AUGUST 17, 2004

HYDROGEOLOGIC REPORT
AQUIFER STORAGE AND RECOVERY PROJECT
SAN DIEGUITO BASIN
SAN DIEGO, CALIFORNIA

VOLUME I

PREPARED FOR:
OLIVENHAIN MUNICIPAL WATER DISTRICT

HARGIS + ASSOCIATES, INC.
HYDROGEOLOGY • ENGINEERING

HARGIS + ASSOCIATES, INC.
HYDROGEOLOGY • ENGINEERING
Mission City Corporate Center
2365 Northside Drive, Suite C-100
San Diego, CA 92108
Phone: 619.521.0165
Fax: 619.521.8580

25th Anniversary 2004

August 17, 2004

COURIER

Mr. Harry Ehrlich
Deputy General Manager
OLIVENHAIN MUNICIPAL WATER DISTRICT
1966 Olivenhain Road
Encinitas, CA 92024

Re: Hydrogeologic Report, San Dieguito Basin Aquifer Storage and Recovery Program

Dear Mr. Ehrlich:

Enclosed is one copy of the report titled:

Hydrogeologic Report
Aquifer Storage And Recovery Project
San Dieguito Basin
San Diego, California
Volume I

If you have any questions or comments, please contact us.

Sincerely,
HARGIS + ASSOCIATES, INC.

Michael A. Palmer, RG 5915, CHG 146
Principal Hydrogeologist
Project Manager

Roger A. Niemeyer, RG 3616, CHG 43
Principal Hydrogeologist
Technical Director

MAP/RAN/kal

Attachments

cc: Mr. George Briest, Olivenhain Municipal Water District
Mr. Jack White, White Environmental Consulting
Ms. Maya Rohr, Kleinfelder
Mr. Chris Johnson, Kleinfelder

689 l ehrlich 2004-1.kal

Other Offices:
Mesa, AZ
Tucson, AZ
Dallas, TX

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AQUIFER STORAGE AND RECOVERY PROJECT
SAN DIEGUITO BASIN
SAN DIEGO, CALIFORNIA

VOLUME I

TABLE OF CONTENTS

Section	Page
ACRONYMS AND ABBREVIATIONS	vi
EXECUTIVE SUMMARY	ES-1
1. 0 INTRODUCTION	1
1.1 PURPOSE	2
1.2 PREVIOUS INVESTIGATIONS	3
1.2.1 SDCWA PHASE I	3
1.2.2 SDCWA PHASE II	4
1.2.3 OLIVENHAIN MUNICIPAL WATER DISTRICT MONITORING PROGRAM	5
1.3 HYDROGEOLOGIC STUDY APPROACH	6
1.4 REPORT ORGANIZATION	6
2. 0 HYDROGEOLOGIC SETTING	8
2.1 OVERVIEW	8
2.2 REGIONAL GEOLOGY	8
2.3 LOCAL GEOLOGY	10
2.4 GROUNDWATER	11
2.5 SURFACE WATER	13
2.6 GROUNDWATER USE	14
3. 0 SUPPLEMENTAL HYDROGEOLOGIC INVESTIGATIONS	16
3.1 WATER LEVEL MONITORING	16
3.2 GROUNDWATER SAMPLING	20
3.3 SAN DIEGUITO RIVER MONITORING	22
3.4 GEOCHEMICAL EVALUATION	23
3.5 AQUIFER TESTING	24
3.6 CPT INVESTIGATION	25
3.7 WELL INVENTORY	26
3.8 WELL INSTALLATION	27
3.9 PILOT TESTING	28
3.9.1 Water Level Response-Injection	29
3.9.2 Water Level Response-Extraction	31
3.9.3 Water Quality Results	32

TABLE OF CONTENTS (continued)

4. 0 MODEL REFINEMENT AND RECALIBRATION 34
4.1 CONCEPTUAL HYDROGEOLOGIC MODEL 34
4.2 MODEL REVISION AND RECALIBRATION 35
5. 0 PROJECT FEASIBILITY EVALUATION 37
5.1 PROJECT DESCRIPTION 37
5.2 MODEL SIMULATION RESULTS 39
5.2.1 Water Level Response 40
5.2.2 Water Quality 41
6. 0 CONCLUSIONS 43
7. 0 REFERENCES 45

TABLES

Table	
1	ACTIVE REGIONAL WELL SUMMARY
2	GROUNDWATER MONITORING, GENERAL MINERAL AND PHYSICAL ANALYSIS RESULTS
3	WATER QUALITY COMPARISON

FIGURES

Figure		Drawing Number
1	REGIONAL SITE LOCATION	120-0862 A
2	PROJECT LOCATION	120-0965 A
3	REGIONAL WELLS	410-4753 A
4	PIEZOMETERS	410-4751 A

TABLE OF CONTENTS (continued)

Figure		Drawing Number
5	TOPOGRAPHIC FEATURES	410-4756 A
6	CONCEPTUAL GEOLOGY	310-0577 A
7	ANNUAL PRECIPITATION	---
8	WATER TABLE ELEVATIONS, OCTOBER 2003	220-1493 C
9	DEEP WATER LEVEL ELEVATIONS, OCTOBER 2003	220-1496 C
10	WATER TABLE ELEVATIONS, MARCH 2004	220-1473 C
11	DEEP WATER LEVEL ELEVATIONS, MARCH 2004	220-1474 C
12	WATER LEVEL HYDROGRAPH, 5-H2 AND MORGAN RUN P-1	----
13	WATER LEVEL HYDROGRAPH, MORGAN RUN P-4S AND P-4D	----
14	WATER LEVEL HYDROGRAPH, 32-JD AND MORGAN RUN P-3	----
15	TOTAL DISSOLVED SOLIDS, 2001/2002	210-2322 B
16	ESTIMATED TOTAL DISSOLVED SOLIDS SHALLOW ZONE AND SURFACE WATER, 2003	410-4752 B
17	SURFACE WATER MEASUREMENT LOCATIONS	220-1530 B
18	WATER LEVEL HYDROGRAPH, MORGAN RUN NORTH BRIDGE	---
19	WATER LEVEL HYDROGRAPH, MORGAN RUN SOUTH BRIDGE	---
20	AQUIFER TEST LOCATIONS	410-4754 B
21	CPT LOCATIONS	410-4755 B
22	INJECTION TEST NO. 1 WATER LEVELS, PIEZOMETER CLUSTER P-11	---
23	INJECTION TEST NO. 2 WATER LEVELS, PIEZOMETER CLUSTER P-11	---

TABLE OF CONTENTS (continued)

Figure		Drawing Number
24	INJECTION TEST NO. 2, CHANGE IN PRESSURE, DEEP AQUIFER	410-4750 B
25	RECOVERY TEST NO. 1, WATER LEVELS P-11A, P-11B, AND P-11D	---
26	ESTIMATED TDS OF RECOVERED WATER	---
27	MODEL PROJECTED WATER LEVEL ELEVATIONS, WELL P-11D	---
28	MODEL PROJECTED MAXIMUM PRESSURE INCREASE - LAYER 3 DEEP AQUIFER	----
29	MODEL PROJECTED WATER LEVEL ELEVATIONS, WELL P-11S	---
30	MODEL PROJECTED MAXIMUM WATER LEVEL RISE - LAYER 1 SHALLOW ZONE	---
31	MODEL PROJECTED MAXIMUM DRAWDOWN - LAYER 3 DEEP AQUIFER	---
32	MODEL PROJECTED TOTAL DISSOLVED SOLIDS – TEST WELL	---
33	PROJECTED RATIO OF RECLAIMED TO NATIVE WATER – 7 YEARS INJECTION	---
34	PROJECTED RATIO OF RECLAIMED TO NATIVE WATER – 13 YEARS OF INJECTION	---

TABLE OF CONTENTS (continued)

VOLUME II

APPENDICES

Appendix

A	WATER LEVEL MONITORING DATA
B	GROUNDWATER SAMPLING DATA
C	GEOCHEMICAL EVALUATION
D	AQUIFER TESTING RESULTS
E	CPT BORINGS
F	PORE PRESSURE DISAPATION TESTS
G	WELL INVENTORY
H	NEW WELL INSTALLATION
I	PILOT TESTING
J	GROUNDWATER FLOW MODEL

Note: Appendices are not included as part of this report. These appendices are available for review at OMWD offices. Please contact Harry Ehrlich at (760) 753-6466 to schedule a time for review.

ACRONYMS AND ABBREVIATIONS

AF	acre-feet
AF/yr	acre-feet per year
AMP	Active Management Plan
ASR	Aquifer Storage and Recovery
bls	Below land surface
CPT	Cone Penetrometer Test
DWR	Department of Water Resources
EC	Electrical Conductivity
gpm	gallons per minute
H+A	Hargis + Associates, Inc.
mg/l	milligrams per liter
msl	mean sea level
Morgan Run	Morgan Run Resort & Club
OMWD	Olivenhain Municipal Water District
RWQCB	Regional Water Quality Control Board
SDCWA	San Diego County Water Authority
TDS	Total Dissolved Solids
USGS	United States Geological Survey

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VOLUME I

EXECUTIVE SUMMARY

This Hydrogeologic Report has been prepared to describe the work conducted to date to evaluate the feasibility of an aquifer storage and recovery (ASR) project for the Olivenhain Municipal Water District (OMWD) for a portion of the San Dieguito Basin located in Central Coastal San Diego County, California. This report is a companion document to the Environmental Impact Report for the San Dieguito Water Storage and Recovery Project, San Diego, California. The ASR project represents one of two reclaimed water storage components that comprise the San Dieguito Water Storage and Recovery Project. The water storage project includes a surface water storage component referred to as Phase I – Fairbanks Ranch which involves storage of reclaimed water in existing ponds located at the Fairbanks Ranch Country Club. The water storage project also includes an underground water storage component, referred to as Phase II – Morgan Run, which involves seasonal storage and recovery of reclaimed water using injection/extraction wells located at the Morgan Resort and Club. The underground water storage project is the focus of this report and is referred to hereafter as the ASR project.

OMWD is proposing to inject and extract water at the southeast corner of the approximate 220-acre parcel that comprises the Morgan Run Resort & Club. The project would utilize the groundwater storage capacity available and increase the dry-year groundwater supply within the basin. The project as proposed would include approximately three injection/extraction wells and connecting pipelines to store up to 150 acre-feet (AF) of Title 22 tertiary-treated reclaimed water per year and withdrawal of up to 150 AF of groundwater per year.

The groundwater resources of the basin have been the subject of a number of studies by various researchers since 1983. Excessive agricultural pumping in the basin combined with drought conditions through the mid 1970's resulted in seawater intrusion, which degraded the groundwater quality in the basin. Since that time, groundwater use has been limited to the upstream portions of the basin due to the poor water quality in the lower portions of the basin. A reclaimed water ASR project in the basin has the potential to improve water quality and better utilize the groundwater resources of the basin.

Since 1997, OMWD has conducted various studies to evaluate the feasibility and potential impact of an ASR project in the San Dieguito basin. These studies have included the following:

- Instituted a groundwater and river monitoring program;
- Conducted a well inventory;
- Collected samples to evaluate groundwater quality and conducted a preliminary geochemical evaluation to assess water compatibility;
- Conducted aquifer tests to evaluate aquifer properties;
- Conducted a test boring program to verify the lithology;
- Installed observation wells to evaluate water table conditions;
- Installed a test injection/extraction well and completed two injection/extraction tests to evaluate well capacity; water recoverability; and water level impacts; and
- Revised and recalibrated a numerical groundwater model of the basin which was used to evaluate project performance and potential groundwater-related impacts.

Based on the work conducted to date it appears that it is feasible to seasonally inject and extract 150 AF of reclaimed water in the southeast corner of the Morgan Run golf course. Overall, the results of the pilot testing and groundwater modeling have confirmed that the groundwater basin is capable of receiving water at the rates anticipated for the project. The water would be injected into a deep aquifer zone consisting primarily of sand and gravel. In the project area the deep aquifer is overlain by fine-grained, silty to clayey layers that confine the deep aquifer and restrict upward migration of water to the water table. During the injection tests, there was no discernable rise in the water table in the vicinity of the test well where the buildup in the underlying aquifer was the greatest. The response to the two injection tests was completely damped out at the water table due to the presence of the aquitard sediments. It appears that there could, however, be some limited water table rise in areas located north of the project based on modeling results, if the aquitard is less competent than observed in the project area. The maximum model projected rise in this area due to the proposed project injection was less than 1 foot. However, two additional shallow piezometers are proposed to be installed in this area to evaluate any water level changes during injection periods. A discussion of the rationale for these two wells is included in the Active Management Plan (AMP).

An AMP has been prepared to document the monitoring that the OMWD will perform in order to track groundwater levels, movement, and quality; surface water levels and quality; and the environmental conditions within the basin during the injection/extraction operations. Furthermore, the data collected as part of the AMP will be used by OMWD to adjust operational conditions of the injection/extraction system, such as, injection and pumping rates; locations and durations, to mitigate, if necessary, potentially significant impacts such as rising water levels in wells caused by the operation of the ASR project.

The results of the groundwater modeling indicate that during injection periods pressure in the deep aquifer could increase to the point where water levels in a few deep wells located near the injection area and in areas to the south, including the Rancho Santa Fe Polo Club well could rise to about 10 to 15 feet above the top of the well. In other words, the groundwater in the deep aquifer does not reach land surface, only the pressure in the deep aquifer near the well exceeds land surface. The injection tests did not result in a rise in the water table in the vicinity of the test well, indicating that the aquitard in this area is competent and effectively restricts the upward movement of water. Existing inactive wells near the injection area would be backfilled with grout and existing production wells at the Rancho Santa Fe Polo Club would be fitted with water tight seals in the event that the water level in the wells rises above the top of the well casings, to prevent them from flowing during the injection periods. Further details regarding this work are provided in the AMP. Monitoring would be implemented in accordance with the AMP in areas surrounding the project to ensure that water levels do not exceed land surface during project operations in wells that have not had their casings properly sealed.

The results of the groundwater modeling indicate that during recovery periods water levels in the deep confined aquifer are not likely to draw down to the point where they would noticeably affect the capacity of existing production wells. Monitoring of water levels in the basin during extraction will be conducted in accordance with the requirements outlined in the AMP to ensure that capacity of existing wells is not affected.

The results of the pilot testing indicate that the proposed ASR project is not likely to affect the water level or water quality in the San Dieguito River. The lack of a water level response in the river and in the shallow piezometers located near the test well during the injection tests indicate that the proposed ASR project is unlikely to cause any significant seepage into the river. Given the relatively large volume of water associated with the river it is highly unlikely that there would be any impact to the river level or river water quality due to the ASR project operations.

The groundwater quality in the vicinity of the proposed ASR project is poor and is likely to be improved due to the operation of the proposed ASR project. Differences in groundwater quality can generally be characterized based on the total dissolved solids (TDS) concentration in the water. Based on the laboratory analysis of a groundwater sample collected from the test well, the TDS in the project area is about 4,400 milligrams per liter (mg/l). The expected TDS of the reclaimed water that will be used for injection is about 800 to 900 mg/l. The results of the pilot testing and groundwater modeling indicate that there will likely be some mixing of injected and native groundwater during each injection-extraction cycle. This mixing will result the development of a zone of lower TDS groundwater in the vicinity of the project. This mixing will also result in an increase in the TDS of the recovered water relative to the injected water during each seasonal recovery cycle. Based on the groundwater modeling results, the increase in TDS will likely diminish over the long term as the zone of improved groundwater quality expands.

The results of the groundwater modeling indicate that the injected water will probably not reach any of the existing active wells in the basin until about year thirteen of the simulation period assuming the amount of water extracted is about equal to the amount injected over time. Water quality monitoring in the basin will be conducted in accordance with the requirements outlined in the AMP to track any changes in water quality in the vicinity of the Project site.

HYDROGEOLOGIC REPORT
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VOLUME I

1.0 INTRODUCTION

This Hydrogeologic Report has been prepared to describe the work that has been conducted to date for evaluation of an aquifer storage and recovery (ASR) project for the Olivenhain Municipal Water District (OMWD) for a portion of the San Dieguito Basin. This report is a companion document to the Environmental Impact Report for the San Dieguito Water Storage and Recovery Project, San Diego, California, (Kleinfelder, 2004). The ASR project represents one of two reclaimed water storage components that comprise the San Dieguito Water Storage and Recovery Project. The water storage project includes a surface water storage component referred to as Phase I – Fairbanks Ranch which involves storage of reclaimed water in existing ponds located at the Fairbanks Ranch Country Club. The water storage project also includes an underground water storage component, referred to as Phase II – Morgan Run which involves seasonal storage and recovery of reclaimed water using injection/extraction wells located at the Morgan Resort and Club. The underground water storage project is the focus of this report and is referred to hereafter as the ASR project.

