration results for each well is presented in the following sections. Time series plots are discussed for wells in a sequence from northwest to southeast.

Figure 3-7
Comparison of Model vs. Actual Water Levels
Corona South



Corona South

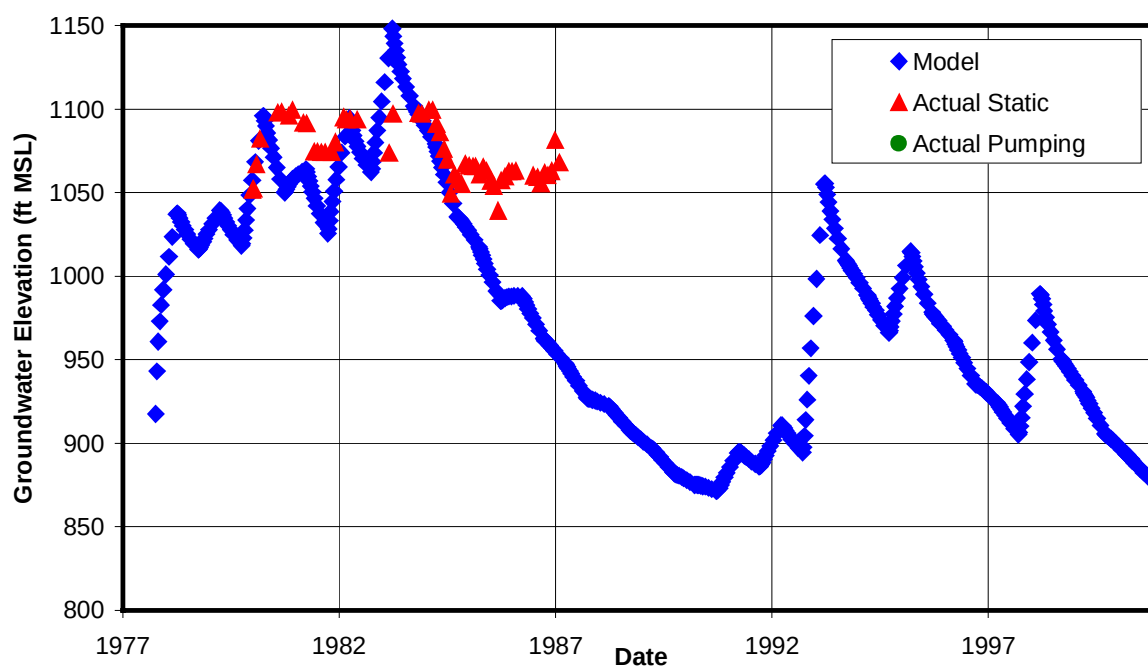
Corona South is a non-pumping calibration target well in the model because pumping data are not available for this well.

Groundwater level data are only available during the first 10 years of the simulation time period, and no trends are discernable in the observed data. It is unknown whether the measured water levels are static levels or pumping levels. For modeling purposes, it is assumed that these water levels are static water levels. Model heads are shown to change as a function of recharge. Trends in the model data do not match well with the observed static water level data, except during the very early portions of the simulation period. Repeated attempts to match actual data at the Corona South well were unsuccessful. It is unclear whether this may be due to unknown geologic heterogeneity or suspect reliability of data.

B Well

The B well is a non-pumping well in the model. Model heads match observed static head values and trends reasonably well for the early portion of the simulation period. There is only limited early time data for this well. Subsequent to 1985, the actual water levels appear to be relatively stable, which could not be matched by the model.

Figure 3-8
Comparison of Model vs. Actual Water Levels
B Well

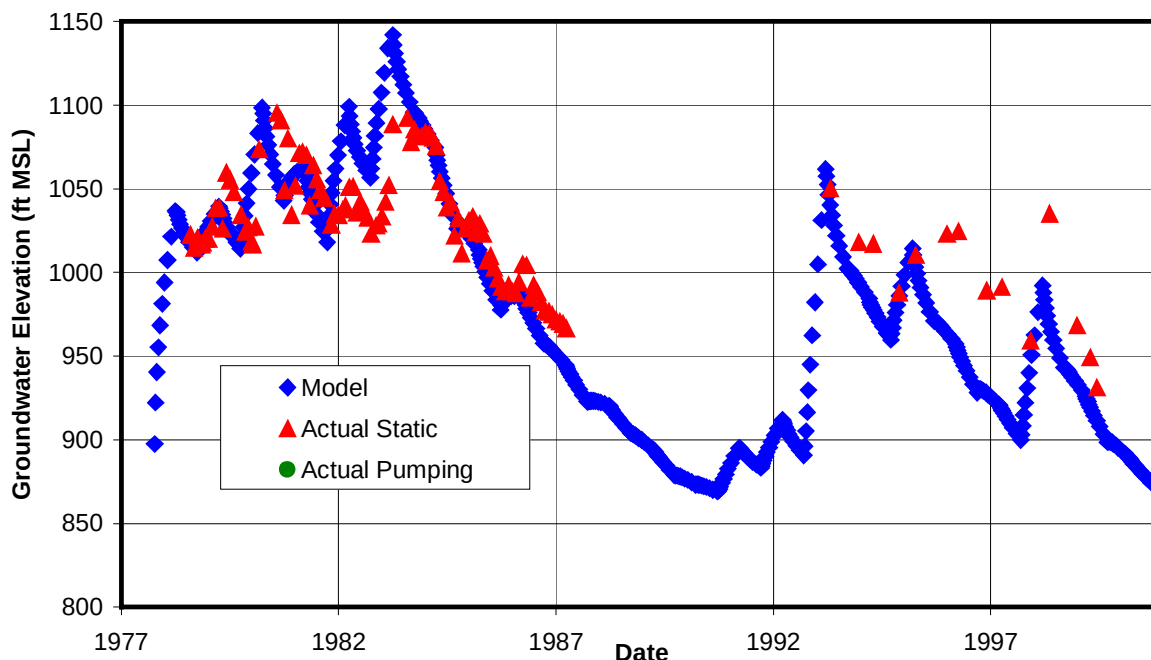


Division Box Well

Model heads at the Division Box well are shown to vary with changes in regional pumping and recharge. No pumping water level data are available for this well. Calculated head levels match observed static head values and trends reasonably well during the first ten years of the simulation period. During later times predicted heads are lower than observed heads. The trend in

declining heads toward the end of the simulation period is matched by the model. The model appears to be reasonably well calibrated at this location.

Figure 3-9
Comparison of Model vs. Actual Water Levels
Division Box Well



Corona #2

Model heads at this location are shown to vary with variation in pumping rate and recharge. Both pumping and static water level data were available for this well, although the former appears to be only available during the years 1989 to 1993 in all three Corona wells. Model heads closely match the values and trends of the observed data, especially in the first 15 years of the simulation period. The dry period from year 1989 to 1993 is matched well by the model. During the last five years, predicted heads are lower than the observed heads. The model appears to be reasonably well calibrated at this location.

Corona #3

Model heads at this location are shown to vary with variation in pumping rate and recharge. Both pumping and static water level data were available for this well. Calculated head values closely match the values and trends of the observed data, especially in the middle of the simulation period. The dry period heads from year 1989 to 1993 are matched well by the model. Early and late in the simulation, model heads are low, but trends are similar. The model appears to be reasonably well calibrated at this location.

Figure 3-10
Comparison of Model vs. Actual Water Levels - Corona #2

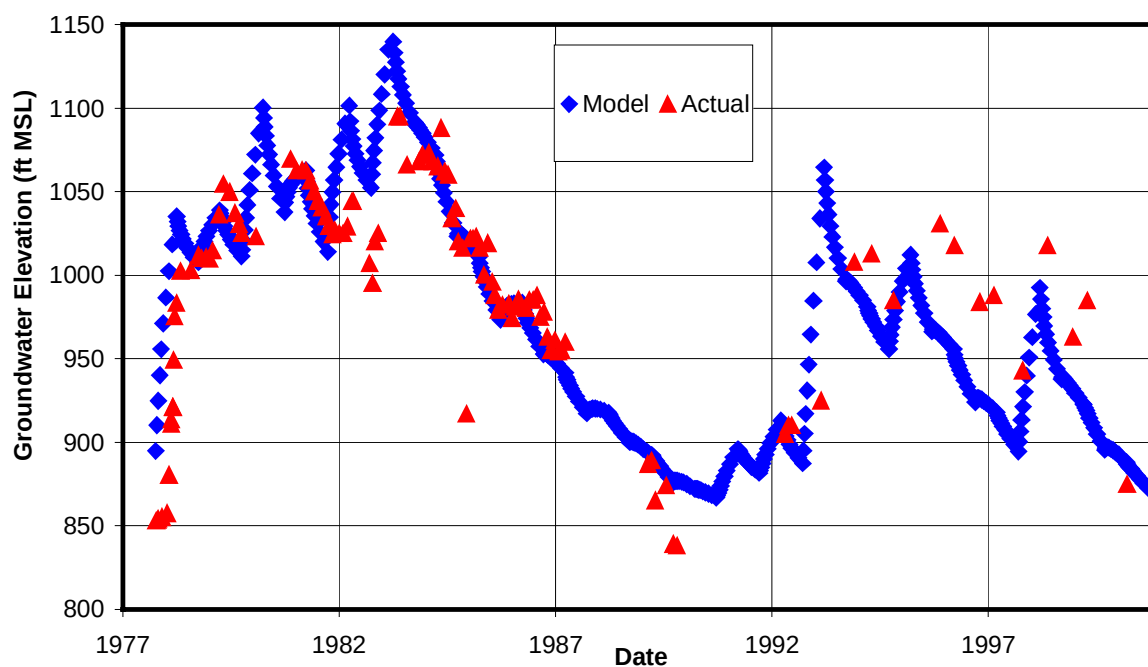
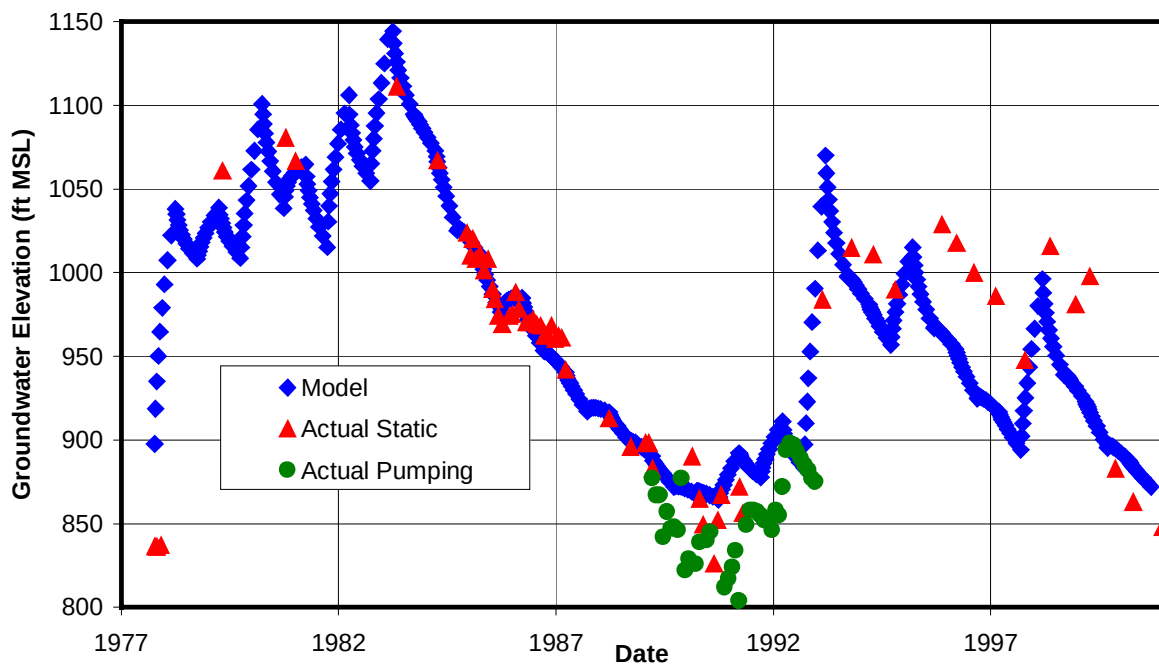


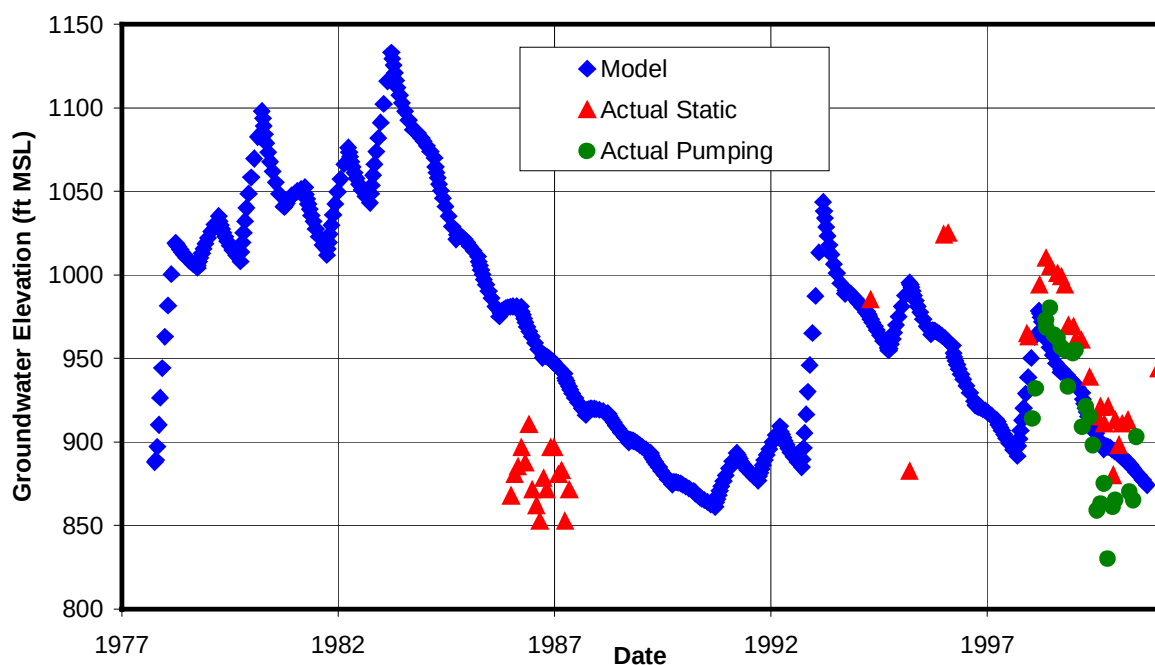
Figure 3-11
Comparison of Model vs. Actual Water Levels - Corona #3



Station 71

Model heads at Station 71 are shown to vary with variation in pumping rate and recharge. Both pumping and static water level data were available for this well. Observed data are available primarily during the later portions of the simulation period. Model heads match the observed trend during the end of the simulation period, but are typically lower than observed heads during this time. The model appears to be reasonably well calibrated at this location.

Figure 3-12
Comparison of Model vs. Actual Water Levels
Station 71



Station 72

Calculated head values at this location closely match the values and trend of the observed data, especially immediately prior to the dry period. No data are available for the dry period heads from year 1988 to 1992. Late in the simulation, model heads are lower than observed heads, but the late time trend is similar to measured values. The model appears to be reasonably well calibrated at this location.

Mayhew #2

Observed data at this well are available only during the later portions of the simulation period. Model heads match the observed pumping heads late in the simulation. The trend is matched reasonably well, but calculated values are typically low compared to observed heads during this time. The model appears to be reasonably well calibrated at this location.

Figure 3-13
Comparison of Model vs. Actual Water Levels - Station 72

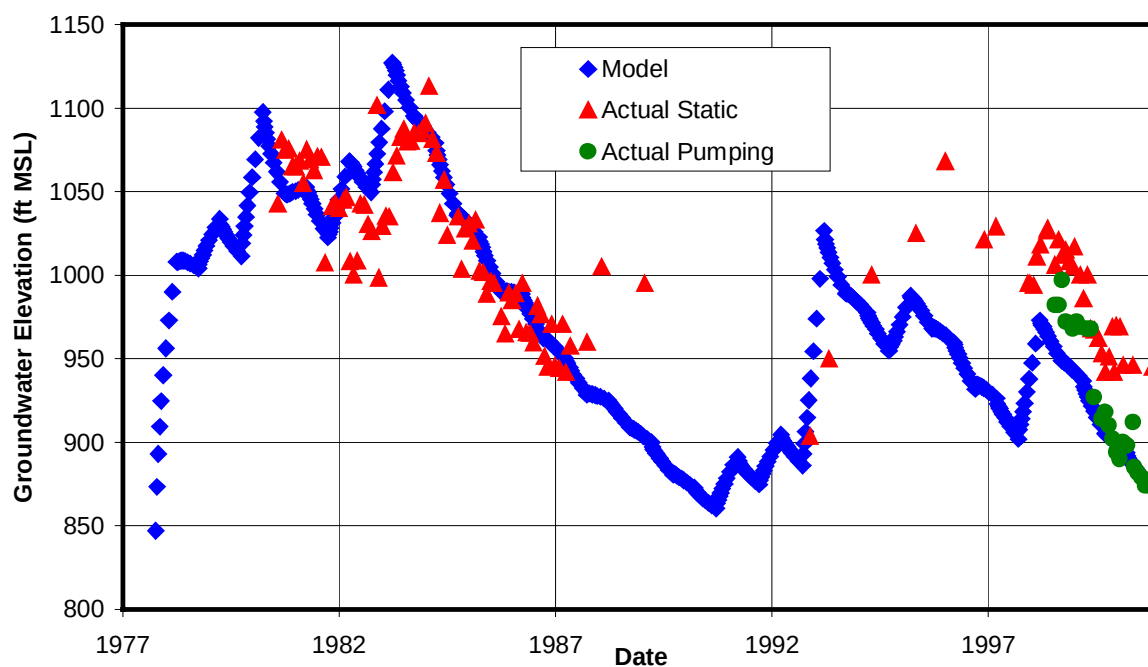
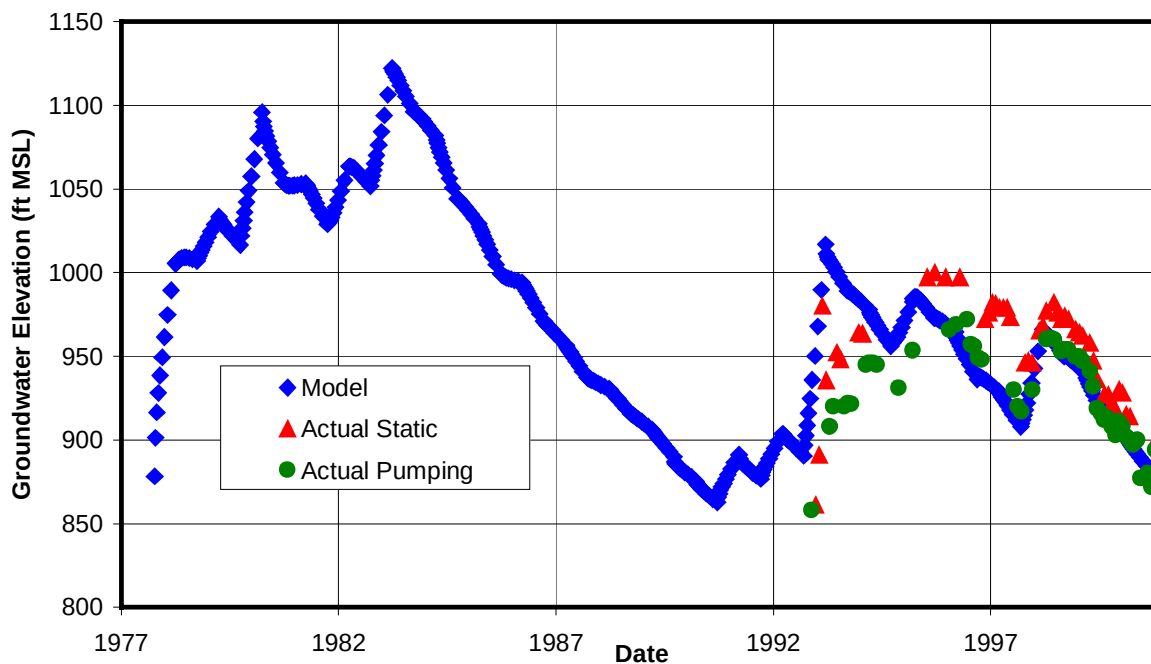


Figure 3-14
Comparison of Model vs. Actual Water Levels - Mayhew #2



Calibration Analysis

Use of pumping heads (as opposed to static heads) for calibration purposes complicates calibration evaluation because of error induced by numerical limitations. In MODFLOW, the extracted volume of groundwater is virtually spread over the entire computational cell, thereby damping the numerical response of the model to changes in pumping rates. For example, measured pumping heads may decrease more quickly than model heads when increasing the extraction rate of a well. Conversely, measured pumping heads may increase faster than model heads when decreasing the extraction rate of a well. During model simulations, extraction rates were varied instantaneously on a semiannual basis. Because of these numerical limitations, calibration plots for the non-pumping calibration target values are usually a better indicator of model calibration.

Model calibration uncertainty with respect to pumping head values is also likely increased due to several physical factors, such as the elapsed time between water level measurement acquisition in a well and time since pumping started, differences in water level measurement methods, and the fact that water levels in a pumping well are not necessarily indicative of the water level in the aquifer.

Where no calibration data are available, such as near the basin margins and the large area between the basin middle and the Corona South well, caution should be exercised when interpreting modeling results. In general, the model performs reasonably well in the central portion of the basin, near the Division Box, Corona #2 and #3 wells, Station 71, Station 72, and Mayhew #2 well. In general, the differences between model and observed heads are less than the 40-foot criterion. However, during the later half of the simulation, the predicted heads are often lower than observed for most of these wells. Possible explanations for this phenomenon could include data uncertainty related to gravel pit size (which changed through time), errors in estimating losses from the model due to gravel washing operations, and errors in ET estimates at the gravel pits. In the model, the depth of the pits remained constant throughout the simulation. This assumption tends to overestimate the evaporative and fault losses in the earlier years of the simulation and underestimate the losses in the later years (particularly if the actual pit depths were substantially greater than 200 feet). Therefore, modeled water levels would tend to be underestimated in the early years and overestimated in the later years. If the actual gravel pit depths were less than 200 feet, then the model would tend to underestimate water levels throughout the simulation. In addition, the returns and losses from gravel washing in the model are assumed to remain constant from 1990 to 2000. If the actual gravel operations differed substantially from the average conditions, the calibration would be dependent upon the difference. However, because the general trend between the actual data and the modeled data are similar, the assumption that the net recharge from the gravel operations remained constant from 1990 to 2000 appears only to smooth out the observed water level changes.

Mass Balance

To verify that the groundwater model predicts a similar water balance as was determined for the conceptual model, a mass balance was calculated and evaluated for the entire flow model domain. The overall mass balance for the calibration period is shown in **Appendix B**. Overall,

the water mass balance calculated by the model matched closely with the water budget presented in Section 2.

Acceptable transient calibration includes a reasonable match between calculated and observed heads, and a mass balance error in the model of less than one percent for each time step. This criterion was satisfied in all instances.

Model Sensitivity Analysis

A sensitivity analysis of the calibrated transient model was conducted to evaluate the effect of possible variations in estimated input parameters on simulation results. The analysis was carried out using four target calibration wells: Mayhew #2, Corona #2, Station 72, and Division Box. The sensitivity analysis was implemented by conducting several unique simulations, wherein input was identical to that in the calibrated model, except for that a single input parameter was changed in each simulation. Thus, the independent effect of varying each input parameter was evaluated. Results of the sensitivity analyses, presented in head versus time plots, are included in **Appendix B**. The remainder of this section provides a brief summary of the results included in Appendix B.

Hydraulic Conductivity

A comparison of changes in water level in Corona #2 as a result of variations in hydraulic conductivity is presented in **Figure 3-15**. Model runs were calculated with hydraulic conductivity ranging from 50 percent to 200 percent of the calibrated value. The resultant water levels varied as much as 33 feet, which occurred in the wet years. During the non-wet periods, varying the hydraulic conductivity appeared to have a lesser effect.

Losses Across Fault

A comparison of changes in water level in Corona #2 as a result of variations in drain conductance across the North Glen Ivy fault is presented in **Figure 3-16**. Model runs were performed with the drain conductance ranging from 10 percent to 200 percent of the calibrated value. The resultant water levels varied as much as 47 feet. The difference in water levels as a result of differences in drain conductance generally increased with time with larger differences observed during the drier periods when water levels were lower. The magnitude of the drain conductance component of the groundwater model, therefore, appears to moderately affect the water level response.

Figure 3-15
Sensitivity of Results to Hydraulic Conductivity - Corona #2

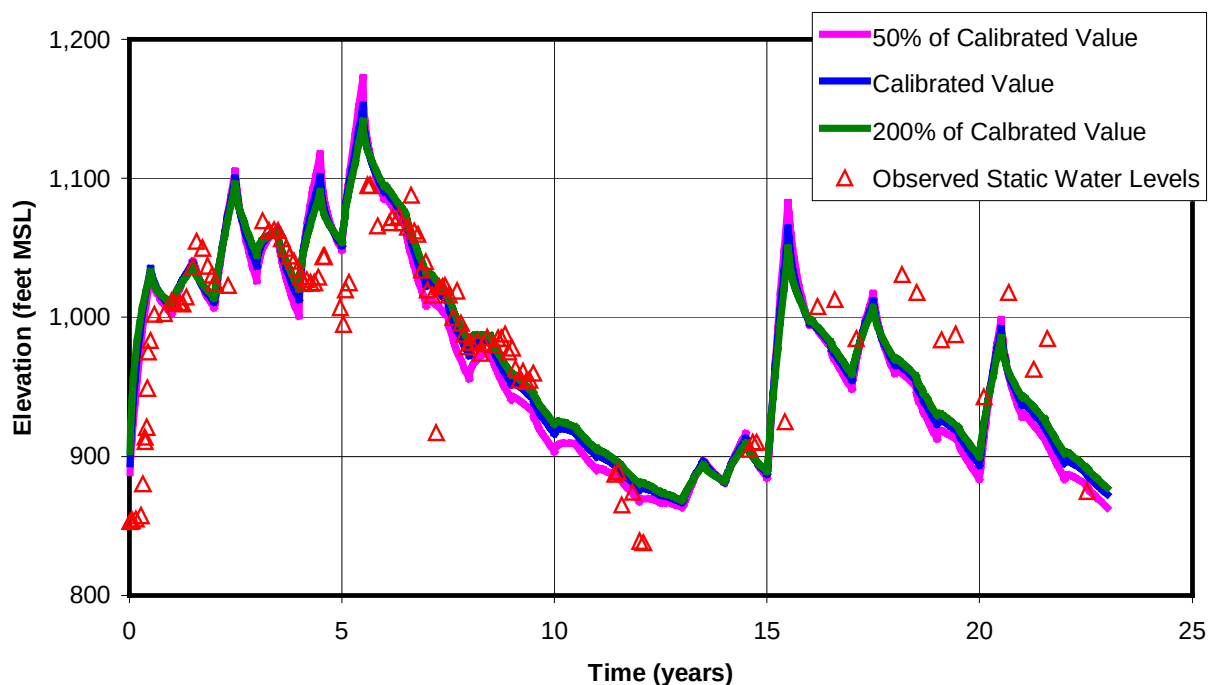
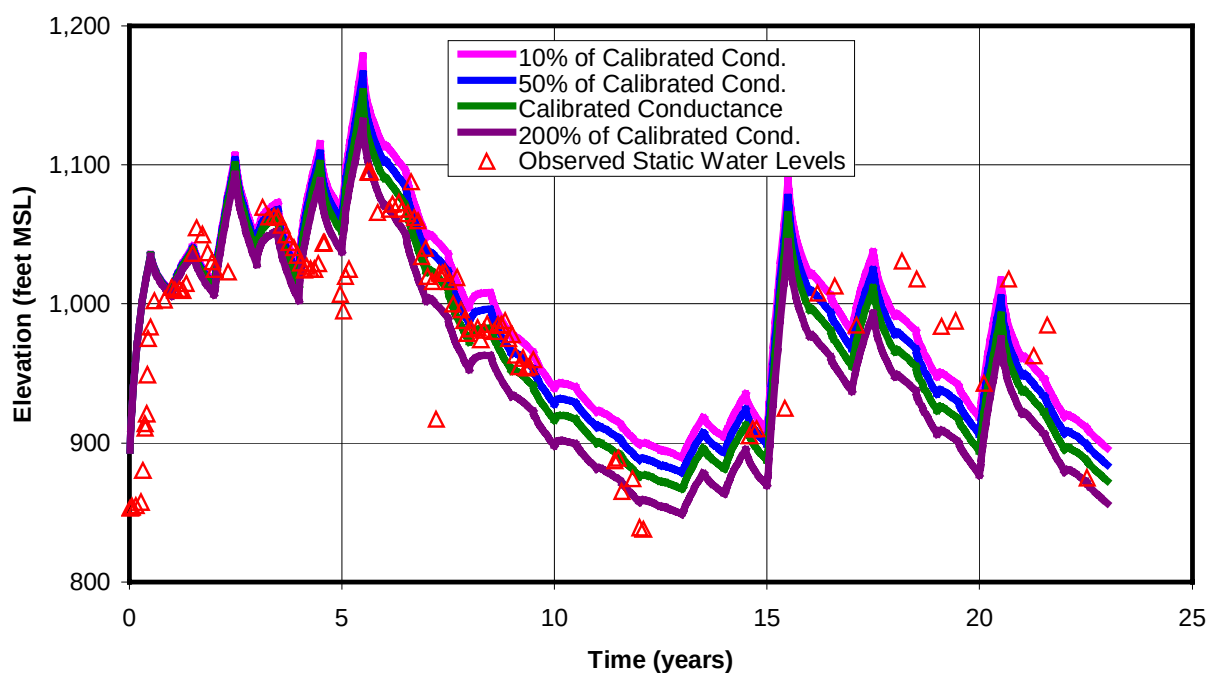


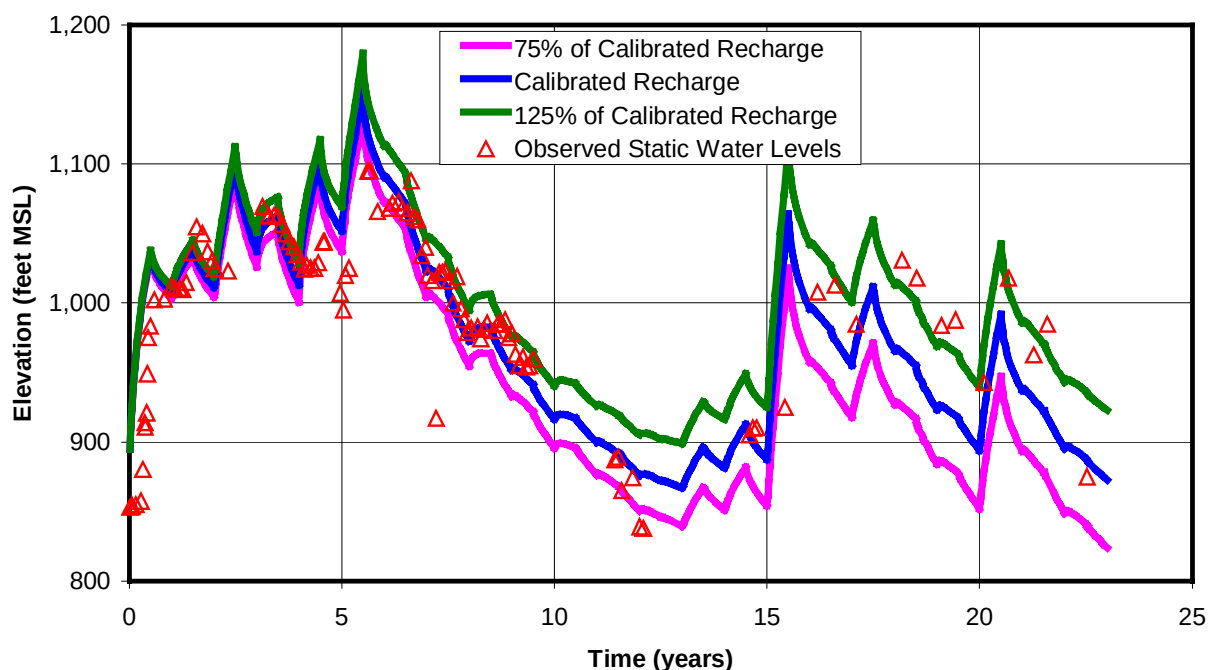
Figure 3-16
Sensitivity of Results to Loss Across North Glen Ivy Fault - Corona #2



Natural Recharge

A comparison of changes in water level as a result of variations in recharge is presented in **Figure 3-17**. Model runs were performed with the recharge ranging from 75 percent to 125 percent of the calibrated value. Over this relatively small range compared with the components described previously, water levels varied nearly 100 feet. Like with drain conductance, the difference increased with time. Because the relatively large groundwater response with minor changes in natural recharge into the model, the model results are highly sensitive to changes in natural recharge. This conclusion is not surprising given that the largest inflow to the basin is infiltration of natural recharge.

Figure 3-17
Sensitivity of Results to Natural Recharge - Corona #2



Specific Yield

A comparison of changes in water level in Corona #2 as a result of variations in specific yield is presented in **Figure 3-18**. Model runs were performed with the specific yield ranging from 6 percent to 18 percent. As shown in this figure, minor changes in specific yield (on the order of 1 to 2 percent) result changes in water level as much as 40 feet. Larger variations appear to occur during the dry periods when water levels are lower. However, during wet periods, specific yield appears to have a lesser effect. Therefore, the model appears to be moderately sensitive to specific yield.

Figure 3-18
Sensitivity of Results to Specific Yield – Corona #2

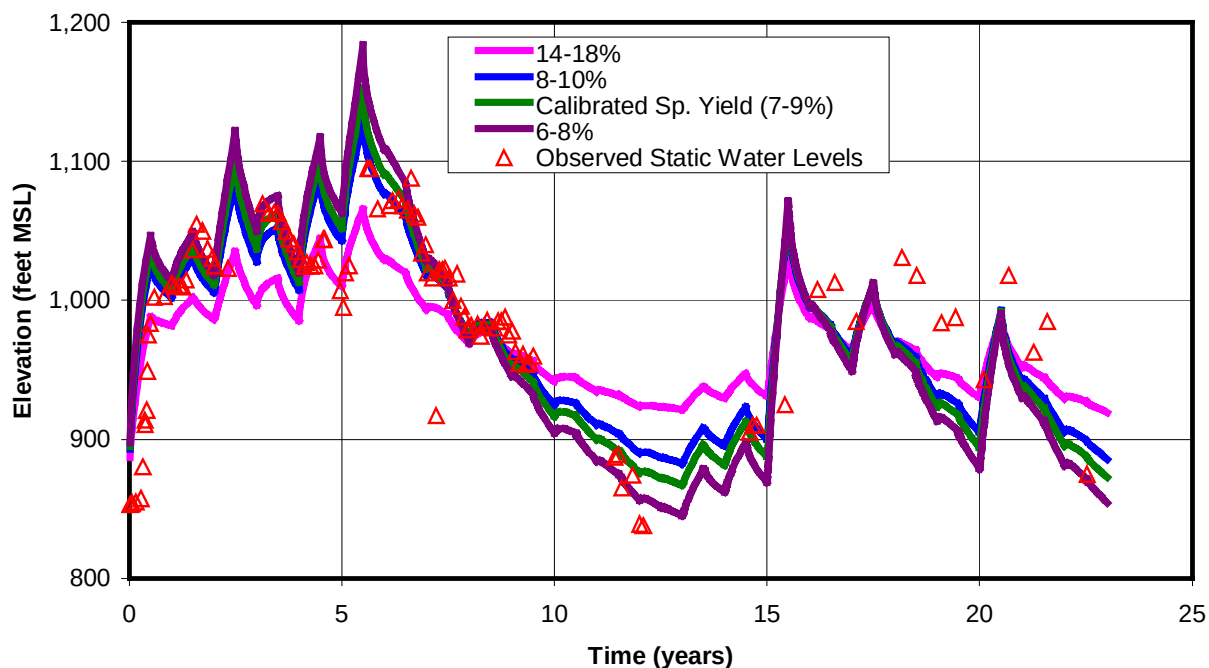


Table 3-3 provides a summary of the sensitivity analysis of the groundwater model for the Coldwater Basin. Based upon the analysis presented herein, the model is very sensitive to net recharge. Recharge input is “averaged” both temporally and spatially over a six-month period. The six-month stress periods attenuate peaks and valleys in net recharge (and pumping rates). Spatial averaging occurs by the use of rainfall and runoff on a subregional basis. The overall effect is that net recharge input is “smoothed.” Therefore, peaks in data may not be captured, but the overall trend is reflected in model results. Future data input that includes recharge and pumping rates specified on a more refined temporal and spatial basis would likely result in improved model calibration.