The San Dieguito Basin is located in Central Coastal San Diego County (Figure 1). OMWD is proposing to inject and extract water on the 220-acre parcel that comprises Morgan Run Resort & Club (Morgan Run) (Figure 2). The project would utilize the groundwater storage capacity available and increase the dry-year groundwater supply within the basin. The project is proposed to include approximately three wells and connecting pipelines to store up to 150 acre-feet (AF) of Title 22 tertiary-treated reclaimed water per year and withdrawal of up to 150 AF of groundwater per year.

It is intended that the information in this report will serve as the basis for the project description and environmental impact analysis being undertaken by OMWD in compliance with the California Environmental Quality Act. The focus of this report is to summarize the hydrogeologic assessment work that has been conducted to date and evaluate the potential performance and groundwater-related impacts associated with the proposed groundwater ASR project.

1.1 PURPOSE

The goals of the proposed ASR project include: 1) store excess reclaimed water in the basin for future extraction and use; 2) provide reclaimed water to Morgan Run and other potential end users; 3) satisfy the Regional Water Quality Control Board's (RWQCB) requirement for an 84-day emergency storage period of reclaimed water for a portion of the 4S Ranch Water Reclamation facility and/or the Santa Fe Valley Water Reclamation Facility; and 4) improve the basin water quality.

To implement this project, OMWD plans to acquire up to 150 acre-feet per year (AF/yr) of excess Title 22 tertiary-treated reclaimed water from one of three water reclamation plants during wet-weather periods, and convey the water, via an existing water delivery system, to appropriate injection wellhead locations on Morgan Run. The water would be placed under ground using injection wells screened in a confined alluvial aquifer located approximately 80 to 155 feet below the land surface (bls). Withdrawal from the aquifer each year would approach, but would not exceed the net amount of water injected during the preceding injection period.

1.2 PREVIOUS INVESTIGATIONS

The San Dieguito groundwater basin has been the subject of a number of hydrogeologic studies conducted by the United States Geological Survey (USGS), academic institutions, and consultants retained by local public agencies since 1983. In the 1990's, the San Dieguito Basin Groundwater Management Planning Study was conducted, which was jointly sponsored by a Task Force made up of nine public entities, including San Diego County Water Authority (SDCWA) and OMWD. The first phase of this study involved the development of a basin-wide groundwater model which could be used to evaluate various groundwater management alternatives intended to improve water quality and maximize the use of groundwater resources in the basin (CH2M Hill, 1995). During the second phase of the study a range of groundwater management alternatives was developed and evaluated (HYA Consulting Engineers, 1997). Alternatives included storage and recovery of both reclaimed water and/or imported raw water using recharge basins and injection/extraction wells. The impact of the management alternatives on the groundwater basin was simulated using the groundwater flow and transport computer model developed during the previous Phase I study. The following sections briefly summarize Phases I and II of this study and highlight some of the key conclusions that resulted from this work.

1.2.1 SDCWA PHASE I

The overall objective of the SDCWA Phase I study was to develop a groundwater management plan and identify project alternatives to protect, replenish, and improve the groundwater resources of the San Dieguito Basin. The first phase of the study involved the construction of a computer-based groundwater flow and transport model of the San Dieguito groundwater basin.

The model was completed in 1995, utilizing the CFEST finite-element model code (CH2M Hill, 1995). The model domain encompassed the San Dieguito watershed below Lake Hodges, which included the alluvial groundwater basin as well as the bounding marine sedimentary rocks. At the time the model was constructed, there was little in the way of detailed geologic information or aquifer test data for the basin. Because of this, the hydraulic properties incorporated into the model and the model layering was based almost entirely on available water well drillers' logs. The portion of the model representing the alluvial basin was constructed using four model layers, each representing hydrogeologic units that appeared to be correlatable within the basin based on the drillers' logs.

1.2.2 SDCWA PHASE II

The objective of the second phase of the San Dieguito Basin Groundwater Management Study was to use the model developed during Phase I to evaluate whether the groundwater resources of the San Dieguito basin could be better utilized while improving the basin water quality. The purpose of the SDCWA Phase II report was to identify technically and economically feasible groundwater management alternatives that would improve, protect, and maximize the use of the San Dieguito groundwater basin as a local water resource. It was also agreed by the Task Force that the study would include the assessment of groundwater storage opportunities using reclaimed water and/or imported water. During the SDCWA Phase II study, a range of groundwater storage and extraction projects ranging from 3,000 to 7,000 AF/yr were developed and simulated using the groundwater model developed during Phase I. The results of the SDCWA Phase II Study were presented in a report dated November 1997 (HYA Consulting Engineers, 1997).

Although the groundwater model simulations performed during the SDCWA Phase II study suggested that both of the simulated management concepts were technically feasible and resulted in improvement in basin groundwater quality, the SDCWA Phase II report concluded that an ASR project of this magnitude within the basin was not likely to be economically feasible.

However, it was concluded that a smaller, focused, local project with minimal capital costs might be feasible for storage of reclaimed water while enhancing the recharge of a segment of the basin. The utilization of existing and planned wastewater reclamation and distribution facilities as well as existing and planned retail water customers was deemed to be a cost-effective option for development of an alternative water supply. This would meet the Strategic Plan Goal of

SDCWA for development of reliable water supply alternatives and the mission goals of OMWD and Santa Fe Irrigation District.

The SDCWA Phase II study also recommended the collection of additional groundwater data to update the current groundwater conditions in the basin and to verify certain assumptions utilized in the SDCWA Phase II groundwater model simulations and to provide data regarding changes in water levels, water quality, and groundwater extraction.

1.2.3 OLIVENHAIN MUNICIPAL WATER DISTRICT MONITORING PROGRAM

Based on the recommendations provided in the SDCWA Phase II report, a focused groundwater monitoring program was established in 1997 under a joint agreement between SDCWA and OMWD. Subsequently, work in the basin has been under the direction of OMWD. The monitoring program consisted of semi-annual measurement of water levels of about 20 wells within the basin. Over 100 wells have been installed in the basin since the 1900's, however, most of these wells have been destroyed (Figure 3). Prior to initiating the groundwater monitoring program, a survey was conducted to identify existing wells, either active or inactive, that could be used for monitoring water levels within the basin. Twenty wells were found to be both suitable and accessible for inclusion in the water level monitoring program. Reference point elevations were surveyed to the nearest 0.01-foot for each of the wells included in the monitoring program.

The groundwater monitoring program has continued from its inception in 1997 to the present time. The specific wells included in the program have varied over time as a result of changes in well status or as new wells have been installed or identified.

1.3 HYDROGEOLOGIC STUDY APPROACH

OMWD has elected to continue to perform the work in the basin in a phased approach. The first phase of work conducted in 2001 included continuation of the monitoring program, evaluation of the administrative feasibility of the project, acquisition of current groundwater use data, acquisition of lithologic data from existing sources, and collection of groundwater samples from the basin for general mineral analysis. The results of this first phase of work indicated that the smaller ASR project is feasible. The second phase of work was conducted primarily between January and June 2002. Tasks that were conducted included aquifer testing at selected wells in the basin, advancement of cone penetrometer test (CPT) borings to evaluate the geology at and in the vicinity of Morgan Run, documentation of the well status within 2,000 feet of Morgan Run, refinement of the conceptual groundwater conditions in the basin, and preliminary groundwater modeling. The results of this phase of work continued to indicate that the injection and extraction of reclaimed water is feasible and that the aquifer should be capable of accepting the additional injection of reclaimed water. The results obtained through this second phase of work were published in a Project Report dated October 3, 2002 and are summarized in this document (Hargis + Associates, Inc. [H+A], 2002).

The most recent phase of work has included continuation of the monitoring program, installation of a test injection/extraction well on Morgan Run, installation of two additional deep piezometers; installation of one intermediate piezometer; installation of 11 shallow piezometers to assess potential impacts to the water table (Figure 4); conducting two pilot injection and recovery tests; revision and recalibration of the groundwater model, simulation of project performance, evaluation of model sensitivity to selected parameters, and further assessment of project feasibility and potential groundwater related impacts. The results of this additional work are summarized in this report.

1.4 REPORT ORGANIZATION

The following summarizes the organization of this report:

- Section 1: Provides overview of the ASR project and summarizes the previous work conducted in the basin;
- Section 2: Provides background information regarding the basin including geology, hydrogeology, and surface water conditions;
- Section 3: Describes the scope and summarizes the results of the various investigations that have been conducted by OMWD;
- Section 4: Describes the refinement and recalibration of the groundwater model;
- Section 5: Evaluates the performance and potential groundwater related impacts associated with the proposed project based on the modeling results;
- Section 6: Provides conclusions regarding the project feasibility and potential groundwater–related impacts; and
- Section 7: Provides references for the documents cited in this report.

2.0 HYDROGEOLOGIC SETTING

This section provides an overview of the San Dieguito basin; describes the geology, hydrogeology, and surface water characteristics of the basin; and provides information regarding groundwater use in the basin.

2.1 OVERVIEW

The San Dieguito groundwater basin is an alluvial-filled valley that extends inland approximately six miles from the coast near Del Mar, California (Figure 5). The valley floor slopes gently from an elevation of approximately 50 feet in the upstream area to near sea level at the coast. The valley is bounded by gentle hills and bluffs that range in elevation from about 100 to 300 feet. The San Dieguito Valley and surrounding upland areas are drained by the San Dieguito River and its tributaries. The area drained by the San Dieguito River and its tributaries below Lake Hodges is approximately 37 square miles.

For the purposes of discussion in this report the alluvial basin has been informally divided into three sub-areas. The upstream area of the basin which includes Osuna Valley, the former sand and gravel quarry, and the Chino Farms area is referred to as the upper basin (Figure 5). The portion of the basin between the upper basin and the San Diego Corporate Boundary is referred to as the middle basin. The portion of the basin between the San Diego Corporate Boundary and the coast is referred to as the lower basin.

2.2 REGIONAL GEOLOGY

The site is located in the foothills of the Peninsular Ranges geomorphic province. The Peninsular Ranges are a northwest-southeast oriented complex of blocks bounded by similarly trending faults (Norris and Webb, 1990). Structural blocks within the Peninsular Ranges are typically tilted gently to the west. Uplift and tilting of these blocks has resulted in a rugged mountain range over 600 miles in length, with a steep eastern escarpment and a relatively gentle western slope. The geology of the Peninsular Ranges is dominated by Cretaceous intrusive rocks of the Peninsular Ranges batholith (Norris and Webb, 1990). Composition of intrusive rocks of the western Peninsular Ranges batholith ranges from peridotite to granite, with rocks of tonalitic composition predominating. Pre-batholithic rocks are exposed adjacent to the western edge of the Peninsular Ranges batholith. The Jurassic-Cretaceous Santiago Peak volcanics represents a subduction-related volcanic arc intruded by the Peninsular Ranges batholith, a later phase of the subduction-generated complex (Walawender, 2000). The Santiago Peak volcanics is composed of volcanic rocks of various compositions, as well as associated volcaniclastic deposits.

Post-batholithic sedimentary rocks are exposed within and west of the foothills of the Peninsular Ranges. These sedimentary rocks range in age from Cretaceous to Pleistocene, and represent both marine and non-marine depositional environments (Kennedy and Peterson, 1975). The uplifted and exposed Peninsular Ranges batholith was one of several source-areas, which contributed sediments to the coastal plain and offshore embayments to the west, where sediments have accumulated since the late Cretaceous.

Following the uplift of the entire Peninsular Ranges block, including the areas underlain by Tertiary sedimentary rocks, the topography of the site vicinity formed as the San Dieguito River drained the western foothills of the Peninsular Ranges. The river, with its source in the Volcan Mountains near Santa Ysabel, eroded granitic rocks of the Peninsular Ranges batholith, carved a deep canyon in the area of the present Lake Hodges, and incised a wide valley through the softer Tertiary sediments of the coastal plain. Sea-level rise in the late Quaternary period resulted in a large estuary in the western river valley, which was infilled by river sediments derived from the east. Presently, the San Dieguito River valley west of the town of Rancho Santa Fe is wide and relatively flat due to the infilling of the basin with Quaternary alluvium. The modern estuary is restricted to the area west of El Camino Real, where tidal mudflats and river channel deposits characterize the valley floor.

2.3 LOCAL GEOLOGY

The San Dieguito groundwater basin consists of Quaternary age alluvial sediments, which occur beneath the San Dieguito Valley. A conceptual cross section illustrating the basin geology has been provided (Figure 6). This alluvium contains the majority of the useable groundwater within the watershed west of Lake Hodges. Estimates of groundwater storage capacity of the alluvial basin by various researchers have ranged from approximately 24,000 AF to 50,000 AF (Carroll, 1985; Izbicki, 1983).

East of Interstate 5, alluvial sediments typically range up to 125 feet to 155 feet in thickness along the axis of the basin, decreasing to less than 50 feet near the margins. Alluvium in the eastern-most portion of the basin is composed primarily of coarse-grained sediments, typically sand and gravel, which can sustain relatively high well yields. A shallow, relatively fine-grained or clayey aquitard unit has been identified throughout much of the basin, which tends to restrict groundwater flow between the shallow and deeper coarse-grained aquifer units. Alluvium in the western portion of the basin has not been well characterized but based on available drillers logs, consists predominantly of fine-grained sediments such as silt and clay with occasional thin sand beds, probably representing channel deposits.

The alluvial sediments of the groundwater basin are flanked and underlain by Tertiary marine sedimentary rocks comprising the Del Mar Formation and Torrey Sandstone, and Jurassic/Cretaceous metavolcanic rocks (Izbicki, 1983). These rock units form the upland areas around the margins of the basin. Although these rock units contain some groundwater, wells completed in these rocks typically have very low yields typically less than 20 gallons per minute (gpm) and water quality is generally poor, especially at depth.

Available information regarding the local geology was incorporated into the SDCWA Phase I model. The following is a description of the modeling layer which has been excerpted from the Phase I report (CH2M Hill, 1995). Layer 1 of the model represents the shallowest layer of alluvium. In the eastern portion of the basin this layer was characterized as a shallow aquifer unit composed largely of coarse-grained sands. This coarse-grained layer was not apparent in the logs of water wells drilled in the western portion of the basin, although some thin sand layers were identified locally. Model Layer 1 was, therefore, pinched out in the western basin area.

Model Layer 2, represents a laterally extensive zone of clay and clay-silt-sand mixtures that form an aquitard layer that tends to restrict the vertical movement of groundwater. This aquitard layer appears to be continuous throughout the middle and lower basin south of El Apajo Road, ranging in thickness from 50 to 100 feet.

Model Layer 3, represents a coarse-grained aquifer unit that is relatively thick in the eastern portion of the basin and transitions into a sequence of interbedded sandy horizons underlying the Layer 2 aquitard in the western portion of the basin.

Model Layer 4, represents a deeper fine-grained zone that occurs primarily in the western portion of the basin where it separates the Layer 3 aquifer unit from the underlying bedrock. In the eastern portion of the basin, Layer 4 tends to increase in coarseness where it is thought to act more as an aquifer. Layer 4 truncates in the far eastern portion of the basin.

Model Layer 5, represents the bedrock, which bounds and underlies the alluvial sediments. Bedrock consists primarily of the marine Del Mar formation and Torrey Sandstone. Model Layer 5, was configured in such a way that it was hydraulically connected to model Layer 1 at the alluvial basin boundary.

2.4 GROUNDWATER

Historically, the quality and quantity of groundwater within the basin has varied substantially, affecting the usefulness of the groundwater resources of the basin. Principal factors which control groundwater quality and the amount of groundwater in storage within the basin include: 1) the amount of groundwater pumped from the basin; 2) sea water intrusion resulting from the inflow of salt water from the ocean and estuary; 3) recharge to the basin from precipitation and surface flow in the San Dieguito River; and 4) inflow of poor quality water from the surrounding marine sedimentary rock formations.

The San Dieguito groundwater basin terminates at the Pacific Ocean where it is in direct communication with the ocean and estuary near the mouth of the San Dieguito basin. Recharge from the ocean and estuary can occur under certain circumstances. During periods when water levels in the basin have been substantially lowered, such as when groundwater extractions exceed other sources of recharge to the basin for a number of years, salt water will begin to migrate inland into the basin in the subsurface. This process, referred to as seawater intrusion, essentially results in recharge to the basin of high total dissolved solids (TDS) seawater. The amount of seawater recharge will vary depending on the extent to which groundwater levels are lowered within the basin.

Seawater intrusion occurred in the basin due to, excessive agricultural pumping combined with drought conditions through the mid-1970's, degrading the groundwater quality in the lower portion of the basin to the point where it is no longer suitable for meeting local irrigation needs. Water quality monitoring conducted by the USGS in 1982 indicated that the concentration of TDS in the lower basin west of El Camino Real ranged from 5,000 to 20,000 milligrams per liter (mg/l) (Izbicki, 1983). Based on the more recent sampling conducted during 2001 and 2002, the concentration of TDS of the groundwater in the middle and upper portions of the basin currently ranges from about 1,600 to 4,600 mg/l. The current distribution of groundwater quality is further discussed in Section 3.2.