The model is moderately sensitive to changes in drain conductance and specific yield. Considering the large effect caused by the net recharge and pumping, these parameters did not significantly affect the overall trend in the calibration, but rather were used to fine tune the initial results.

The model appears to be only minimally affected by changes in hydraulic conductivity. This observation is not unrealistic considering that most of the basin is has a relatively high hydraulic conductivity. This parameter was used to achieve better calibration in local areas.

Table 3-3
Summary of Sensitivity Analysis

Parameter	Sensitivity
Hydraulic Conductivity	Low
Drain Conductance	Moderate
Natural Recharge	High
Specific Yield	Moderate

MODEL LIMITATIONS

Computer models are limited by the availability and accuracy of site physical data. Limitations of the model include the following:

- The model strives to simulate discontinuous water-bearing hydrostratigraphic units with varying aquifer characteristics. It is impractical for the model to capture all hydrogeologic variations in the alluvium. Limited basin data available at the time of model development does not allow for incorporation of all such aquifer heterogeneities.
- With a few exceptions, aquifer pumping test data (for determination of alluvial aquifer hydraulic properties) were unavailable. Model hydraulic conductivity values were estimated using well specific capacity data. Aquifer specific yield was estimated, then adjusted in the model during calibration.
- The model is discretized temporally into six-month stress periods. As a result, large, short-term variations in pumping rates or significant recharge events are masked over a six-month average, and thereby affect the model calibration results.
- The geometry of the gravel pits was assumed to remain constant through the entire simulation. Because limited historical gravel pit geometry data are available a constant depth was used in the model. This assumption would most affect calibration results for wells nearest the pits.

Although the groundwater flow model has inherent limitations, it can be effectively used to predict trends in aquifer reaction to pumping stresses. Site data is limited; however, data was sufficient in number and accuracy to calibrate the model for use as a predictive tool of water level trends in the aquifer. Among other uses, the model can be expected to be a good predictive tool to evaluate trends for proposed groundwater recharge scenarios. The model is most useful in the southeastern half of the basin with a confidence interval of about 30 feet. However, it

should not be used to evaluate site-specific water level variations or be used to evaluate absolute water levels.

The model can be used effectively to evaluate different groundwater recharge scenarios in fulfillment of development of alternatives. The groundwater model presented herein is a good predictive tool for analysis of aquifer response to induced stresses in the groundwater basin and proposed groundwater use scenarios.

Section 4

Project Alternatives

The following section describes the development and evaluation of project alternatives for groundwater storage in the Coldwater Basin. Topics include an inventory of potential recharge sites, a description of the alternative development process, and evaluation of the project alternatives.

INVENTORY OF POTENTIAL RECHARGE SITES

Potential options for groundwater recharge in the Coldwater Basin include:

- Recharge basins
- Dual purpose wells
- Gravel pits

Each of these options is discussed below.

Recharge Basins

Recharge basins require large amounts of land, but are often the most cost-effective method for groundwater recharge particularly in areas consisting of sand and gravel such as the Coldwater Basin. Based upon field reconnaissance performed by MWH staff during December 2002, there is limited available vacant land in the Coldwater Basin for surface recharge basins. As discussed in Section 2, the northwestern portion of the basin is characterized by finer sands and silts, which are not suitable for surface recharge. Therefore, the canyon areas or the southeastern portion of the basin (which is currently used for the gravel mining operations) are the only potential sites for surface recharge. As discussed previously, the gravel pits occupy approximately 745 acres (nearly 50 percent) of the Coldwater Basin. Because of recent urban development, the canyons (particularly Anderson and Bixby Canyons) another 776 acres are no longer vacant and would not be available for recharge ponds. Therefore, because of the large area needed for recharge ponds, surface recharge appears to be limited to the existing Coldwater Canyon recharge basins as described below.

Surface runoff from Coldwater Canyon is currently diverted to the City of Corona's recharge ponds. The existing ponds could potentially be used to store additional imported water supplies in the Coldwater Basin. One disadvantage of recharge basins is clogging caused by silts, clay and organic material. In many cases, groundwater recharge rates decline with time. Loss in infiltration capacity can be limited by routine maintenance of the ponds.

Table 4-1 presents the recharge potential in the Coldwater Canyon recharge basins assuming an infiltration rate of approximately 2 feet per day. This recharge rate is consistent with percolation tests performed in the nearby pits as described in **Section 2**. An annual average of about 1,500

acre-ft currently infiltrates through the Coldwater Canyon recharge basins. An additional 5,800 acre-ft/yr could be infiltrated with imported water.

Table 4-1
Summary of Recharge Potential – Coldwater Recharge Ponds

Component	Units	Parameter
Acres of Ponds	acres	15
Infiltration Capacity	ft/day	2
Annual Capacity of Recharge Ponds ¹	acre-ft/yr	7,300
Existing Annual Runoff	acre-ft/yr	1,500
Average Additional Capacity	acre-ft/yr	5,800

Note: ¹ Capacity of recharge ponds assumes that only 2/3 of the available ponds are in operation at one time.

Dual Purpose Wells

Because of limited surface area available for recharge ponds, dual purpose wells (wells that are equipped for both injection and extraction) are an option for groundwater recharge in the Coldwater Basin. Because water is directly injected into the aquifer, this method bypasses the unsaturated zone and any intervening low permeability layers and eliminates evaporation losses. However, injection wells usually have higher capital costs than recharge basins considering well construction and treatment costs. In addition, the injected water would need to meet DHS and RWQCB monitoring guidelines, which could add substantial cost.

A summary of the recharge potential from dual-purpose wells is provided in **Table 4-2**. Two new dual-purpose wells could be constructed in the Coldwater Basin. Assuming an injection capacity of approximately 1,000 gpm and an extraction capacity of approximately 1,500 gpm for each well, the recharge potential would be about 1,600 acre-ft/yr (assuming that recharge would only occur during the winter months from October through March). The capacities of these wells are based upon the capacity of the District's existing wells.

Three of EVMWD's wells (Division Box, Station 22, and Station 26) could also be converted to dual purpose wells. These wells would increase the injection capacity of the basin by about 800 acre-ft/yr assuming that recharge would only occur in the winter months. Because these wells are shallow, they are not currently in frequent use. Therefore, their use as dual-purpose wells would increase their use. Other wells, such as the City of Corona's well could also be converted to dual purpose if necessary.

Table 4-2
Summary of Recharge Potential – Dual Purpose Wells

Component	Units	Parameter
New Wells		
Number of Wells	#	2
Injection Capacity	gpm	2,000
Extraction Capacity	gpm	3,000
Additional Recharge Capacity ¹	acre-ft/yr	1,600
Additional Extraction Capacity	acre-ft/yr	4,800
Conversion of Existing Wells		
Number of Wells	#	3
Injection Capacity	gpm	1,000
Extraction Capacity	gpm	1,500
Additional Recharge Capacity ¹	acre-ft/yr	800
Additional Extraction Capacity	acre-ft/yr	0

Note: ¹ Recharge is projected to only occur in winter months (October-March).

Gravel Pits

Infiltration of imported water in the gravel pits is also a valid approach for groundwater recharge in the Coldwater Basin. Gravel pits provide large areas for recharge along the bottom and sides of the pits. However, large water depths can cause compaction of the soils on the pit bottom and can lead to lower infiltration rates with time. In addition, siltation can occur with time, also limiting the infiltration capacity. The locations of the gravel pits are shown in **Figure 4-1**.

Surface runoff from Mayhew Canyon is currently diverted into the gravel pits downstream of Mayhew Canyon and from Coldwater Canyon into the City of Corona's recharge ponds. Additional imported water could be recharged in the gravel pits. In theory, the storage potential of the pits is the total volume of the pits (more than 80,000 acre-ft). However, because the Sunwest pit lies across the North Glen Ivy fault, a significant portion of the water that could be stored in the gravel pits would be lost across the fault. Therefore, the feasible storage is substantially less than the volume of all the pits. To prevent water from leaving the basin across the North Glen Ivy fault, only the northwesternmost pit (the Chandler pit) is proposed for potential recharge. To avoid groundwater levels from going up the ground surface adjacent to the Chandler pit, the maximum recharge capacity of the gravel pit is approximately 9,000 acre-ft in a 6-month period.

Figure 4-1
Location of Gravel Pits in the Coldwater Basin



Table 4-3
Summary of Recharge Potential – Gravel Pits

Component	Units	Parameter
Number of Wells	#	2
Extraction Capacity	gpm	3,000
Additional Recharge Capacity in Pits ¹	acre-ft/yr	9,000
Additional Extraction Capacity	acre-ft/yr	4,800

Note: ¹ Recharge is projected to only occur in winter months (October-March).

To extract the water, two new wells would need to be constructed. Assuming an extraction capacity of 1,500 gpm, the additional extraction capacity would be about 4,800 acre-ft/yr

ALTERNATIVES DEVELOPMENT

The following section describes the alternative development process for this project. In developing the alternatives, the following issues were considered.

- Target Groundwater Storage Level
What level should the basin be?
- Operation
How will existing wells and proposed wells be operated?
- Recharge facilities
How much recharge could be done?
- Gravel pits
How will the project impact the gravel pits?

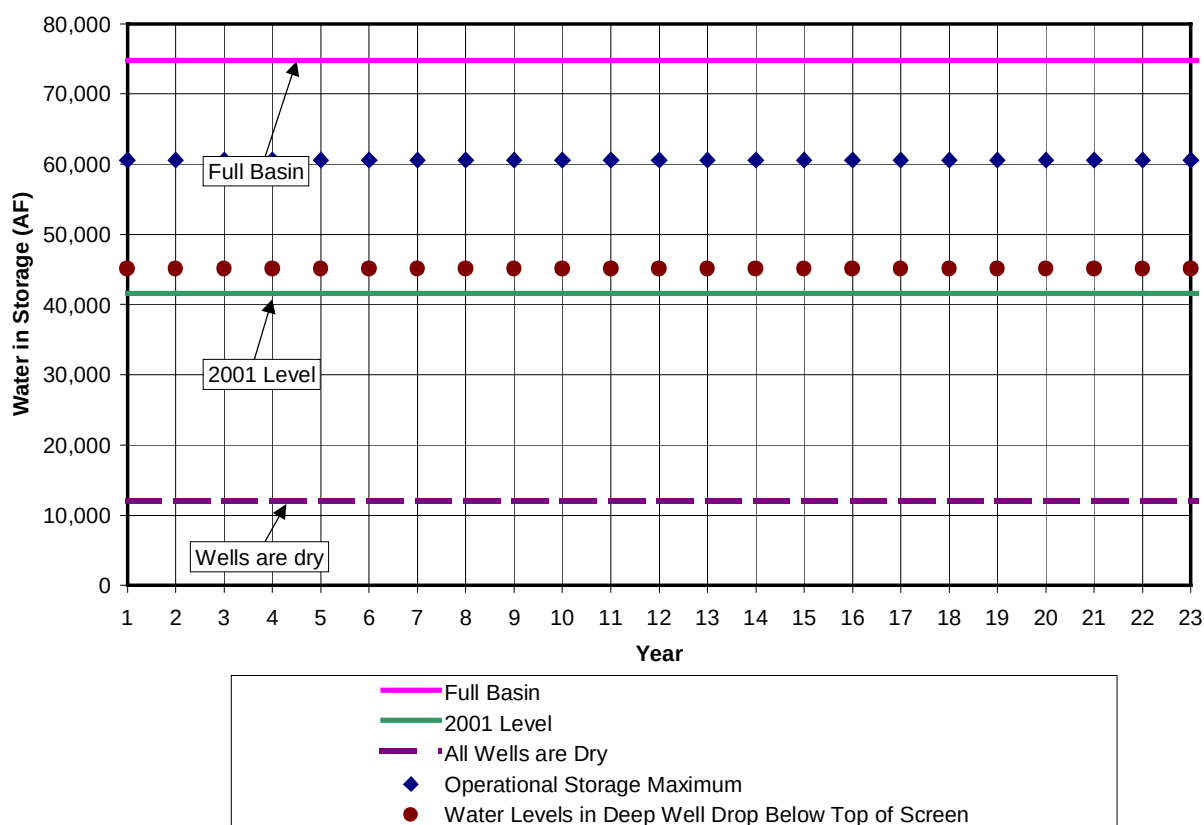
Based upon the historical water balance presented in Section 2, the Coldwater Basin, when full, contains approximately 74,800 acre-ft of groundwater in storage. When all existing wells are dry, the basin contains approximately 12,000 acre-ft of groundwater in storage. The water in storage at the end of water year 2000 was approximately 41,600 acre-ft. These levels are shown in **Figure 4-2**. To allow for a repeat of the 1997-98 wet season, the operational storage should not exceed 60,600 acre-ft (approximately 80 percent full). When the storage exceeds this operational storage maximum, recharge of imported water would be stopped.

Both existing and proposed wells would be operated based upon the amount of water in storage. As water levels drop below the tops of the screens in existing wells, the extraction capacity decreases. When water levels are higher, wells can pump more. Each alternative, as described later in this section, includes this type of operation.

The amount of recharge possible is dependent upon the capacity of facilities, the water source, and the amount of storage space available in the basin. As described previously, the potential facilities include: dual purpose wells, recharge basins and use of the gravel pits. Because dual purpose wells and recharge basins both require additional extraction wells to extract the stored

water, these two components are grouped together. The use of the gravel pits as recharge basins would require coordination with the gravel pit owners and is considered separately.

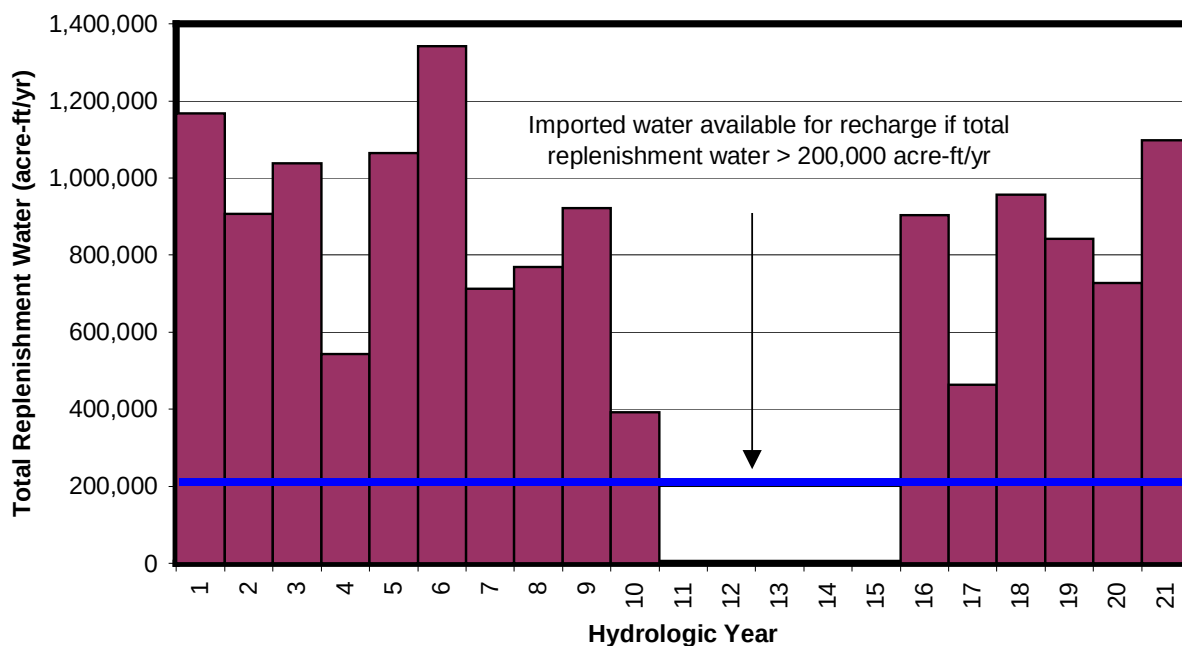
Figure 4-2
Summary of Target Storage Levels in the Coldwater Basin



For purposes of this analysis, the water source is assumed to be imported water from the Temescal Valley Pipeline (TVP). Other water sources such as recycled water from the District wastewater treatment facilities (e.g. Regional WWTP) could also be used for recharge in the basin provided the project is acceptable to the Santa Ana Regional Water Quality Control Board and the California Department of Health Services (DHS). However, the delivery points would be similar and would not affect the volume of recharge that could be performed in the basin. Additional requirements and separation distances would apply if other sources such as recycled water were used. In addition, the water availability is based upon the availability of surplus water from MWDSC as shown in **Figure 4-3**. Imported water would only be available for recharge during the winter months between October and March.

Because increased recharge would likely impact the gravel mining operations in the basin, conceptual recharge operations were designed to minimize the impact to gravel operations. A detailed description of each alternative is described in the following section.

Figure 4-3
Projected Imported Water Availability



DESCRIPTION OF ALTERNATIVES

This report includes two project alternatives and the Baseline condition. The alternatives are defined as:

- Baseline - Continuation of current operation
- Alternative 1 - Storage with dual purpose wells and surface spreading
- Alternative 2 - Storage with gravel pits

The components of each alternative are summarized in **Table 4-4**, and described in the remainder of this subsection.

Baseline

The baseline alternative simulates the continuation of current basin operation. It includes the following assumptions:

- Repeat of 1977-2000 hydrology with future urban development
- Maintain 2003 conditions for gravel pits (250' depth to bottom of pit)
- Groundwater production varies with groundwater in storage to account for loss in production as water levels drop below the tops of the well screens.

The remainder of this section includes a description of the baseline hydrology, amount of groundwater pumping and imported water recharge included in this alternative.

**Table 4-4
Summary of Alternatives**

Component	Baseline	Alternative 1	Alternative 2
Maintain existing conditions with future development	▲		
Convert 3 existing wells to dual purpose		▲	
Construct 2 new dual purpose wells		▲	▲
Deliver imported water to Coldwater recharge ponds		▲	
Deliver imported water to gravel pits			▲

Baseline Hydrology

As described in Section 2, the base period for this study is October 1977 to September 2000. The 776-acre Trilogy at Glen Ivy development and golf course was recently completed. Therefore, future hydrology and water budget estimates include the effects of this development on basin inflows. The components of the Trilogy development are based upon data provided in Ground Water Systems (1992). For purposes of this analysis, no other developments are projected to be constructed during the time period of the baseline. A comparison of the projected and historical water budgets is provided in **Table 4-5**.

The Trilogy development includes approximately 306 acres overlying the groundwater basin (remaining portion of development is within watershed portion not directly overlying the groundwater basin), which resulted in the conversion of agricultural land use to urban land use. Based upon the infiltration estimates by land use type developed in Section 2, the amount of precipitation and applied water that would infiltrate into the basin is projected to be about 1,400 acre-ft/yr with the Trilogy development, about 300 acre-ft/yr lower than the actual historical average.

Flood control facilities constructed as part of the Trilogy development are projected to divert nearly all the runoff from Anderson and Bixby Canyons out of the Coldwater Basin.

Table 4-5
Comparison of Historical and Projected Water Budget

Component	Historical Average 1977-2000 (acre-ft/yr)	Projected Average (acre-ft/yr)
Inflows		
Precipitation and Applied Water	1,700	1,400
Surface Diversions	2,200	2,200
Returns from Gravel Washing	1,000	1,300
Subsurface Inflow	1,800	1,400
Total Average Inflow	6,700	6,300
Outflows		
Groundwater Pumpage	6,100	5,300
Evaporation	200	0
Losses from Gravel Operations	700	900
Subsurface Outflow	200	0
Total Average Outflow	7,200	6,200
Net Surplus or Deficit	-500	100

Approximately 12 acres of debris basins have been constructed in Anderson and Bixby Canyons. These structures are projected to capture and infiltrate an average of approximately 152 acre-ft/yr of runoff (Ground Water Systems, 1992). Therefore, the average subsurface inflows are projected to be about 1,400 acre-ft/yr, about 400 acre-ft/yr lower than the actual estimated inflows from 1977 to 2000.

Because the current gravel pits are projected to remain in operation at their current rates, the return flows from gravel washing and losses in gravel transport are projected to remain at 2000 levels. Therefore, the projected 23-year average returns and losses are higher than the historical average. The net inflows to the groundwater basin due to gravel pit operation remain approximately the same.

As shown in Table 4-5, the average annual inflow to the basin is projected to decrease from the historical average of about 6,700 acre-ft/yr to 6,300 acre-ft/yr as a result of the current development in the basin.

Projected outflows across the faults and evaporation from the pits are largely controlled by the groundwater pumping. The projected groundwater pumping estimates are discussed in the following section.

Groundwater Pumping

Figure 4-4 shows the pumping capacity versus basin storage under baseline conditions. With the existing wells in the basin, the well capacity when the basin is full is nearly 14,600 acre-ft/yr and decreases as water levels drop. As discussed previously, all existing wells in the basin are dry when storage in the basin is below 12,000 acre-ft. The shape of the curve is dictated by the depth of perforations and capacities of existing wells. Production is assumed to decrease as the water levels drop below the tops of the screens in each well.

Figure 4-4
Pumping Capacity versus Basin Storage - Baseline

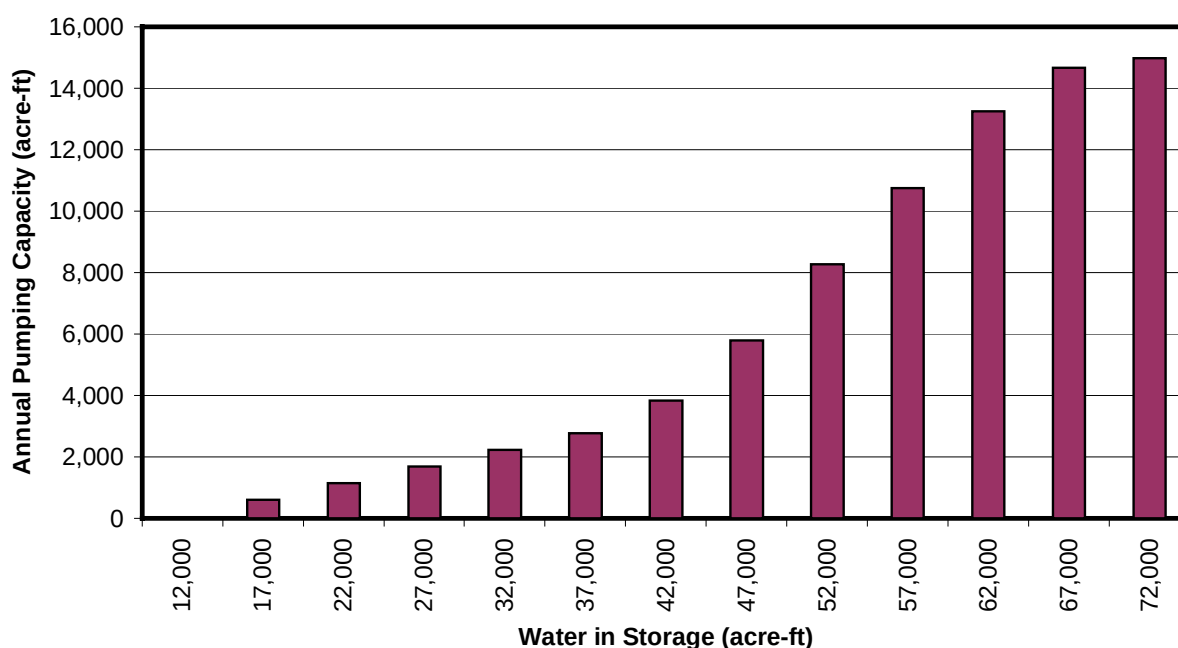
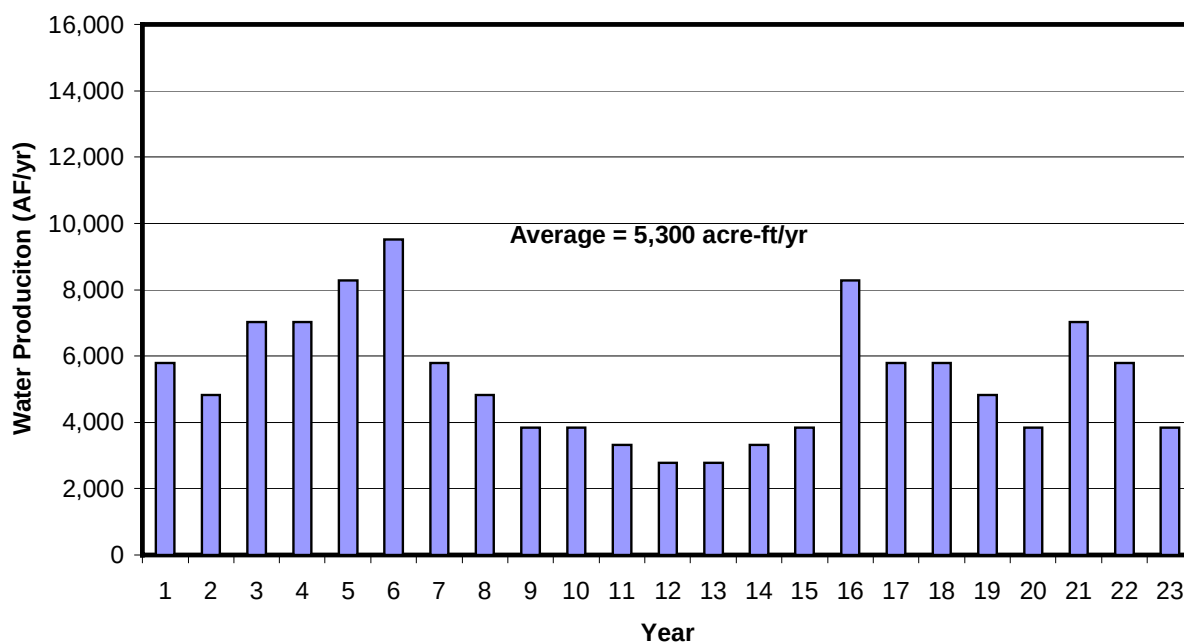


Figure 4-5 shows the projected annual pumping with baseline conditions. Projected pumping ranges from about 2,500 acre-ft/yr in dry years to about 9,500 acre-ft/yr in wet years with an average of about 5,300 acre-ft/yr. As shown in Table 4-5, the groundwater pumping is projected to be less in the future than the actual pumping was during the period from 1977 to 2000. This reduction is, in part, due to the lower projected inflows under future conditions. Note, however, that the evaporative losses and losses across the North Glen Ivy fault are lower, which is a function of the controlled pumping.

As demand increases during summer months, the ability of the basin to yield additional supplies is critical. For purposes of this analysis, a dry period is defined a 6-month period in which the precipitation was less than 40 percent of the average. The average dry period yield (defined as the average pumping during a 6-month dry period) under baseline is approximately 2,100 acre-ft per 6-month period with a range of 1,400 acre-ft to 2,900 acre-ft.

Figure 4-5
Projected Pumping - Baseline



Alternative 1 – Dual Purpose Wells and Spreading Basins

Alternative 1 simulates groundwater storage using dual-purpose wells and spreading basins. Alternative 1 includes the following components:

- Repeat of 1977-2000 hydrology with future development as described in Baseline
- Five dual purpose wells (3 existing + 2 new wells)
- Surface spreading in Coldwater Canyon
- Injection-spreading only occurs in winter months (October through March) when surplus water is available from MWDSC
- Injection-spreading only occurs if groundwater in storage is less than ~80 percent of basin storage
- Groundwater production varies with groundwater in storage - no pumping occurs when injection and/or spreading occurs.

The remainder of this section includes a description of the facilities required and the amount of groundwater pumping and recharge included in this alternative.

Facilities Required

Alternative 1 facilities could convey water from the TVP to the spreading grounds, and the two new wells. The locations of the facilities required for Alternative 1 are shown in **Figure 4-6**. The pipeline could use the existing TVP connection at Matri Road. Preliminary estimates show that no additional pump stations would be necessary. The pipe sizes and lengths are summarized

in **Table 4-6**. The pipeline to the spreading grounds is based on an alignment along Glen Ivy Road to the highest level of the spreading grounds. The pipeline between Temescal Canyon Road and Trilogy Road is aligned along an existing dirt road shown in aerial photographs.

Table 4-6
Alternative 1 Pipe Diameters and Length

Location	Pipe Length (feet)	Diameter (inches)
Temescal Canyon Road	2,020	24
Glen Ivy Road	3,410	18
Temescal Canyon Road to Trilogy Pkwy	1,460	16
Trilogy Pkwy to New Well 1	440	10
Trilogy Pkwy to New Well 2	880	10
To Station 22	280	8
To Station 26	1,080	8
To Division Box	1,110	18

In addition, Alternative 1 includes the construction of two dual-purpose wells (New Well 1 and New Well 2). Each well would be completed to an approximate depth of 800 fbs and constructed of 16-inch diameter Type 304 stainless steel with above-ground completions similar to the existing District wells in the Coldwater Basin (e.g. Station 71).

The existing Coldwater Canyon spreading basins would need to be rehabilitated, which should include removal of trees and vegetation from the bottom of ponds and regrading to improve percolation and stabilization of existing berms.

Groundwater Recharge

Figure 4-7 shows the projected annual recharge with Alternative 1. The time of recharge is based upon the estimated availability of long-term storage water from MWDSC as shown in Figure 4-3. Projected recharge ranges from no recharge during dry years or years when the basin is nearly full to 5,100 acre-ft/yr. The average projected recharge under Alternative 1 is approximately 3,000 acre-ft/yr (1,700 acre-ft/yr from the dual-purpose wells and 1,300 acre-ft/yr from the recharge basins).

Figure 4-6
Additional Facilities for Alternative 1

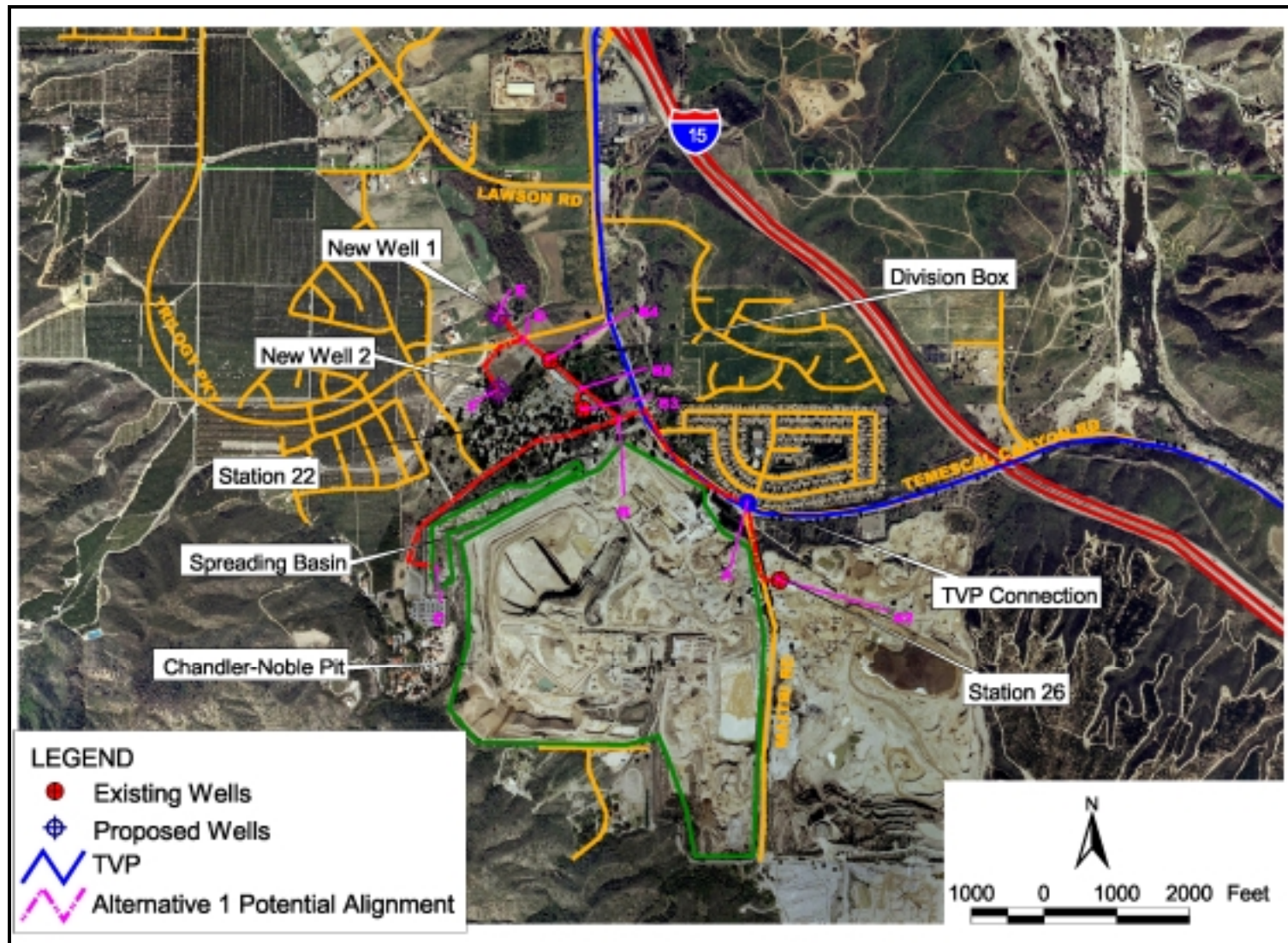
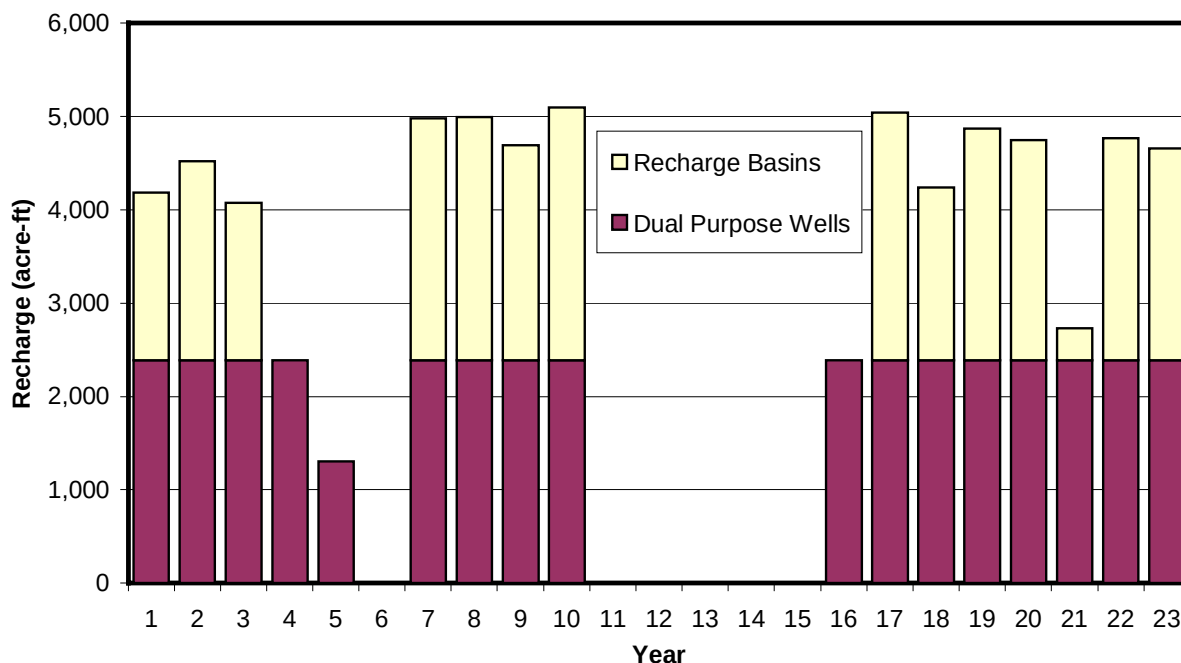


Figure 4-7
Projected Additional Recharge - Alternative 1



Groundwater Pumping

Figure 4-8 presents the pumping capacity versus basin storage for Alternative 1. Because of the additional capacity of the new dual-purpose wells and their greater depth, the pumping capacity in the basin increases to about 18,500 acre-ft/yr. These wells would be constructed to allow for continued pumping as water levels drop. Therefore, the extraction capacity during drier periods would be higher than under baseline conditions. All wells would still remain dry when water in storage drops below 12,000 acre-ft.

Figure 4-9 shows the annual projected pumping with Alternative 1 compared to baseline conditions. Pumping ranges from about 4,700 acre-ft/yr in dry years to about 17,400 acre-ft/yr in wet years with an average pumping rate of about 8,200 acre-ft/yr. As described previously, the average pumping under baseline conditions is only 5,300 acre-ft/yr. Because pumping is reduced during the winter months when imported water is available, during some years, pumping under baseline is actually higher than Alternative 1. Most of the additional pumping occurs during dry periods.