Recharge to the basin also occurs from subsurface inflow from the marine sedimentary rocks that bound the alluvial basin (Izbicki, 1983). The amount of this inflow likely varies from year to year depending on the difference between basin water levels and water levels in the upland areas around the margin of the basin. Evidence suggests that inflow from the marine sediments is limited when the alluvial basin is full. Hence, inflow from the marine sediments is likely to be greatest when water levels in the basin have been lowered due to pumping. Recharge from these rocks is expected to be of poor quality typically 3,000 to 5,000 mg/l TDS and can potentially degrade the quality of the groundwater stored within the basin.

When water levels in the basin are high, indicating that the groundwater basin is essentially full, subsurface outflow will occur from the basin to the ocean and estuary. The amount of subsurface outflow is likely to vary seasonally depending on the balance between groundwater extraction and recharge. When water levels are lowered within the basin due to excessive groundwater extraction, subsurface outflow stops and subsurface inflow results.

2.5 SURFACE WATER

The San Dieguito River is the principal surface water feature within the San Dieguito basin. Prior to the construction of Hodges Dam in 1919, the San Dieguito River flowed naturally depending on variations in local precipitation. Since the dam was constructed, flow within the San Dieguito River has been substantially reduced.

Annual precipitation in the area has varied from six inches to 33 inches in the 1920 to 1996 period, averaging 14.6 inches as shown on Figure 7. Precipitation patterns appear to be cyclic within the basin, as they are throughout Southern California. During dry years, Lake Hodges Dam does not spill and surface water flow in the upper reaches of the basin is minimal, limited to the dam underflow and seepage from the surrounding sedimentary rocks. Lake Hodges Dam spills during wet years, which occur on average about once in every three years, although there have been periods of up to 25 years during which no spills have occurred. The last time Lake Hodges spilled was the winter of 1997-98. The amount of spillage during these events can exceed estimates of the total volume of the groundwater stored within the entire alluvial basin. The majority of this water flows out to the ocean as surface flow in the San Dieguito River. The amount of this surface water that percolates and recharges the basin depends in part on how full the basin was just prior to the runoff event. If groundwater levels are high prior to the spill event, then little of the surface flow in the river will percolate and recharge the groundwater basin. If basin groundwater levels have been lowered due to extensive pumping prior to the runoff event, then the river will tend to recharge the basin until groundwater levels recover. Groundwater recharge appears to occur quickly, based on the rapid rise in water levels observed during the winter of 1997-98.

Data regarding water quality for the San Dieguito River below Lake Hodges for the period 1946 to 1981 indicate that the TDS in the river varies substantially over time. Reported TDS concentrations during this period ranged from less than 500 mg/l to over 2,500 mg/l (Izbicki, 1983). Lower TDS values are indicative of surface water quality during larger storm events (Izbicki, 1983). If groundwater levels have been lowered due to groundwater extraction prior to storm runoff events, then significant recharge of lower TDS water probably occurs along the San Dieguito River in the upper reaches of the basin. This may account in part for the better groundwater quality observed near the San Dieguito River in this portion of the basin.

2.6 GROUNDWATER USE

Information regarding current groundwater use within the basin was obtained from well owner interviews, when possible, and field observation when property owners could not be contacted. Available information indicates that there are at least 31 parties currently extracting groundwater from within or immediately adjacent to the alluvial basin (Table 1). The total annual groundwater extracted by these users is currently estimated at about 1,800 AF/yr. Most groundwater extraction occurs from wells located in the middle and upper portions of the basin, where the effects of previous seawater intrusion are least. The bulk of the groundwater extraction occurs in the spring and summer when irrigation requirements are greatest, with a lesser amount being extracted during the fall and winter. Approximately 45 percent of the groundwater extracted from the basin is currently used for golf course irrigation, approximately 30 percent is used by equestrian facilities for pasture and field irrigation and/or animal maintenance, approximately 20 percent is used for landscape and recreational field irrigation, and less than 5 percent is used for agricultural production (Table 1).

There is no known potable use of groundwater within the alluvial basin. The nearest known potable well 7BA is located approximately 400 feet south and 1,200 feet east of El Camino Real and about 2.5 miles south west of the proposed ASR wells located on Morgan Run (Figure 3). This well is completed within the marine sedimentary rocks outside the alluvial basin.

A groundwater sample obtained from this well in 2001 had a TDS concentration of 5,100 mg/l. The water from this well is treated using reverse osmosis prior to use.

Based on the sampling conducted during 2001 and 2002, the TDS of groundwater currently being extracted from the alluvial basin ranges from about 1,600 mg/l to about 4,600 mg/l with the better quality water generally being extracted from wells located in the upper portion of the basin and the poorest quality being extracted from wells located in the lower middle portion of the basin.

3.0 SUPPLEMENTAL HYDROGEOLOGIC INVESTIGATIONS

Based on the data collected as of 2001 and the analysis performed in previous investigations, OMWD determined that an ASR project appeared feasible and has undertaken a series of supplemental hydrogeologic investigations to further plan for an ASR project in the San Dieguito basin. This section summarizes the data collection activities and hydrogeologic evaluations performed in support of the ASR project thru June 2004. Information regarding the water level monitoring program, groundwater sampling, geochemical mixing evaluation, aquifer testing, CPT investigations, piezometer and test well installation, pilot testing, groundwater model refinement and recalibration and project feasibility and groundwater impact evaluation are presented in this section.

3.1 WATER LEVEL MONITORING

Several hydrogeologic units have been defined in the project vicinity which respond differently to hydraulic stresses within the basin and are therefore monitored separately. The shallowest unit, referred to as the shallow zone or water table zone is composed of predominantly silty and sandy sediments which extend from land surface to a depth of approximately 20 to 40 feet bls in the project area. The depth to the water table is approximately equivalent to the depth where groundwater is first encountered in the subsurface. The shallow groundwater that occurs in this zone is unconfined i.e. it is not under pressure. Twelve shallow zone piezometers are currently being monitored in the middle basin to provide data on the depth to the water table in the project vicinity. The shallow zone corresponds to Layer 1 of the groundwater model.

The second hydrogeologic unit, which is composed primarily of silty to clayey sediments, is referred to as the aquitard zone because it restricts the vertical movement of groundwater between the shallow and deep zones. In the project area the aquitard zone underlies the shallow zone and ranges in thickness from approximately 20 feet to 60 feet. Due to the very low permeability of this zone it is not used for groundwater production in the basin. Groundwater monitoring is not conducted in the aquitard zone except at an intermediate depth piezometer located adjacent to the test well. The aquitard zone corresponds to Layer 2 of the groundwater model.

The third hydrogeologic unit, which is composed primarily of sand and gravel, is referred to as the deep zone or deep aquifer. In the project area the deep aquifer underlies the aquitard zone and ranges in thickness from approximately 30 feet to 60 feet. Most of the existing production wells are screened in the deep aquifer and it is the source of nearly all the groundwater produced from the basin. Three piezometers were installed in the deep aquifer in support of the ASR project evaluation. Groundwater that occurs in the deep zone is confined or under pressure. Water level data obtained from the production wells included in the monitoring program and the deep piezometers provide an indication of the change in hydraulic head or pressure in the deep aquifer. The pressure in the deep aquifer is strongly influenced by seasonal changes in regional pumping as exhibited by the substantial change in water levels in the deep wells. The deep aquifer corresponds to Layer 3 of the groundwater model.

Since the inception of the groundwater monitoring program in 1997, water levels have been monitored in approximately 20 active and inactive regional wells on a semi-annual basis. (H+A, 2000). The number of active and regional wells monitored during any measurement round varies due to access restrictions and well conditions. A series of shallow piezometers has been installed within the past several years, and these piezometers are currently being monitored to provide an indication of the behavior of the water table at these locations. As discussed above, water levels measured in deep regional wells are representative of the hydraulic head in the deeper, confined aquifer and the water level in these wells are not indicative of the shallow water table.

Water levels are measured by hand to the nearest 0.01 foot using a water level sounder. Water levels have also been monitored in the wells using pressure transducers which provide a continuous record of the water level in the well being monitored. Pressure transducers are able to record the rapid drawdown and recovery of water levels caused by local pumping. Production well pumping schedules are variable, with different wells turning on and off at irregular intervals. Transducer data plots allow the change in the static water level to be identified over time under these pumping conditions.

The following discussion is specific to the conditions observed during the past seven years of groundwater monitoring. Water levels within the deep aquifer are generally higher in winter and early spring and lower in the summer and fall as is typical for groundwater basins. Given the limited amount of precipitation that has fallen over the past seven years, the observed fluctuations in the deep zone water levels appear to be related more to seasonal variations in the amount of groundwater pumping rather than to variations in the amount of recharge to the basin.

Since the installation of a series of shallow piezometers in the vicinity of Morgan Run between March 2002 and June 2003, water levels have also been monitored in the shallow zone, representing the water table, as well as in the deep aquifer zone, where most of the active water supply wells are screened. Water level contour maps for October 2003 and March 2004 are provided for both the deep aquifer zone and the water table (Figures 8 to 11).

Water level contour maps for the two most recent monitoring events in October 2003 and March 2004 are typical of the seasonal variation in groundwater levels that have been observed during the 7-year monitoring program (Figures 8 to 11; Appendix A). During the late spring and summer, a substantial pumping depression typically forms in the central portion of the basin where most of the groundwater is pumped (Figure 9). During these periods of maximum pumping, water levels in this area of the basin have been observed to decline to more than 10 feet below sea level. These pumping depressions have been observed to persist well into the fall. A smaller, localized pumping depression has also been observed in the southwest portion of the monitored area due to extraction from one or two wells at the Rancho Santa Fe Polo Club (Appendix A). The water level elevations within the main pumping depression are often low enough to result in a local reversal of the natural gradient, which is normally toward the ocean. This causes groundwater in the southern portion of the middle basin to change direction and flow to the northeast toward the northern portion of the middle basin during these periods.

The water level contour maps for March 2004 are representative of periods when pumping has declined allowing water levels in the middle basin to rebound (Figures 10 and 11). This typically occurs during the winter and early spring when irrigation demand is minimal due to the cooler wetter weather. During March 2004, water level elevations in the deep zone ranged from about 31 feet above mean sea level (msl) in the upper area of the basin to about eight feet above msl in the middle basin area, then increased to approximately 16 feet above msl in the southern portion of the study area (Figure 11). This indicates that although the predominant groundwater flow direction was downstream toward the ocean, a residual reversal in the middle portion of the basin persisted into the spring of 2004, later than the observed pattern in previous years, particularly 2003 (Appendix A).

Based on the data obtained from shallow piezometers, the water table is generally higher in elevation than the hydraulic head or pressure in the deeper aquifer and appears to be relatively stable (Appendix A). Comparative graphs of the water level within the deep aquifer and in the water table in the southern, central, and northern portion of the Morgan Run property during the monitoring program are provided in Figures 12 to 14.

The change in the water level in the deep aquifer at well 5H2 located in the southeast corner of Morgan Run since monitoring began in 1998 is shown in Figure 12. Also shown on the graph is the change in the water table at this same location based on a shallow Morgan Run piezometer P-1, installed in 2002. The seasonal fluctuation in the deep zone water level at well 5-H2 has ranged from 10 to 15 feet, primarily due to seasonal changes in groundwater extraction from deep wells located in the middle basin. In contrast, the water table at this location has been relatively constant, with a seasonal fluctuation of less than two feet. The limited response in the water table is due the presence of low permeability aquitard sediments that effectively confine the deep aquifer and prevent the vertical transmission of water level changes occurring in the deep aquifer.

The change in the water level in the deep aquifer and the water table over time at piezometer cluster P-4 in the central area of Morgan Run is shown on Figure 13. A seasonal fluctuation ranging from 13 to 15 feet is evident in the deep aquifer primarily due to the variation in pumping, whereas the water table fluctuation at this location is less than three feet.

The change in the water level in the deep aquifer and at the water table at one of the golf course production wells 32-JD, and piezometer cluster P-4 in the northern portion of Morgan Run is shown on Figure 14. A seasonal fluctuation ranging from 9 to 16 feet is evident in the deep zone due to the variation in pumping, whereas the water table fluctuation is about 9 to 12 feet. It is apparent that the water table response to local pumping is greater in the northern area of Morgan Run compared to that observed in the central and southern areas of the property. This appears to be related to the fact that some production wells located in the northern portion of the middle basin are screened within the shallow zone and/or that the sediments that comprise the aquitard zone tend to pinch out and become less fine-grained in the area north of Morgan Run, resulting in somewhat greater seasonal fluctuation in the water table in the northern area of the Morgan Run property.

3.2 GROUNDWATER SAMPLING

As part of the groundwater monitoring program, water samples were collected during 2001 and 2002 from 16 wells within the basin to assess the variation in water quality and to aid in evaluating the chemical compatibility of potential injection source water and native groundwater (Appendix B) (Table 2). Prior to this recent sampling, the last relatively complete set of groundwater quality data for the basin was obtained by the USGS in 1982. The 2001 groundwater sampling program involved the collection of samples from eight active production wells and four inactive wells. Four of the active wells were sampled again in 2002 as part of the aquifer-testing program. Groundwater samples for all wells were submitted to Del Mar Analytical, Irvine, California, for analysis for one or more of the following constituents:

- Cations including, Calcium, Magnesium, Potassium, Sodium, Iron, Manganese, Boron; and
- Anions including, Bromide, Chloride, Fluoride, Nitrate, Nitrite, Phosphate, Sulfate; TDS.

The following water quality parameters were also measured and recorded in the field:

- Temperature;
- PH;
- Electrical Conductivity (EC);
- Oxidation/Reduction Potential; and
- Dissolved Oxygen.

The groundwater sample from the inactive Morgan Run Fairway No. 2 well also identified as 5-H2, during 2001, was also analyzed for odor, turbidity, color, and MBAS to characterize the well discharge water for evaluation of disposal options in anticipation of conducting an aquifer test at this well.

The distribution of groundwater quality in the deep aquifer within the basin, based on the TDS of water samples, is shown on Figure 15. The concentration of TDS in groundwater samples collected during 2001 and 2002, ranged from 1,600 mg/l to 5,100 mg/l (Table 2). The highest quality groundwater, as indicated by the lower TDS concentrations, tended to occur in the upper portion of the basin in wells located in closer proximity to the river. Water quality was typically poorest i.e., TDS was generally highest in wells located furthest downstream. The TDS of a groundwater sample collected from the project test well was 4,400 mg/l which is consistent with the poor quality in the southern area of the Morgan Run golf course. A comparison of the water quality data recently collected from the basin to the RWQCB basin plan objectives has been provided (Table 3).

During December 2004, as part of the monitoring program, field measurements of EC were made on groundwater samples collected from shallow piezometers to characterize the distribution of water quality within the shallow groundwater system in the vicinity of Morgan Run. The TDS of the shallow groundwater was estimated based on temperature corrected field EC data using the following formula:

$$TDS\ (mg/l) = EC\ (umho/cm) * 0.65 * 1000$$

Note: umho/cm = micromho per centimeter

The distribution of estimated TDS in the shallow groundwater ranges from about 1,700 to about 6,000 mg/l which is similar to the range of TDS in the deep aquifer (Figure 16).

3.3 SAN DIEGUITO RIVER MONITORING

As part of the monitoring program, surface water levels have been periodically measured at five locations along the channel of the San Dieguito River, where bridge crossings provide locations where a measurement from a surveyed reference point can be taken.

Transducers were placed beneath the Morgan Run north and south bridges for the near-continuous measurement of river levels during the 2003-04 winter season (Figure 17, Appendix A). River water level data are included on the water table contour maps for comparison to adjacent groundwater levels (Figures 8 and 10). Hydrographs that illustrate the change in river levels have been provided (Figures 18 and 19). At the North Bridge the river typically goes dry in the summer months at an elevation of approximately 17.5 feet msl. Water levels at the North Bridge ranged up to 18.5 feet msl during the past year (Figure 18). At the South Bridge there is standing water in the river throughout the year. Water levels ranged between approximately 14.5 and 17 feet msl during the past year (Figure 19).

During 2004, field measurements of EC were made on surface water samples collected from the San Dieguito River (Figure 16). The samples were collected from the river at various accessible locations from upstream of the alluvial basin to just downstream of El Camino Real. The estimated TDS of the river water samples was calculated as described in Section 3.2 to provide a comparison to groundwater samples. The estimated TDS of a river water sample collected approximately 2.6 miles upstream from the alluvial basin was about 1,800 mg/l. The TDS of the river within the upper basin ranged from about 2,600 to 2,900 mg/l (Figure 16). The TDS of the river within the middle basin ranged from about 2,400 to 2,700 mg/l (Figure 16). Given the low precipitation, which occurred during the prior winter, the river water within the upper and middle basin at the time the samples were collected probably represented base flow derived from Hodges Dam underflow and seepage from the surrounding bedrock areas upstream of the sampling points.

The estimated TDS in the river water samples collected in the lower portion of the basin, downstream of Morgan Run, were higher than the estimated TDS of surface water samples collected in the middle and upper portions of the basin (Figure 16). The estimated TDS of the surface water in the river at the El Camino Bridge exhibited an increase in TDS with depth from about 3,500 to about 7,300 mg/l. The same trend was noted at a location approximately 0.5 mile downstream of the El Camino Bridge where the estimated TDS increased from about 11,000 mg/l near the water surface to about 30,000 mg/l at a depth of about 18 inches. Based on the elevated TDS and apparent stratification, the surface water in the San Dieguito river in the lower portion of the basin appears to be effected by inland migration of seawater via the estuary.

3.4 GEOCHEMICAL EVALUATION

A geochemical evaluation was performed to assess whether the reclaimed water proposed for project use is compatible with native groundwater and to what extent precipitation of minerals would be expected when reclaimed water is injected (Appendix C). Geochemical simulations using the USGS model PHREEQC were performed to calculate equilibrium conditions between dissolved constituents in solution to assess the potential for in-situ mineral precipitation which may result in a reduction in aquifer permeability, ASR efficiency, or recovered water quality.

For the purposes of the geochemical evaluation, it was assumed that water would be injected at well location 5-H2. One model simulation was performed to evaluate mixing of groundwater at this well location with reclaimed water from the North City Reclamation Plant and a second simulation using the anticipated water quality for reclaimed water from the 4S Ranch Waste Water Treatment Plant. The simulations evaluated progressive mixing of the native groundwater from well 5-H2 and injected reclaimed water types in 10 percent increments. The equilibrated water quality for each of the mixing steps was then evaluated. Additionally, the saturation indices for potential mineral phases were also evaluated as the waters were mixed. Although some mineral phases showed an increased tendency to precipitate, most saturation indices decreased. Results of these simulations indicate that precipitation of minerals phases due to mixing of water types is not likely to have a negative impact on proposed ASR operations based on the data currently available.

3.5 AQUIFER TESTING

An aquifer testing program was conducted in the San Dieguito groundwater basin in the vicinity of Morgan Run to obtain site-specific estimates of aquifer parameters and assess the preliminary feasibility of the project (Appendix D). Constant rate aquifer pumping tests were performed on four active production wells located in the vicinity of the proposed ASR project (Figure 20). Aquifer tests were conducted on two active production wells owned by Morgan Run, one active well owned by Rancho Paseana, and one active well owned by the Rancho Santa Fe Polo Club to estimate aquifer parameters and assess potential well extraction/injection rates. Aquifer test duration was often constrained by owner water demands and ranged from 47 to 218 hours. Pumping rates for the pumped wells ranged from 141 to 675 gpm. Drawdown and recovery data were obtained from both the pumped well and nearby inactive wells, when available.

An aquifer test scheduled for an inactive well located near the southeast corner of the Morgan Run golf course could not be completed. When the well was pumped using a temporary test pump installed in the well, it was found that the pumping level rapidly drew down to the pump intake. This response indicated that the well had become plugged and could no longer yield water at a sufficient rate to conduct the planned test. This well reportedly pumped at rates of approximately 200 to 300 gpm in the past.

In addition to the planned aquifer tests, useful drawdown data was obtained from an inactive well located near the Schoenfelder south production well. The inactive well had been fitted with a pressure transducer as part of the water level monitoring program, which allowed it to record drawdown data when the nearby production well began pumping. Drawdown data combined with water meter data obtained during and after the pumping period were used to provide an estimate of aquifer transmissivity at this location. During this event the production well pumped at a rate of 710 gpm for 33.5 hours.

Aquifer test data were analyzed using a number of methods depending on the nature of the aquifer response. Preliminary aquifer transmissivity estimates obtained from the above tests ranged from 1,600 to 2,700 ft^2/day at the Rancho Santa Fe Polo Club well 5-FA, to 11,000 to 15,000 ft^2/day at the Morgan Run No. 3 Green North well. Preliminary estimates of aquifer storativity ranged from approximately 0.02 at the Schoenfelder south production well to 0.0004 near the Morgan Run wells.

During the aquifer testing it was noted that the drawdown response tends to propagate to a greater degree along the axis of the valley compared to transverse to the valley. This is most likely related to the fact that the deep aquifer is not laterally continuous but rather appears to be composed of stream channel deposits which tend to be oriented along the axis of the valley. Because of this, the aquifer test results do not strictly conform to the Theis assumptions and the calculated transmissivity values should therefore be considered order-of-magnitude estimates. The drawdown observed during the aquifer tests was subsequently simulated using the model and used to adjust the hydraulic conductivity distribution within Layer 3 of the San Dieguito basin groundwater model. As discussed in Section 2.3, Layer 3 represents the deeper confined aquifer from which most production wells in the basin derive their water.

3.6 CPT INVESTIGATION

After reviewing available drillers' logs for the basin, it was determined that the available information was insufficient to adequately characterize geologic conditions in the project vicinity. Additional detailed lithologic data were therefore obtained in the project vicinity and surrounding area using direct-push CPT equipment. CPT borings were advanced at 27 locations at Morgan Run, Rancho Paseana, Rancho Santa Fe Polo Club, and Fairbanks Ranch Country Club

(Appendix E) (Figure 21). The total depth of the CPT borings ranged from approximately 10 feet to approximately 155 feet. Refusal was occasionally encountered at depths considerably shallower than the expected depth to bedrock. In these instances, it is likely that the shallow refusal was related to the CPT rod encountering a gravel or cobble zone, which prevented further advancement of the rod.

CPT data were compiled and incorporated into a three-dimensional visualization computer program which was used to further evaluate the lateral and vertical continuity of aquitard and aquifer units in the vicinity of the proposed recharge area. At most CPT locations, the results obtained were generally consistent with the basin conceptual model and the layering utilized in the Phase I groundwater model, although the CPT logs tended to exhibit considerably greater lithologic detail and complexity compared to the drillers' logs. The CPT data indicate that the Layer 2 aquitard is present in all borings installed on Morgan Run. Pore pressure dissipation tests were conducted to provide preliminary data regarding the hydraulic conductivity of the aquitard sediments (Appendix F). The CPT data were also used to rank potential locations for the test well. Potential test well sites were eliminated from further consideration, if soils were found to be predominantly fine grained.

3.7 WELL INVENTORY

A well inventory and field reconnaissance were conducted during 2002 to identify the location and status of all wells within 2,000 feet of the proposed project wells (Appendix G). Previous review of historical documents indicated that over 100 wells may have been installed within the basin since the early 1900s (Figure 3). However, the current status of many of these wells is unknown. It was anticipated that most of these wells had been abandoned or destroyed. Geographic coordinates of potentially abandoned and destroyed wells whose status was unknown were digitized from historical well location maps maintained by the California Department of Water Resources (DWR), the USGS, and information in local agency files. Well coordinates were subsequently downloaded into a GPS unit to facilitate locating these wells in the field. Several field reconnaissance trips were conducted to interview property owners and to document the apparent presence or absence of these wells. In addition, interviews have been conducted with local drillers and pump service companies in the area to obtain additional information on the status of the wells and to improve the reliability of the historical well data collected.

A review of historical well location maps obtained from DWR indicated that three wells, 5-B1, 5-C1, and 32Q1, which may have been located on the Morgan Run property were not identified in the field during the well inventory task described above. A more intensive search of agency documents and historical aerial photographs was conducted in December 2003, in order to establish the condition and confirm the location of these wells. However, no clear evidence of these wells was found.

3.8 WELL INSTALLATION

A series of shallow and deep piezometers were installed at the site between March 2002 and July 2003 (Appendix H) (Figure 4). In addition, a test injection-extraction well, and an adjacent exploratory boring were installed in the southeast corner of the Morgan Run golf course (Figure 4). Well construction information and available lithologic logs are provided in Appendix H.

Eleven shallow piezometers were installed to total depths of 23 feet bls to 35 feet bls, and provide data regarding the depth to the water table in the area. Two deep piezometers were screened in the deep confined aquifer, to total depths of approximately 90 feet bls to 99 feet bls. The depth to water in the deep piezometers indicates the hydraulic head or water pressure within the deep confined aquifer, which can differ significantly from the water table.

Piezometers P-1 and P-2 were installed near the southeast corner of the Morgan Run golf course to monitor the water table during a planned aquifer test. Piezometer P-3 was installed at the north end of the Morgan Run golf course to monitor the water table response to regional water extractions.

At two locations, multiple piezometers were installed at adjacent locations to different depths forming a piezometer cluster. Clustered piezometers provide data regarding the water table and deeper zones at the same location. Piezometer cluster P-4, located in the central portion of the Morgan Run golf course, adjacent to the residential area, includes both a shallow P-4S and deep P-4D piezometer. Piezometer cluster P-11 was constructed 60 feet north of the test well to provide data regarding the response to injection and extraction in the immediate vicinity of the test well. Piezometer cluster P-11 includes a shallow P-11A, an intermediate P-11B, and a deep P-11D piezometer. The intermediate depth piezometer was screened from 40 feet bls to 45 feet bls, within the aquitard sediment sequence overlying the deep confined aquifer.

Shallow piezometers P-5 through P-10, were installed throughout the Morgan Run residential area to evaluate to what extent the water table would respond to injection and extraction in this area.

Prior to installing the test well, an exploratory boring EB-1 was drilled 10 feet north of the proposed test well location to provide lithologic data for the design of the test well. The test well was drilled to a depth of 137 feet bls and completed as an 8-inch diameter well within the deep confined aquifer screened from 87 feet bls to 137 feet bls. The test well was subsequently used to conduct a series of pilot injection and recovery tests within the deep confined aquifer at the project site.

3.9 PILOT TESTING

Two pilot injection and extraction tests were conducted at the test well located near the southeast corner of the Morgan Run golf course to further evaluate the feasibility and potential impacts related to the proposed storage and recovery of water in the deep aquifer (Appendix I). These tests involved the injection of water at a flow rate of 400 gpm, for periods ranging from 8 to 10 days. Injection tests were conducted utilizing potable water obtained from a fire hydrant and brought to the test well via a temporary 6-inch pipeline. The injected water was then recovered by pumping the test well for a period of time approximately equal to the duration of the prior injection period.

The principal objectives of the pilot testing program were to:

- Evaluate the injection well capacity and potential for plugging;
- Evaluate the potential water level build-up in the deep confined aquifer;
- Evaluate the drawdown as a result of withdrawal from the extraction well;
- Evaluate the impact on the water table from injection; and
- Evaluate water quality of the injected and recovered water.

Details regarding each of the injection and recovery test cycles are provided in Appendix I. Results of the pilot injection and extraction tests indicate that the deep aquifer is capable of accepting and yielding water at sufficient rates to support the proposed project. However, during the two injection tests the test well experienced a significant reduction in capacity, which appears to be related to gradual plugging by the small amount of suspended sediment in the source water. A third injection test, which will incorporate a filtration unit, has been conducted to evaluate whether the well capacity can be sustained using conventional filtration technology.

3.9.1 Water Level Response-Injection

Hydrographs showing the water level response in the vicinity of the test well during the two injection tests have been prepared (Figures 22 and 23). Water levels within the deep confined aquifer P-11D, an intermediate depth P-11B, and the water table P-11A are shown together for comparison based on data obtained from piezometer cluster P-11 located 60 feet north of the test well. Data are shown for a 10-day period preceding the injection test, during the injection period, and for approximately 10 days following the test.

It should be noted that static water level in the intermediate and deep wells were 5 to 12 feet lower than the water table at the start of the first injection test (Figure 22). In contrast, the static water levels in all three wells were higher at the start of the second injection test because it was conducted following the winter rainy months when water levels are near their highest level due to minimal pumping in the basin (Figure 23).

The hydrographs indicate that pressure in the deep zone increased by as much as 13 feet of water during the two injection tests, however, based on the regional water level trend before and after the injection phase it appears that about two feet of this pressure change can be attributed to the regional trend (Figures 22 and 23). Therefore, about 10 to 11 feet of the observed buildup in the pressure in the deep zone appears to be related to the injection.

The water level rise in the intermediate depth piezometer P-11B was damped compared to the response in the deep aquifer during both injection tests due to the presence of fine-grained aquitard sediments overlying the deep aquifer (Figures 22 and 23). The total water level rise in the intermediate depth piezometer P-11B was about 2.5 to 3 feet.

There was no discernable rise in the water table in the vicinity of the test well where the buildup in the underlying aquifer was the greatest. The response to the two injection tests was completely damped out at the water table due to the presence of the aquitard sediments (Figures 22 and 23). Although there were some minor daily fluctuations, there was no discernable test-related response at the water table due to the injection. There was some minor fluctuation of less than 0.2 feet in the water table at several piezometers located to the north of the test well, these fluctuations appear to be related to regional pumping in the vicinity rather than the injection of water during the test. There was also no discernable rise in the water table at the Morgan Run middle bridge which is located near the test well where the buildup in the underlying aquifer is likely to be greatest.

The change in pressure within the deep aquifer due to the injection of water decreases with distance away from the test well. The change in pressure observed in other piezometers screened in the deep aquifer ranged from approximately 11 feet at piezometer P-11D, located near the test well to about 2.5 ft in piezometer P-4D located about 1,800 feet north of the test well (Figure 24).

Overall, the results of the pilot testing indicated that the deep aquifer is capable of receiving water at the rates anticipated for the project. The test well did experience some loss of capacity during the pilot injection tests, which appears to be due to plugging by suspended solids. This plugging may be significantly reduced or eliminated by the use of conventional filtering and chlorination of the reclaimed water prior to injecting. Plugging of injection wells can also be addressed by periodic redevelopment by pumping the well for a short period.

During the pilot testing the change in pressure in the deep aquifer near the test well was about 11 feet. For any well constructed in the deep zone in the vicinity of the test well the change in pressure is sufficient to result in the water level in the well rising above land surface if the injection is conducted during the winter high water level conditions. In other words, the groundwater in the deep aquifer does not reach land surface, only that the pressure in the deep aquifer near the well exceeds land surface. The injection tests did not result in a rise in the water table in the vicinity of the test well, indicating that the aquitard in this area is competent and effectively restricts the upward movement of water within the alluvial sediments. The change in pressure measured during the injection tests decreased with distance away from the test well, ranging from about 4 to 5.5 feet in the nearest active wells.

An Active Management Plan (AMP) has been prepared to document the monitoring that the OMWD will perform in order to track groundwater levels, movement, and quality; surface water levels and quality; and the environmental conditions within the basin during the injection/extraction operations (H+A, 2004). Furthermore, the data collected as part of the AMP will be used by OMWD to adjust operational conditions of the injection/extraction system, such as, injection and pumping rates; locations and durations, to mitigate, if necessary, potentially significant impacts such as rising water levels in wells caused by the operation of the ASR project.

3.9.2 Water Level Response-Extraction

The water injected during the first injection test was recovered beginning on November 4, 2003, approximately one month following the completion of injection. During the first recovery test the test well was continuously pumped at a rate of 400 gpm for a period of 10 days. A hydrograph showing the water level response in the vicinity of the test well during the first recovery test have been prepared (Figure 25). Water levels within the deep confined aquifer P-11D, an intermediate depth P-11B, and the water table P-11A are shown together for comparison based on data obtained from piezometer cluster P-11 located 60 feet north of the test well. Data are shown for a 10-day period preceding the recovery test, during the extraction period, and for approximately 10 days following the test. During the second recovery test which followed the second injection test the test well had to be pumped on an intermittent basis due to constraints imposed by Morgan Run in terms of their ability to utilize the extracted water, and thus a hydrograph for this test was not prepared.

It should be noted that static water level in the intermediate and deep wells were 4 to 9 feet lower than the water table at the start of the first recovery test (Figure 25). The hydrograph indicates that the water level in the deep piezometer, P-11D, declined by approximately 9 feet during the recovery test (Figure 25). The water level decline in the intermediate depth piezometer P-11B was damped compared to the response in the deep aquifer during the recovery test due to the presence of fine-grained aquitard sediments overlying the deep aquifer (Figure 25). The total water level decline in the intermediate depth piezometer P-11B was less than two feet (Figure 25). There was no discernable change in the water table in the vicinity of the test well where the drawdown in the underlying aquifer was the greatest. The response to the groundwater extraction was completely damped out at the water table due to the presence of the aquitard sediments (Figures 25).

Overall, the results of the recovery test indicated that the deep aquifer is capable of producing water at the rates anticipated for the project.

3.9.3 Water Quality Results

The water quality of the native groundwater, the injected water, and the recovered water were also evaluated during the injection and recovery tests based on laboratory analysis of water samples collected during testing and field measurements of EC. Laboratory results and field parameter measurement data are provided in Appendix I. Differences in water quality can be generally characterized based on the TDS concentration in the water samples. The water quality of the native groundwater in the vicinity of the test well is poor based on the laboratory reported TDS of 4,400 mg/l. In contrast, the TDS of the injected potable was 490 mg/l.