The average dry year yield under Alternative 1 is approximately 5,700 acre-ft per 6-month period, nearly triple the yield under the baseline conditions. Pumping during dry periods ranges from 2,400 acre-ft to 8,700 acre-ft with this alternative. This measure is particularly important when surplus supplies are not available.

Figure 4-8
Pumping Capacity versus Basin Storage – Alternative 1

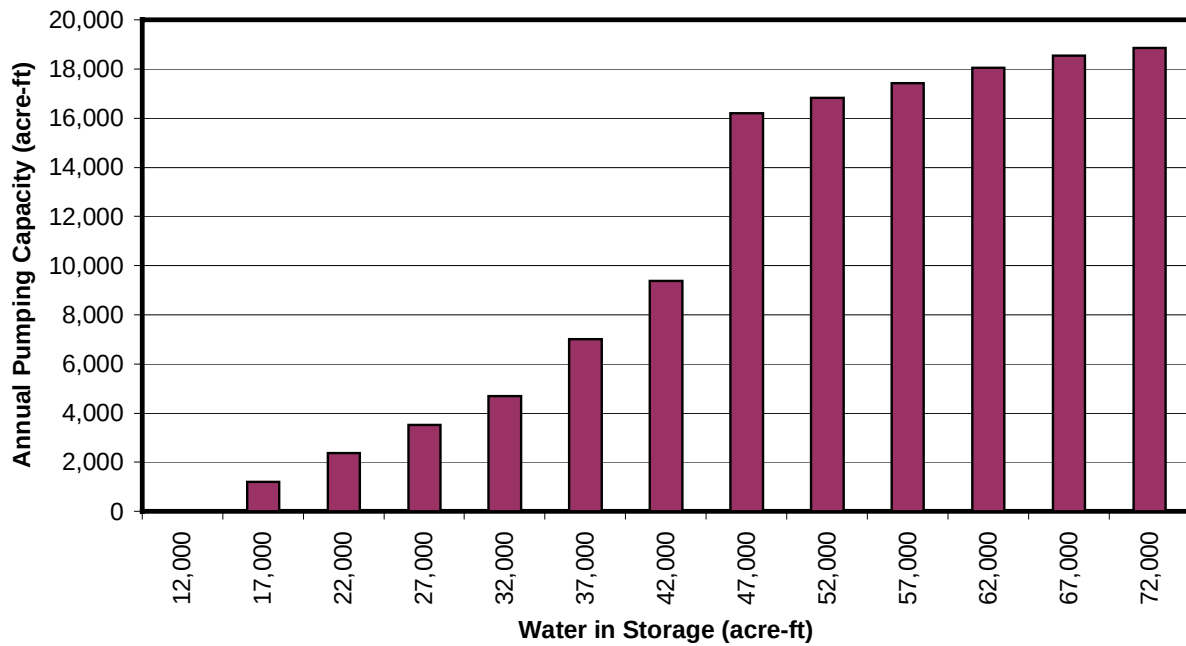
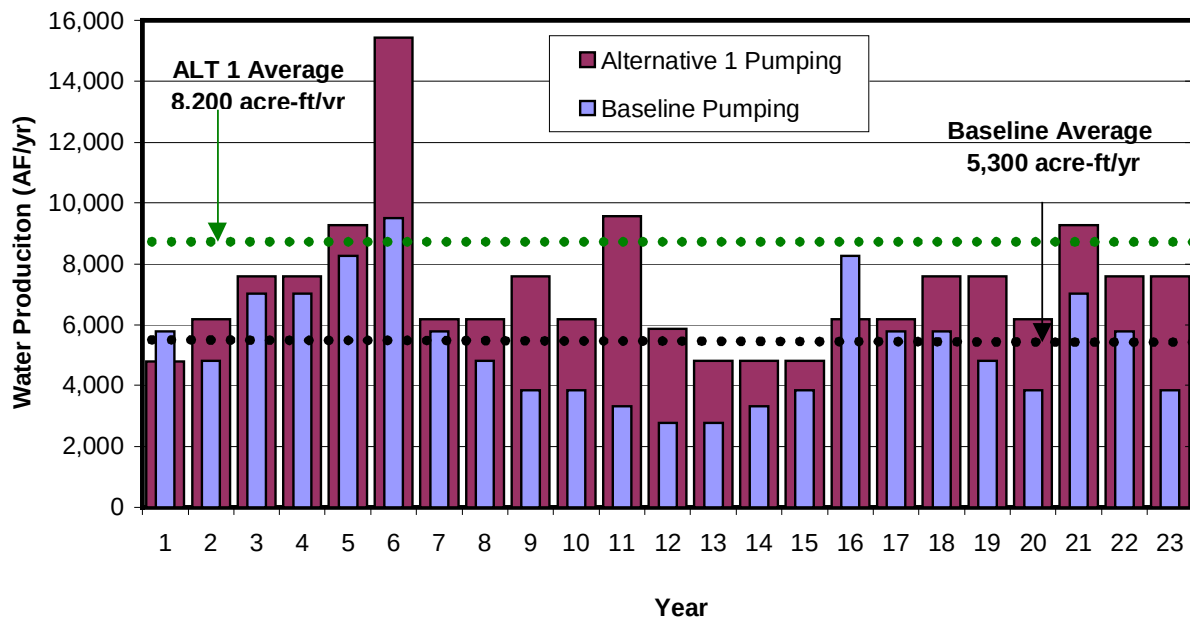


Figure 4-9
Projected Pumping - Alternative 1



Alternative 2 – Gravel Pit Storage

Alternative 2 simulates groundwater recharge using gravel pits. This alternative includes the following components:

- Repeat of 1977-2000 hydrology with future development as described in Baseline
- Surface recharge in the Chandler-R.J. Noble Pit
- 2 new extraction wells
- Storage only occurs in winter months when surplus water is available from MWDSC
- Storage only occurs if groundwater in storage is less than ~80 percent of basin storage
- Groundwater production varies with groundwater in storage - no pumping occurs when recharge occurs within the 6-month recharge period

The remainder of this section includes a description of the facilities required and the amount of groundwater pumping and recharge included in this alternative.

Facilities Required

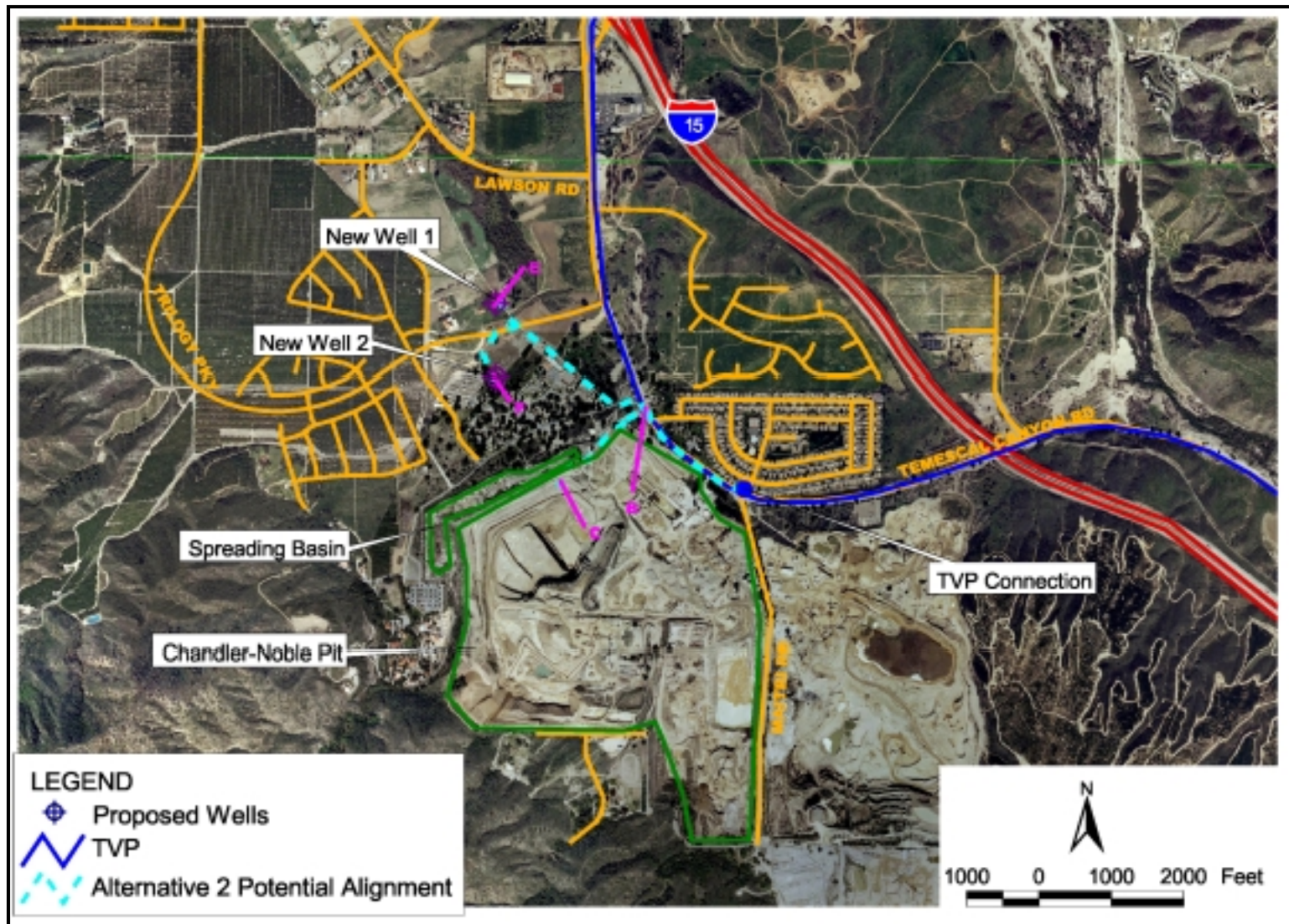
Alternative 2 facilities could convey water from the TVP to the Chandler-Noble Pit, and the two new wells. **Figure 4-10** shows the locations of the additional facilities required for Alternative 2. The pipeline could use the existing TVP connection at Matri Road. Preliminary estimates show that no additional pump stations would be necessary. The pipe sizes and lengths are summarized in **Table 4-7**. The pipeline to the Chandler-Noble pit follows an alignment along the northwestern edge of the property. The pipeline between Temescal Canyon Road and Trilogy Road is constructed in an existing dirt road shown in aerial photographs.

Table 4-7
Alternative 2 Pipe Diameters and Length

Location	Pipe Length (feet)	Diameter (inches)
Temescal Canyon Road	1,840	36
Temescal Canyon Road to Chandler-Noble Pit	1,170	30
Temescal Canyon Road to Trilogy Pkwy	1,890	16
Trilogy Pkwy to New Well 1	440	10
Trilogy Pkwy to New Well 2	880	10

In addition, Alternative 2 includes the construction of two groundwater production wells. Each well would be completed to an approximate depth of 800 fbg and constructed of 16-inch diameter Type 304 stainless steel with above-ground completions similar to the existing District wells in the Coldwater Basin (e.g. Station 71).

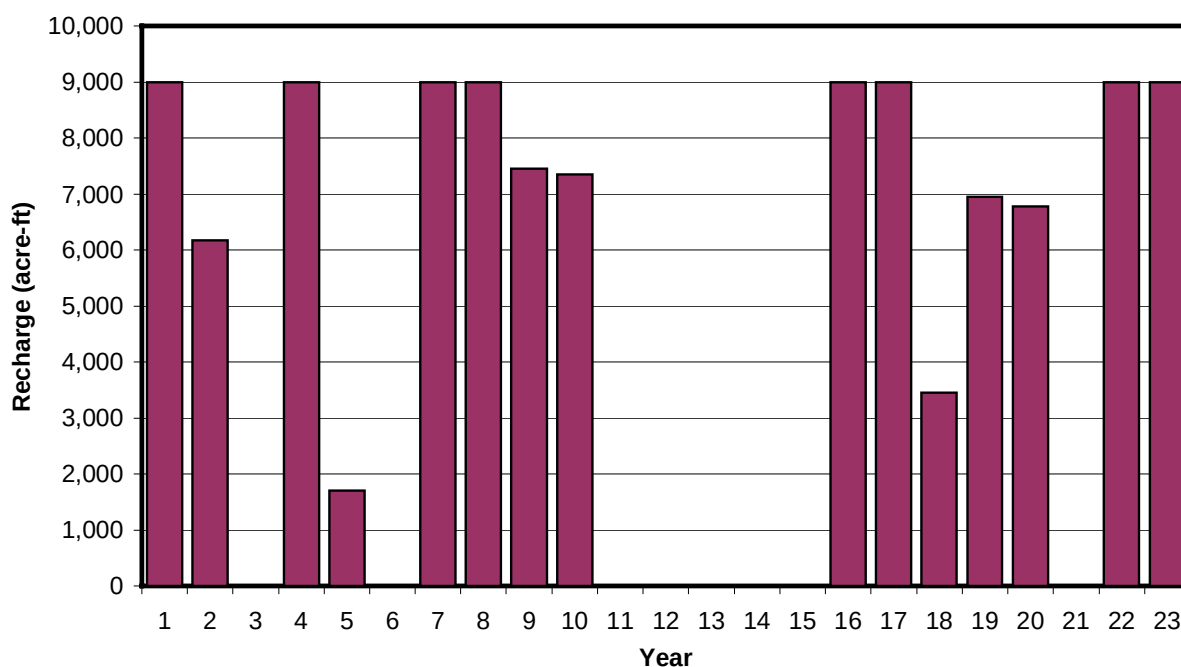
Figure 4-10
Additional Facilities for Alternative 2



Groundwater Recharge

Figure 4-11 presents the projected annual recharge with Alternative 2. Projected recharge under Alternative 2 ranges from no recharge during dry years when water is not available from MWDSC or when the basin is full to 9,000 acre-ft/yr. The average recharge with Alternative 2 is approximately 4,900 acre-ft/yr.

Figure 4-11
Projected Recharge – Alternative 2



Groundwater Pumping

Figure 4-12 presents the pumping capacity versus basin storage with Alternative 2. Because Alternative 2 also includes the installation of two new wells, the pumping capacity under Alternative 2 is the same as under Alternative 1.

Figure 4-13 shows the projected annual pumping with Alternative 2 compared to baseline conditions. Projected pumping ranges from about 4,700 acre-ft/yr to about 17,500 acre-ft/yr with an average of about 9,500 acre-ft/yr. The projected pumping is based upon the expected changes in groundwater storage due to the proposed recharge program.

The average dry year yield under Alternative 2 is approximately 6,100 acre-ft per 6-month period. The range in pumping during these dry periods is approximately 2,400 acre-ft to 8,700 acre-ft, the same as Alternative 1.

Figure 4-12
Pumping Capacity versus Basin Storage – Alternative 2

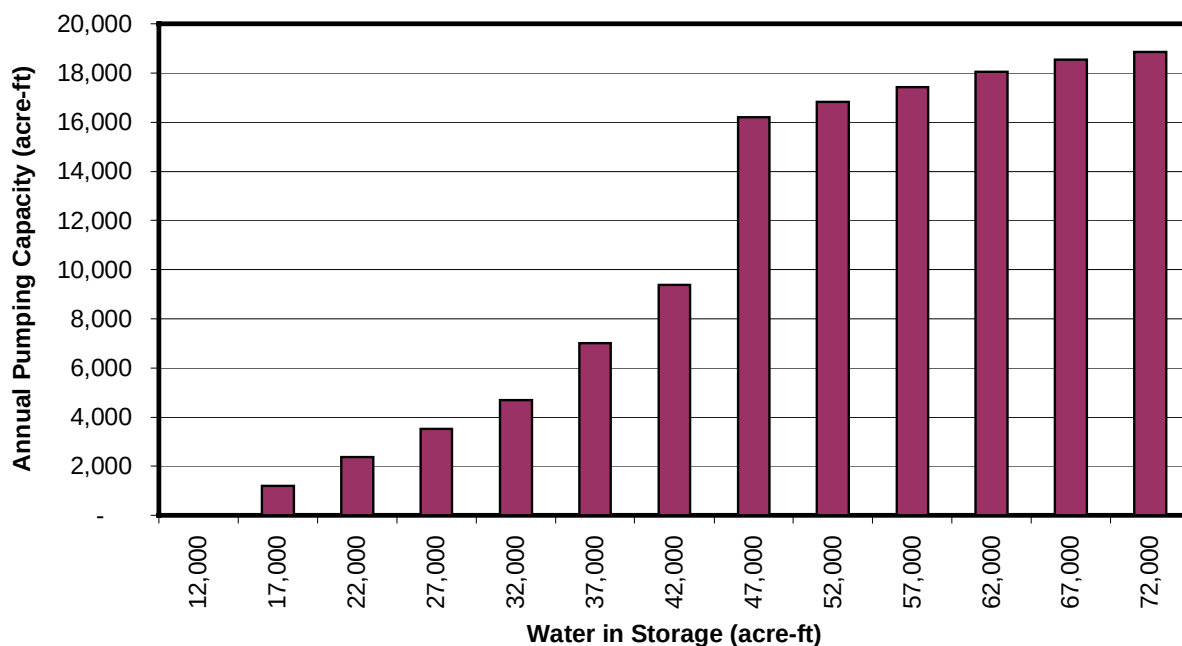
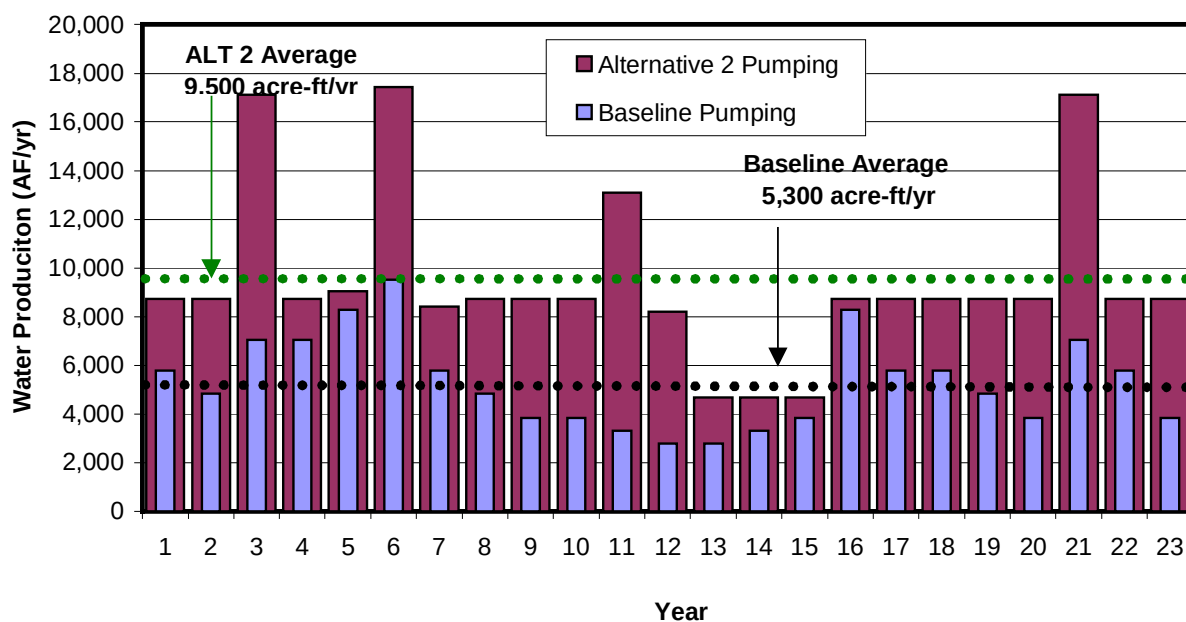


Figure 4-13
Projected Pumping - Alternative 2



GROUNDWATER RESPONSE OF ALTERNATIVES

The following section provides an evaluation of groundwater levels and aquifer storage under the baseline and the two alternatives.

Groundwater Model

For each alternative, separate model input files have been prepared to represent the conditions of each alternative. Numerical groundwater model input consist of the following:

- recharge due to infiltrating precipitation,
- recharge due to infiltration from canyons, irrigation water and septic tank effluent,
- groundwater pumping,
- direct injection recharge (Alternative 1),
- surface spreading recharge (Alternative 1), and
- gravel pit recharge (Alternative 2).

These volumes are calculated for the 23-year hydrologic period from 1977 to 2000 with six-month time steps and input into the groundwater model.

Table 4-8 compares the groundwater budget for each alternative based upon the hydrologic period from 1977 to 2000.

Table 4-8
Summary of Groundwater Budget for each Alternative (1977-2000)

	Baseline	Alternative 1	Alternative 2
Inflows			
Precipitation and Applied Water	1,400	1,400	1,400
Surface Diversions	2,200	2,200	2,200
Returns from Gravel Washing	1,300	1,300	1,300
Subsurface Inflow	1,400	1,400	1,400
Dual Purpose Wells	0	1,700	0
Recharge Basins	0	1,300	0
Gravel Pits	0	0	4,900
Total Average Inflow	6,300	9,300	11,200
Outflows			
Groundwater Pumpage	5,300	8,200	9,500
Evaporation	0	100	200
Losses from Gravel Operations	900	900	900
Subsurface Outflow	0	100	200
Total Average Outflow	6,200	9,300	10,800
Net Average Inflow	100	0	400

All units are acre-ft/yr

Total average inflows range from 6,300 acre-ft/yr under the baseline condition to 11,200 acre-ft/yr under Alternative 2. Outflows range from about 6,200 acre-ft/yr under the baseline condition to 10,800 acre-ft/yr under Alternative 2. The basin is nearly balanced under both the baseline condition and Alternative 1. There is a net average inflow of approximately 400 acre-ft/yr under Alternative 2.

Baseline

The following section presents the results of the water level analysis for baseline conditions. **Figure 4-14** shows the projected change in groundwater storage under baseline conditions. Water in storage ranges from about 39,000 acre-ft during dry years to 53,000 acre-ft during the wet years, an operational range of about 14,000 acre-ft.

Figure 4-14
Summary of Water in Storage - Baseline

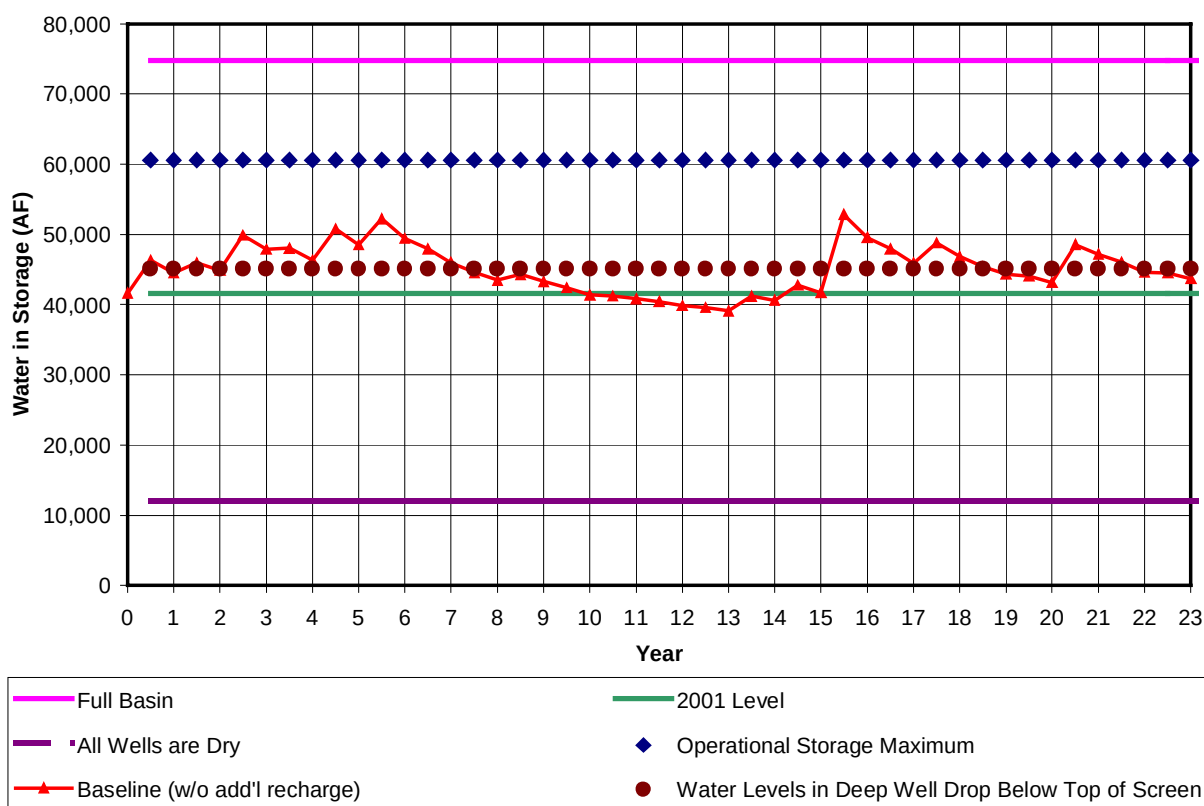


Figure 4-15 presents projected water levels in the vicinity of the City of Corona's Well #2 under baseline conditions. Because this well was recently abandoned to allow continued mining in the Chandler pit, this well represents water levels in the pits. In addition, this well is roughly located in the center of the basin and is a good representation of average water levels in the basin. Projected water levels in this well range from about 870 feet MSL to about 1,010 feet MSL. Note that under the baseline conditions, the highest projected water levels (for a six-month period) are projected to be below the level of the bottom of the existing gravel pits.

Figure 4-15
Projected Water Levels in Corona #2 - Baseline

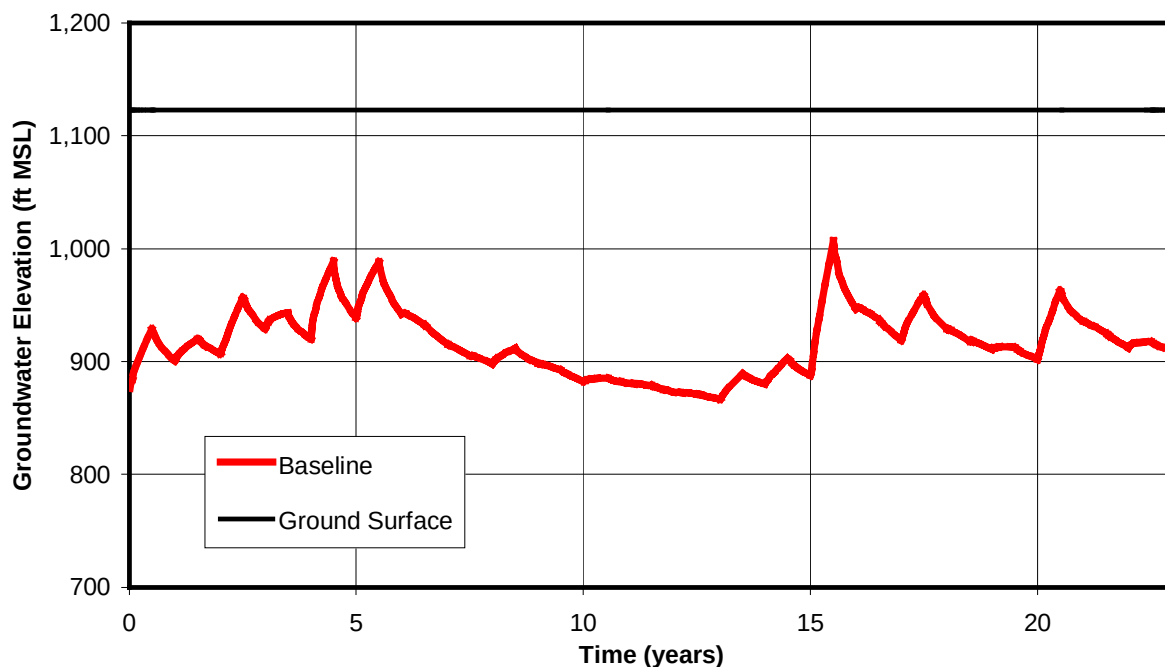


Figure 4-16
Projected Range in Water Levels along Cross Section A-A' – Baseline

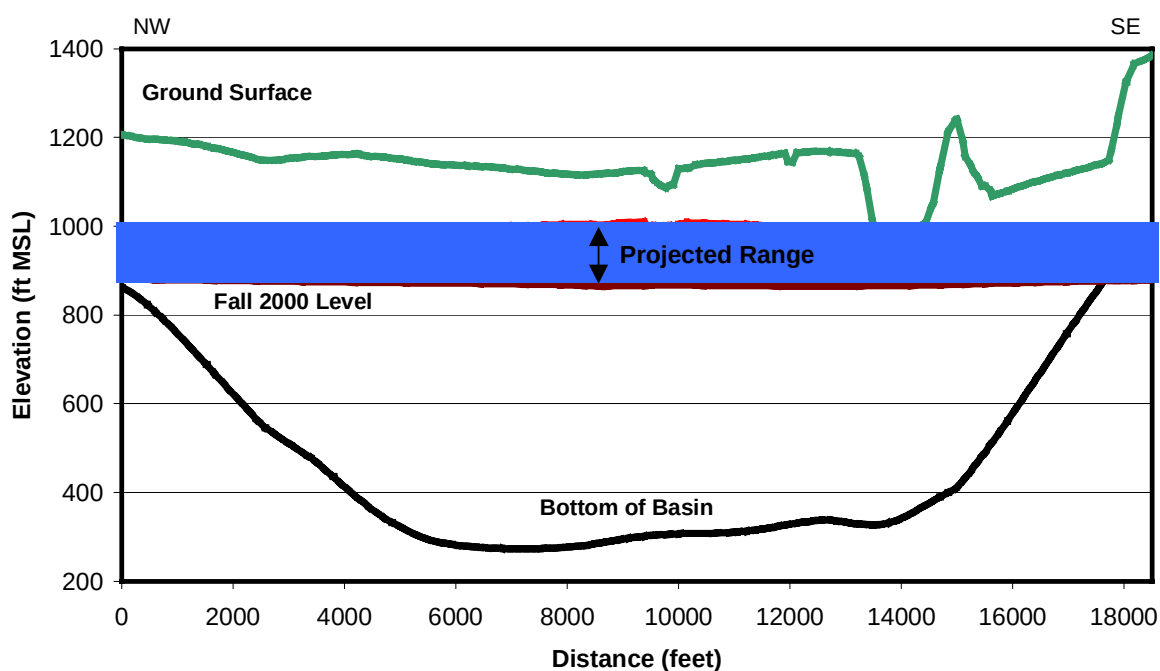


Figure 4-16 presents the projected range in water levels throughout the basin under baseline conditions. As shown in this figure, water levels in the center portion of the basin are higher in the wet years and lower in the dry years than the edges of the basin. This observation is consistent with the fact that most of the recharge and most of the pumping in the basin occurs in the center of the basin.

Alternative 1 – Dual Purpose Wells and Spreading Basins

The following presents the results of the water level analysis for Alternative 1. **Figure 4-17** shows the projected change in water in storage under Alternative 1. Projected water in storage ranges from about 30,000 acre-ft in dry years to about 60,000 acre-ft in wet years with an operational storage range of about 30,000 acre-ft.

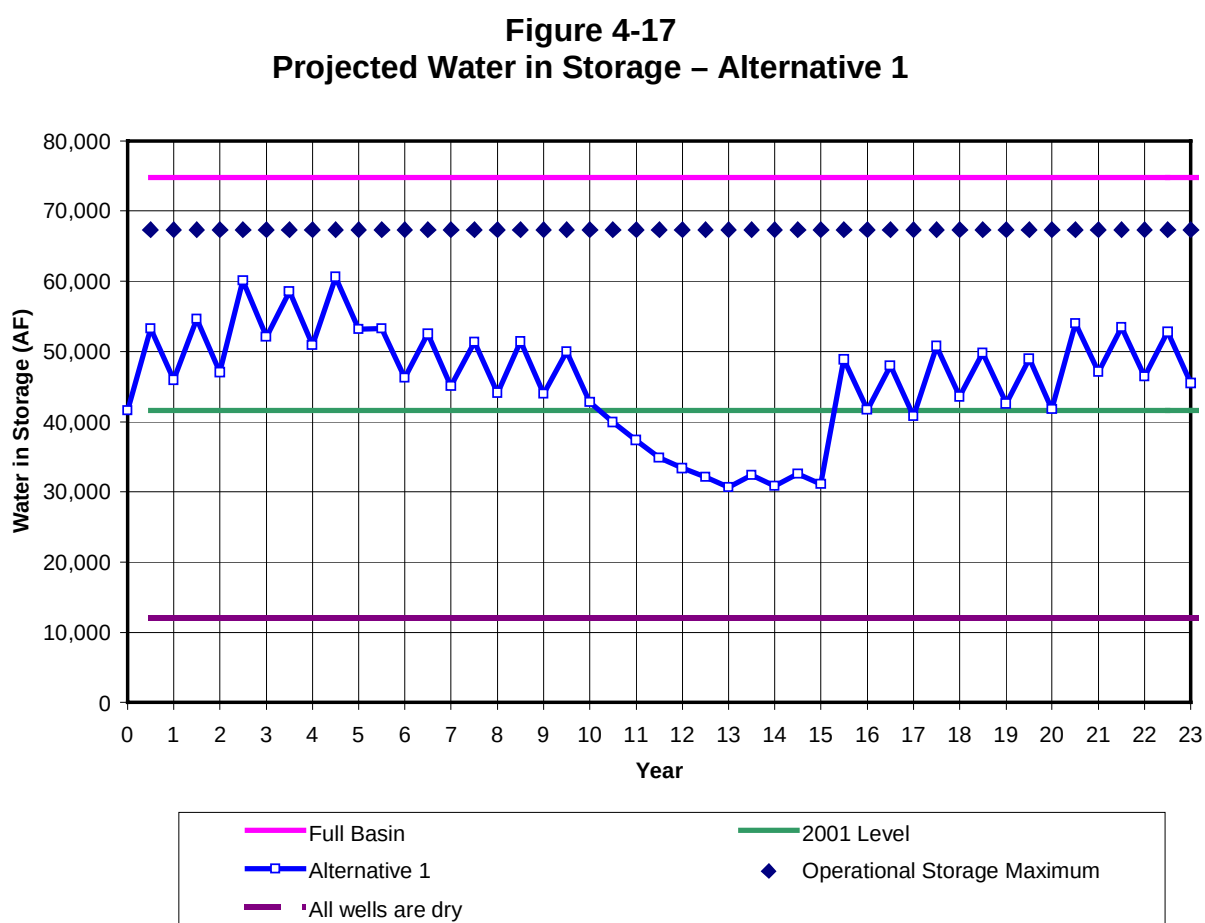


Figure 4-18 presents the projected change in water levels in the City of Corona's Well #2 under Alternative 1. Projected water levels range from about 800 feet MSL to about 1,100 feet MSL in this well. Because of the additional well capacity from the new dual-purpose wells, the projected water levels during dry years are about 70 feet lower than baseline conditions. Additional pumping occurs in the summer months, resulting in a drop in water levels relative to baseline.