During the recovery test, the TDS of the recovered water gradually increased from about 500 mg/l to about 3,000 mg/l by the end of each injection test, indicating the there is significant mixing of injected and native groundwater during the storage and recovery process (Figure 26). Although on most ASR projects, the recovered water quality typically improves during subsequent injection/recovery cycles, this was not observed during the second test. During the second recovery period, the TDS increased above what which occurred during the first recovery test but returned to about the same TDS by the end of the recovery period (Figure 26). This may be due in part to differences in the amount of groundwater extraction occurring within the basin during the first and second tests which effects the regional gradient or it may be due in part to the longer period of storage between the second injection and recovery tests. Both of these factors may have caused the injected water to migrate further from the test well during the second test. It is likely that the recovered water quality will improve during subsequent cycles if the injection and recovery are conducted during the winter season each year when groundwater flow conditions are similar.

4.0 MODEL REFINEMENT AND RECALIBRATION

Prior to conducting the model wellfield simulations, the data collected from the supplemental hydrogeologic investigations were incorporated into the existing groundwater model. The following sections briefly describe key elements of the conceptual hydrogeologic model and summarizes the revisions that were made to the numerical groundwater model prior to using the model to simulate the project performance. Additional details regarding the groundwater model may be found in Appendix J.

4.1 CONCEPTUAL HYDROGEOLOGIC MODEL

Data obtained during the recent investigations described above were compiled and evaluated to refine the understanding of the hydrogeology of the project site. Available lithologic data from both drillers' logs and CPT borings were digitized and entered into a three-dimensional visualization software package that allows presentation of data in various orientations from cross section to map view. The following discussion briefly summarizes key aspects of basin hydrogeology that may impact ASR project feasibility based on the data obtained during the recent field investigations.

The bulk of the sediments, which comprise the alluvial basin in the vicinity of the recharge site, consist predominantly of finer-grained clayey to silty flood-plain deposits. These fine-grained deposits do not transmit appreciable amounts of groundwater and therefore tend to act as aquitards. The principal aquifer within the basin is composed of coarser-grained channel deposits, consisting primarily of sands with varying amounts of gravel, which are typically encountered at depths of about 60 to 110 feet. These deeper, more permeable channel deposits form what is referred to as the deep confined aquifer. This deep aquifer provides the bulk of groundwater that is extracted from production wells in the project area. The depth, thickness, lateral extent, and permeability of the channel deposits vary from location to location within the project vicinity. In some localized areas the channel deposits comprise a substantial thickness of predominantly coarse sand and gravel and may support well yields of 500 to 1,000 gpm. In other locations the channel deposits are either largely absent, or not as coarse and of limited thickness. In these areas well yields tend to be lower and may only sustain flow rates of from less than 100 gpm, up to several hundred gpm.

Based on the magnitude of the drawdown at different piezometers during the aquifer testing program, the channel deposits appear to have greater hydraulic continuity along the longitudinal axis of the basin and less continuity transverse across the width of the basin. This pattern is expected given the nature of river channels, which tend to exhibit long, narrow meandering configurations, which shift position across the valley floor over time due to ongoing sediment deposition and periodic flooding.

Based on the water level monitoring data collected to date, water levels in the deeper confined channel deposits rise and fall seasonally, primarily due to the variation in the amount of groundwater pumped from the basin. These data also indicate that the water table in the project vicinity is generally higher in elevation than the water level in the deeper confined zone and that the water table does not appreciably fluctuate in response to regional pumping. This indicates that the fine-grained aquitard sediments overlying the deep aquifer function as an effective confining zone. The results of the pilot testing were consistent with the long-term monitoring results in that there was no observable water table response to injection in the vicinity of the test well where the change in pressure in the confined aquifer was greatest.

4.2 MODEL REVISION AND RECALIBRATION

The current numerical groundwater model is based on a previous three-dimensional, finite-element, groundwater flow and transport model of the San Dieguito basin (CH2M-Hill, 1995; HYA, 1997). The model, which was originally developed using the CFEST code, was subsequently converted to the USGS finite difference code MODFLOW to facilitate appropriate model revisions based on additional field investigations (H+A, 2002). Once the model was converted, selected model parameters were then modified and the model recalibrated to better replicate the hydraulic responses observed during the aquifer testing and pilot testing programs. Details regarding the model revisions, recalibration, and the results of a model sensitivity analysis are provided in Appendix J. The following briefly summarizes the model revisions made prior to conducting the project well field simulations.

Initially, a detailed topographic map of the land surface at the Morgan Run golf course and vicinity was prepared. Updated land surface topography was then incorporated into the groundwater model to allow a more accurate assessment of the shallow groundwater conditions relative to land surface in the study area.

The alluvium-bedrock contact and the geometry of hydrostratigraphic units within the basin alluvium were revised based on new lithologic data obtained from the CPT program. The hydraulic conductivity of the deep aquifer Layer 3 was adjusted based on the response observed during the aquifer testing and pilot testing programs. The hydraulic conductivity data obtained from the pore pressure dissipation tests were used to refine the previously assigned hydraulic conductivity of the aquitard sediments Layer 2. The rates and locations of recharge, water level conditions at the river and at the alluvium/ocean boundary, and rates and locations of regional groundwater extraction wells were also updated based on the results of field investigations and other available data.

The flow model was recalibrated to benchmark the model against measured groundwater conditions in the study area. Two phases of calibration were conducted: 1) Steady–state calibration; and 2) Transient calibration, which included seasonal extraction from regional wells. The flow calibration obtained acceptable agreement between measured and projected groundwater elevations, flow directions, and vertical gradients.

A sensitivity analysis was also performed to evaluate the sensitivity of the model results to uncertainty in selected hydraulic properties (Appendix J). Sensitivity of the flow model to aquitard Layer 2 vertical hydraulic conductivity, bedrock hydraulic conductivity, and the horizontal hydraulic conductivity of the deep aquifer Layer 3 were evaluated.

5.0 PROJECT FEASIBILITY EVALUATION

The following sections describe the proposed project and evaluate the performance and potential groundwater-related impacts based on the project simulations that were performed using the numerical groundwater flow and transport model. Potential groundwater-related impacts evaluated based on the model simulations include: impacts to existing groundwater users, shallow water table response to injection and extraction, and changes in groundwater quality, specifically TDS.

5.1 PROJECT DESCRIPTION

To implement this project, OMWD plans to inject up to 150 AF/yr of excess Title 22 tertiary-treated reclaimed water from one of three water reclamation plants during wet-weather periods, and convey the water, via an existing water delivery system, to appropriate injection wellhead locations on Morgan Run. The water would be placed under ground using injection wells screened in a deep confined alluvial aquifer located approximately 80 to 155 feet bls.

The proposed project location is in the southeast corner of the Morgan Run golf course. This area of the basin was selected for several reasons:

- The area contains deep coarse-grained channel deposits which appear to be capable of receiving injected water;
- The area is underlain by shallow fine-grained deposits which likely acts as an effective aquitard and therefore minimize any associated rise in the water table during injection;
- It is located away from existing residential areas;
- Groundwater quality is marginal;
- Most existing groundwater users are located to the north of the proposed project area;
- The hydraulic gradient is relatively flat in the area, which would minimize migration of injected water;

- There appears to be sufficient potential well sites on Morgan Run;
- Morgan Run is a potential user of reclaimed water;
- The location is near the terminus of an OMWD pipeline; and
- Management of the ASR project is expected to prevent impact upon other well owner/operators in the basin.

It is anticipated that the ASR project would consist of the injection and extraction of excess reclaimed water on a seasonal basis. During the wet winter months each year, up to 150 AF of excess reclaimed water would be injected using wells completed in the deep confined aquifer. Typically, injection would occur during three months in the period between November and April. During the injection period, the total system flow rate is anticipated to range up to a maximum of 400 gpm. During the following summer months, when local demand for reclaimed water exceeds the available supply, the injected water would be extracted using the same wells or additional wells if necessary and made available for irrigation by local subscribers.

The number of wells required to achieve the anticipated injection rate will depend on the actual capacity of the project wells, which will depend on the geologic conditions at available well sites. The actual number of wells required will be determined after the wells are installed and tested. It is currently estimated that two wells would be required to achieve the maximum reclaimed water project injection rate. It is anticipated that a third well would be installed to act as a backup well should the capacity of the two primary wells decline over time due to plugging, so that one well can be taken out of service for a short period of time for redevelopment.

Reclaimed water is considerably lower in TDS than existing groundwater at the project location and would therefore improve basin water quality by reducing TDS and would be available for extraction for local irrigation use during summer months. The storage of excess reclaimed water in the basin during the winter could also help reduce the capital costs required for handling excess reclaimed water such as for storage ponds or ocean disposal.

5.2 MODEL SIMULATION RESULTS

Model simulations were conducted to evaluate the long-term feasibility and potential impacts associated with the proposed project. The project well field was assumed to consist of two wells located in the southeast corner of the Morgan Run golf course. One of the well locations represents the existing test well. The location of the second injection well was approximately 1,000 feet south of the test well. This location was selected in consultation with Morgan Run personnel and based on local CPT data, which suggest that well yields should be reasonable in this area. It should be noted that due to the preliminary nature of the modeling, the well flow rates were not optimized and pumping was assumed to be distributed evenly between the two project wells. Existing regional production wells were assumed to be active during the model simulations.

The aquifer storage and recovery project was simulated using the model for a period of 13 years. In order to evaluate the project performance during extremes in possible weather conditions, the simulation was conducted assuming seven years of project injection/extraction under dry conditions followed by six years of project injection/extraction under wet conditions. The amount of recharge to the basin from precipitation and the San Dieguito River were varied during the wet and dry model simulation periods based on precipitation data from historical wet and dry periods and by defining selected segments of the river as being either wet or dry. During each year of the simulation 150 AF of reclaimed water was injected into two project wells for three months each winter at a combined rate of 372 gpm. The injected water was recovered over a period of six months during the spring and summer using the same two project wells pumping at a combined rate of 186 gpm. Water level hydrographs were prepared comparing the simulated baseline seasonal water level fluctuations with no project, to the water level fluctuations that are projected to occur with project injection and extraction.

5.2.1 Water Level Response

The water level change in the deep aquifer near the test well during the 7-year dry and 6-year wet periods is shown on Figure 27. The pressure in the deep aquifer rises about 10 to 15 feet above land surface in the deep aquifer near the injection location at the end of each injection cycle. Note that this does not indicate that groundwater actually reaches land surface, only that the pressure in the deep aquifer near the well exceeds land surface. The distribution of the maximum model-projected change in pressure in the deep aquifer during the 13-year simulation is shown on Figure 28. The change in pressure is greatest in the vicinity of the project wells reaching approximately 14 feet. The change in pressure decreases to about 11 feet at the Rancho Santa Fe Polo Club well 5-FC located west of the project. The maximum change in pressure decreases to about two feet at the north end of the Morgan Run golf course (Figure 28).

The level of the water table in the vicinity of the injection/extraction well during the 13-year project simulation is shown on Figure 29. There is no discernable difference in the water table in this area due to the project, which is consistent with the results of the injection/extraction pilot testing. The rise in the water table at year 7 is due to the shift from dry to wet boundary and recharge conditions in the basin. Figure 30 indicates that there could be an area of limited change in pressure in the water table in the area north of the project and east of Morgan Run. Based on available drillers logs, the fine-grained sediments which comprise the aquitard may thin and/or pinch out in this north area which may allow some change in pressure to occur. The maximum model-projected change in pressure in the water table in this area is about 0.7 feet. The depth to water during the winter months in this area is expected to range from about 15 to 20 feet bls, therefore the amount of projected water table rise should not have any adverse effects.

The projected drawdown in the deep aquifer in the vicinity of the test well during the spring and summer pumping periods is shown on Figure 31. The project is projected to cause about eight feet of additional drawdown in the vicinity of the project wells. The distribution of the maximum model-projected drawdown in the deep aquifer during the 13-year simulation is shown on Figure 31. The drawdown is greatest in the vicinity of the project wells reaching approximately eight feet. The drawdown decreases to about 5.5 feet at the Rancho Santa Fe Polo Club well 5-FC located west of the project. The maximum drawdown also decreases to about two feet at the north end of the Morgan Run golf course (Figure 31). This amount of drawdown is not expected to noticeably affect the capacity of existing wells.

Water level graphs for the 13-year project simulation for the deep confined aquifer and the water table for other well locations in the basin are also provided in Appendix J. Of the active wells, the only well experiencing a water level above land surface is the Rancho Santa Fe Polo Club well. At this well, the pressure in Layer 3 is conservatively projected to exceed land surface by as much as 12 feet. This suggests that this well would need to be fitted with a water tight seal at the top or the casing to prevent it from flowing during the injection periods. The water table at this location is not projected to change appreciably from the baseline level. The change in pressure in the deep aquifer is not projected to exceed land surface at any existing wells located north of the project, however the pressure in the deep aquifer may approach land surface in the nearest wells to the north. Monitoring would need to be implemented in this area to ensure that water levels in these wells do not exceed land surface during project operation, if these wells are not also sealed.

5.2.2 Water Quality

The change in TDS of the water recovered from the Test Well during the 13-year project simulation as shown on Figure 32. The starting concentration of TDS in the deep aquifer at this location is 4,200 mg/l. During the first injection cycle the TDS drops to a concentration approaching the injected reclaimed water. The TDS increases during each extraction cycle but attains a lower concentration at the end of each cycle due to the zone of lower TDS water, which builds up in the aquifer around the test well. After 13 injection cycles the simulated TDS increases to approximately 1,500 mg/l during the recovery cycle.

The extent of reclaimed water in the deep aquifer in the area surrounding the project well field at the end of 7 and 13 years respectively is shown on Figures 33 and 34. Because the reclaimed water mixes with the native groundwater the map presents the ratio of reclaimed water to native groundwater. After 7 years of project operation it appears that the reclaimed water has yet to reach the nearest active wells. After 13 years of operation, groundwater containing about 1 percent reclaimed water is projected to reach the nearest active well, Polo Club Well (Figure 34).

6.0 CONCLUSIONS

Based on the work conducted to date it appears that it is feasible to seasonally inject and extract 150 acre-feet of reclaimed water in the southeast corner of the Morgan Run golf course. The water would be injected into a deep aquifer zone consisting primarily of sand and gravel. In the project area the deep aquifer is overlain by fine-grained, silty to clayey layers that confine the deep aquifer and restrict upward migration of water. The results of the pilot testing and groundwater modeling indicate that the water table is unlikely to experience significant increase in pressure or drawdown due to the project injection and extraction. It appears that there could, however, be some limited water table rise in the area located north of the project, if the aquitard is less competent than observed in the project area. Given the expected depth to water in this area of 15 to 20 feet the small water table rise is not expected to result in any adverse impact. Monitoring of water levels in the basin during injection and extraction would be conducted in accordance with the requirements outlined in the AMP (H+A, 2004). If necessary, the rate and location of injection or extraction would be adjusted to prevent significant water level impacts.

The results of the groundwater modeling indicate that during injection periods the pressure in the deep aquifer could rise to about 10 to 15 feet above land surface near the injection wells and in areas to the south, including the RSF Polo Club well. This suggests that existing inactive wells in this area would need to be grouted up and existing production wells at the Polo Club would need to be fitted with water tight seals on the top of the casings to prevent them from flowing during the injection periods. Further detail regarding this work is provided in the AMP (H+A, 2004). The results of the groundwater modeling indicate that the pressure in the deep confined aquifer do not build up to levels above land surface at existing production wells located to the north of the project wells. The model results do however indicate that during injection periods the pressure in the deep aquifer could rise to levels approaching land surface at the nearest existing wells located to the north. Monitoring will be conducted in accordance with the AMP to ensure that water levels do not exceed land surface during project operations if these wells are not also sealed.

The results of the groundwater modeling indicate that during recovery periods the pressure in the deep confined aquifer are not likely to draw down to the point where it would noticeably affect the capacity of existing production wells. Monitoring of water levels in the basin during extraction will be conducted in accordance with the requirements outlined in the AMP to ensure that capacity of existing wells is not affected (H+A, 2004).

The TDS of the recovered reclaimed water is likely to increase up to roughly 3,000 mg/l during the initial recovery cycles. The maximum concentration reached at the end of each subsequent recovery cycle may decrease in each subsequent year although some variation should be expected depending on the variability of groundwater extraction elsewhere in the basin. It will likely require on the order of 13 years of repeated injection and extraction before TDS concentrations would remain at or below 1,500 mg/l throughout the recovery cycle. The results of the groundwater modeling also indicate that the injected water will probably not reach any of the existing active wells in the basin until the end of the thirteen-year simulation period assuming the amount of water extracted is equal to the amount injected over time (Figure 34). Water quality monitoring will also be done in accordance with the AMP to monitor the changes in water quality in the project area (H+A, 2004).

7.0 REFERENCES

CH2M Hill and Dr. David Huntley, Ph.D., 1995. Final Report San Dieguito Basin Groundwater Model, San Diego County, California. April 1995.