Figure 4-18
Projected Water Levels in Corona #2 – Alternative 1

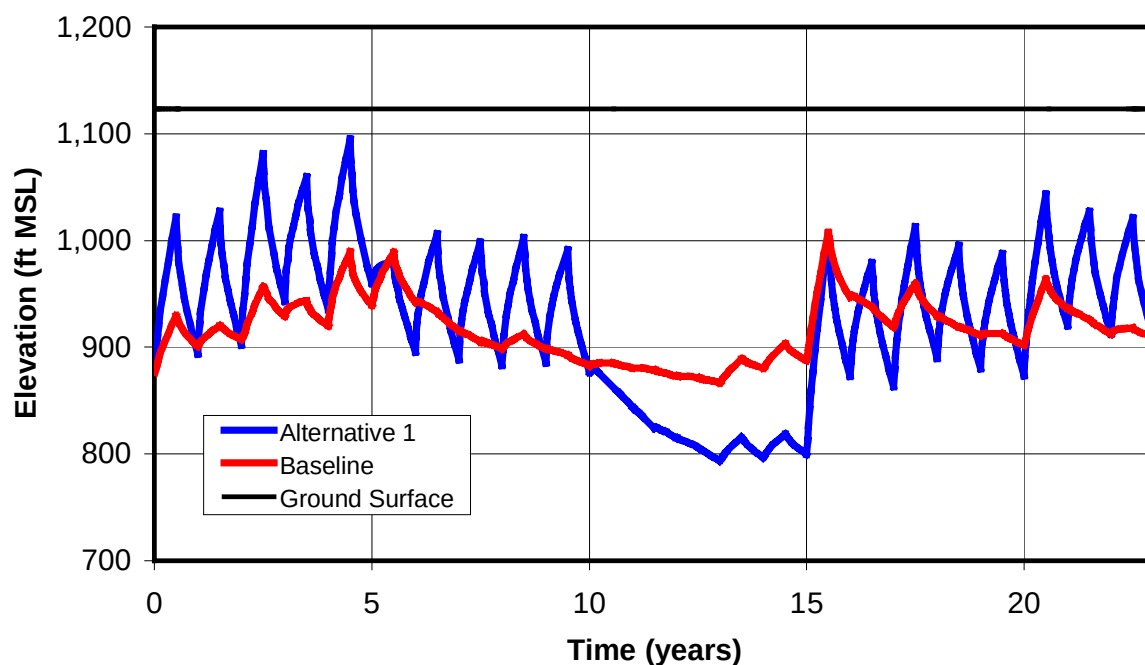


Figure 4-19
Projected Range in Water Levels along Cross Section A-A' – Alternative 1

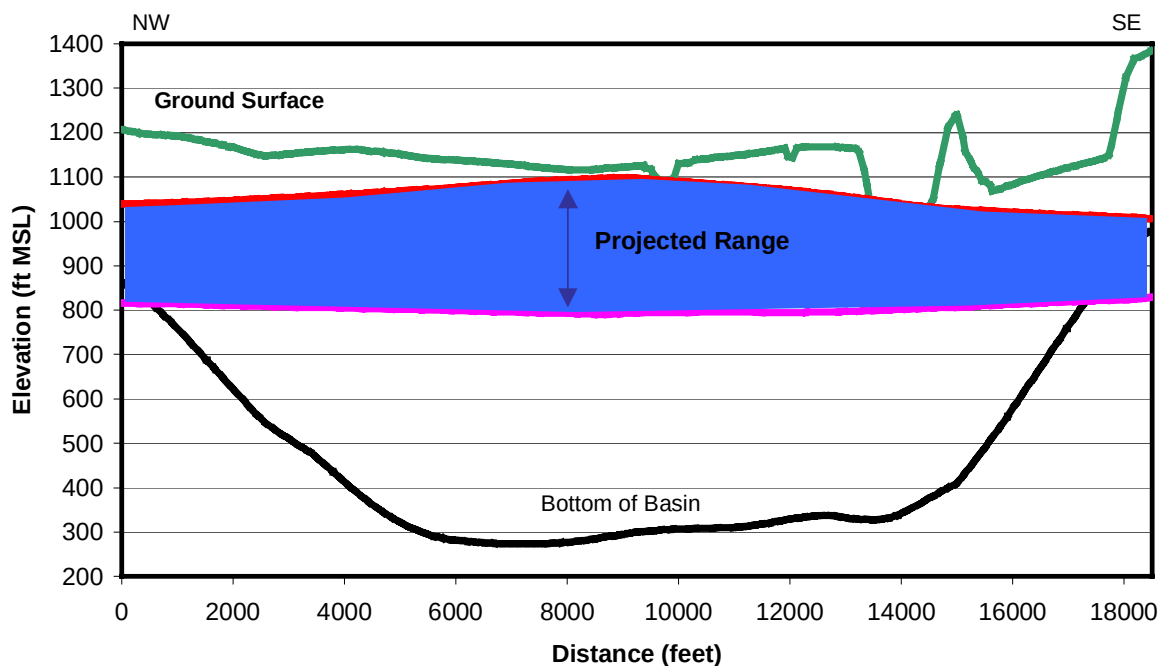


Figure 4-19 presents the projected range in water levels throughout the basin under Alternative 1. High water levels range from about 1,100 feet MSL in the center of the basin to about 1,040 feet MSL near the edges of the basin. During the wettest periods, water levels are as much as 160 feet above the bottom of the gravel pits. This pattern occurs because most of the recharge (from the dual-purpose wells and surface recharge basins) is in this portion of the basin. During the dry periods, the gradient across the basin is relatively flat with water levels about 800 feet MSL.

Alternative 2 – Gravel Pit Storage

The following presents the results of the water level analysis for Alternative 2. **Figure 4-20** shows the projected water in storage under Alternative 2. Projected water in storage ranges from about 33,000 acre-ft in dry years to about 60,000 acre-ft in wet years with an operational storage range of about 27,000 acre-ft.

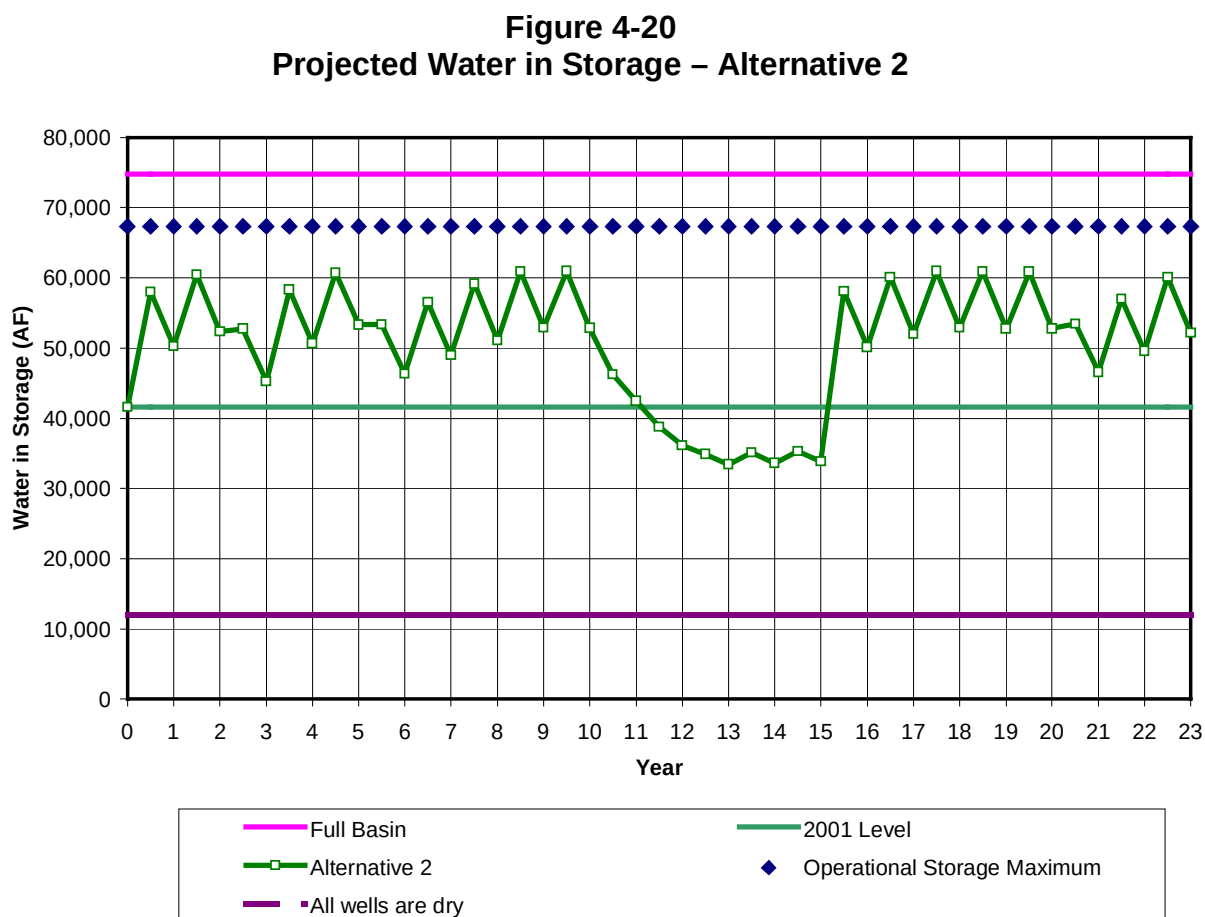


Figure 4-21 shows the projected water levels in the City of Corona's Well #2 under Alternative 2. Projected water levels range from about 820 feet MSL to about 1,120 feet MSL in this well. Because of the additional capacity of the new extraction wells, the projected water levels during dry years are about 50 feet lower than baseline conditions. Additional pumping occurs in the summer months, resulting in a drop in water levels relative to baseline in a few years.

Figure 4-21
Projected Water Levels in Corona #2 – Alternative 2

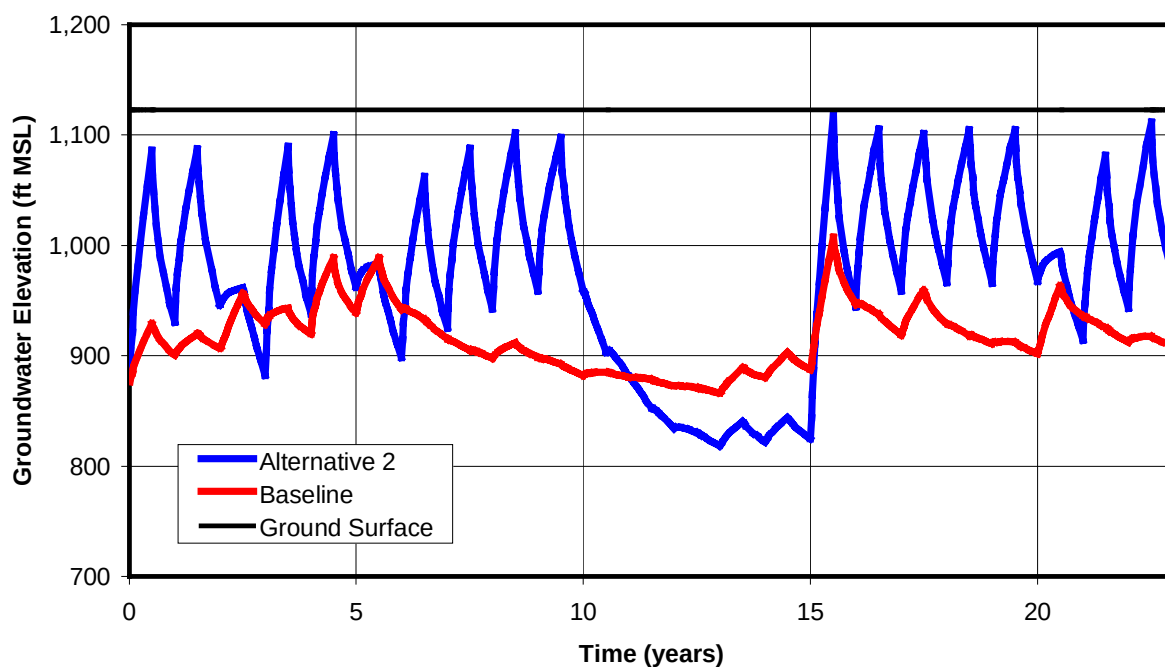


Figure 4-22
Projected Range in Water Levels – Alternative 2

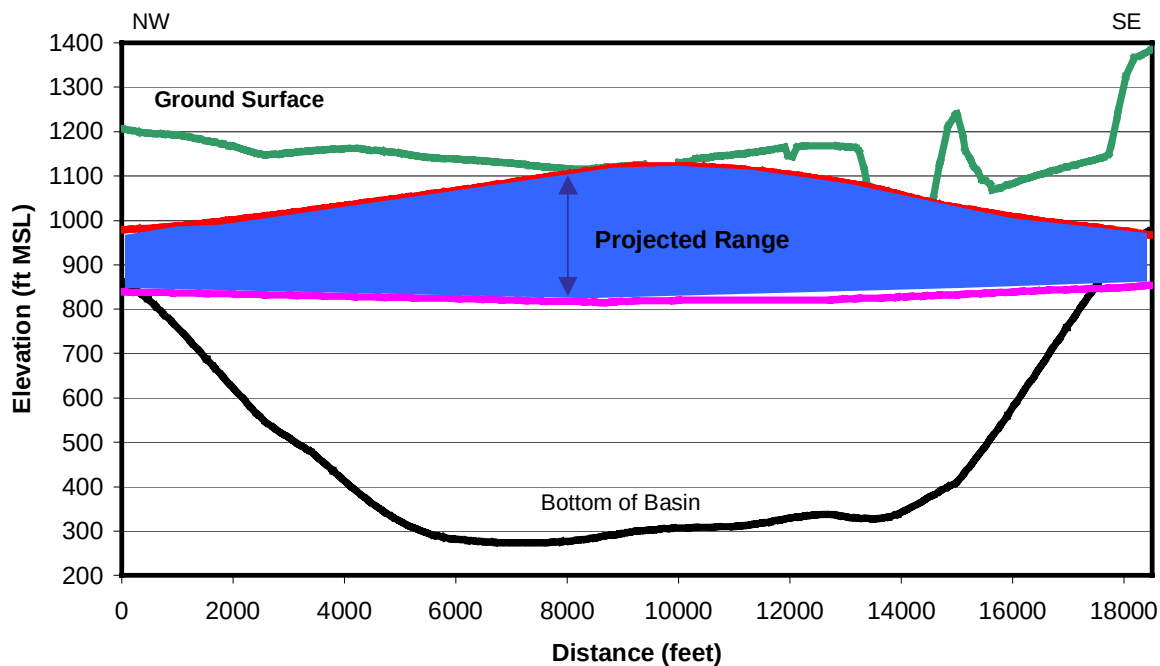


Figure 4-22 shows the projected range in water levels throughout the basin under Alternative 2. High water levels range from about 1,120 feet MSL in the center of the basin to about 980 feet MSL near the edges of the basin. During the wettest periods, water levels are as much as 200 feet above the bottom of the gravel pits. During the drier periods, the gradient across the basin is relatively flat with water levels about 820 feet MSL.

SUMMARY

This section has included the evaluation of three alternatives. Alternatives include:

- Baseline – Continuation of current conditions
- Alternative 1 – Dual purpose wells and recharge basins
- Alternative 2 – Gravel pit storage

Table 4-9 summarizes the components and technical feasibility for each alternative. From a groundwater storage perspective, all three project alternatives are feasible.

**Table 4-9
Summary of Project Alternatives**

Parameters	Baseline	Alternative 1	Alternative 2
Technical Feasibility	Feasible	Feasible	Feasible
Project Components and New Facilities	• Continue existing operation • No new facilities	• 2 new dual purpose wells • 3 converted wells • Rehabilitation of existing recharge basins • Pipelines from TVP to new facilities	• Surface storage in gravel pits • 2 new dual purpose wells • Pipelines from TVP to new facilities
Operational Yield (Average Pumping)	5,300 acre-ft/yr	8,200 acre-ft/yr	9,500 acre-ft/yr
Dry Period Yield	2,100 acre-ft	5,700 acre-ft	6,100 acre-ft
Water Levels in Gravel Pits	Below bottom of pits	As much as 160 feet above bottom of pit (in Chandler Pit)	As much as 200 feet above bottom of pit (in Chandler Pit)
Range in Storage	39,000-53,000 acre-ft	30,000-60,000 acre-ft	33,000-60,000 acre-ft
Range in Water Level	870 – 1,010 feet MSL	800 – 1,100 feet MSL	820 – 1,120 feet MSL

The average groundwater pumping (referred to as the operational yield) ranges from 5,300 acre-ft/yr under baseline conditions to 9,500 acre-ft/yr under Alternative 2. Similarly, the dry period yield ranges from about 2,100 acre-ft under baseline conditions to 6,100 acre-ft/6-month period

under Alternative 2. The increased yield relative to baseline is a direct result of the additional recharge as well as additional extraction capacity created by the alternative.

Storage in the basin is projected to range from about 50 to 70 percent full under baseline conditions. Storage for Alternatives 1 and 2 is projected to range from about 40 to 80 percent, which allows for more use of the basin storage to meet demands during dry periods. Water levels are projected to range from about 870 to 1,010 feet MSL under baseline conditions. The range in water levels under Alternatives 1 and 2 is wider, varying from 800 to 1,100 feet MSL and 820 to 1,120 feet MSL respectively. Alternatives 1 and 2 are projected to increase water levels in the gravel pits (particularly the Chandler pit) with water levels projected to be as much as 200 feet above the bottom of the pit during wet periods under Alternative 2. It is important to note, however, that there are periods (particularly during the summer months) when water levels are projected to be below the level of existing pits and gravel operations could continue under dry conditions.

MWH evaluated the reduced water production during periods of recharge by using the entire average annual production of each well during the 6-month extraction period. MWH determined the additional pumping/recharge facilities required for each alternative.

The remainder of this report addresses other potential issues that would affect the feasibility of each alternative. Cost estimates are provided in Section 5 and environmental issues are described in Section 6.

Section 5

Cost Estimates

The following section presents cost estimates for the alternatives described in the previous section. Backup for cost estimates are provided in **Appendix C**.

GENERAL COST ASSUMPTIONS

Capital cost assumptions are developed based on data obtained from industry manufacturers, MWH's experience on similar planning projects and data provided by the District. Pipeline costs have been calculated using recent cost data for work completed by MWH. All estimates have been adjusted to an Engineering News Record (ENR) Construction Cost Index (CCI) of 7,572 (Los Angeles, March 2003) and are consistent with the American Association of Cost Engineers guidelines for developing reconnaissance-level estimates which should range between 50 percent above and 30 percent below actual capital expenditures. A 30 percent contingency is included in the construction cost estimates. The engineering, administration, and legal costs are estimated to be 25 percent of construction costs. The engineering, administration, and legal costs also include typical services such as inspection, materials testing, and construction management. Cost estimates do not include the cost of the land acquisition or groundwater monitoring. All costs are presented in current (2003) dollars.

The costs of the recharge alternatives are compared based upon the total annual cost, which includes the annual capital cost and the operational and maintenance (O&M) cost. For the conversion of capital cost to annual cost a discount rate of two percent (5 percent interest minus 3 percent inflation) is used based on direction from EVMWD. Pipelines are depreciated over 40 years, electrical and mechanical equipment and pump stations over 20 years, wells over 75 years, and spreading basins over 20 years.

The unit cost per supply source that are used in the cost calculations are summarized in **Table 5-1**. Note that imported water costs are MWDSC rates effective January 1, 2004.

Table 5-1
Summary of Water Supply Costs

Water Supply Source	Cost (\$ per acre-ft)
Groundwater Pumping	\$59 to \$64
Treated Imported Water – Tier 1	\$418
Treated Imported Water – Tier 2	\$499
Treated Imported Replenishment Water	\$300

BASELINE

As discussed in **Section 4**, the baseline alternative involves no additional facilities and represents continuation of existing conditions. Therefore, the baseline alternative includes no capital costs. O & M costs include pumping and treatment costs only. The average annual cost for the continuation of existing conditions is approximately \$0.32 million per year.

ALTERNATIVE 1

As discussed in **Section 4**, Alternative 1 includes additional pipelines and facilities to deliver imported water from the TVP for injection in new dual purpose wells and for surface recharge in the Coldwater Canyon recharge basins. Capital costs for these additional facilities are estimated to be approximately \$3.59 million. O & M costs include pumping and treatment costs as well as the cost of imported water. Because imported water would be available during surplus years, this water would be purchased at the replenishment water rate of \$300 per acre-ft. The average annual cost for Alternative 1 is approximately \$1.52 million per year.

ALTERNATIVE 2

As discussed in **Section 4**, Alternative 2 includes additional pipelines and facilities to deliver imported water from the TVP for surface recharge in the gravel pits. Capital costs for these additional facilities are estimated to be approximately \$2.95 million. O & M costs include pumping and treatment costs as well as the cost of imported water. Because imported water would be available during surplus years, this water would be purchased at the replenishment water rate of \$300 per acre-ft. The average annual cost for Alternative 2 is approximately \$2.22 million per year.

SUMMARY

The costs for each alternative are compared in **Table 5-2**. As shown in Table 5-2, annual costs range from about \$0.35 million with the baseline condition to \$2.35 million with Alternative 2. Note that most of this cost is the cost of purchasing imported water supplies. The baseline condition includes no imported water purchases while Alternative 2 includes an average of 4,900 acre-ft/yr.

Unit costs range from \$66 per acre-ft of produced water under baseline conditions to \$248 per acre-ft of produced water under Alternative 2. Capital costs range from none with the baseline condition to \$4.05 million under Alternative 1. It is important to note that most of the unit cost is a result of additional purchases of imported water and higher produced water. Under baseline conditions, about 5,300 acre-ft/yr is pumped from the baseline while under Alternative 2, about 9,500 acre-ft/yr is pumped from the basin. The additional cost of water under the two alternatives reflects the additional water supply.

Table 5-2
Summary of Costs for each Alternative

Item	Unit	Baseline	Alternative 1	Alternative 2
Total Capital Costs	million \$	\$0.00	\$4.05	\$3.35
Annual Costs				
Annual Capital Costs	million \$	\$0.00	\$0.13	\$0.11
Annual O & M Costs	million \$	\$0.35	\$1.50	\$2.24
Total Annual Costs	million \$	\$0.35	\$1.63	\$2.35
Incremental Costs ¹				
Incremental Annual Cost	million \$	--	\$1.28	\$2.00
Incremental Supply	acre-ft	--	2,853	4,168
Annual Water Supply	acre-ft	5,302	8,155	9,470
Cost of Water Used for Recharge	\$/acre-ft		\$300	\$300
Annual Unit Cost of Water	\$/acre-ft	\$66	\$199	\$248
Incremental Unit Cost of Water	\$/acre-ft		\$447	\$479

Note: ¹ Incremental costs represent the increased cost over the baseline alternative.

The incremental cost of Alternatives 1 and 2 above the cost of baseline is also presented in **Table 5-2**. Alternative 1 is estimated to increase the annual cost of produced water in the Coldwater Basin by about \$1.3 million. Similarly, Alternative 2 is estimated to increase the annual cost of water by about \$2 million. As discussed previously, under Alternative 1, the average annual pumping increases by about 2,900 acre-ft/yr and under Alternative, it increases by about 4,200 acre-ft/yr. The unit cost of this increment ranges approximately \$450 per acre-ft to \$480 per acre-ft under Alternative 1 and 2, respectively, which is less than the cost of Tier 2 water (\$499 per acre-ft) but higher than Tier 1 water (\$418 per acre-ft). Therefore, either Alternative 1 or Alternative 2 would be a feasible alternative to purchasing additional Tier 1 water. Note, however, that these estimates do not include costs for land acquisition that would be required under Alternative 2. The acquiring of the gravel pits could add substantial cost to the project and may make Alternative 2 infeasible.

Section 6

Environmental Issues

A preliminary evaluation of environmental constraints associated with the proposed Alternatives 1 and 2 is presented below. After the preferred alternative is selected, preparation of appropriate environmental documentation under the California Environmental Quality Act (CEQA) and, if a federal agency is involved, the National Environmental Policy Act (NEPA) would be required. The evaluation provided herein is intended to be preliminary in nature to identify potential environmental issues that would make either project alternative infeasible.

AIR QUALITY

The Coldwater Basin is located within the Lake Elsinore Area Air Monitoring Subregion of the South Coast Air Basin (SCAB), which is under the jurisdiction of South Coast Air Quality Management District. SCAB is a designated non-attainment area for ozone, carbon monoxide, and particulate matter less than 10 microns in diameter (PM10).

Alternatives 1 and 2 include construction of new facilities (wells and/or pipelines). Temporary potential air pollutant emissions from project construction include fugitive dust (PM10) from excavation operations and direct emissions from construction vehicles. Construction air impacts would be approximately proportional to the acreage of disturbance. Mitigation measures are available to minimize construction-related air quality impacts. Therefore, construction impact on air quality is not anticipated to be a significant environmental constraint.

Long term operation and maintenance activities with potential air quality impacts include berm maintenance and vegetation control. Air quality impact from such activities would be minor emissions from vehicles and equipment and small amounts of dust, and is anticipated to be less than significant. Therefore, no significant air quality impacts are anticipated during operation of the spreading basins, wells or pipelines.

BIOLOGICAL RESOURCES

The spreading grounds and gravel pit areas have been disturbed from their natural state due to existing mining and spreading operations. The disturbed state of the site is not expected to support sensitive wildlife. Therefore, the occurrence of sensitive plant species is unlikely and no impacts or mitigation measures are expected.

The location of well facilities and pipelines under both Alternatives 1 and 2 could have potential biological impacts. Therefore, a records search of the California Department of Fish and Game (CDFG) Natural Diversity Data Base (CNDDDB) has been conducted for known occurrences of agency-listed sensitive biological resources in the project area. **Table 6-1** summarizes the possible sensitive species in the project area.

**Table 6-1
Threatened, Endangered, and Candidate Wildlife Species
That Could Occur in Project Area**

<i>Species/Common Name</i>	Federal Status	State Status	Remarks
<i>Phrynosoma coronatum</i> San Diego horned lizard	C2	CSC	Inhabits open sandy areas in brushy habitats.
<i>Poliophtila californica</i> California gnatcatcher	T	CSC	Inhabits coastal sage scrub habitat.
<i>Dipodomys stephensi</i> Stephens kangaroo rat	E	T	Inhabits open grasslands and disturbed areas, and open brushy habitats.
<i>Vireo bellii pusillus</i> Least Bell's vireo	E	E	
<i>Aimophila ruficeps canescens</i> Southern California rufous-crowned sparrow	None	None	
<i>Aspidoscelis hyperthrus</i> Orange-throated whiptail	None	CSC	
<i>Icteria virens</i> Yellow-breasted chat	None	None	

CNDDDB – California Natural Diversity Data Base

C2 – Federal Category 2 Candidate Species

EPA – Protected under Eagle Protection Act

CSC – California Department of Fish and Game Species of Special Concern

CFP – California Fully Protected

E – Endangered

T – Threatened

Natural communities in the area may include the following:

- Southern Sycamore Alder Riparian Woodland,
- Southern Willow Scrub,
- Southern Coast Live Oak Riparian Forest.

Rare and threatened plants in the area may include the following:

- Many stemmed dudleya (*Dudleya multicaulis*),
- Smooth tarplant (*Centromadia pungens* ssp. *laevis*),
- Munz's onion (*Allium munzii*).

Upon selection of final well locations and pipeline alignments, a more detailed biological survey should be performed. Because the wells will have relatively small footprints and the pipelines would be located primarily in or adjacent to existing roadways, the biological issues do not appear to impact the feasibility of either alternative.

CULTURAL RESOURCES

No cultural resources are expected in the Chandler-Noble Pit and the existing spreading basin because these locations are highly disturbed. A cultural resources survey may be performed at the locations of the new proposed wells and pipeline alignments. Because the wells will have a relatively small footprint and the pipelines would be located primarily in or adjacent to existing roadways, the cultural resources issues do not appear to impact the feasibility of either alternative.

GEOLOGY AND SOILS

Because the proposed project does not involve construction of habitable structures, no significant impacts are anticipated from risk of damage due to hazardous geological or soil conditions. The site is in proximity of the North Glen Ivy fault and the South Glen Ivy fault as described in Section 2. Part of the Chandler-Noble Pit is within the South Glen Ivy Fault Special Studies Zone (California Geological Survey, 2002). The Station 26 wells is within the North Glen Ivy Fault Special Studies Zone (California Geological Survey, 2002). However, since none of the structures are intended for human occupancy, no fault-rupture hazard investigation is necessary.

Depending on the rate and volume of recharge involved, spreading and injection operations at the proposed basins may result in a rise in water table at down-gradient locations. This may in turn increase the potential for liquefaction and soil stability hazards, particularly in the gravel pit areas. This issue needs to be examined further once the specifics of the spreading and injection operations have been determined. A soil stability analysis should be performed to assess whether recharge operations would impact side slope stability in the existing pits.

HAZARDS AND HAZARDOUS MATERIALS

The proposed spreading or gravel pit storage operations under Alternatives 1 and 2 would not be expected to involve hazardous materials. No known history of soil contamination was identified in the Coldwater Basin (SARWQCB, 2003b).

WATER QUALITY

The spreading area has an NPDES permit on record with the Santa Ana Regional Water Quality Control Board (SARWQB) and is included in a group monitoring plan for storm water pollution prevention plan (SWPPP) stormwater discharges (Noble, 1994).

Using the gravel pits as recharge basins may increase potential for groundwater contamination because there is no protective soil above the groundwater at certain times of the year. The potential for contamination can be reduced by limiting potential sources of contamination in the vicinity of the pit.

Regional Board Water Quality Requirements

The proposed recharge programs under Alternatives 1 and 2 would be subject to review by the SARWQCB. Recharge operations would be required to comply with the Basin Plan and proposed amendments for the Santa Ana Region (SARWQCB, 1995; SARWQCB, 2003a).

Spreading and injection operations at any of the sites would have the potential to impact the groundwater quality of the Coldwater Basin. Water quality objectives of the Basin Plan that are applicable to the proposed project are shown in **Table 6-2**.

Table 6-2
Comparison of Basin Plan Water Quality Objectives for Coldwater Basin
and Imported Metropolitan Water Quality

Parameter	Basin Plan Objective ¹	Mills WTP ²
TDS	350 ¹ , 380 ³	262-345
Hardness	175 ¹ , none	98-120
Sodium	45 ¹ , 180 ³	55-80
Chloride	25 ¹ , 500 ³	79-127
Nitrate (as N)	3 ¹ , 1.5 ³	ND-1.3
Sulfate	125 ¹ , 500 ³	27-47

Sources:

¹ Current Basin Plan Objective, SARWQCB, 1995.

² Metropolitan, 2003.

³ Proposed Basin Plan Amendments, SARWQCB, 2003a.

Imported water from MWDSC's Mills Water Treatment Plant (WTP) is potentially available through the TVP for the recharge program. Table 6-2 compares the quality of effluent water the Mills WTP for 2002 to the Basin Plan objectives. Mills WTP water quality exceeds the current Basin Plan objectives for sodium and chloride. However, revisions to the Basin Plan Objectives for these constituents are proposed (SARWQCB, 2003a) and concentrations of chloride and sulfate as well as other constituents of concern are below the proposed water quality objectives. Therefore, the proposed water supply from the TVP would meet the Basin Plan Objectives. If other sources of water were used or the future water quality of the TVP did not meet the Basin Plan Objectives, potential mitigation measures include blending the imported water with higher quality water to conform to the Basin Plan objectives.

In addition, under Alternative 2, additional surface water treatment may apply.

Recharging the Coldwater Basin with imported potable water is not expected to have any negative impacts to the water quality of existing wells. As identified in Section 2, the average concentrations TDS and Nitrate in the Coldwater Basin are above the concentrations of the source water identified.

DHS Regulations for Recharge with Recycled Water

If recycled water is used for groundwater recharge, California Department of Health Services (DHS) regulations apply. Current regulations require DHS to make recommendations regarding recycled water recharge projects to the Regional Board for projects on a project by project basis (DHS, 2001). Recommendations from DHS are generally based on the distance and travel time between recharge operations and domestic water supply wells.

DHS has developed additional recycled water and drinking water regulations that have not yet entered the formal rulemaking process. The proposed regulations include requirements for quarterly groundwater monitoring near domestic water supply wells and requirements to provide backup water supply or treatment in cases where water supply wells are degraded by groundwater recharge operations (DHS, 2003). The proposed regulations, dated July 21, 2003, have different requirements for spreading and injection projects:

- Surface spreading projects – all recharge water shall be retained underground for a minimum of six months prior to extraction for use as drinking water supply and shall not be within 500 feet of a point of recharge.
- Subsurface injection – all the recharge water shall be retained underground for a minimum of twelve months prior to extraction for use as a drinking water supply and shall not be extracted within 2000 feet of a point of recharge.

In addition, the proportion of recycled water in any production well cannot exceed 50 percent recycled water.

No alternative includes the use of recycled water. However, if the District elects to use recycled water, additional evaluation of the potential water quality impacts will be necessary.

LAND USE

The Coldwater Basin is within unincorporated Riverside County where zoning coordination is required under Ordinance 348. Alternative 1 includes construction of wells and the use of the Coldwater Canyon recharge basins and Alternative 2 includes surface storage in the Chandler-Noble Pit. Land use issues at each of the proposed sites is discussed below.

Wells

Alternatives 1 and 2 include the addition of two dual purpose wells. The final locations for the wells have not yet been determined. The well sites should be chosen and constructed to minimize impacts on sensitive receptors.

Coldwater Canyon Spreading Basins

Alternative 1 includes the use of the Coldwater Canyon spreading basins. The Coldwater Canyon spreading basins are zoned M-R-A. Adjacent land uses include rural residential, mineral extraction and the Glen Ivy Hot Springs Resort. No sensitive adjacent land uses were found. Use of the spreading basin for groundwater recharge is not a significant change to the current land use but would require coordination with and approval from the Riverside County Flood Control and Water Conservation District. Recharge activities would need to be timed to avoid potential conflicts with the use of the basin for flood control purposes.

Chandler-Noble Pit

Alternative 2 includes the use of the Chandler-Noble Pit for surface recharge. The Chandler-Noble Pit is currently a gravel and sand pit with designated Mineral Resources and Related

Manufacturing (M-R-A) zoning. Public utilities, water development and storage are permitted uses for M-R-A zones. Therefore, no conditional use permit or change in zoning are expected to use the pit for groundwater recharge. Surrounding land uses include the spreading grounds, the Glen Ivy Hot Springs Resort, and rural residential. No sensitive adjacent land uses were found.

In 1996, Chandler's Sand and Gravel and R.J. Noble/Goldwater Aggregates submitted a joint application to mine the area between their respective properties. This combined the two pits into one 300-acre pit used to mine gravel and rock primarily used as concrete and building product aggregate and sand. The State Geologist has designated this site Mineral Resource Zone – 2a (MRZ –2a). The State Mining and Geology Board recognized this mineral resource as having regional and economic significance (Chandler 1996). The permitted mining depth is approximately 500 feet below grade (Chandler, 1996). In 1996, the Chandler-Noble Pit's operational life was estimated as 2028. The average production of sand and gravel was 970,000 tons per year from 1980 through 1992 (Chandler, 1996).

Spreading activities in the pit may impact access to mineral resources in the pit. Impacts on extraction efforts would only occur in the winter, when water is available from MWDSC, and when groundwater storage space is available. As discussed in Section 4, water levels in the pits would be as much as 160 feet above the bottom of the Chandler-Noble pit under Alternative 1 and as much as 200 feet above the bottom of the Chandler-Noble pit under Alternative 2. Each alternative could potentially affect the gravel pit operations. This impact would be significant. Coordination with the pit operators could minimize impacts on the extraction process.

NOISE

Construction at any of the proposed sites would temporarily elevate noise levels over ambient conditions. Based on the proximity to nearby residences, noise impacts on human sensitive receptors would be comparable for the Chandler-Noble Pit and the spreading grounds and greater for the wells. In addition to construction required at the recharge sites, construction noise impacts along the alignment of the pipeline may be significant, although temporary. Construction noise impacts may require standard mitigation such as noise barriers and/or construction hour limitations, and are expected to be mitigatable to a less than significant level.

No permanent noise is expected for either Alternative 1 or Alternative 2. Impacts would be less than significant.

TRAFFIC

Implementation of any of the proposed alternatives would temporarily increase traffic levels from construction vehicles. Traffic impact is expected to be the greatest at the locations of new wells. Impact from pipeline construction within roadways may include temporary lane closures and increased traffic congestion.

AGENCY COORDINATION, APPROVALS AND PERMITS

Table 6-3 summarizes the potential coordination with and approvals required from other agencies.

Table 6-3
Potential Agency Coordination, Approvals and Permits

Agency	Permit, approval, or coordination required
Federal	
Fish and Wildlife Service	California gnatcatcher survey
	Least Bell's vireo survey
	Southwestern willow flycatcher survey
	Migratory Bird Treaty Act coordination
State and Regional	
Department of Fish and Game	State listed sensitive species surveys
Santa Ana RWQCB	Approval of groundwater recharge
Department of Health Services	Well Drilling Permit
Riverside County	
RCFCWCD	Coordination for use of flood control basin
Planning Department	Conditional use permits or other land use approvals

SUMMARY

Based on a preliminary review of the existing conditions, the only significant and unavoidable environmental impacts per CEQA are the potential soil stability and land use issues associated with the gravel pits under Alternatives 1 and 2. In the event other impacts are determined to be significant upon further evaluation, they can most likely be mitigated to a less than significant level without substantial interference with program implementation. A soil stability analysis and coordination with the gravel pit owners will need to be performed prior to implementation.

Section 7

Summary and Recommendations

This section provides a summary of the report and presents recommendations for further action in the Coldwater Basin.

SUMMARY

The following provides a brief summary of the work performed as part of the Coldwater Basin recharge feasibility study.

Hydrogeology

MWH has reviewed and compiled available data to evaluate the geometry and update the hydrogeologic conceptual model for the Coldwater Basin. Based upon the data compiled as part of this report, the Coldwater Basin watershed contains the following stratigraphic units:

- Alluvium
- Bedford Canyon Formation
- Volcanic rocks and
- Granitic basement rocks

Only the alluvium produces significant groundwater resources and is the focus of the feasibility evaluation.

Based upon the data compiled as part of this study, there do not appear to be any significant confining layers within the alluvium except in the western portion of the basin where there is substantial clay. Shallow and deep groundwater appears to flow toward the pumping depression near the City of Corona's wells. Water levels are generally declining throughout the basin. Recharge to the alluvium occurs along the margins of the basin through Mayhew, Coldwater, Anderson, Bixby and Brown Canyons. Faults within the basin appear to be complete barriers to subsurface flow except where faults cross gravel pits.