Carroll, A.C., 1985. A Numerical Model of Potential Conjunctive Use in San Dieguito Basin, San Diego County, California. A Thesis Presented to the Faculty of San Diego State University. Spring 1985.

Izbicki, J.A., 1983. Evaluation of the San Dieguito, San Elijo and San Pasqual Hydrogeologic Subareas for Reclaimed Water Use, San Diego County California.

Hargis + Associates, Inc. (H+A), 2000. San Dieguito Basin Groundwater Monitoring Report 1997-1999. June 19, 2000.

_____, 2002. Project Report, Aquifer Storage and Recovery Program, San Dieguito Basin, San Diego, California. October 3, 2002.

_____, 2004. Active Management Plan, Aquifer Storage and Recovery Project, San Dieguito Basin, San Diego, California. August 2, 2004.

HYA Consulting Engineers, H+A, Goodwin & Associates, and Dr. David Huntley, Ph.D., 1997. San Dieguito Basin Groundwater Management Planning Study, Phase II – Feasibility Analysis. November 1997.

Kennedy, M.P., and G.L. Peterson, 1975. Geology of the San Diego Metropolitan Area, California. California Division of Mines and Geology, Bulletin 200.

Kleinfelder, Inc., 2004. Environmental Impact Report for the San Dieguito Water Storage and Recovery Project, San Diego, California. July 19, 2004.

Norris, R.M., and R.W. Webb, 1990. Geology of California. Second edition. New York: John Wiley & Sons, Inc.

Walawender, M.J., 2000. The Peninsular Ranges: A Geologic Guide to San Diego's Back Country. Dubuque: Kendall/Hunt Publishing Company.

TABLE 1

ACTIVE REGIONAL WELL SUMMARY

Township/ Range	Well Identifier	Well Owner/Alternate Name	Well Usage	Approx. Property Acreage	Annual Pumpage (AF/yr)	Source of Data / Remarks
Active Wells						
13S / 3W	28-QA	Former Owner: Bauce	Irrigation, landscape	14	32	Calculated based on acreage.
13S / 3W.	28-RA...	Buie	Equestrian; Irrigation, pasture	10	23	Calculated based on acreage.
13S / 3W	28-RB	International Farms (Shallow Well)	Irrigation, landscape; ponds	39	88	Calculated based on acreage.
13S / 3W	32-HA	Friedkin	Irrigation, landscape	7	16	Calculated based on acreage. Completed in older alluvium and bedrock.
13S / 3W	32-JD	Morgan Run (Gun R Well)	Irrigation, golf course	NA	226	Annual Pumpage = 566 AF/yr based on booster pump hour meters and assummed pump efficiency (10/2001). Assumed 40:60 ratio for No.3 Green N : Gun R Extraction Rates.
13S / 3W	32-RB	Morgan Run (No.3 Green N. Well)	Irrigation, golf course	NA	340	
13S / 3W	33-BA	Albert Court	Equestrian; Irrigation, pasture	46	104	Calculated based on acreage.
13S / 3W	33-EA	Mac Farlane (North Well)	Construction; future landscape irrigation	NA	45	Rough Estimate
13S / 3W	33-FB	Schoenfelder (South Well)	Fairbanks Ranch golf course	373	200	Maintentance Manager estimate is 180 AF/yr. Contract is for 200 AF/yr.
13S / 3W	33-FA	Schoenfelder (North Well)	Irrigation, landscape	20	45	Calculated based on acreage.
13S / 3W	33-K8	Helen Woodward Animal Center	Irrigation, lawn/field (neighbor's property)	8.5	10	Calculated based on neighbors acreage (x0.4).
13S / 3W	33-LC	Harris	Irrigation, landscape	5	11	Calculated based on acreage.
13S / 3W	33-LA	FBR Homeowners	Irrigation, landscape; ponds	NA	15	Property Manager estimate.
13S / 3W	33-MB	Altman	Irrigation, landscape	5	11	Calculated based on acreage.
13S / 3W	33-MD	Goldberg	Irrigation, landscape	2	5	Calculated based on acreage.
13S / 3W	33-ME	Wassermann	Irrigation, landscape	4.7	11	Calculated based on acreage.
13S / 3W	33-MF	Farhood	Irrigation, landscape	5	11	Calculated based on acreage.
13S / 3W	33-ND	Bosstick	Irrigation, landscape	10	23	Calculated based on acreage.
13S / 3W	33-NE	Hazel	Irrigation, landscape	3	7	Calculated based on acreage.
13S / 3W	33-CA	Rancho Paseana (North Well)	Equestrian; Irrigation, pasture		90	Assumed to be 50 percent of south well extraction.

Refer to Page 2 for footnotes and references

TABLE 1

ACTIVE REGIONAL WELL SUMMARY

Township/ Range	Well Identifier	Well Owner/Alternate Name	Well Usage	Approx. Property Acreage	Annual Pumpage (AF/yr)	Source of Data / Remarks
13S / 3W	33-PA	Rancho Paseana (South Well)	Equestrian; Irrigation, pasture	228	180	Based on south well totalizer readings; Property also uses 200 AF/yr of reclaimed water.
13S / 3W	33-PB	Fairbanks Country Day School	Irrigation, lawn/field	9	20	Calculated based on acreage.
13S / 3W	33-C7	Chino Farms	Irrigation, agriculture	56	60	Owner Estimate
14S / 3W	5-FA 5 FC	RSF Polo Club (No. 1 and 2R Wells)	Equestrian; Irrigation; field	NA	125	Property Manager Estimate
14S / 3W	7-BA	Rancho Del Mar	Equestrian; Domestic Supply	5.5	5	Rough Estimate; located outside alluvial basin; Completed in marine sedimentary rock water treated using reverse osmosis unit.
14S / 3W	7-K3	Far West Farms	Equestrian	20	5	Rough Estimate
14S / 3W	7-LA	Rancho El Camino	Equestrian	10	5	Rough Estimate
13S / 3W	33-L8	Nativity Catholic Church	Irrigation, lawn/field	10	15	Calculated based on acreage (x0.5).
Existing / Probably Active Wells						
13S/3W	33-CB	Edwards	Equestrian, Irrigation	7.8	18	Calculated based on acreage.
13S / 3W	32-JC	Skeets-Dunn	Irrigation, landscape	4	9	Calculated based on acreage. Completed in older alluvium and bedrock.
13S / 3W	33-LD	Heller	Irrigation, landscape	5	11	Calculated based on acreage.
13S / 3W	33-LE	Champion	Irrigation, landscape	2.5	6	Calculated based on acreage.
13S / 3W	33-MC	Rogers	Irrigation, landscape	2	5	Calculated based on acreage.
Probably Existing and Active Wells						
13S / 3W	28-JA	Vinci	Irrigation, landscape	3.15	7	Calculated based on acreage.
13S / 3W	32-GA	Williams	Irrigation, landscape	3.5	8	Calculated based on acreage. Completed in older alluvium and bedrock.
				TOTAL	1,791	

FOOTNOTES: gpm = gallons per minute
AF/yr = acre-feet per year
NA = not available

Note: For those wells where yield is calculated based on acerage, groundwater pumpage = acreage * landscape area * estimated water use
where: landscape area is assumed to be 75 percent of total acreage
estimated water use is 3 feet of water per acre per year

TABLE 2

GROUNDWATER MONITORING
GENERAL MINERAL AND PHYSICAL ANALYSIS RESULTS

YEAR SAMPLED		2001	2002	2001	2001	2001	2001	2002	2001	2002	2001	2001	2001	2001	2001	2001	2002	2003			
	PROJECT WELL NUMBER	5-FA	5-FA	5-GA	5-H2	7-BA	32-JD	32-JD	32-RB	32-RB	33-FA	33-K8	33-LA	33-PB	33-NC	33-PA	33PA				
	WELL IDENTIFIER	RSF Polo Club No. 2R	RSF Polo Club No. 2R	RSF Polo Club Test Well	Morgan Run Fairway 2	Rancho Del Mar	Morgan Run Newest Gun R	Morgan Run Newest Gun R	Morgan Run No. 3 Green North	Morgan Run No. 3 Green North	Schoenfelder No. 1 North	Helen Woodward New	Fairbanks HOA El Apajo W. #2	Fairbanks Country Day School	Morgan Run East Well	Rancho Paseana South Active	Rancho Paseana South Active	OMWD Test Well	MINIMUM	MAXIMUM	AVERAGE
COMPOUND	UNITS																				
Aluminum	mg/l	NA	<0.050	NA	NA	NA	NA	<0.050	NA	NA	NA	NA	NA	NA	NA	NA	0.056	<0.050	<0.050	0.056	NA
Barium	mg/l	NA	0.27	NA	NA	NA	NA	0.32	NA	0.15	NA	NA	NA	NA	NA	NA	0.27	NA	0.15	0.32	0.25
Boron	mg/l	0.93	NA	1.1	0.78	2.7	0.22	NA	0.25	NA	0.24	1.3	0.28	0.20	0.41	0.38	NA	0.57	0.20	1.1	0.70
Calcium	mg/l	290	290	380	170	390	220	240	220	240	150	220	300	230	96	200	190	320	96	390	241
Iron	mg/l	2.0	0.21	470	18	<0.080	<0.040	0.044	0.049	<0.040	2.5	4.8	1.3	5.3	25	2.6	<0.040	0.280	<0.040	470	31.3[1]
Magnesium	mg/l	190	140	320	290	93	110	130	130	130	78	170	170	120	61	120	110	190	61	320	152
Manganese	mg/l	1.6	1.4	9.1	0.48	0.97	0.89	0.99	0.97	1.0	1.3	1.5	2.5	3.4	0.96	1.4	1.3	1.5	0.48	9.1	2.2
Potassium	mg/l	50	53	200	19	18	12	13	11	11	9.3	62	18	17	14	24	28	52	9.3	200	42
Sodium	mg/l	1,200	1,000	630	920	1,400	410	400	460	490	310	1,100	440	350	390	660	660	930	310	1,400	681
Bromide	mg/l	5.0	NA	<2.5	<2.5	<5.0	<5.0	NA	<5.0	NA	1.0	<5.0	<5.0	<2.5	<1.0	<5.0	NA	NA	<1.0	5.0	3.0[2]
Chloride	mg/l	2,300	1,800	1,000	1,700	2,400	1,000	880	940	860	600	1,900	1,400	930	490	1,400	1,100	1,600	490	2,300	1,268
Fluoride	mg/l	<2.5	<5.0	<2.5	<2.5	<5.0	<5.0	<2.5	<5.0	<2.5	<1.0	<5.0	<5.0	<2.5	<1.0	<5.0	<2.5	<2.5	<1.0	<5.0	ND
Zinc	mg/l	NA	0.14	NA	NA	NA	NA	0.084	NA	0.024	NA	NA	NA	NA	NA	NA	0.033	0.056	0.024	0.14	0.08
Nitrate-N	mg/l	<0.55	<1.1	<0.55	<0.55	<1.1	1.7	2.0	2.8	1.4	<0.22	<1.1	<1.1	<0.55	0.22	<1.1	<0.55	<0.55	<0.22	2.8	1.6[2]
Nitrite-N	mg/l	<7.5	<1.50	<0.75	<3.0	<7.5	<3.0	<1.5	<3.0	<0.750	<1.5	<3.0	<3.0	<1.5	<0.75	<1.5	<0.75	<0.75	<0.75	<7.5	ND
Orthophosphate	mg/l	<2.5	0.56	<2.5	<2.5	<5.0	<5.0	<0.050	<5.0	0.097	<1.0	<5.0	<5.0	<5.0	<1.0	<5.0	<0.050	NA	<1.0	<5.0	NA
Sulfate	mg/l	770	610	530	840	920	510	440	570	510	410	650	510	470	430	580	400	610	410	920	573
TDS	mg/l	4,600	4,400	2,500	3,700	5,100	2,600	2,400	2,500	2,600	1,600	4,200	3,000	2,300	1,600	3,100	2,800	4,400	1,600	5,100	3,082
EC	µmhos/cm	7,080	7,100	4,000	5,905	7,540	3,700	4,000	3,880	4,200	1,854	6,490	4,690	3,570	1,891	4,600	4,800	6,700	1,891	7,540	4,687
DO	mg/l	3.35	NA	1.38	1.44	2.09	4.16	NA	3.23	NA	6.17	1.79	1.62	1.76	1.24	1.4	NA		1.24	6.17	2.59
pH	pH units	6.88	7.59	7.31	7.7	7.10	6.84	7.14	7.03	6.91	7.37	7.22	7.04	6.93	7.42	7.25	7.29	7.37	6.64	7.7	7.22
Temperature	°C	23.7	NA	24.0	21.3	23.9	21.4	NA	21.8	NA	25.4	23.5	21.6	25.0	21.9	20.6	NA	21	20.6	25.4	22.68
Redox Potential	mv	-80	NA	-125	-190	45	87	NA	100	NA	-130	-118	-52	-105	-155	-15	NA		-190	100	-58
Odor	T.O.N.	NA	NA	NA	<1.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<1.0	–	–	–
Turbidity	NTU	NA	14	NA	180	NA	NA	<1.0	NA	<1.0	NA	NA	NA	NA	NA	NA	26	NA	<1.0	180	NA
MBAS	mg/l	NA	NA	NA	<0.10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	–	–	–
Color	Color units	NA	NA	NA	20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	–	–	–
Silicon	mg/l	NA	32	NA	NA	NA	NA	31	NA	30	NA	NA	NA	NA	NA	NA	29	33	29	32	31
Bicarbonate	mg/l	NA	330	NA	NA	NA	NA	260	NA	340	NA	NA	NA	NA	NA	NA	420	380	260	420	344
Hardness	mg/l	NA	1,300	NA	NA	NA	NA	1,100	NA	1,100	NA	NA	NA	NA	NA	NA	1,000	1,600	1,000	1,300	1,191

FOOTNOTES

(1) Average calculated using detected and non-detected values.
(2) Average calculated using only detected values.

mg/l = Milligrams per liter
NA = Not analyzed
(<) = Less than
TDS = Total dissolved solids
EC = Electrical conductivity
DO = Dissolved oxygen
MBAS = Methylene Blue – Activated Substances
ND = Non-detect
µmhos/cm = Micromhos per centimeter
°C = Degrees centigrade
mv = Millivolts
T.O.N. = Threshold Odor Number
NTU = Nephalometric turbidity units
NA = Not analyzed
(–) = Not applicable

TABLE 3

WATER QUALITY COMPARISON

		GROUNDWATER MONITORING RESULTS			NORTH CITY RECLAMATION PLANT[1]	4S WWTP EXPECTED EFFLUENT[2]	WATER QUALITY OBJECTIVES SOLANA BEACH (HA-905.10)[3]
COMPOUND	UNITS	MINIMUM	MAXIMUM	AVERAGE	AVERAGE		
Boron	mg/l	0.20	1.1	0.73	0.508	0.51	0.75
Calcium	mg/l	96	390	239	57.6		
Iron	mg/l	<0.040	470	44.3[4]	0.153	0.07	0.85
Magnesium	mg/l	61	320	154	23.1		
Manganese	mg/l	0.48	9.1	2.1	0.074	0.05	0.15
Potassium	mg/l	9.3	200	38	11.0		
Sodium	mg/l	310	1,400	689	147		
% Sodium	mg/l/%	--	--	61.5	59	49	60
Bromide	mg/l	<1.0	5.0	3.0[5]			
Chloride	mg/l	490	2,300	1,340	187	175	500
Fluoride	mg/l	<1.0	<5.0	ND	0.4	0.4	1.0
Nitrate-N	mg/l	<0.22	2.8	1.6[5]			45
Nitrite-N	mg/l	<0.75	<7.5	ND			
Orthophosphate	mg/l	<1.0	<5.0	ND			
Sulfate	mg/l	410	920	599	226	246	500
TDS	mg/l	1,600	5,100	3,100	772	906	1,500
EC	µmhos/cm	1,891	7,540	4,600			
DO	mg/l	1.24	6.17	2.47			
PH	pH units	6.84	7.7	7.17	7.42	6.5 – 8.5	
Temperature	°C	20.6	25.4	22.8			
Redox Potential	Mv	-190	100	-61.5			
Odor	T.O.N.			<1.0[6]			NONE
Turbidity	NTU			180[6]	1.5	2	5
MBAS	mg/l			<0.10[6]	0.17	0.08	0.5
Color	Color units			20[6]			15

NOTE: Refer to page 2 of this table for footnotes.