MWH evaluated the inflows and outflows of the Elsinore Basin. Based upon these estimates, the average groundwater deficit between 1977 and 2000 was approximately 500 acre-ft/yr. This estimate is generally consistent with the observed trend in groundwater levels during this time period. Total storage in the Coldwater Basin is approximately 74,800 acre-ft. Groundwater in storage in the fall of 2000 was approximately 41,600 acre-ft, about 55 percent of the available storage.

Groundwater Model

Based upon the hydrogeologic conceptual model, a single layer numerical groundwater flow model was constructed and calibrated to evaluate conjunctive use alternatives. The model was

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calibrated using static and pumping water level information from seven wells in the Coldwater Basin. Calibration is generally good throughout the basin, with the best calibration near the City of Corona's and the District's wells. The model is most sensitive to net recharge and least sensitive to changes in hydraulic conductivity.

Project Alternatives

Based upon a review of the hydrogeologic setting of the Elsinore Basin, discussions with District staff and field reconnaissance, three project alternatives (including baseline) have been identified. These include:

Baseline – Continuation of current conditions

Alternative 1 – Dual purpose wells and recharge basins

Alternative 2 – Gravel pit storage

Each alternative is described below. A summary of each alternative is provided in **Table 7-1**.

Baseline

Continuation of the current pumping scenario of higher pumping during wet years and lower pumping dry years would maintain a sustainable water balance. Average extractions are projected to be about 5,300 acre-ft/yr. The dry period yield (i.e. the amount of pumping during a 6-month dry period) under baseline conditions would be about 2,100 acre-ft.

Under baseline conditions, water levels are projected to range from about 870 feet MSL to 1,010 feet MSL. Water levels in the vicinity of the gravel pits would remain below the level of the pits. Because of the existing well capacity, the basin is projected to range from about 50 percent to 70 percent full under baseline conditions. This scenario would not significantly impact the operation of the basin or result in significant environmental issues.

Continuation of existing operations would not result in additional capital expenditures. O & M costs are projected to average approximately \$0.35 million per year, which results in an average unit cost of approximately \$ 66 per acre-ft.

Alternative 1

Alternative 1 appears feasible for the Coldwater Basin. Alternative 1 includes the construction of two new dual purpose injection and extraction wells, conversion of three existing wells to dual purpose and groundwater recharge in the existing Coldwater Canyon recharge ponds. This alternative results in a sustainable water balance with an average pumping of 8,200 acre-ft/yr. The average dry period yield of Alternative 1 would be about 5,700 acre-ft per 6-month period.

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**Table 7-1
Summary of Project Alternatives**

Parameters	Baseline	Alternative 1	Alternative 2
Technical Feasibility	Feasible	Feasible	Feasible
Project Components and New Facilities	- Continue existing operation - No new facilities	2 new dual purpose wells 3 converted wells - Rehabilitation of existing recharge basins - Pipelines from TVP to new facilities	- Surface storage in gravel pits 2 new dual purpose wells - Pipelines from TVP to new facilities
Operational Yield (Average Pumping)	5,300 acre-ft/yr	8,200 acre-ft/yr	9,500 acre-ft/yr
Dry Period Yield	2,100 acre-ft	5,700 acre-ft	6,100 acre-ft
Range in Storage	39,000-53,000 acre-ft	30,000-60,000 acre-ft	33,000-60,000 acre-ft
Range in Water Level	870 – 1,010 feet MSL	800 – 1,100 feet MSL	820 – 1,120 feet MSL
Capital Cost	\$0	\$4.05 million	\$3.35 million
Annual Cost	\$0.35 million	\$1.63 million	\$2.35 million
Unit Cost (per acre-ft)	\$66	\$199	\$248
Incremental Unit Cost (acre-ft)	--	\$447	\$479
Potential Issues	None	Increased water levels in gravel pits	- Increased water levels in gravel pits - Surface water treatment

Under Alternative 1, water levels are projected to range from about 800 feet MSL to 1,100 feet MSL. The basin is projected to operate in a range from about 40 percent to 80 percent full. This alternative would result in higher water levels in the gravel pits. This could be a potentially significant environmental impact with respect to slope stability, land use and potential loss in mineral resources.

Alternative 1 is projected to result in capital expenditures of nearly \$4 million. Annual costs are projected to be about \$1.6 million with an annual unit cost of about \$199 per acre-ft. Most of the additional unit cost of Alternative 1 relative to Baseline comes from the cost of imported water.

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The incremental cost to increase the operational yield of the basin is approximately \$447 per acre-ft. This increment is less than the cost of Tier 2 water (\$499 per acre-ft).

Alternative 2

Alternative 2 appears feasible for the Coldwater Basin. Alternative 2 includes the construction of two new extraction wells and surface spreading in the gravel pits. This alternative results in a sustainable water balance with average pumping of about 9,500 acre-ft/yr. The average dry period yield of Alternative 2 would be about 6,100 acre-ft per 6-month period. Alternative 2 provides the most additional yield of the three alternatives.

Under Alternative 2, water levels are projected to range from about 820 feet MSL to 1,120 feet MSL. Like Alternative 1, Alternative 2 is projected to operate in range from about 40 to 80 percent full. This alternative would result in higher water levels in the gravel pits. This could be a potentially significant environmental impact with respect to slope stability, land use and potential loss in mineral resources.

Alternative 2 is projected to result in capital expenditures of nearly \$3 million. Annual costs are estimated to be about \$2.4 million with an annual unit cost of about \$248 per acre-ft. The incremental cost to increase the operational yield under this alternative is about \$480 per acre-ft, similar to Alternative 1. Although Alternative 2 is the most expensive option, it provides additional dry year reliability. As with Alternative 1, the incremental cost is less than the cost of Tier 2 water.

Based upon the feasibility evaluation provided herein, a conjunctive use program appears feasible in the Coldwater Basin.

RECOMMENDATIONS

As described above, each proposed alternative is potentially feasible for the Coldwater Basin. Therefore, MWH recommends a phased implementation approach that incorporates components of each alternative that could be implemented over the long-term. Because the dual purpose wells provide the most flexibility in operation, this component could be implemented first. Because gravel pit storage would involve coordination with gravel pit owners, this component could be implemented after other storage opportunities have proven successful. Specific activities include pilot testing and the construction of project facilities. Each of these items is discussed below. **Table 7-2** presents a summary of the recommendations for each alternative.

Recommendations for Pilot Study

The following provides recommendations for future studies based upon this feasibility study:

- Perform pilot testing to confirm feasibility of dual purpose injection program

The pilot study should include injection and extraction testing in an existing well south of Trilogy Parkway nearest the TVP. The purpose of this study would be to confirm the

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injection and extraction potential in this portion of the basin as well as evaluate the effectiveness of the North Glen Ivy fault as a barrier to flow.

- If pilot testing proves successful, convert existing wells (Division Box, Station 22, and Station 26 or other suitable wells) to dual purpose and construct associated pipelines
- Perform additional pilot testing upon completion of conversion

The purpose of the second phase of pilot testing is to confirm that the recharged water can be injected and extracted with limited adverse impacts to other users in the basin. These wells would be used for injection and extraction over a period of about 1 year.

- If pilot testing proves successful, an additional hydrology study will be necessary to evaluate further the feasibility of surface recharge in Coldwater Canyon

A more detailed hydrology study is necessary to evaluate the recharge potential in the Coldwater Canyon recharge basins and quantify the natural inflows from this source.

Table 7-2
Summary of Recommendations

Alternative	Feasibility	Future Action or Recommendation
Baseline	Feasible	• Current operation could continue without negative effects
Alternative 1	Feasible	• Proceed with dual purpose well construction and pilot testing • If feasible, proceed with surface recharge program • Perform additional hydrology study in Coldwater Canyon to evaluate surface recharge
Alternative 2	Potentially Feasible	• Proceed forward with pilot testing if implementation of Alternative 1 suggests that additional recharge and storage is necessary

Recommendations for Future Implementation

Based upon the feasibility analysis provided herein, a conjunctive use program is feasible in the Elsinore Basin. However, current operations within the basin could continue without adverse effects. Therefore, MWH recommends that the District and the City of Corona coordinate to

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implement the future program. MWH recommends the following for future implementation upon completion of pilot testing to confirm feasibility:

- Convert existing wells to dual purpose
- Construct two new dual purpose wells and associated pipelines northwest of the existing City of Corona's well field
- Construct pipeline to surface recharge ponds
- Evaluate gravel pit storage

Each of these projects could be implemented in phases as additional yield and storage potential becomes necessary.

Appendix A

References

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Appendix A

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Appendix A

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Appendix B

Groundwater Model Results

Figure B - 1
Mayhew #2

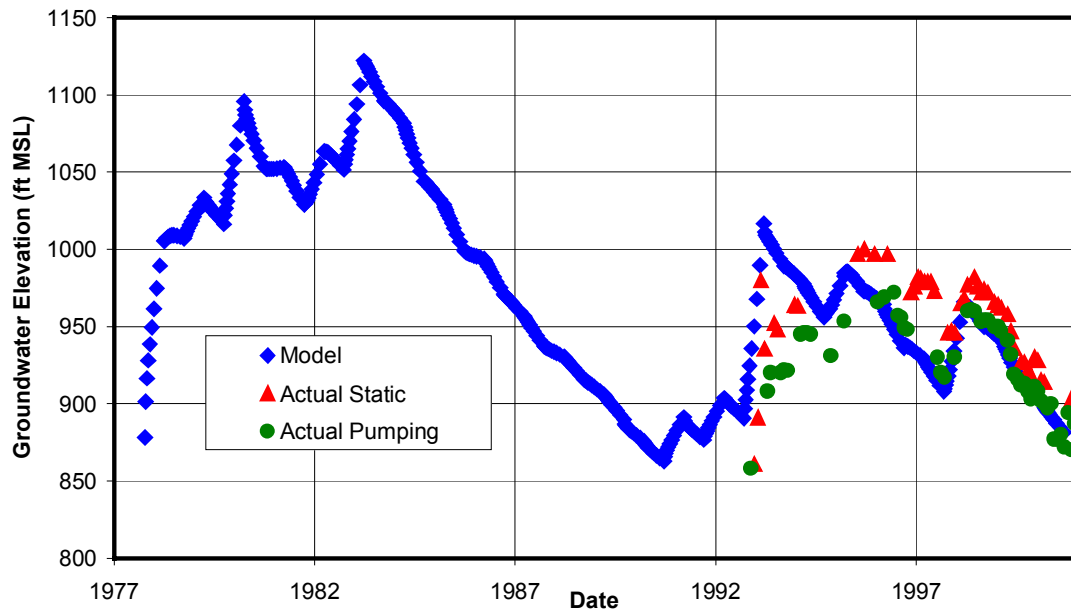
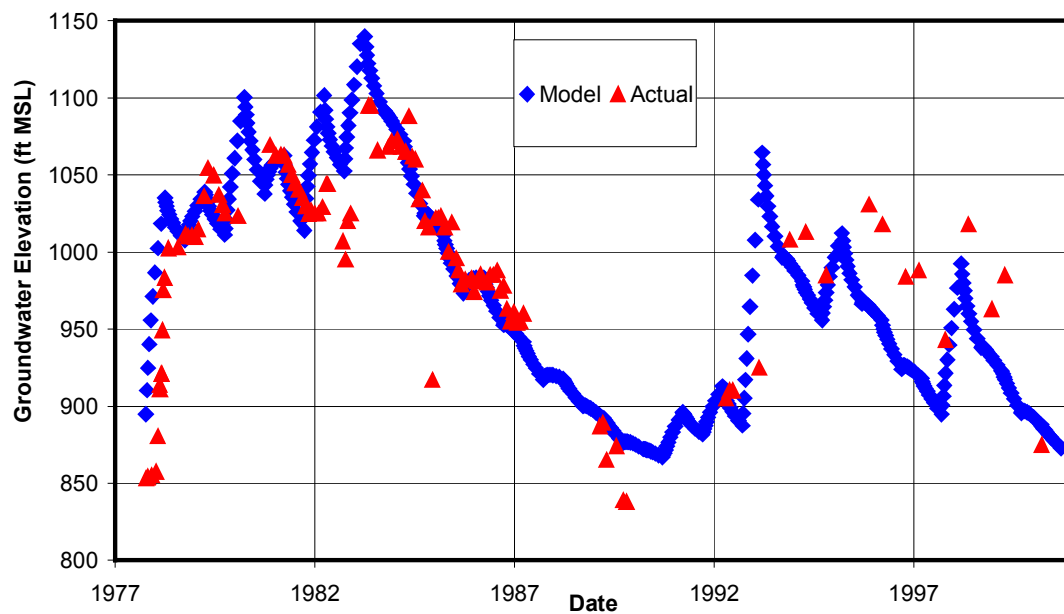


Figure B - 2
Corona #2



Appendix B

Groundwater Model Results

Figure B - 3
Corona #3

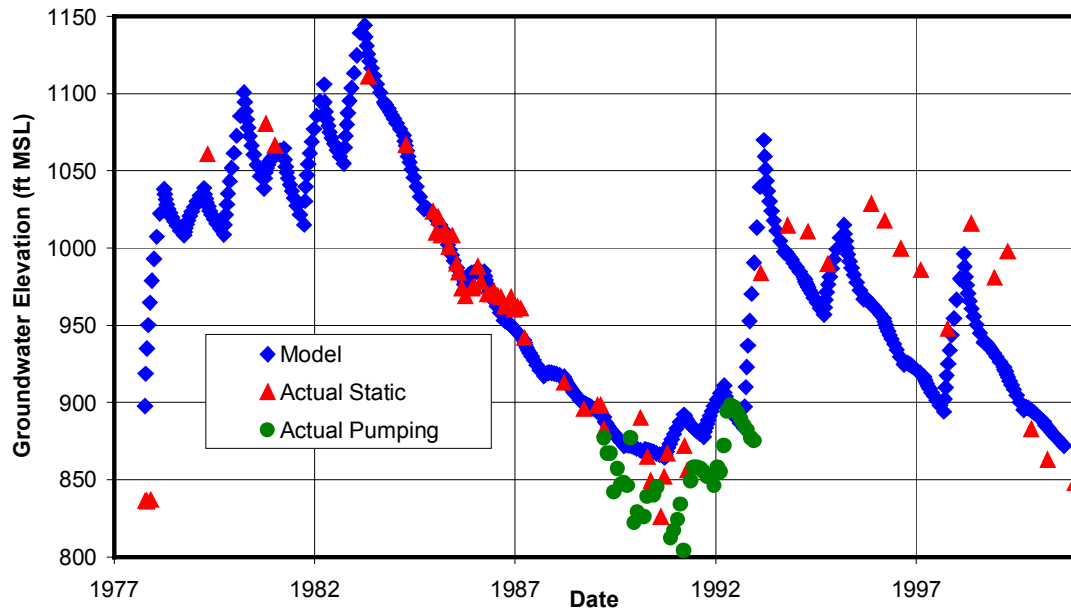
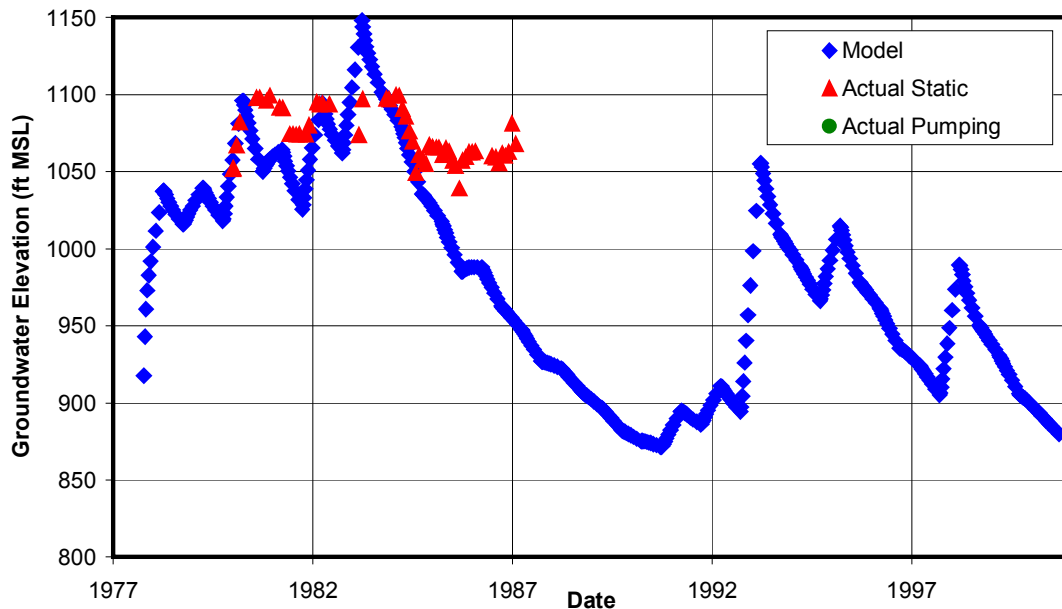


Figure B - 4
B Well



Appendix B

Groundwater Model Results

Figure B - 5
Division Box

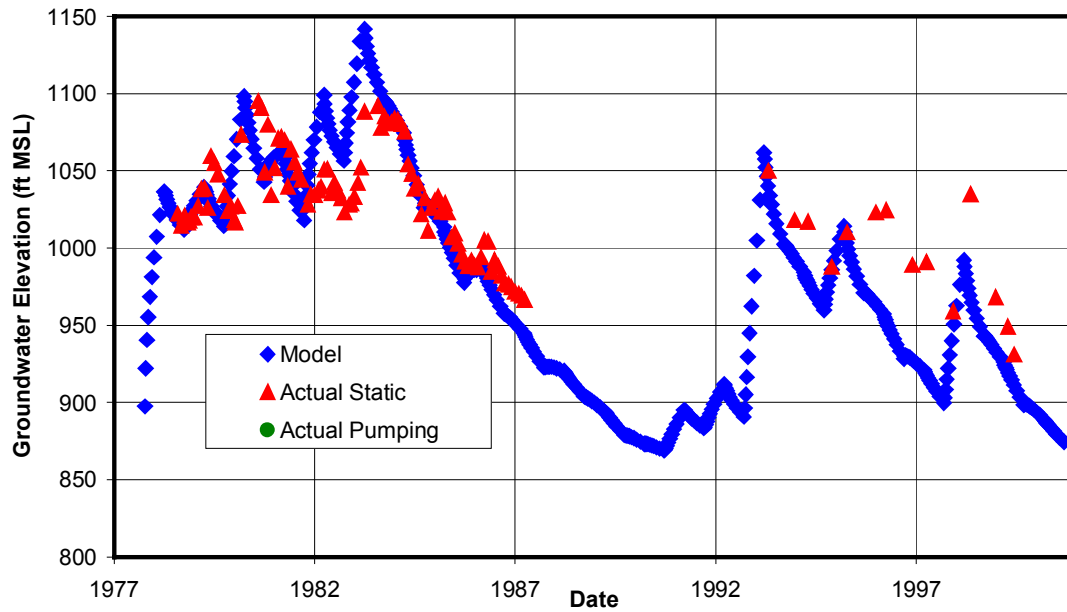
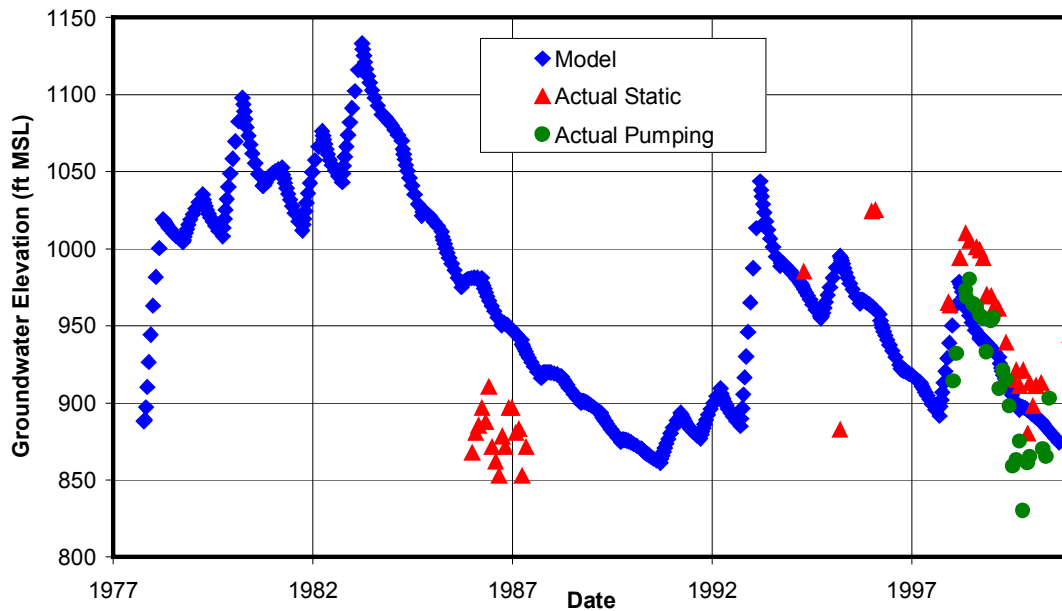


Figure B - 6
Station 71



Appendix B

Groundwater Model Results

Figure B - 7
Station 72

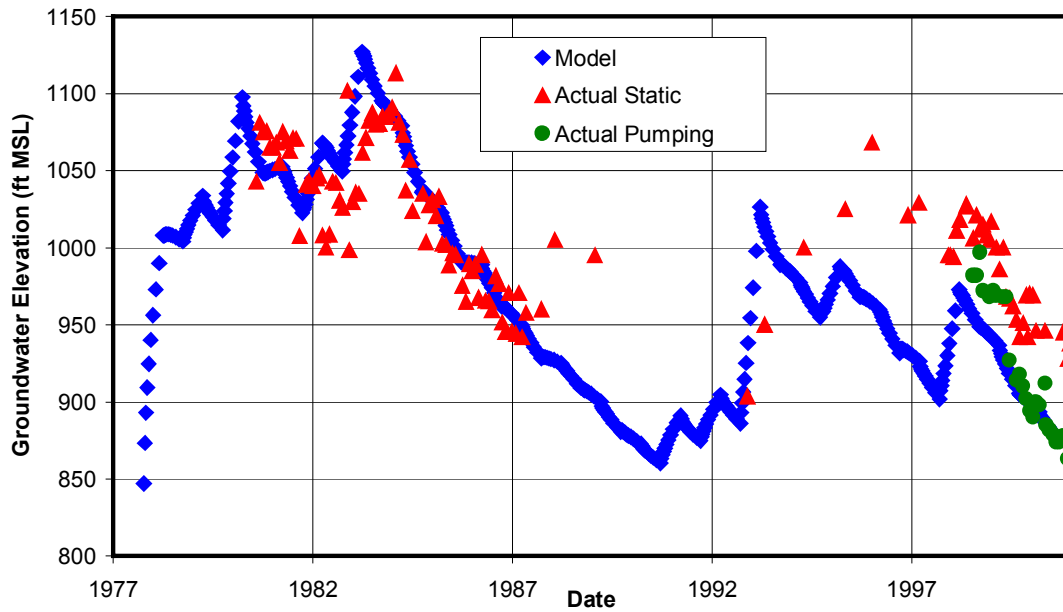
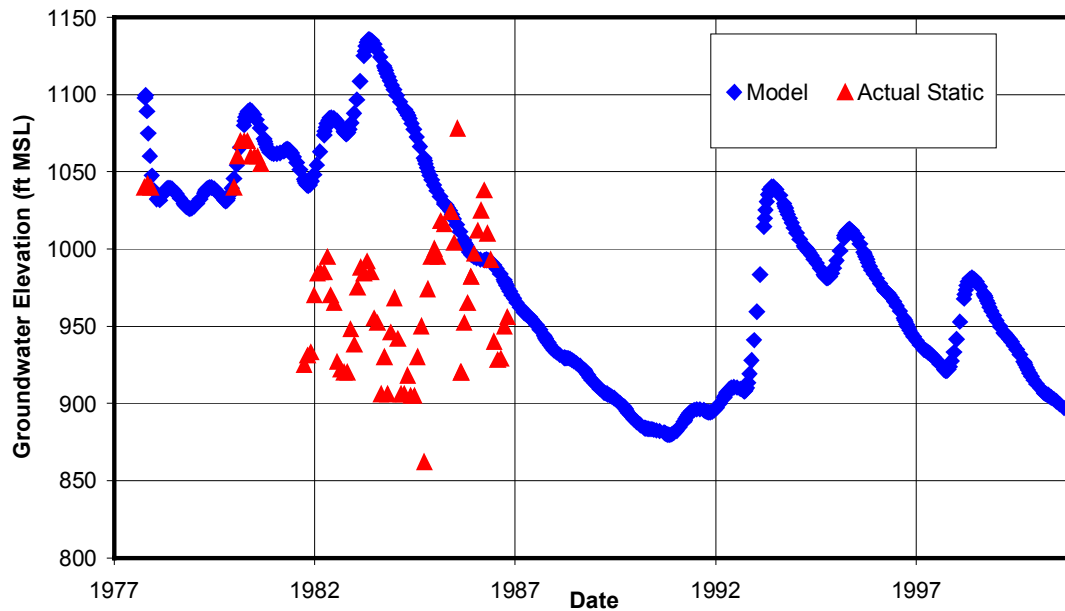
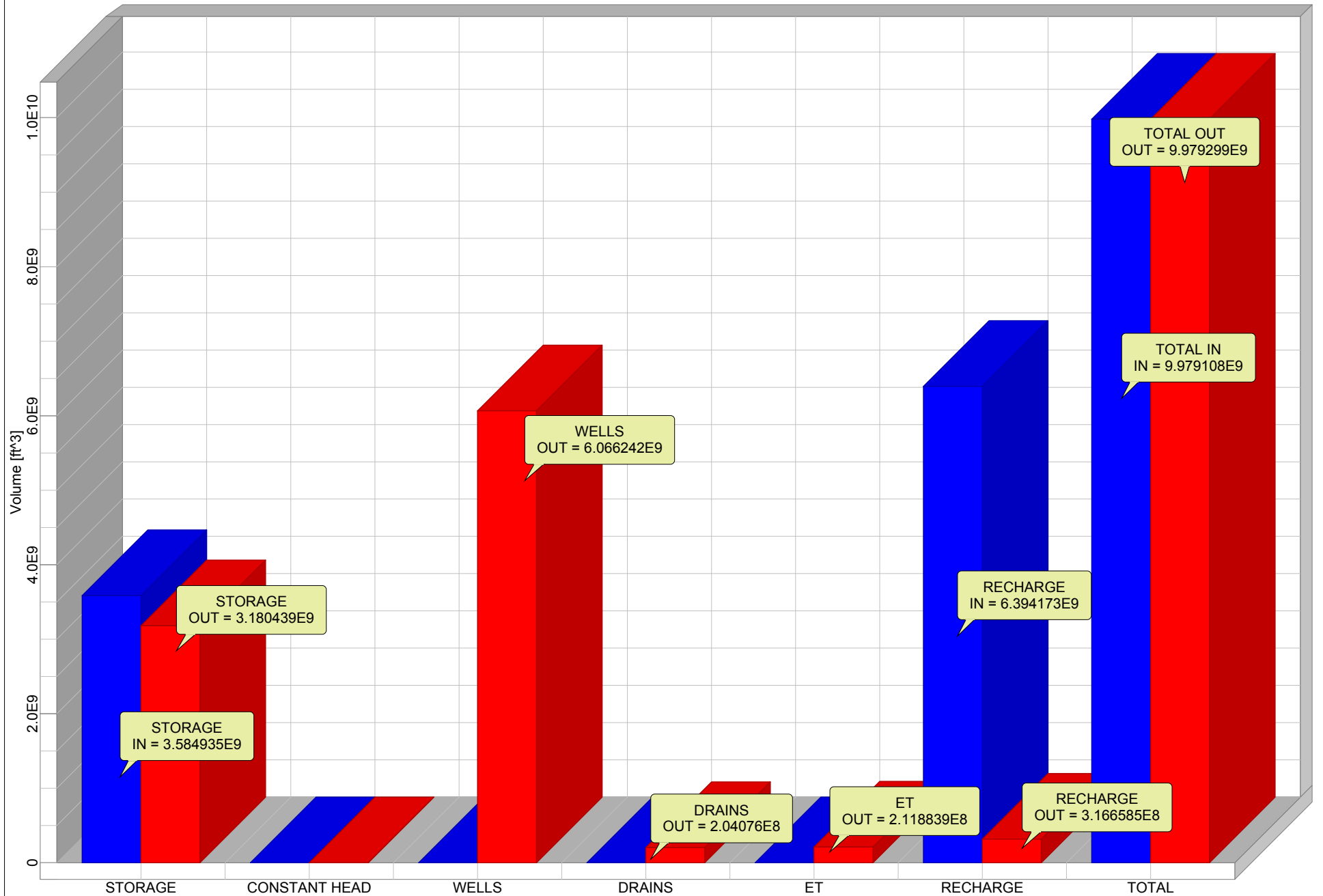


Figure B - 8
Corona South



Time = 23

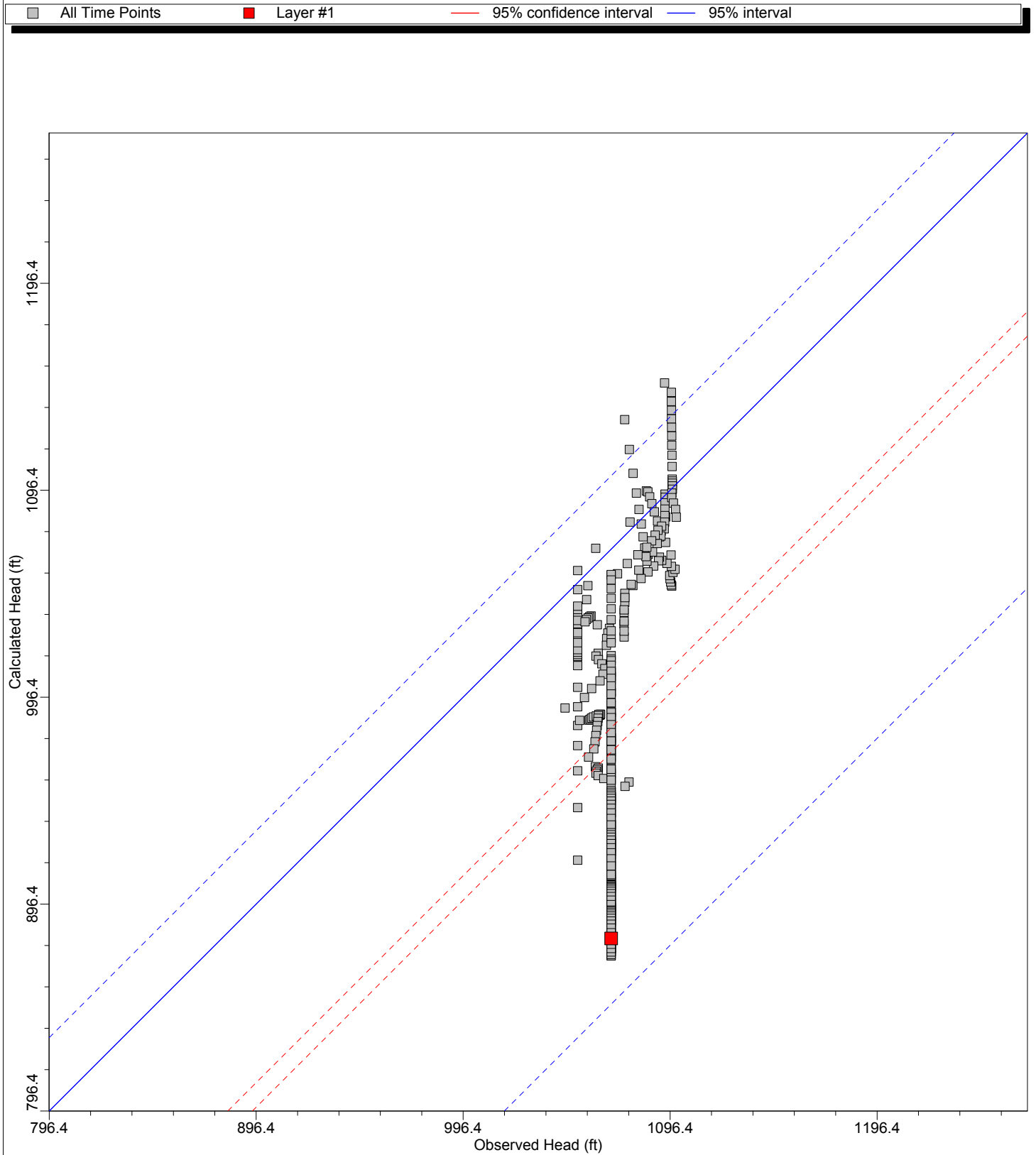
IN OUT



Coldwater 40 Mass Balance
Final Stress Period
Cumulative volumes
MWH

Coldwater Groundwater Model

Calculated vs. Observed Head : Time = 23 yr

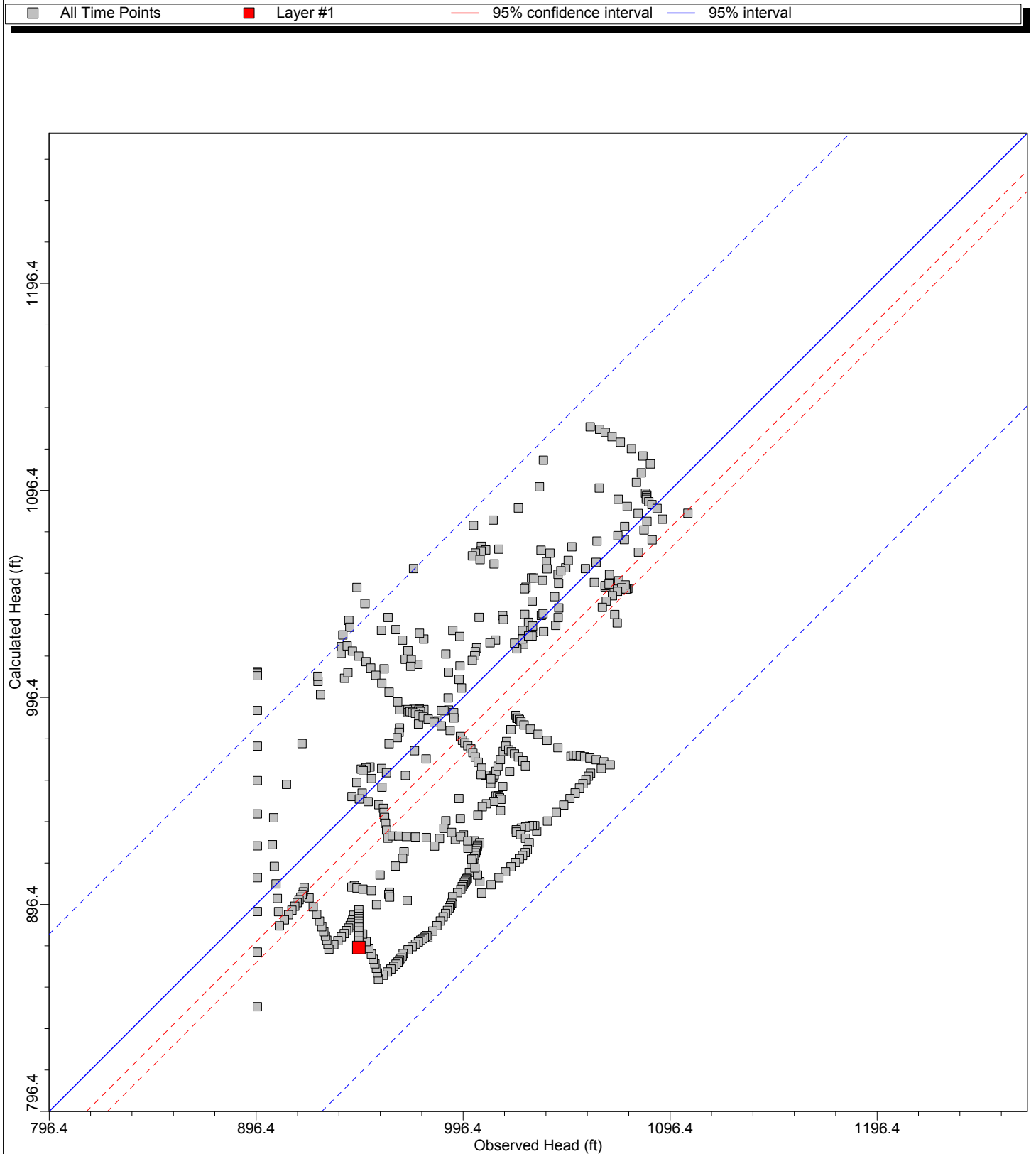


Num. of Data Points : 460
 Max. Residual: -196.514 (ft) at B_WELL/STATIC
 Min. Residual: -0.588 (ft) at B_WELL/STATIC
 Residual Mean : -92.219 (ft)
 Abs. Residual Mean : 94.48 (ft)