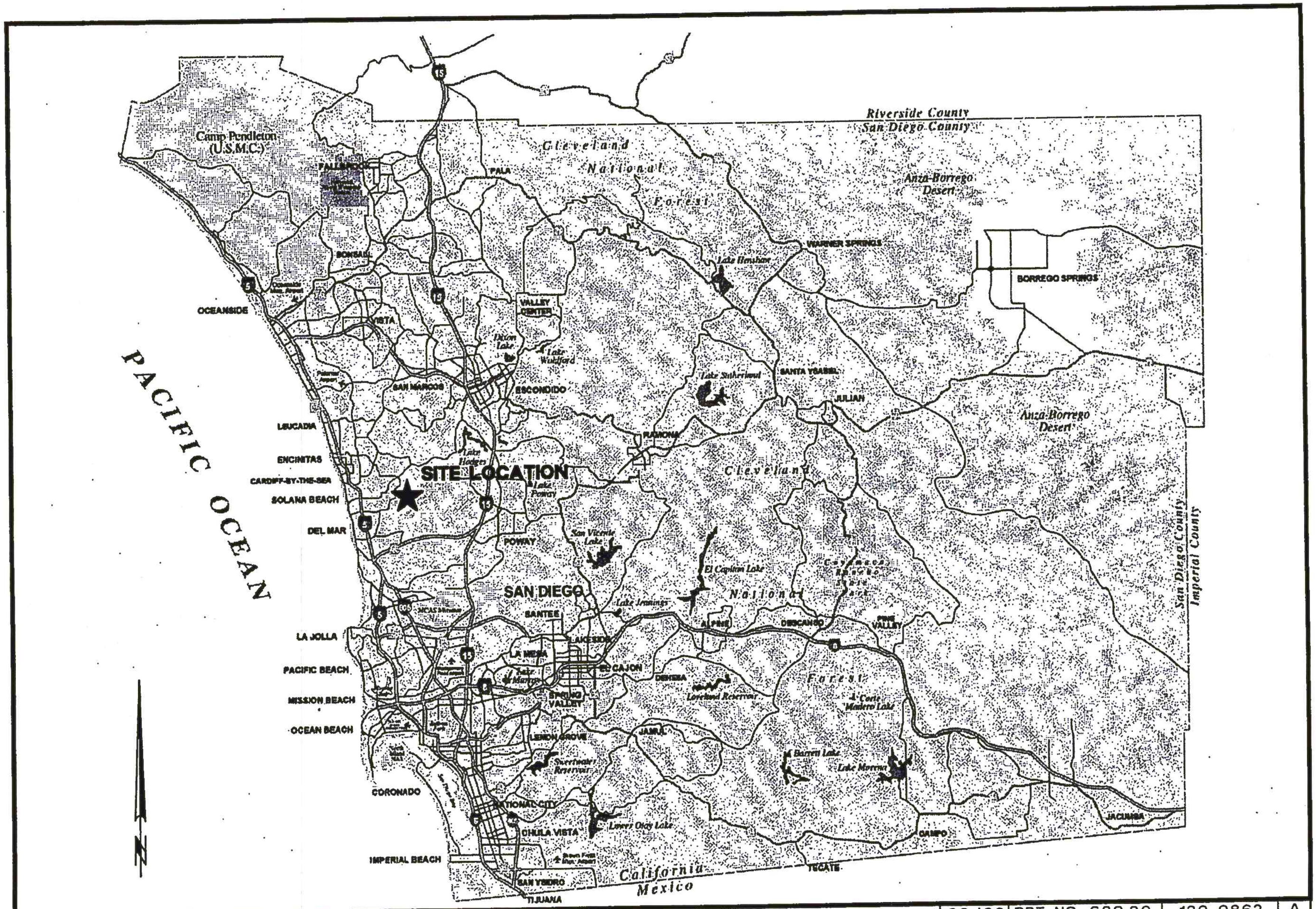
TABLE 3

WATER QUALITY COMPARISON

FOOTNOTES

(1) Average of data from April – December 2000.
(2) From Table 2-2 of Montgomery Watson report.
(3) San Diego Regional Water Quality Control Board Basin Plan, 1994.
(4) Average calculated using detected and non-detected values.
(5) Average calculated using only detected values.
(6) Only one analysis was run for these analytes.

mg/l = Milligrams per liter
(<) = Less than
% Sodium = Na ÷ (Na + Ca + Mg + K) x 100%
TDS = Total dissolved solids
EC = Electrical conductivity
DO = Dissolved oxygen
MBAS = Methylene Blue – Activated Substances
µmhos/cm = Micromhos per centimeter
°C = Degrees centigrade
mv = Millivolts
T.O.N. = Threshold Odor Number
NTU = Nephalometric turbidity units
NA = Not analyzed
WWTP = Waste Water Treatment Plant



09/02	RPT NO. 689.20	120-0862	A

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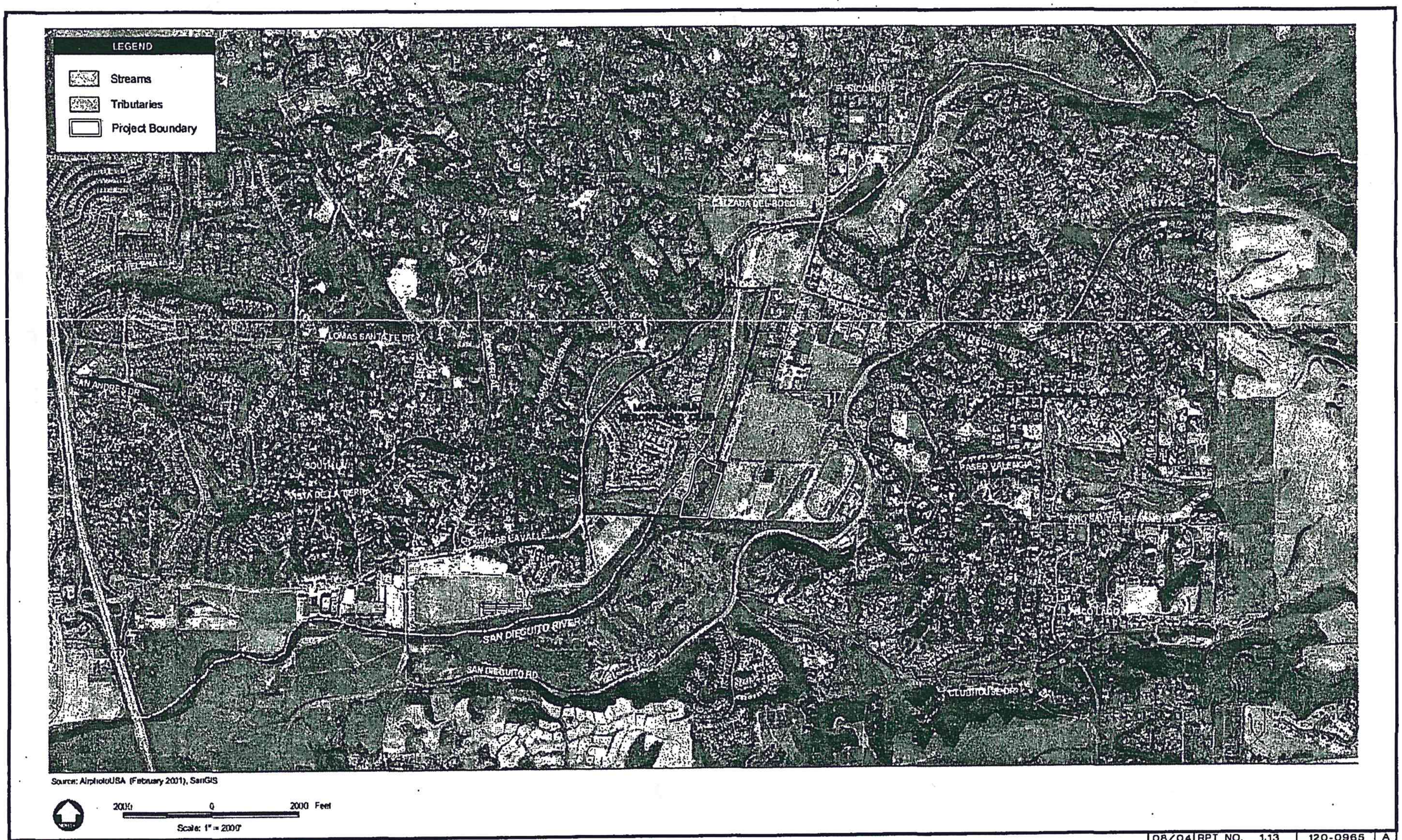
Hydrogeology/Engineering

FIGURE 1. REGIONAL SITE LOCATION



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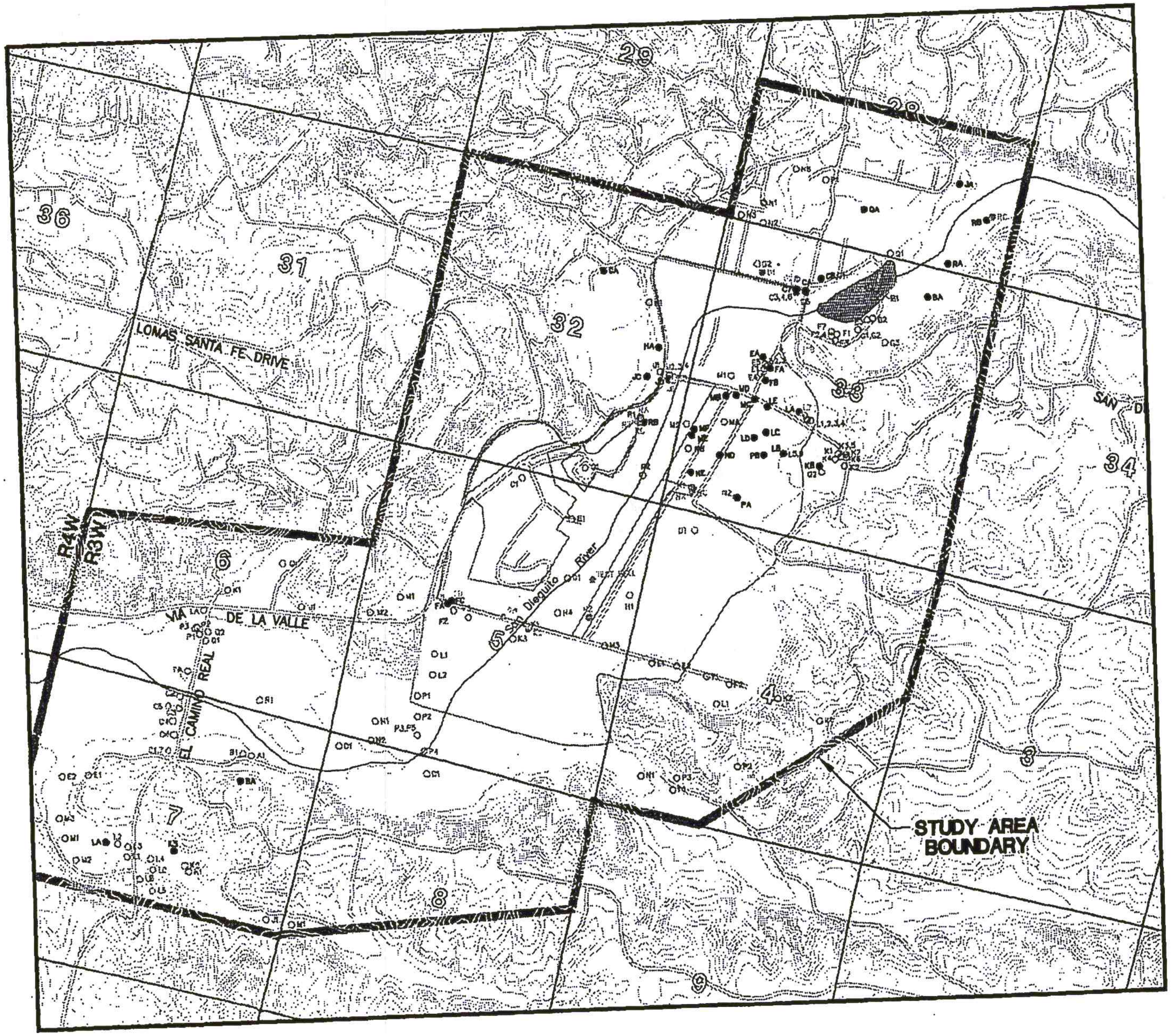
Hydrogeology/Engineering

08/04	RPT NO. 1.13	120-0965	A

FIGURE 2.
PROJECT LOCATION



EXPLANATION

JA ● LOCATION OF ACTIVE AND PROBABLY ACTIVE WELL IN STUDY AREA

RC ⊕ LOCATION OF INACTIVE WELL IN STUDY AREA

Q1 ○ LOCATION OF DESTROYED WELL IN STUDY AREA AND WELLS THAT COULD NOT BE LOCATED OR WHOSE EXISTENCE IS UNCERTAIN

NOTE: WELL IDENTIFIERS ENDING IN NUMBERS ARE AN ABBREVIATION OF THE STATE WELL NUMBER. WELLS WITH IDENTIFIERS ENDING IN LETTERS HAVE NOT BEEN ASSIGNED A STATE WELL NUMBER, BUT ARE BASED ON A SIMILAR IDENTIFICATION SCHEME.

0 1,800 3,600

FEET

SAN DIEGUITO GROUNDWATER BASIN

REGIONAL WELLS

HARGIS + ASSOCIATES, INC
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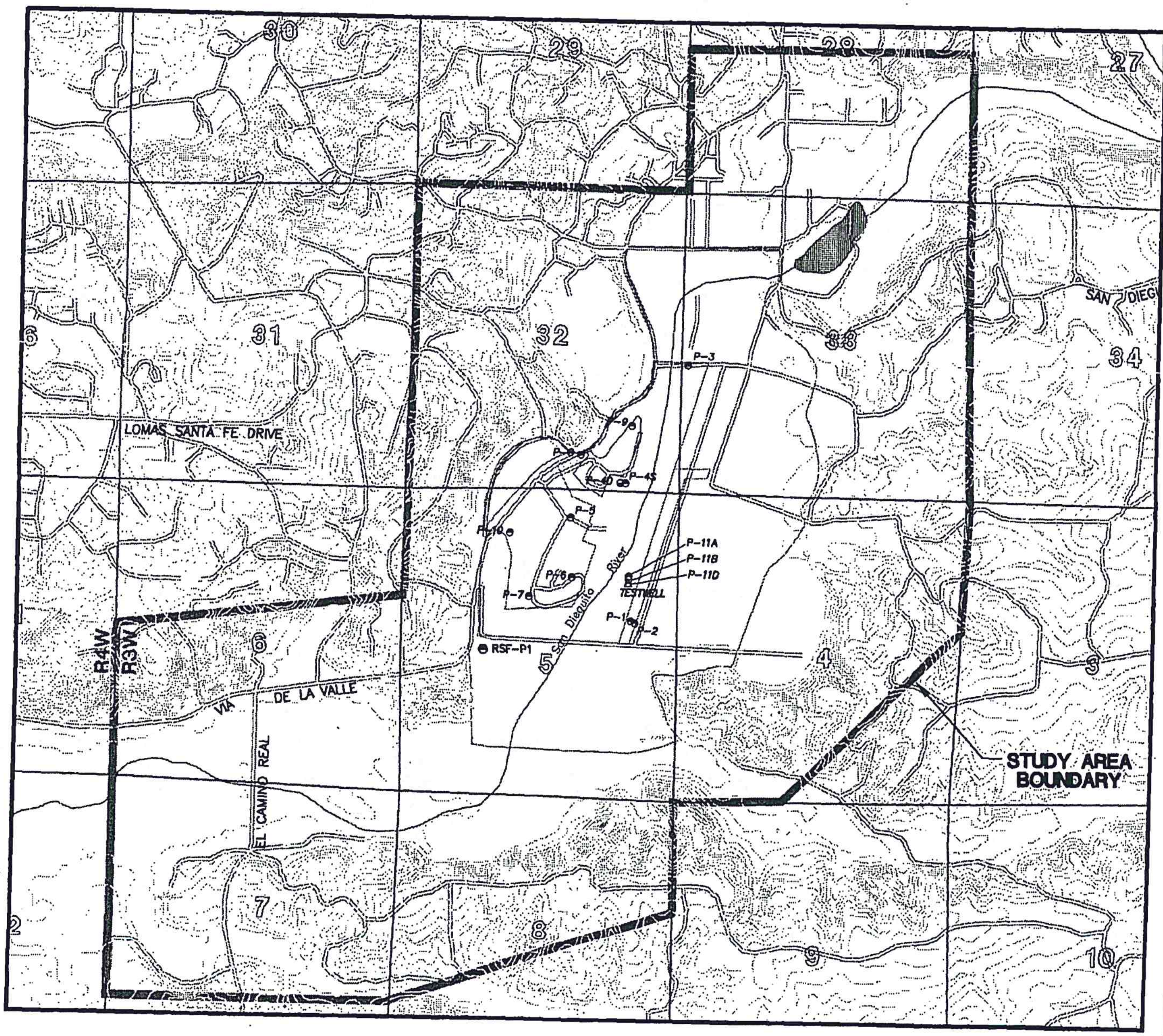
08/04