Standard Error of the Estimate : 3.038 (ft)
 Root Mean Squared : 112.873 (ft)
 Normalized RMS : 209.937 (%)
 Correlation Coefficient : 0.43

31 Coldwater
 September 30, 2003
 SY = 6,8,9% varies N to S

Calculated vs. Observed Head : Time = 23 yr



Num. of Data Points : 460

Max. Residual: 111.822 (ft) at STATION_72/STATIC

Min. Residual: 0.335 (ft) at STATION_72/STATIC

Residual Mean : -23.049 (ft)

Abs. Residual Mean : 49.82 (ft)

Standard Error of the Estimate : 2.586 (ft)

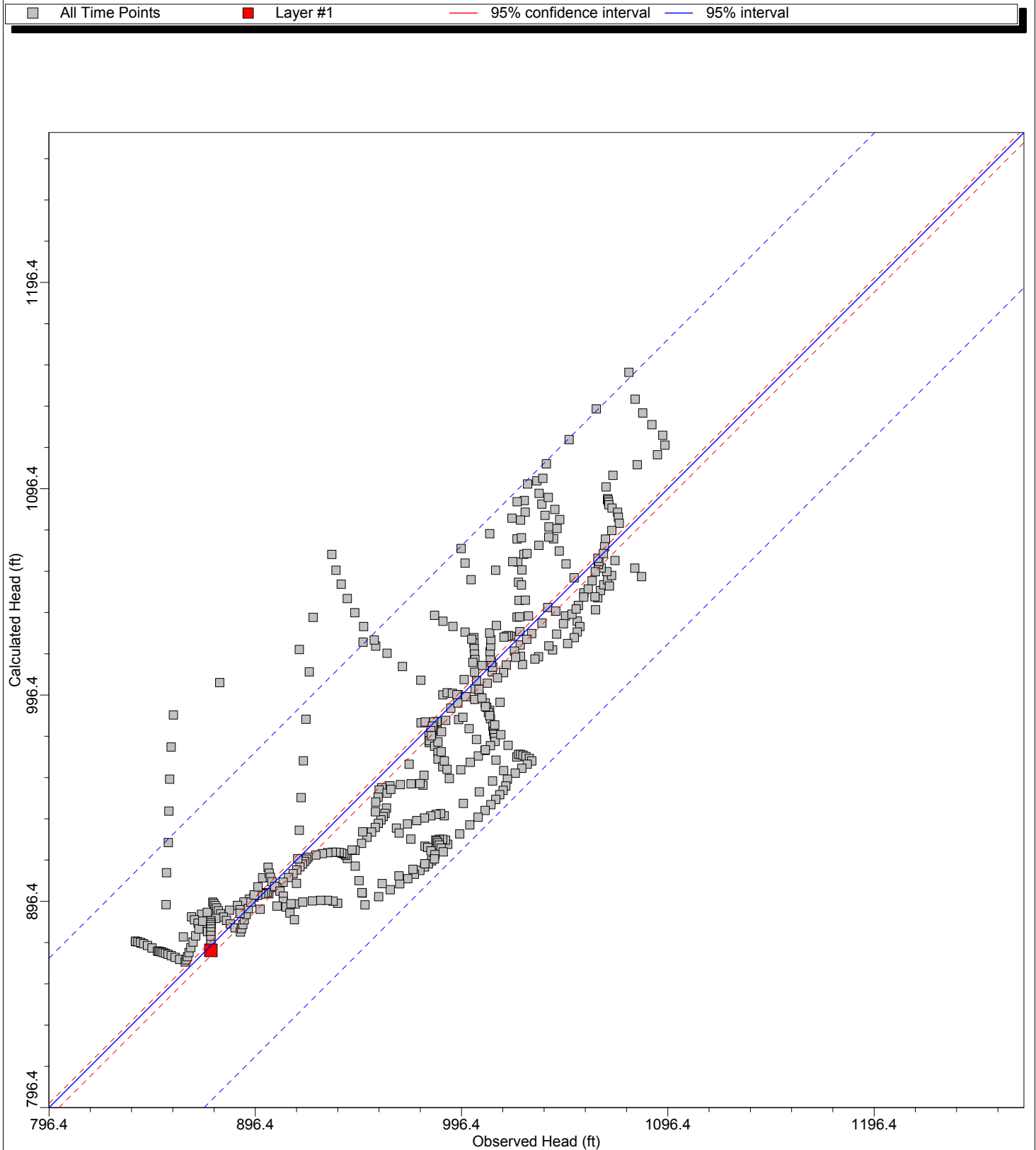
Root Mean Squared : 60.002 (ft)

Normalized RMS : 28.849 (%)

Correlation Coefficient : 0.581

31 Coldwater
September 30, 2003
SY = 6,8,9% varies N to S

Calculated vs. Observed Head : Time = 23 yr

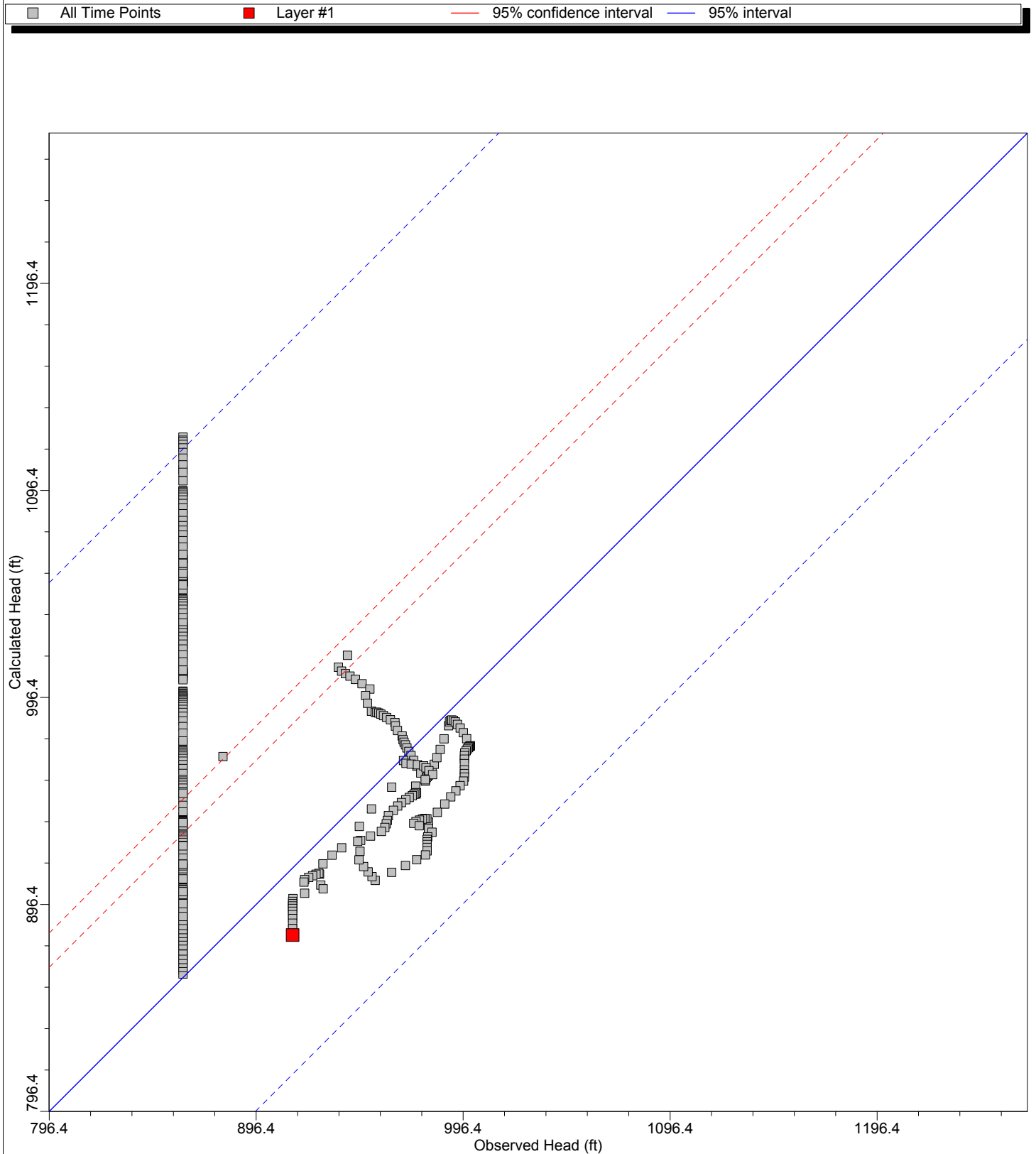


Num. of Data Points : 460
 Max. Residual: 131.085 (ft) at CORONA_#2/STATIC
 Min. Residual: -0.024 (ft) at CORONA_#2/STATIC
 Residual Mean : -1.403 (ft)
 Abs. Residual Mean : 27.838 (ft)

Standard Error of the Estimate : 1.755 (ft)
 Root Mean Squared : 37.633 (ft)
 Normalized RMS : 14.657 (%)
 Correlation Coefficient : 0.845

31 Coldwater
 September 30, 2003
 SY = 6,8,9% varies N to S

Calculated vs. Observed Head : Time = 23 yr



Num. of Data Points : 460

Max. Residual: 261.176 (ft) at MAYHEW_#2/STATIC

Min. Residual: 0.198 (ft) at MAYHEW_#2/STATIC

Residual Mean : 77.896 (ft)

Abs. Residual Mean : 91.644 (ft)

Standard Error of the Estimate : 4.223 (ft)

Root Mean Squared : 119.394 (ft)

Normalized RMS : 85.956 (%)

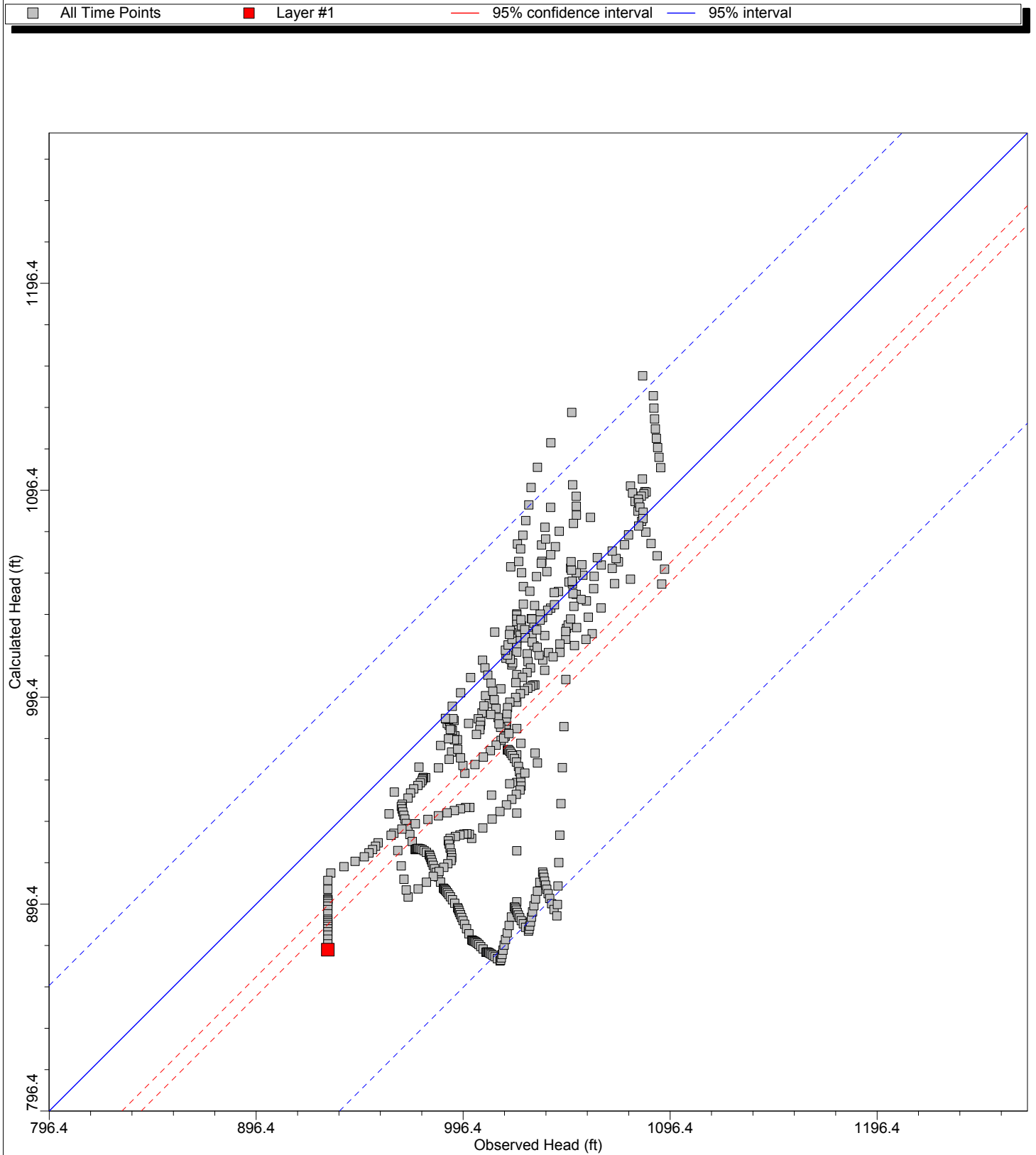
Correlation Coefficient : -0.198

31 Coldwater

September 30, 2003

SY = 6,8,9% varies N to S

Calculated vs. Observed Head : Time = 23 yr



Num. of Data Points : 460

Max. Residual: -150.955 (ft) at DIV_BOX_WELL/STATIC

Min. Residual: 0.082 (ft) at DIV_BOX_WELL/STATIC

Residual Mean : -39.807 (ft)

Abs. Residual Mean : 48.71 (ft)

Standard Error of the Estimate : 2.39 (ft)

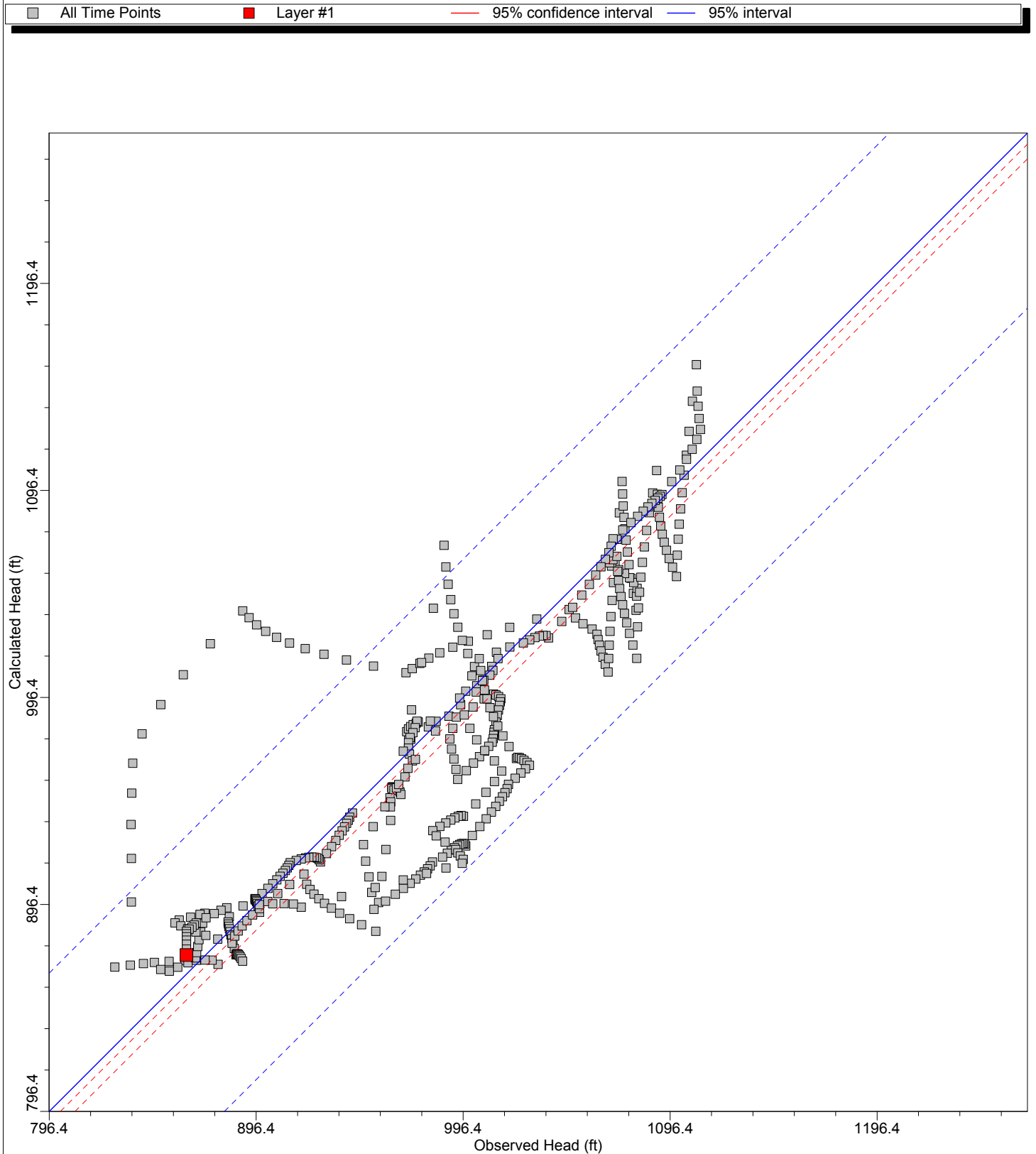
Root Mean Squared : 64.849 (ft)

Normalized RMS : 39.856 (%)

Correlation Coefficient : 0.697

31 Coldwater
September 30, 2003
SY = 6,8,9% varies N to S

Calculated vs. Observed Head : Time = 23 yr

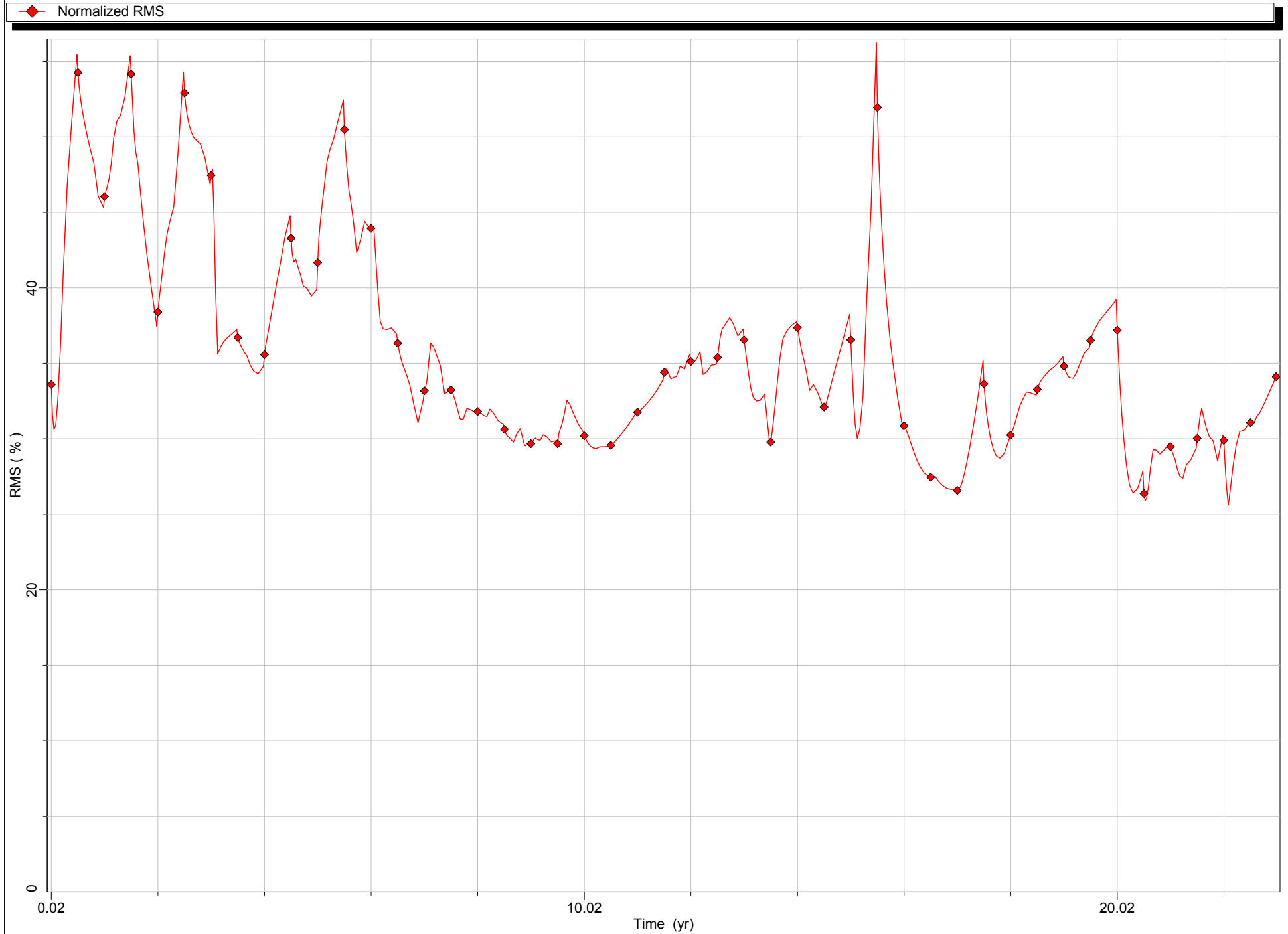


Num. of Data Points : 460
 Max. Residual: 148.267 (ft) at CORONA_#3/STATIC
 Min. Residual: -0.209 (ft) at CORONA_#3/STATIC
 Residual Mean : -8.919 (ft)
 Abs. Residual Mean : 27.483 (ft)

Standard Error of the Estimate : 1.801 (ft)
 Root Mean Squared : 39.6 (ft)
 Normalized RMS : 13.993 (%)
 Correlation Coefficient : 0.861

31 Coldwater
 September 30, 2003
 SY = 6,8,9% varies N to S

Normalized RMS vs. Time [Head]



31 Coldwater-No Mayhew underflow
Sept 30, 2003
SY = 6,8,9% varies N to S

Appendix B

Groundwater Model Results

Figure B - 9
Mayhew #2

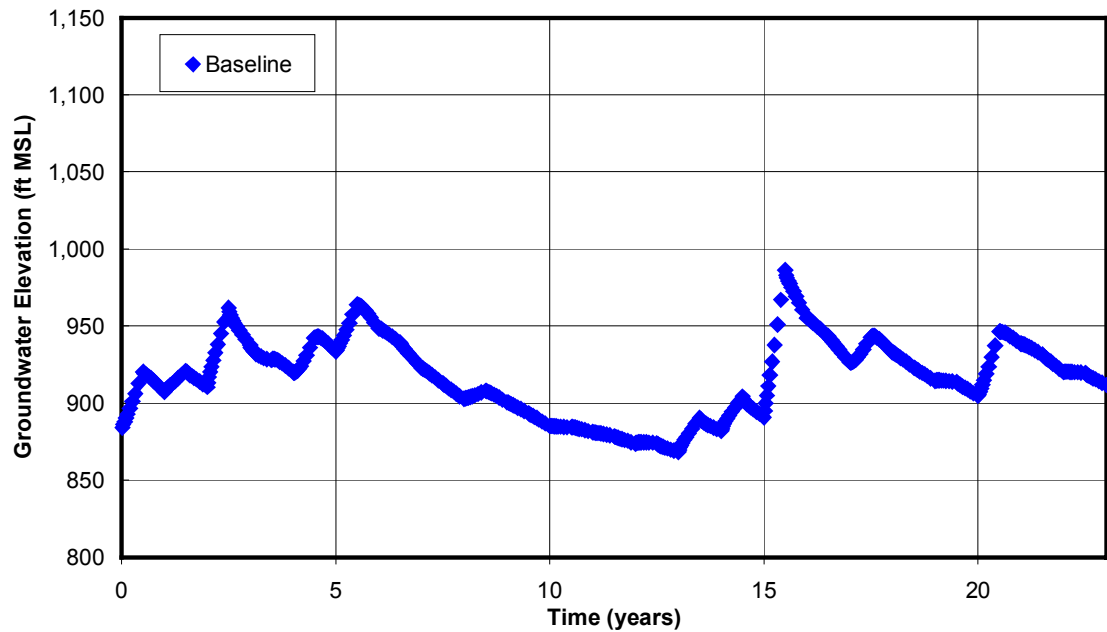
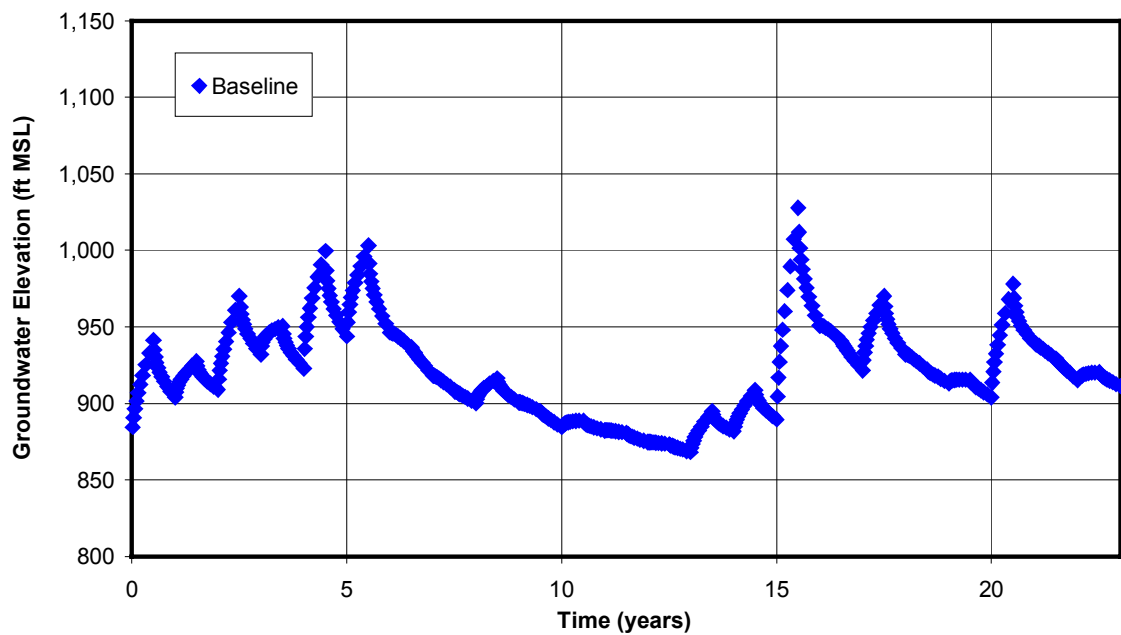


Figure B - 10
Corona #1



Appendix B

Groundwater Model Results

Figure B - 11
Corona #2

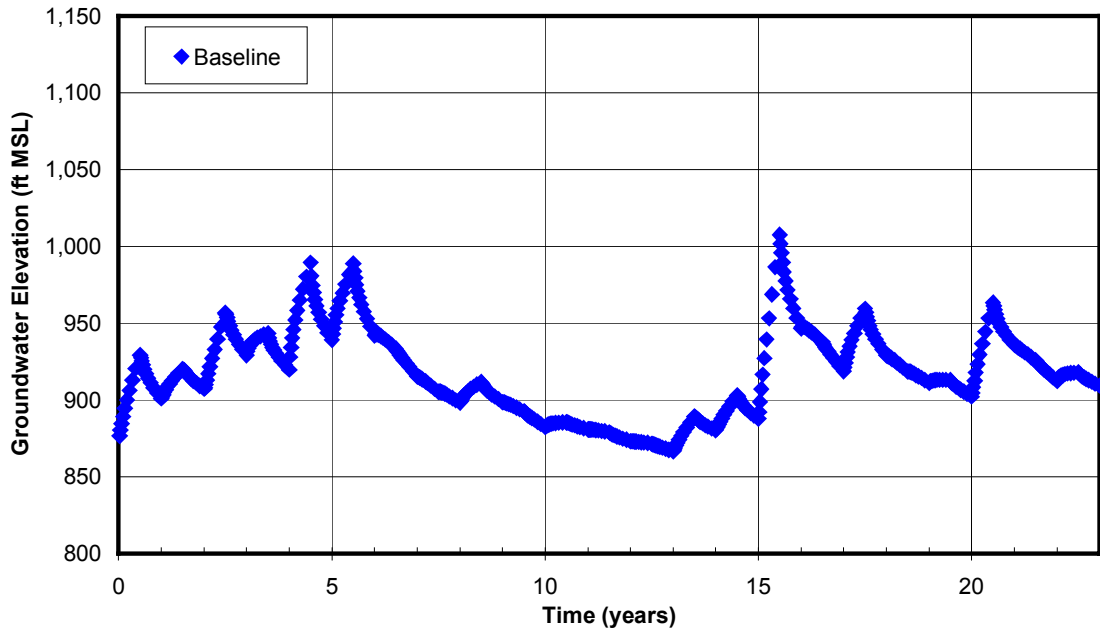
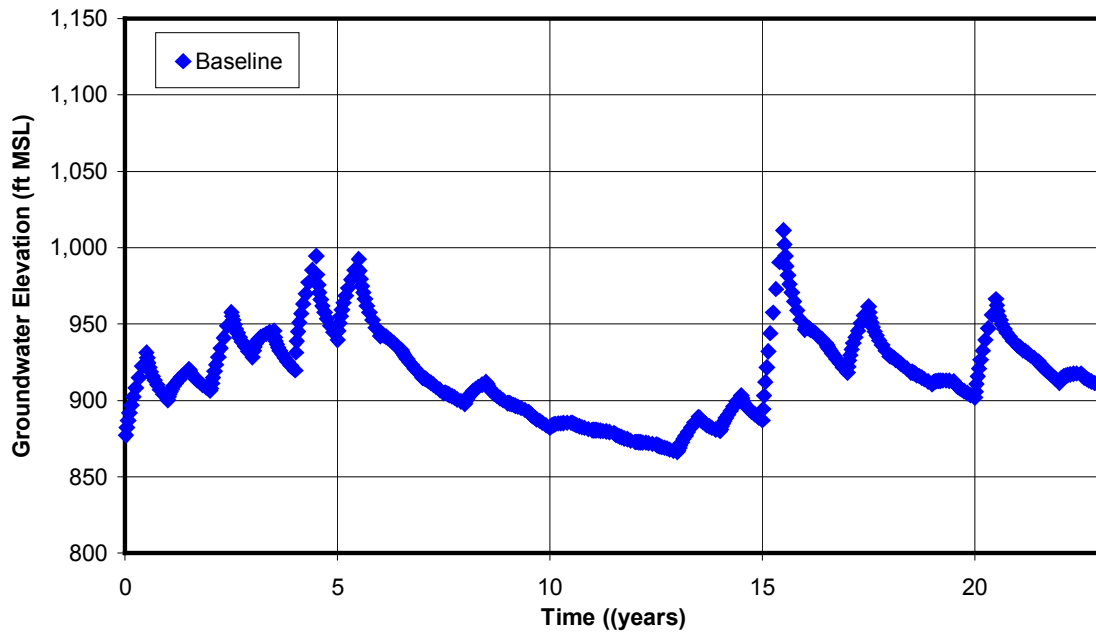


Figure B - 12
Corona #3



Appendix B

Groundwater Model Results

Figure B - 13
B Well

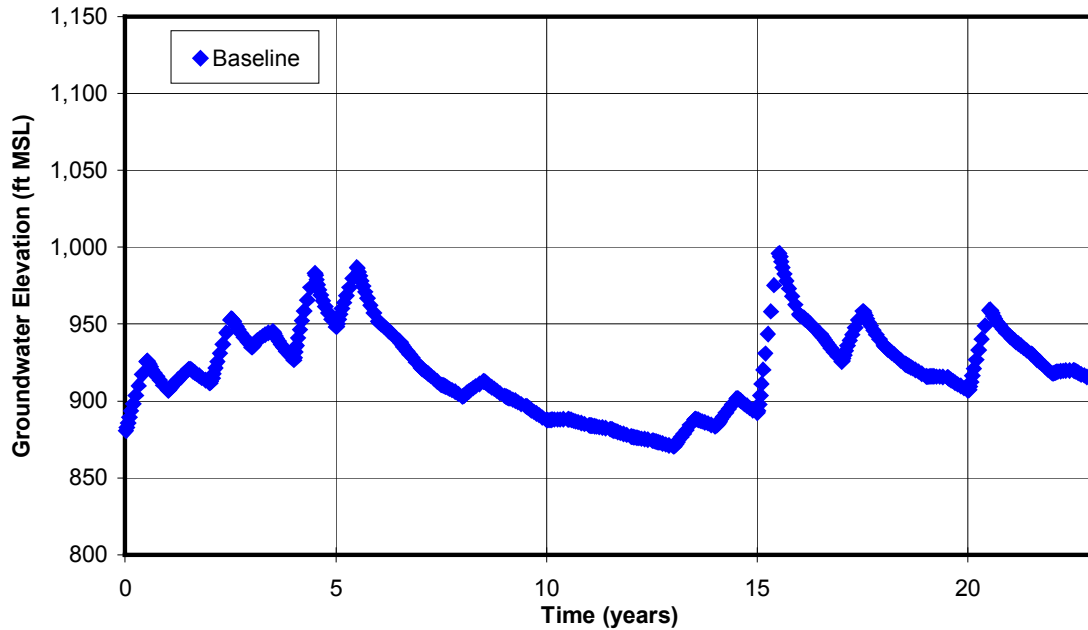
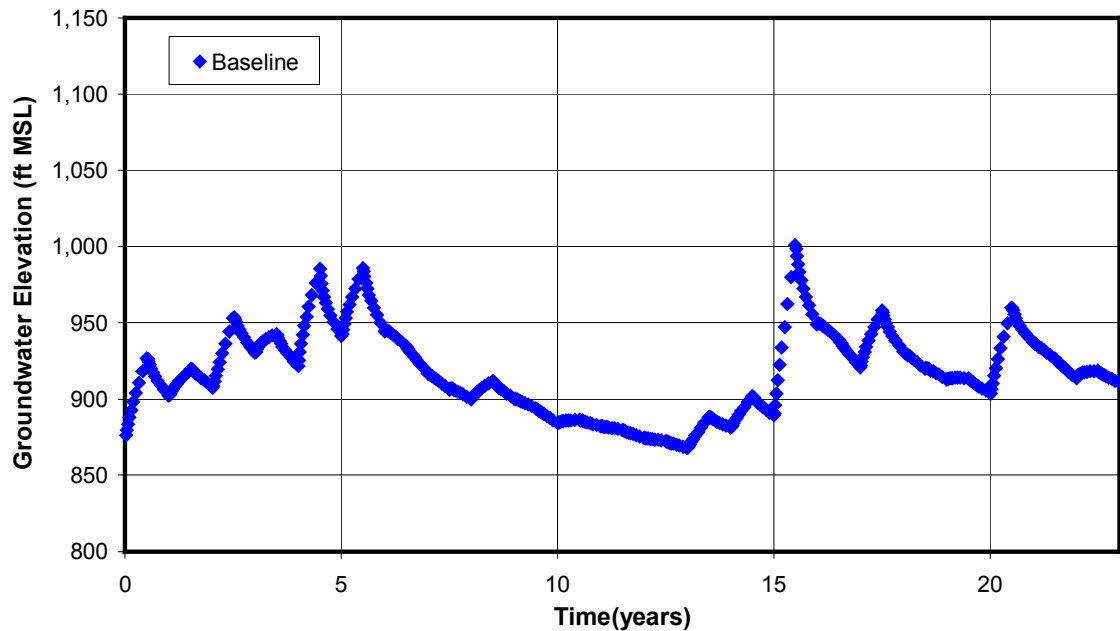


Figure B - 14
Division Box



Appendix B

Groundwater Model Results

Figure B - 15
Station 71

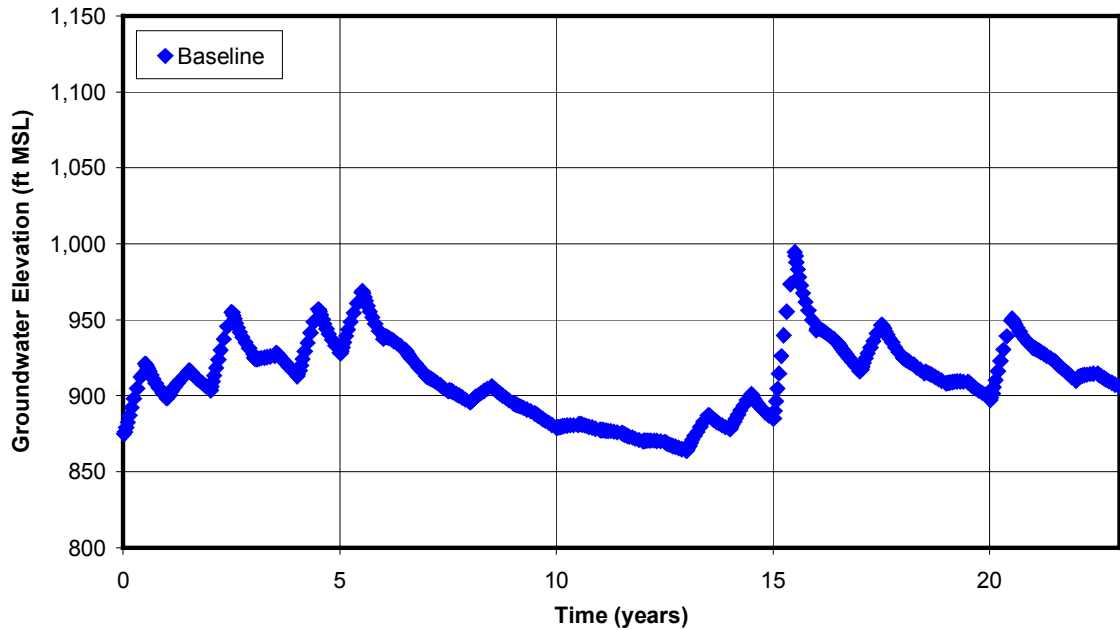
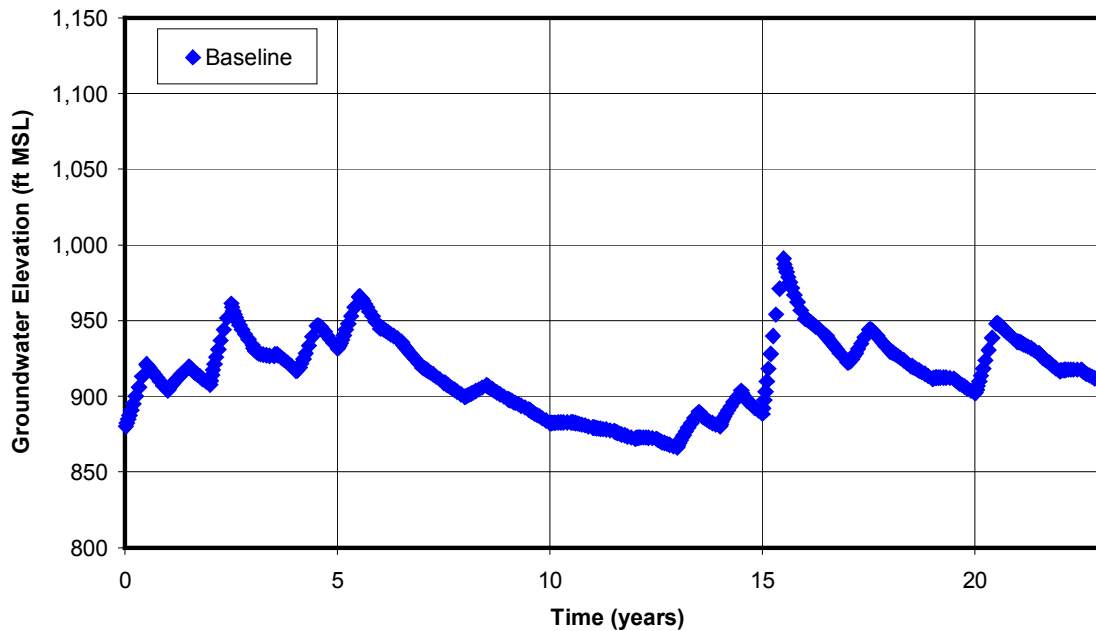


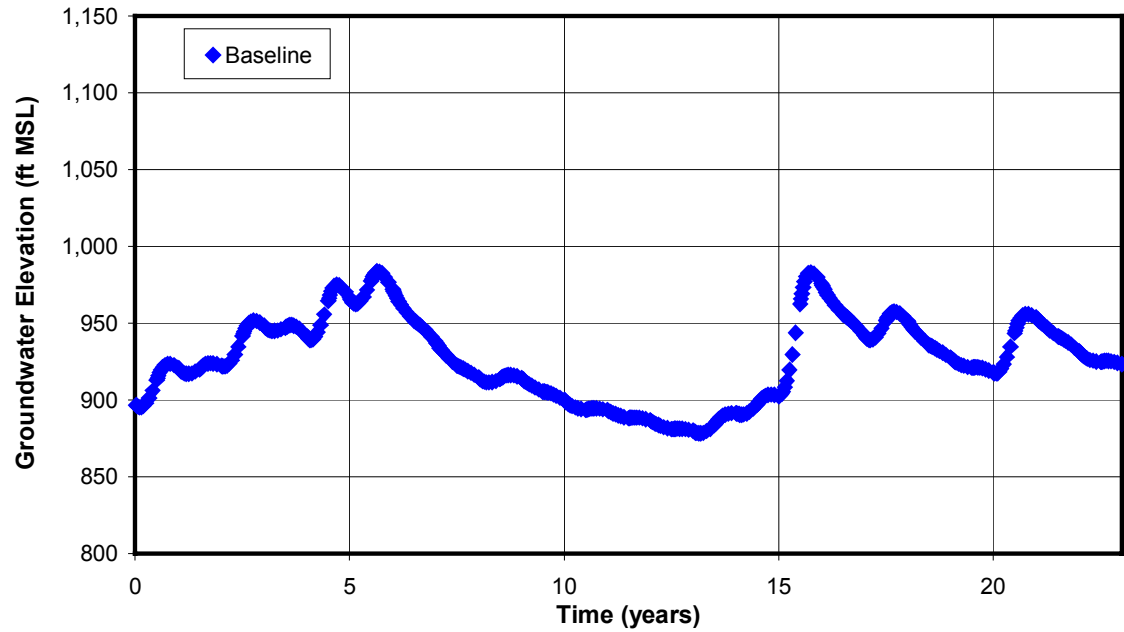
Figure B - 16
Station 72



Appendix B

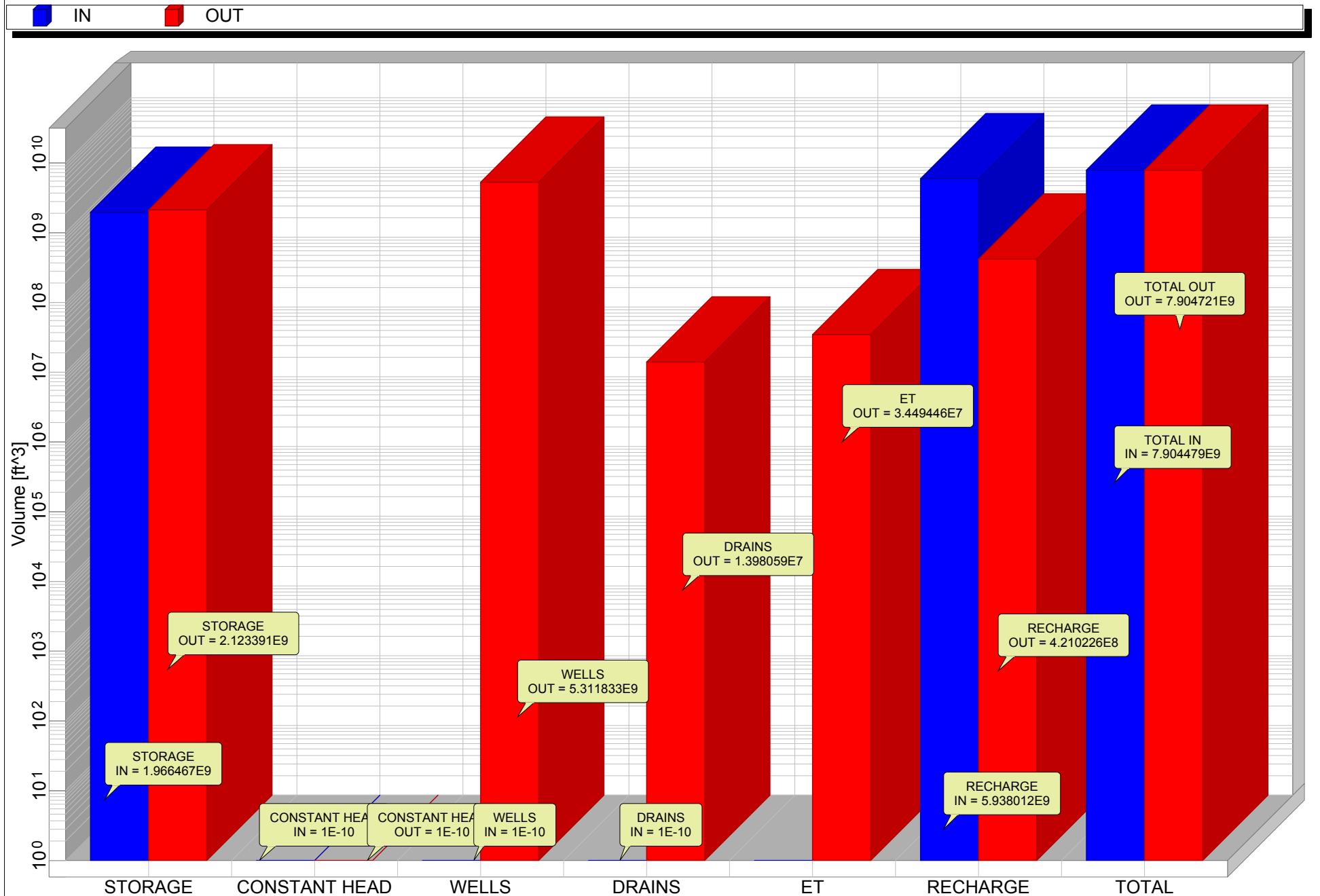
Groundwater Model Results

Figure B - 17
Corona South



Coldwater Baseline Model Mass Balance

Time = 23 Years



Baseline Mass Balance
Time = 23 Years

MWH

Coldwater Groundwater Model
Date: 10/09/2003

Appendix B

Groundwater Model Results

Figure B - 18
Mayhew #2

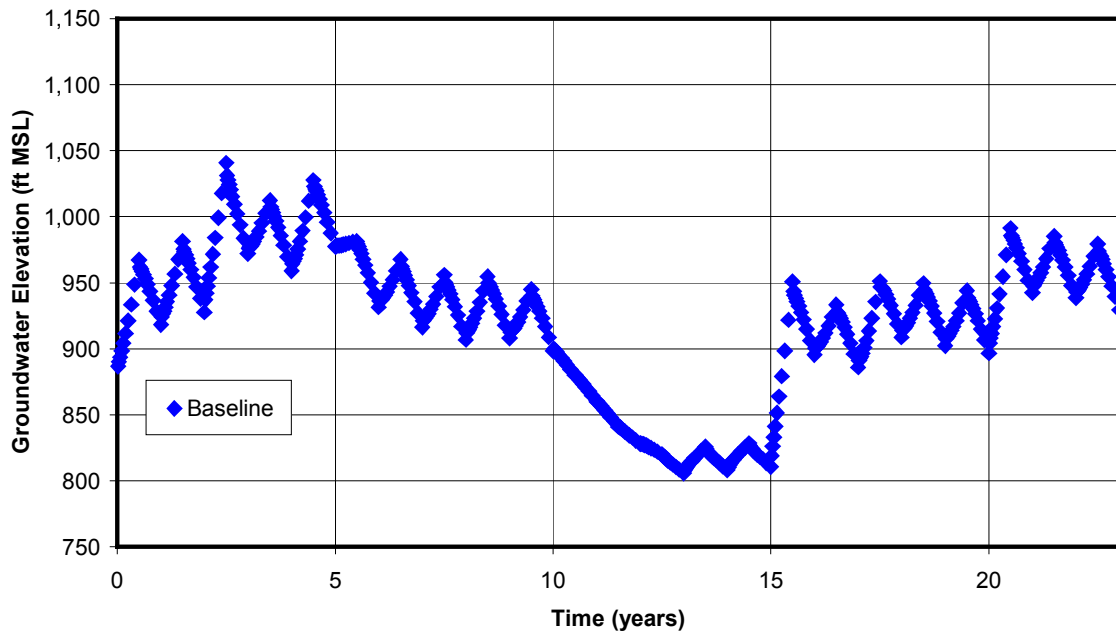
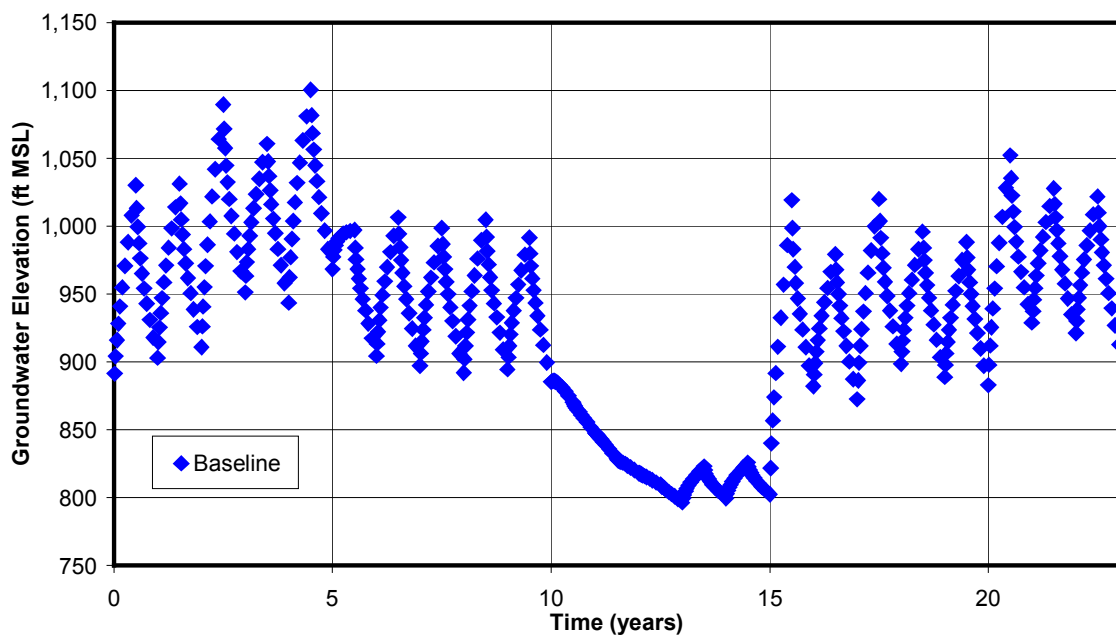


Figure B - 19
Corona #1



Appendix B

Groundwater Model Results

Figure B - 20
Corona #2

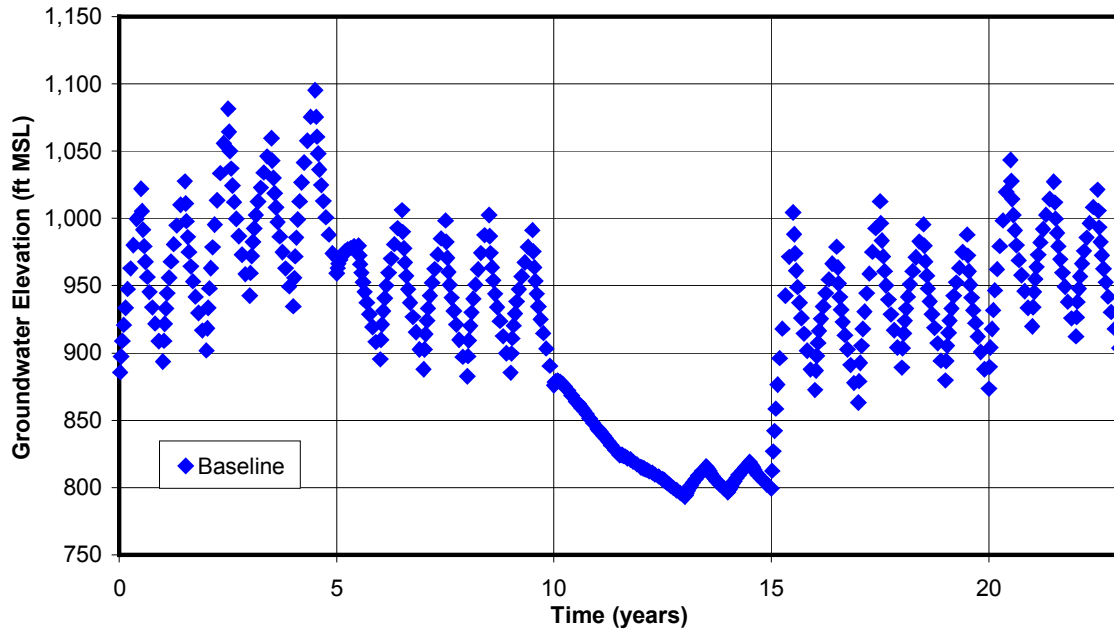
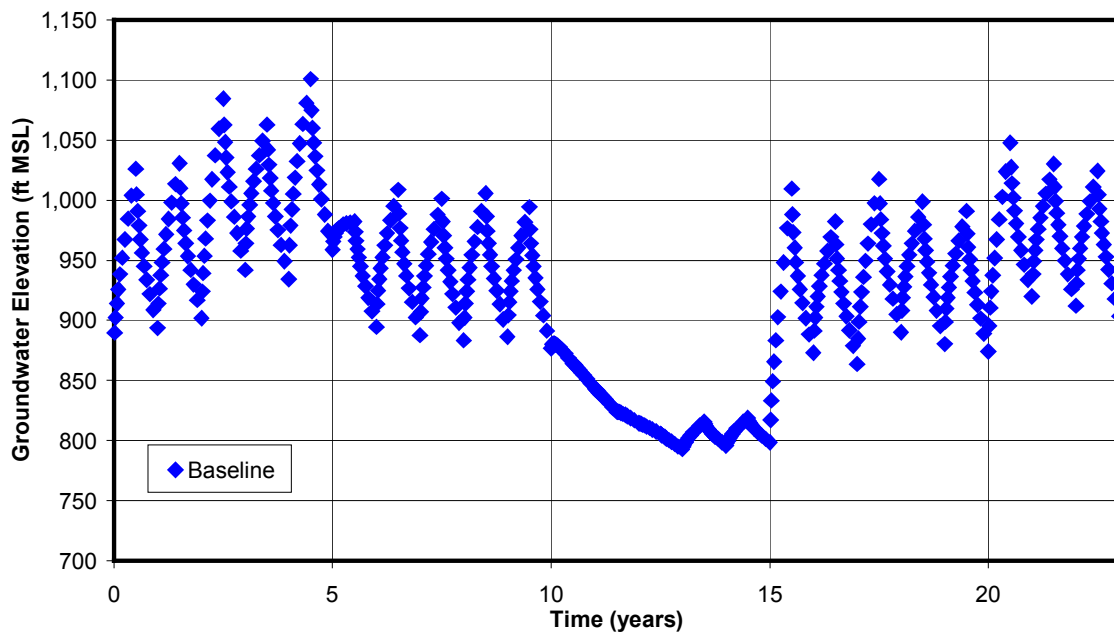


Figure B - 21
Corona #3



Appendix B

Groundwater Model Results

Figure B - 22
B Well

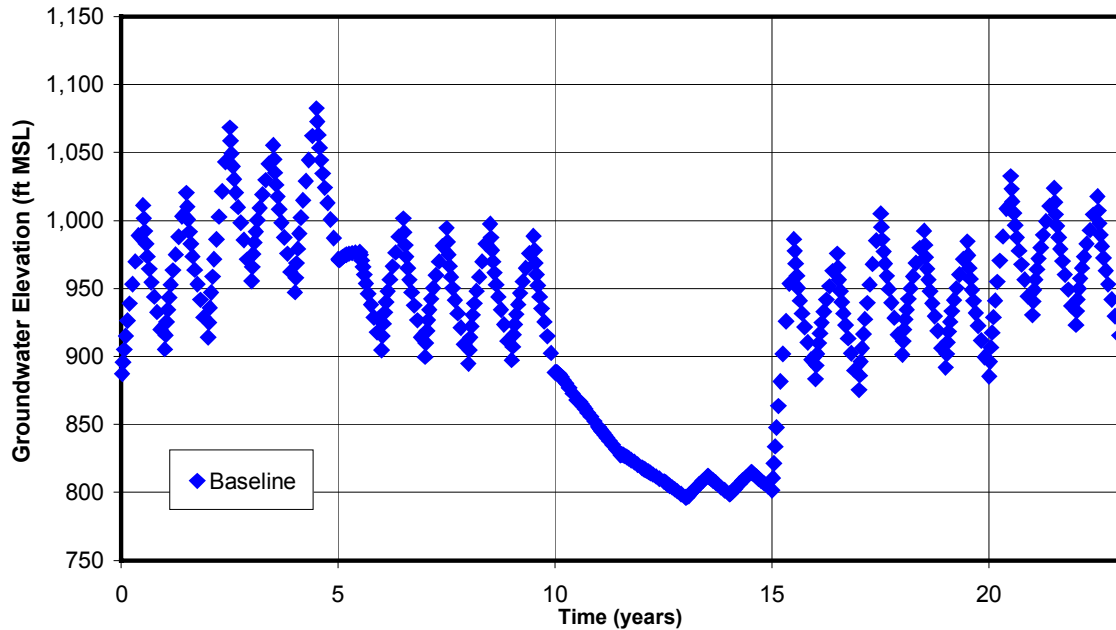
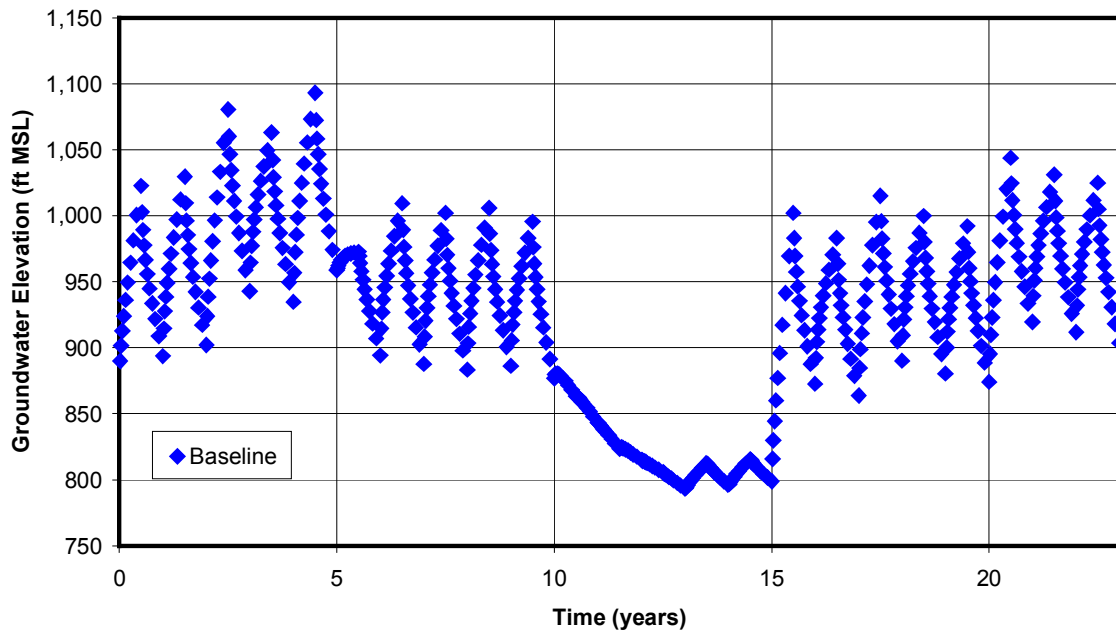


Figure B - 23
Division Box



Appendix B

Groundwater Model Results

Figure B - 24
Station 71

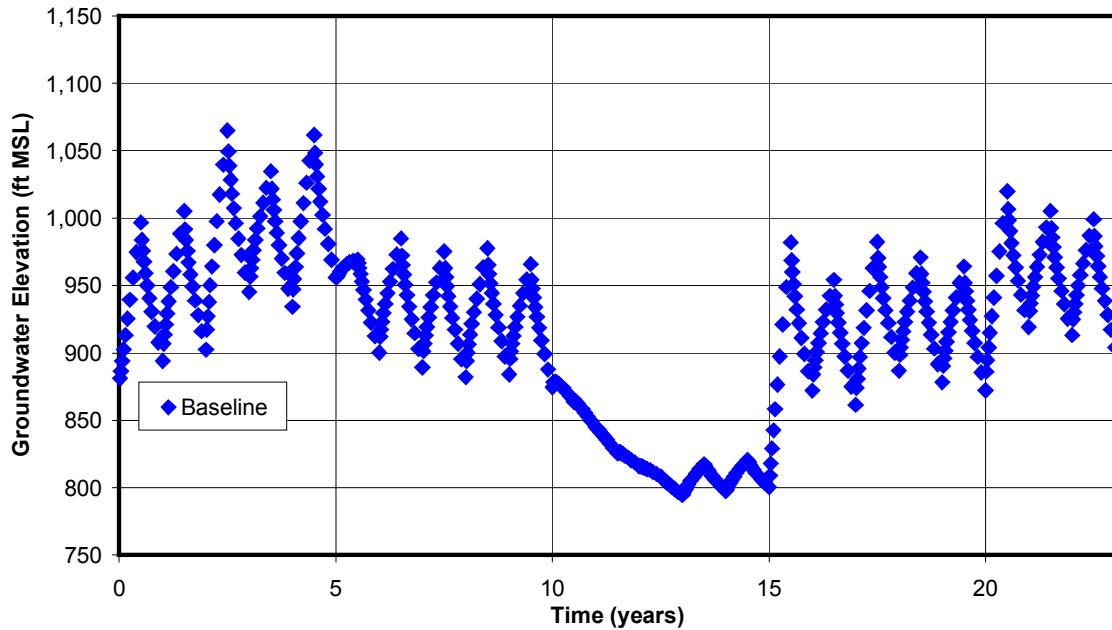
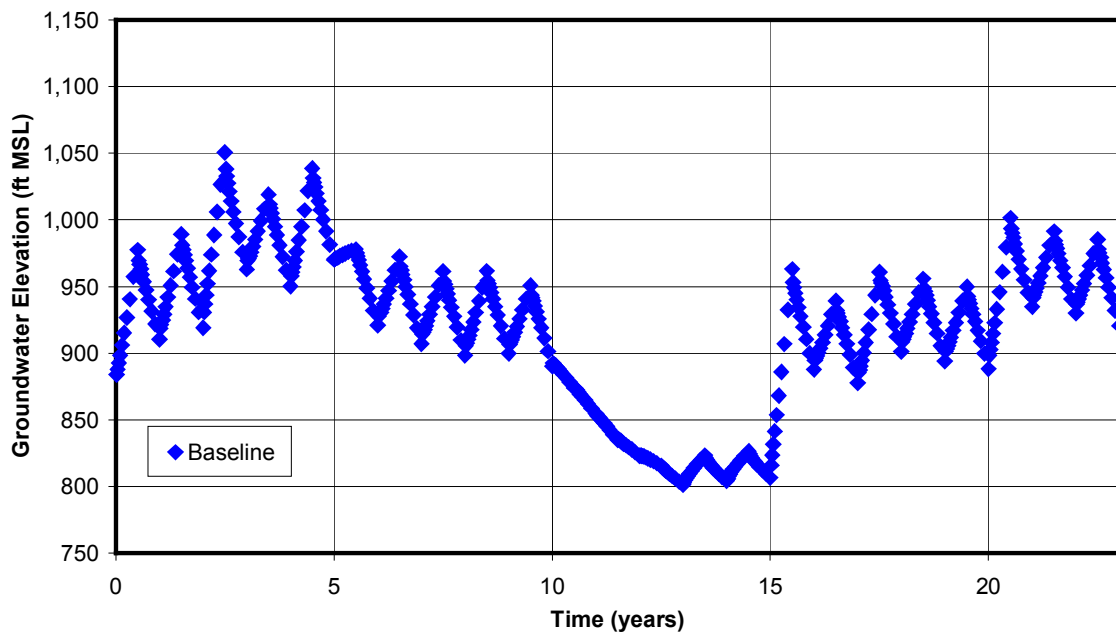


Figure B - 25
Station 72



Appendix B

Groundwater Model Results

Figure B - 26
Corona South

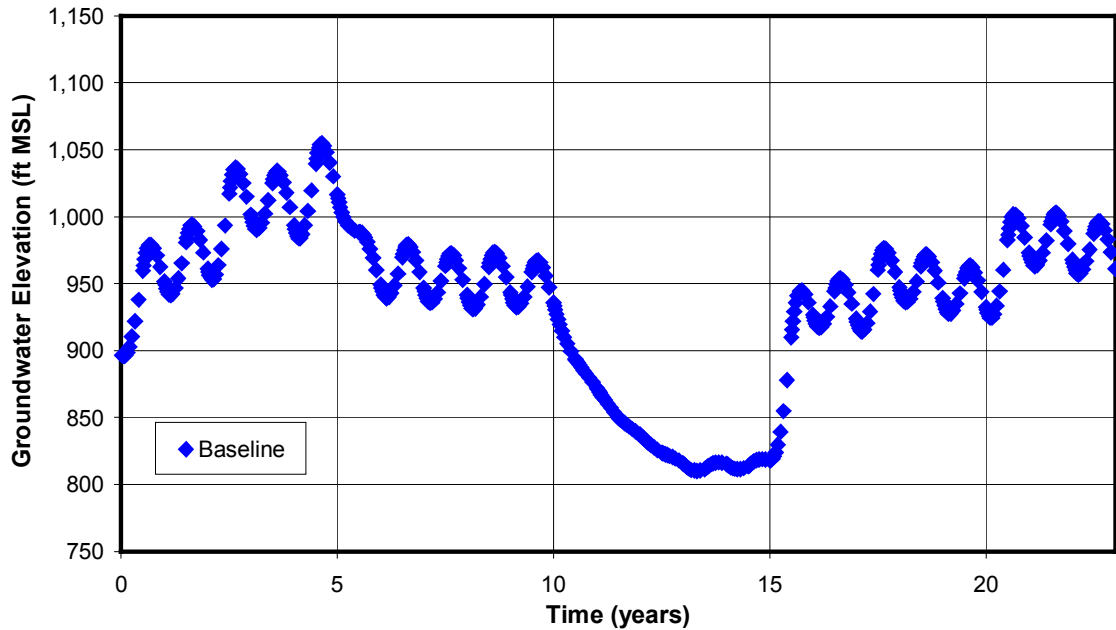
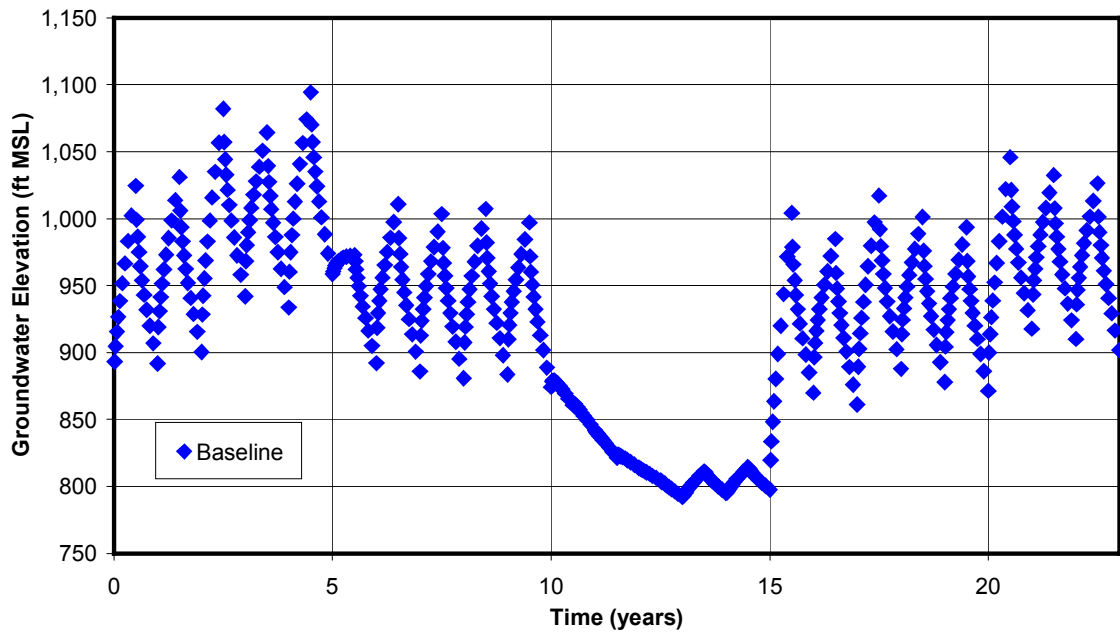


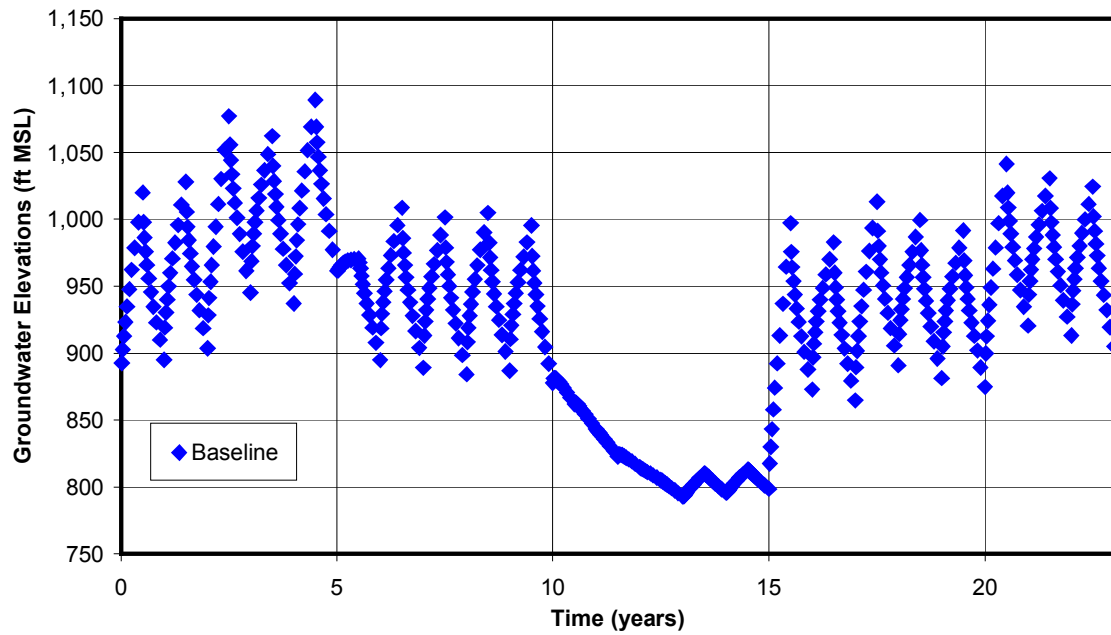
Figure B - 27
Injection 1



Appendix B

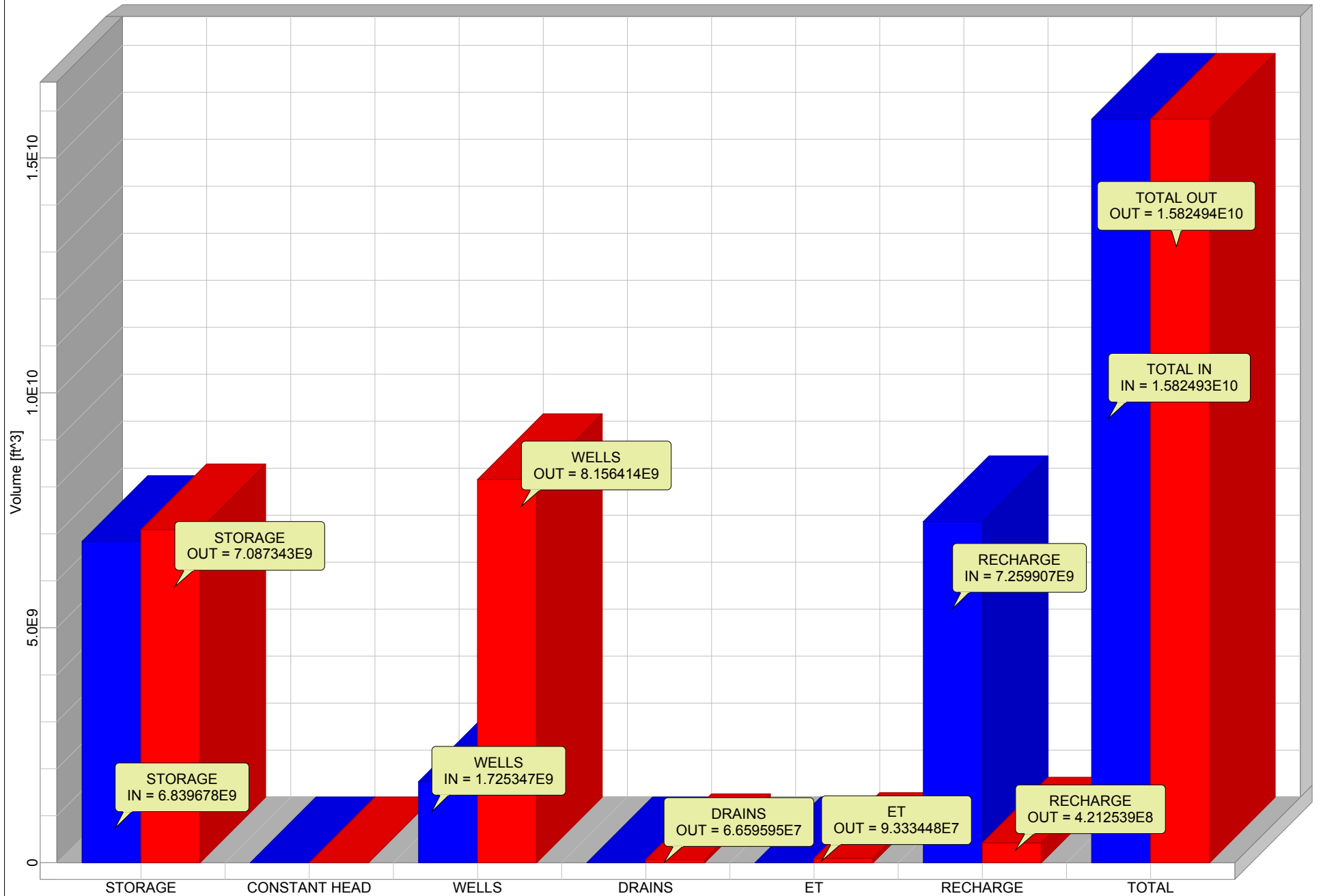
Groundwater Model Results

Figure B - 28
Injection 2



Time = 23

IN OUT



Appendix B

Groundwater Model Results

Figure B - 29
Mayhew #2

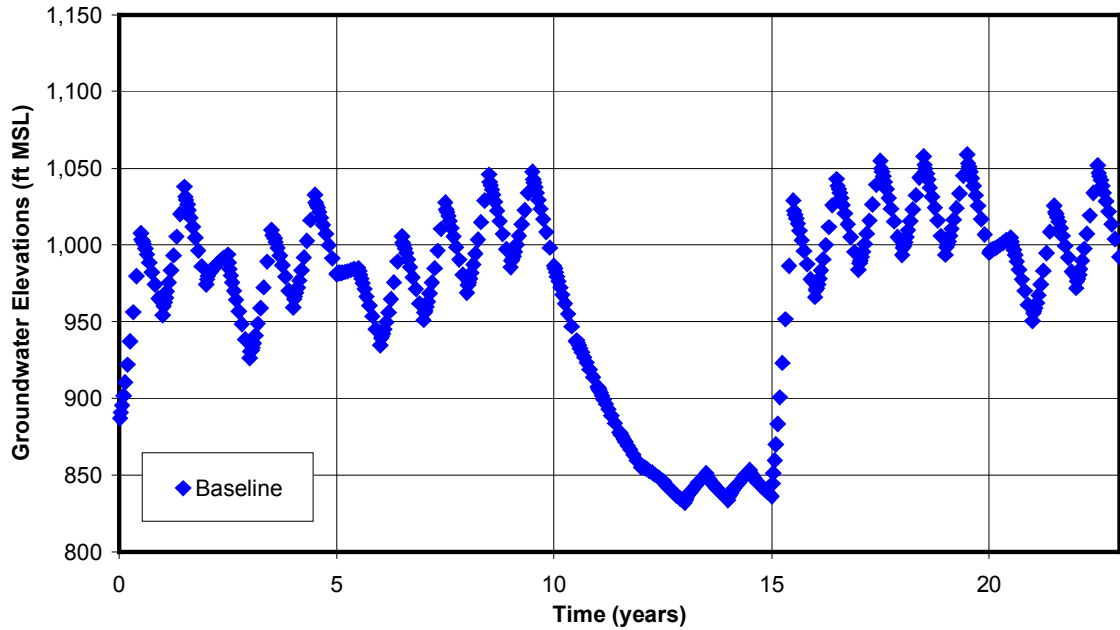
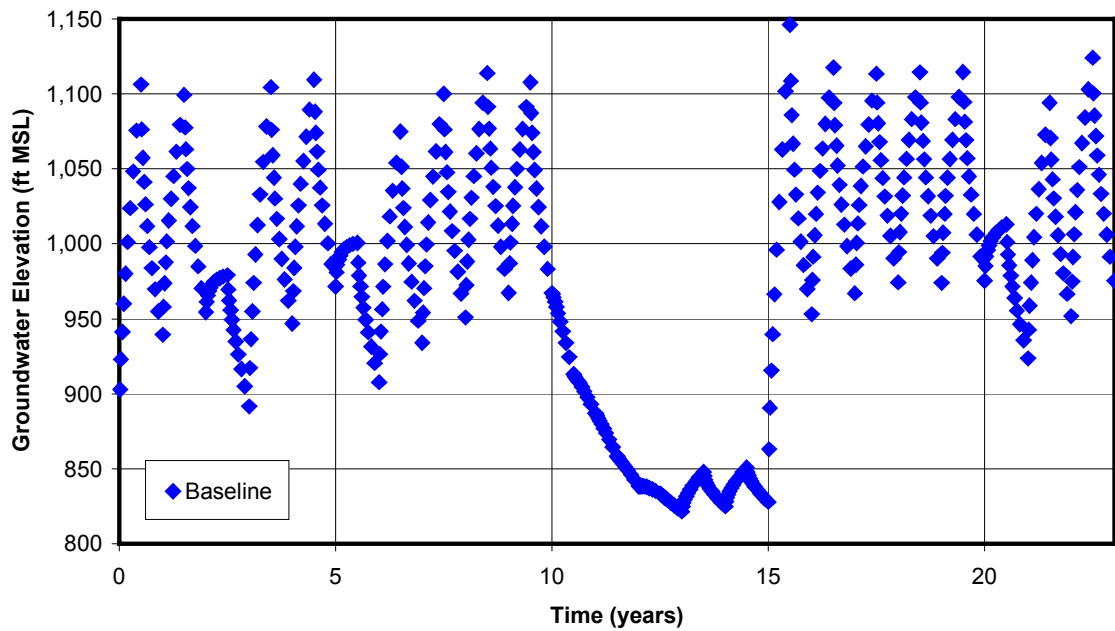


Figure B - 30
Corona #1



Appendix B

Groundwater Model Results

Figure B - 31
Corona #2

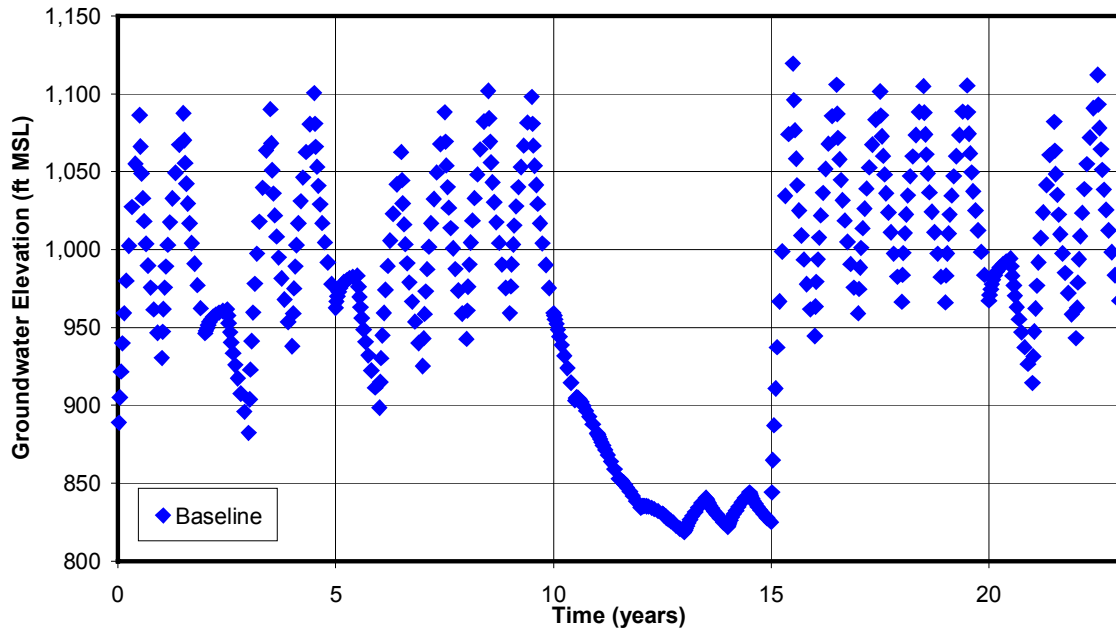
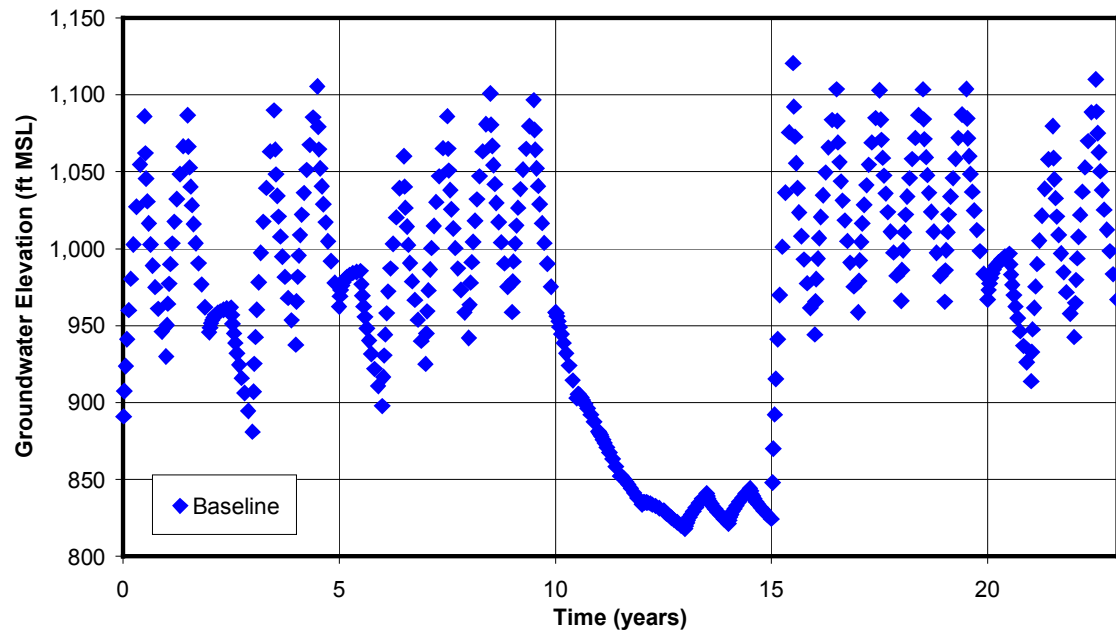


Figure B - 32
Corona #3



Appendix B

Groundwater Model Results

Figure B - 33
B Well

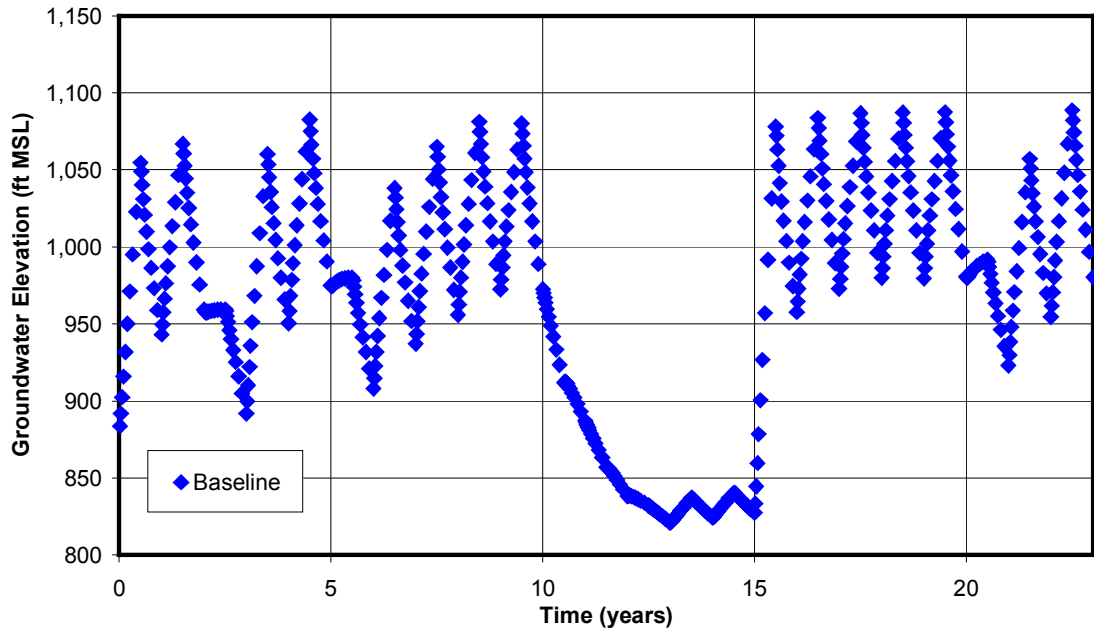
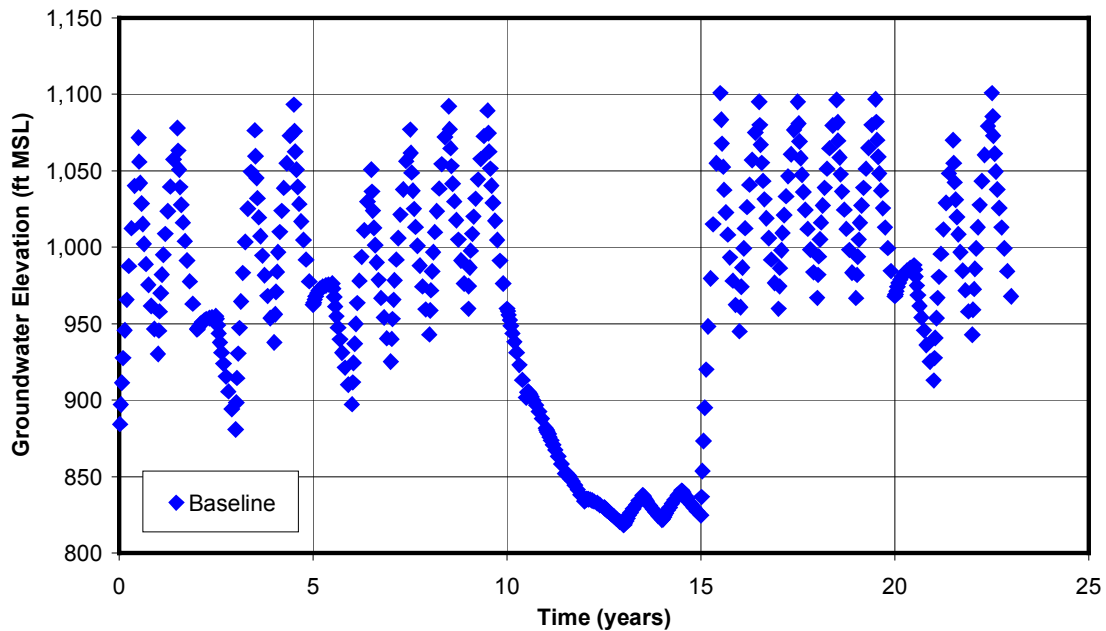


Figure B - 34
Division Box



Appendix B

Groundwater Model Results

Figure B- 35
Station 71

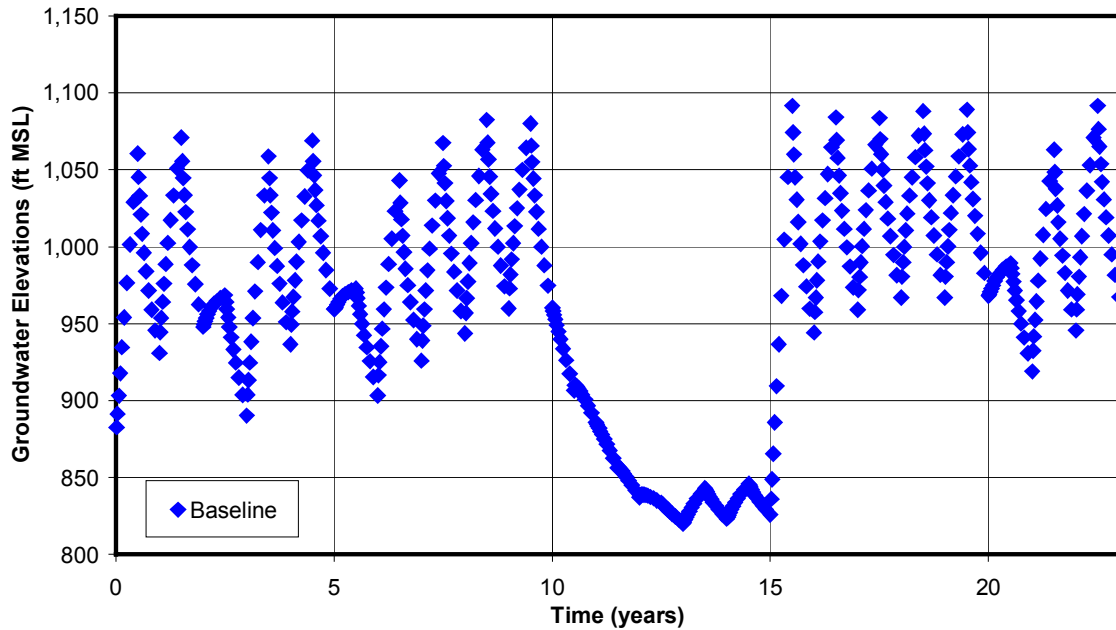
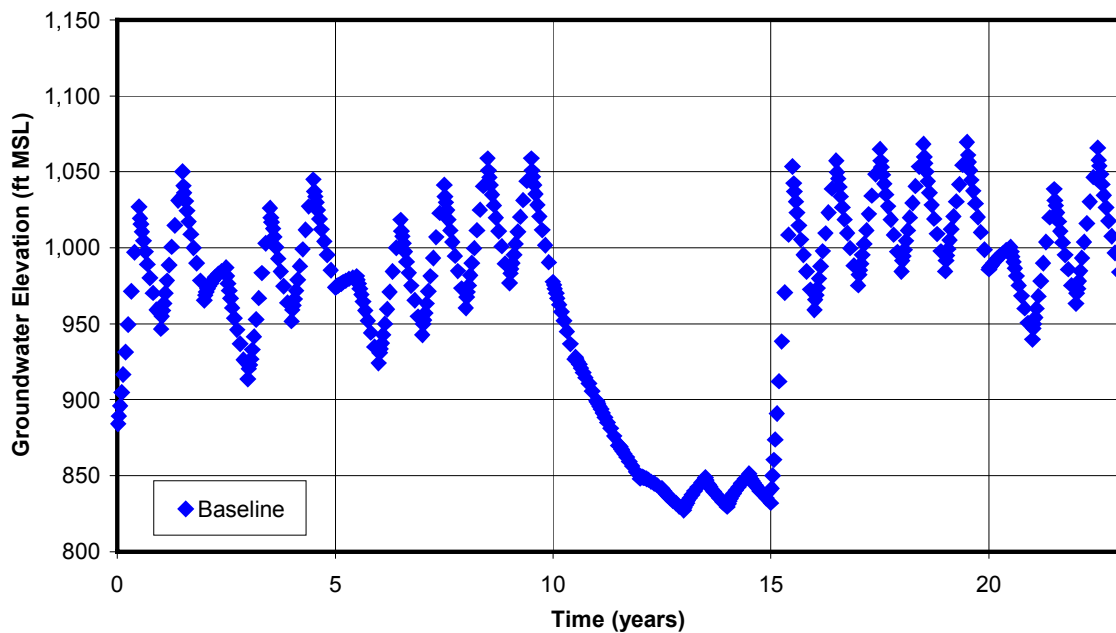


Figure B- 36
Station 72



Appendix B

Groundwater Model Results

Figure B – 37
Corona South

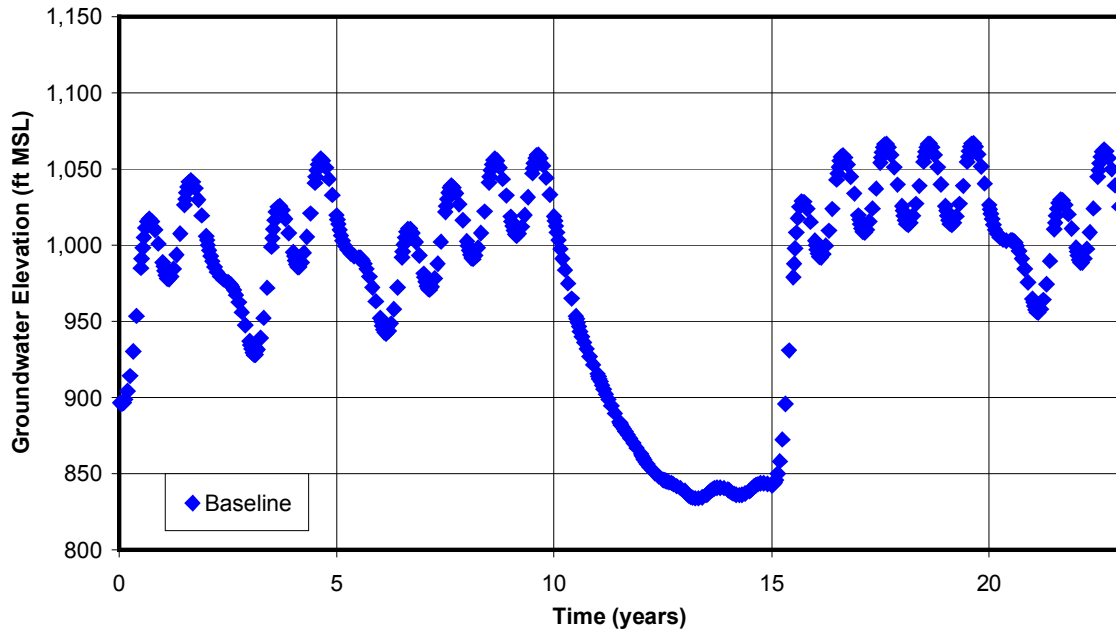
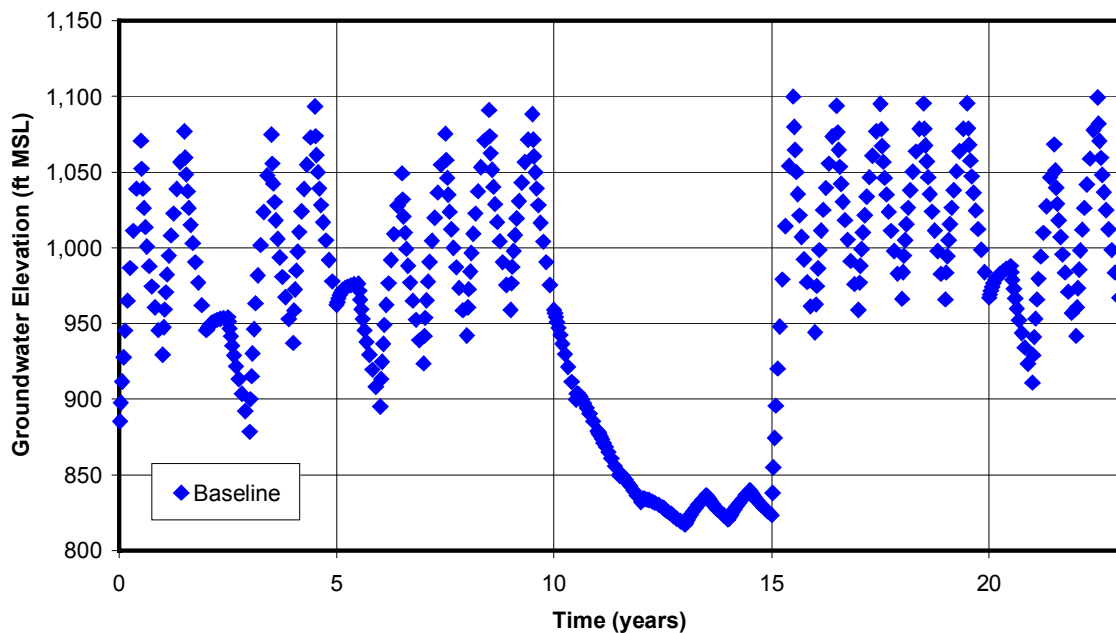


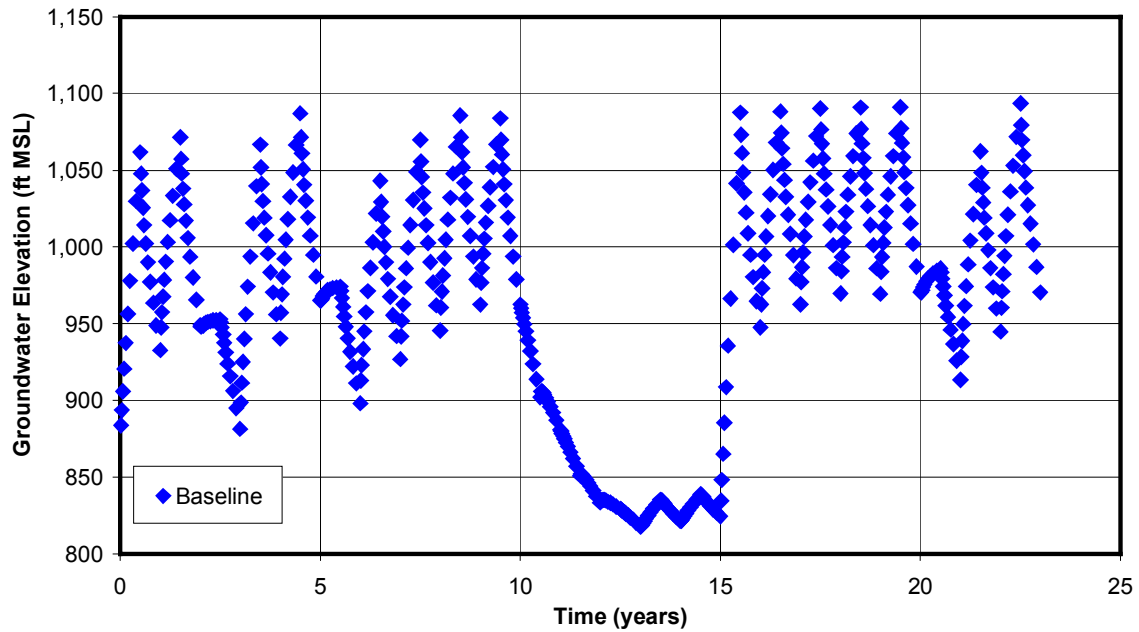
Figure B – 38
Injection 1



Appendix B

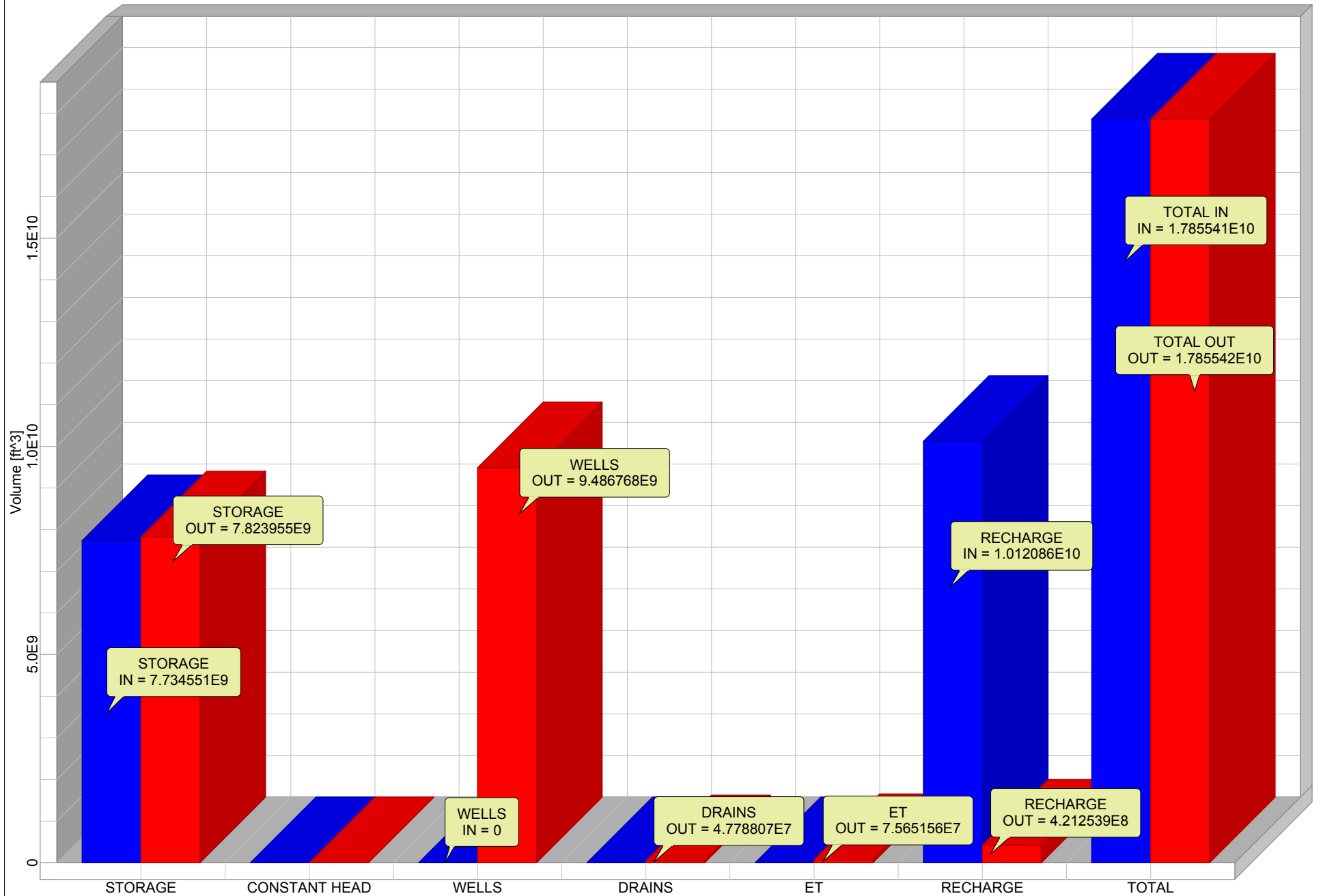
Groundwater Model Results

Figure B - 39
Injection 2



Time = 23

IN OUT



Appendix C

Cost Estimates

Baseline

Capital Cost

Item	Number	Unit	Unit Capital Cost	Total Capital Cost	Depreciation Period (yrs)	Annual Capital Cost
This alternative has no capital costs.						
Total				\$ -		\$ -

O & M Costs

Item	Quantity	Unit	Unit Cost	Annual Cost
Groundwater Pumping	5,302	acre-feet/yr	\$ 66	\$ 352,000
Purchase of MWD Water for Surface Spreading	0	acre-feet/yr	\$ 300	\$ -
Purchase of MWD Water for Injection	0	acre-feet/yr	\$ 300	\$ -
Maintenance of Surface Spreading Ponds or Pits	0	acre-feet/yr	\$ 10	\$ -
Pumping Cost of Imported Water to Injection Wells	0	acre-feet/yr	\$ 70	\$ -
Pumping Cost of Imported Water to Spreading Basins	0	acre-feet/yr	\$ 70	\$ -
Treatment Cost	0	acre-feet/yr	\$ 25	\$ -
Total				\$ 352,000

Unit Cost per Acre-foot - Alternative 2

Item	Annual Cost	Water Supply (acre-feet/yr)	Water Supply Cost (\$/acre-foot)
Capital Cost	\$ -		
O & M Cost	\$ 352,000		
Total	\$ 352,000	5,302	\$ 66

Appendix C - Cost Estimates

Alternative 1 - Dual Purpose Wells and Recharge Basins

Capital Cost

Item	Number	Unit	Unit Capital Cost	Total Capital Cost	Depreciation Period (yrs)	Annual Capital Cost
Dual Purpose Injection Wells						
Dual purpose injection well	2	wells	\$ 786,000	\$ 1,572,000	75	\$ 41,000
Conversion of existing wells	3	wells	\$ 163,000	\$ 489,000	75	\$ 13,000
8-inch diameter pipeline (A-A2)	1	pipelines	\$ 137,000	\$ 137,000	40	\$ 6,000
24-inch diameter pipeline (A-B)	1	pipelines	\$ 549,000	\$ 549,000	40	\$ 21,000
18-inch diameter pipeline (B-B2)	1	pipelines	\$ 135,000	\$ 135,000	40	\$ 5,000
8-inch diameter pipeline (B2-B3)	1	pipelines	\$ 36,000	\$ 36,000	40	\$ 2,000
18-inch diameter pipeline (B2-B4)	1	pipelines	\$ 111,000	\$ 111,000	40	\$ 5,000
16-inch diameter pipeline (B4-D)	1	pipelines	\$ 73,000	\$ 73,000	40	\$ 3,000
10-inch diameter pipeline (D-E)	1	pipelines	\$ 67,000	\$ 67,000	40	\$ 3,000
10-inch diameter pipeline (D-F)	1	pipelines	\$ 132,000	\$ 132,000	40	\$ 5,000
Spreading Basins						
18-inch diameter pipeline (B-C)	1	pipelines	\$ 748,000	\$ 748,000	40	\$ 28,000
Total				\$ 4,049,000		\$ 132,000

O & M Costs

Item	Quantity	Unit	Unit Cost	Annual Cost
Groundwater Pumping	8,155	acre-feet/yr	\$ 70	\$ 572,000
Purchase of MWD Water for Surface Spreading	1,313	acre-feet/yr	\$ 300	\$ 394,000
Purchase of MWD Water for Injection	1,716	acre-feet/yr	\$ 300	\$ 515,000
Maintenance of Surface Spreading Ponds	1,313	acre-feet/yr	\$ 10	\$ 14,000
Pumping Cost of Imported Water to Injection Wells	1,716	acre-feet/yr	\$ -	\$ -
Pumping Cost of Imported Water to Spreading Basins	1,313	acre-feet/yr	\$ -	\$ -
Treatment Cost		acre-feet/yr	\$ 25	\$ -
Total				\$ 1,495,000

Unit Cost per Acre-foot - Alternative 1

Item	Annual Cost	Water Supply (acre-feet/yr)	Water Supply Cost (\$/acre-foot)
Capital Cost	\$ 132,000		
O & M Cost	\$ 1,495,000		
Total	\$ 1,627,000	8,155	\$ 199

Appendix C - Cost Estimates

Alternative 2 - Gravel Pits

Capital Cost

Item	Number	Unit	Unit Capital Cost	Total Capital Cost	Depreciation Period (yrs)	Annual Capital Cost
Additional Extraction Wells						
New Extraction Wells	2	wells	\$ 786,000	\$ 1,572,000	75	\$ 41,000
36-inch diameter pipeline (A-B)	1	pipelines	\$ 808,000	\$ 808,000	40	\$ 30,000
16-inch diameter pipeline (B-D)	1	pipelines	\$ 369,000	\$ 369,000	40	\$ 14,000
10-inch diameter pipeline (D-E)	1	pipelines	\$ 67,000	\$ 67,000	40	\$ 3,000
10-inch diameter pipeline (D-F)	1	pipelines	\$ 132,000	\$ 132,000	40	\$ 5,000
Gravel Pits						
30-inch diameter pipeline (B-C)	1	pipelines	\$ 398,000	\$ 398,000	40	\$ 15,000
Total				\$ 3,346,000		\$ 108,000

O& M Costs

Item	Quantity	Unit	Unit Cost	Annual Cost
Groundwater Pumping	9,470	acre-feet/yr	\$ 64	\$ 609,000
Purchase of MWD Water for Surface Spreading	4,864	acre-feet/yr	\$ 300	\$ 1,460,000
Purchase of MWD Water for Injection	0	acre-feet/yr	\$ 300	\$ -
Maintenance of Surface Spreading Ponds or Pits	4,864	acre-feet/yr	\$ 10	\$ 49,000
Pumping Cost of Imported Water to Injection Wells	0	acre-feet/yr	\$ -	\$ -
Pumping Cost of Imported Water to Spreading Basins	4,864	acre-feet/yr	\$ -	\$ -
Treatment Cost	4,864	acre-feet/yr	\$ 25	\$ 122,000
Total				\$ 2,240,000

Unit Cost per Acre-foot - Alternative 2

Item	Annual Cost	Water Supply (acre-feet/yr)	Water Supply Cost (\$/acre-foot)
Capital Cost	\$ 108,000		
O & M Cost	\$ 2,240,000		
Total	\$ 2,348,000	9,470	\$ 248



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