FIGURE 3

PREP BY RAN REV BY MAP RPT NO. 659.20 | 410-4753 | B



EXPLANATION

- P-8 ⊖ SHALLOW ZONE PIEZOMETERS INSTALLED IN 2002 AND 2003
- RSF-P1 ⊖ SHALLOW ZONE OBSERVATION WELL INSTALLED BY OTHERS
- P-11B ○ INTERMEDIATE ZONE PIEZOMETERS INSTALLED IN 2002 AND 2003
- P-4D ⊖ DEEP ZONE PIEZOMETERS INSTALLED IN 2002 AND 2003
- △ TEST WELL

SAN DIEGUITO GROUNDWATER BASIN

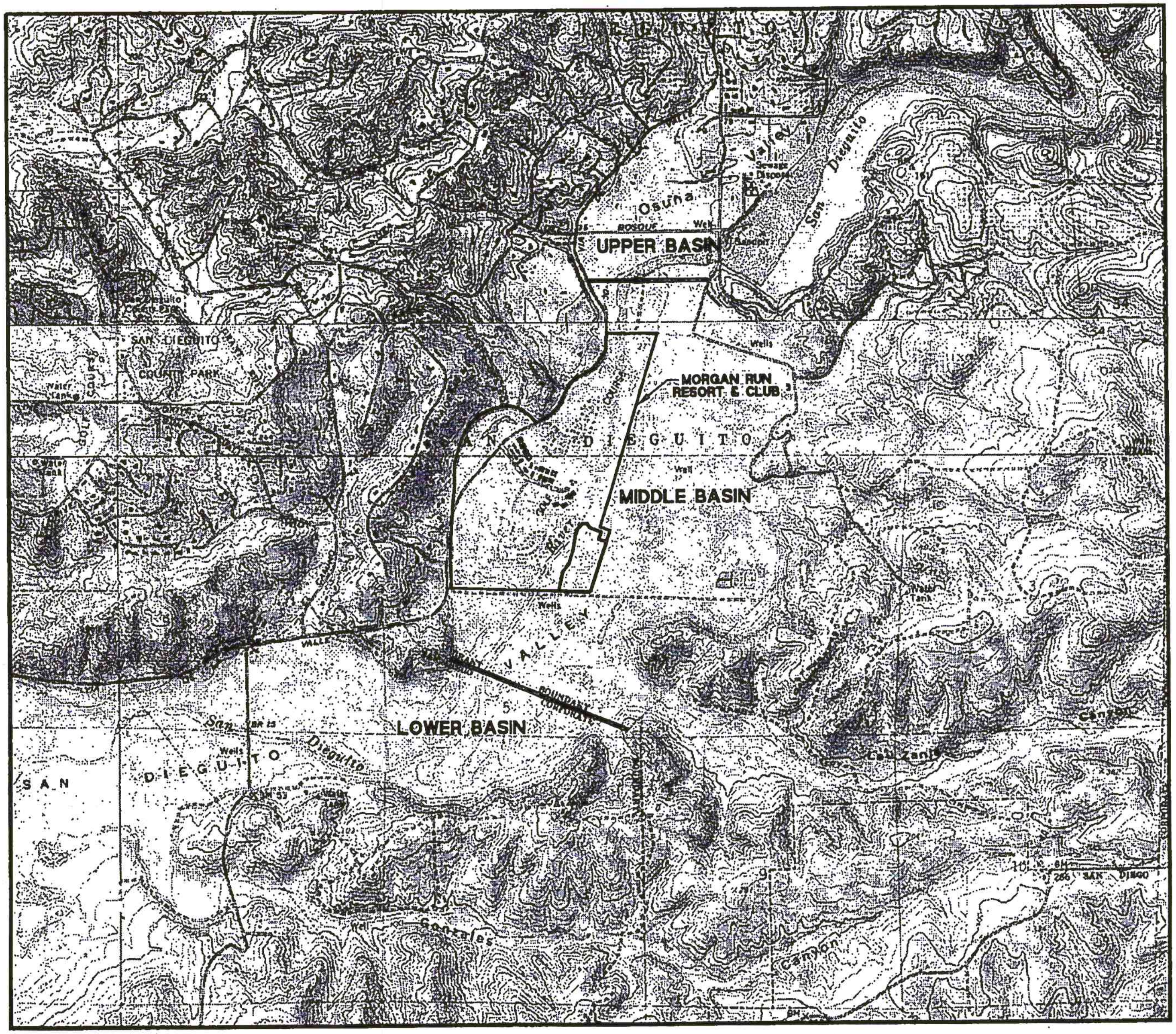
PIEZOMETERS

HARGIS+ASSOCIATES, INC
Hydrogeology/Engineering

06/04

FIGURE 4

PREP BY SLB REV BY MAP RPT NO. 689.20 | 410-4761 | A



EXPLANATION

PROJECT AREA

0 2,000 4,000
FEET

SAN DIEGUITO GROUNDWATER BASIN

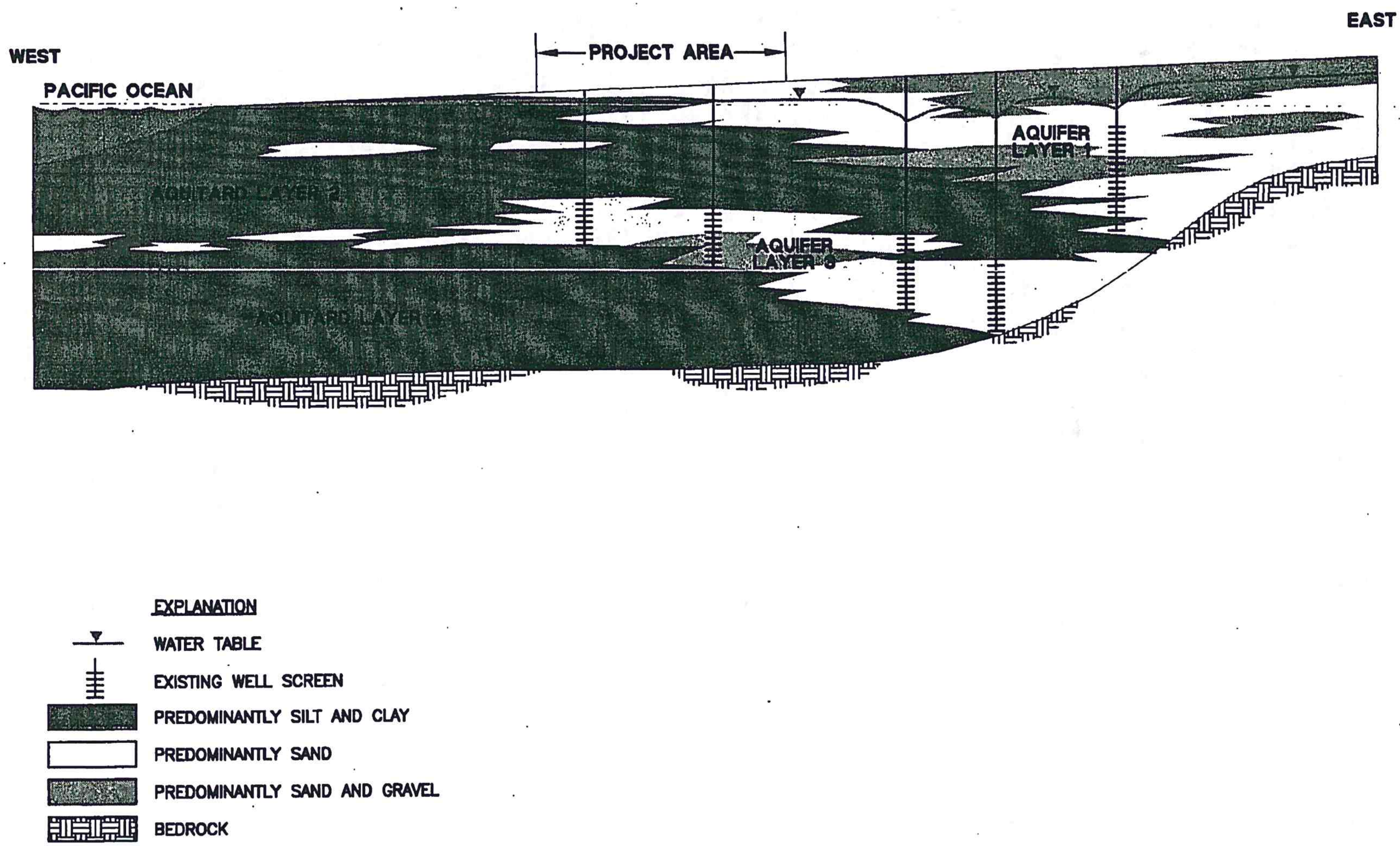
TOPOGRAPHIC FEATURES

HARGIS+ASSOCIATES, INC
Hydrogeology/Engineering

08/04

FIGURE 5

PREP BY SLB REV BY RAN RPT NO. 889.1 | 410-4756 | B



06/04	RPT NO. 689.20	310-0577	A

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FIGURE 6. CONCEPTUAL GEOLOGY

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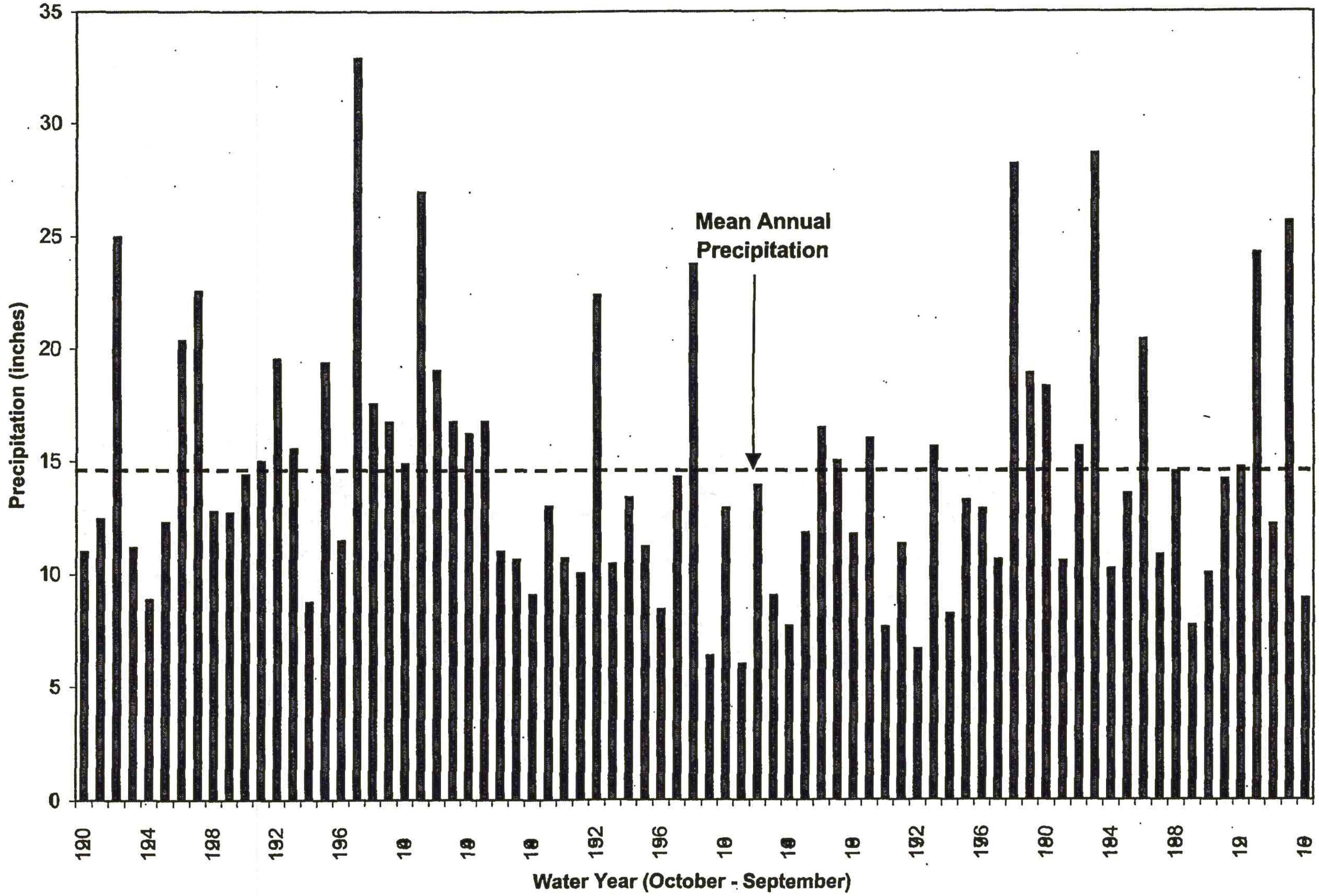
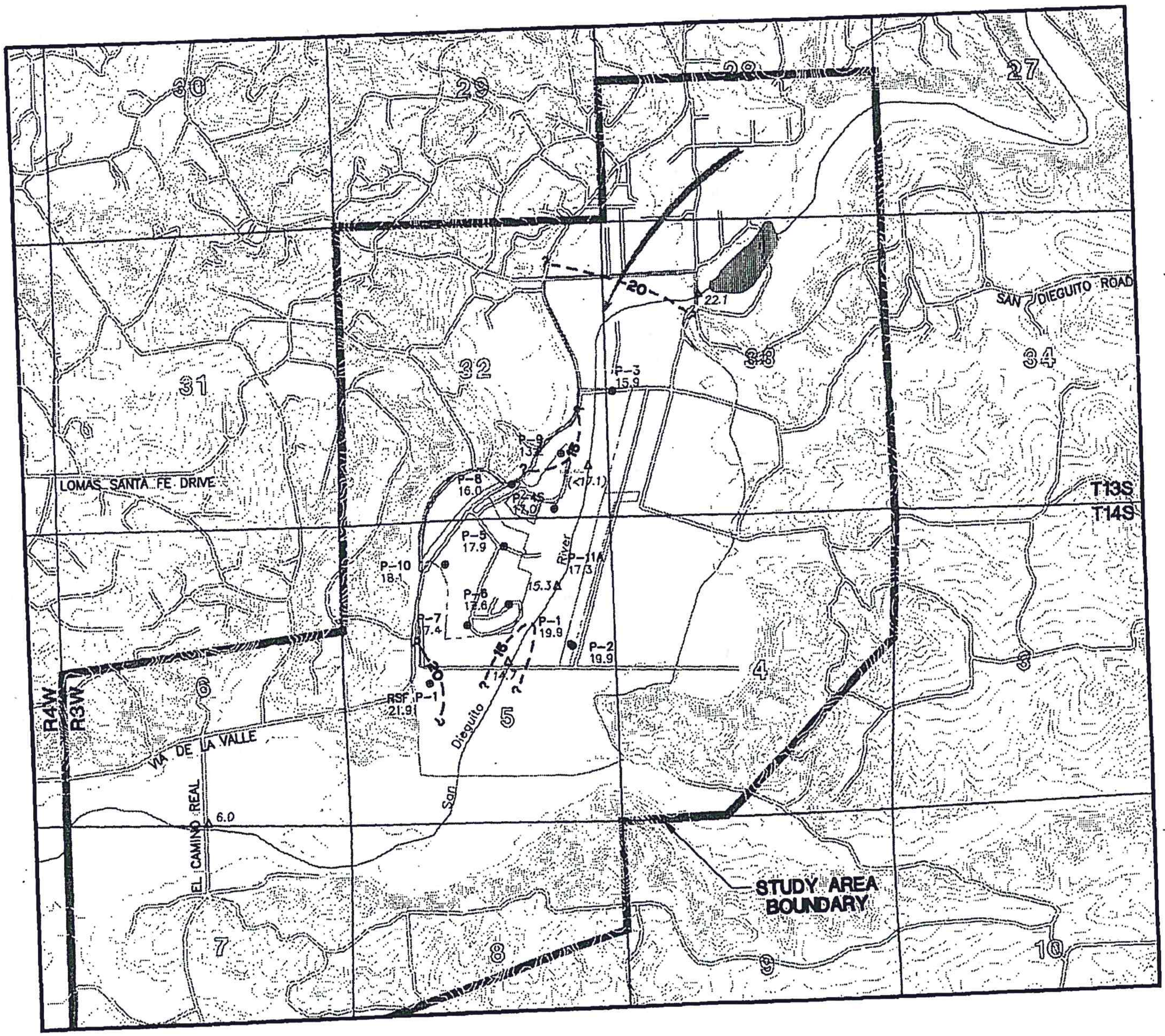


89Rp2004l Fig 07
08/17/04

FIGURE 7: ANNUAL PRECIPITATION



EXPLANATION

15.5 Δ SURFACE WATER ELEVATION, SAN DIEGUITO RIVER

P-1 ● SHALLOW PIEZOMETER

19.9 WATER LEVEL ELEVATION, IN FEET MEAN SEA LEVEL

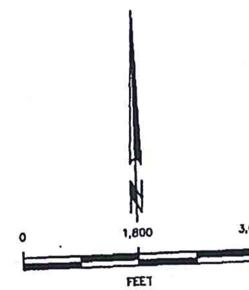
(23.5) WATER LEVEL ELEVATION NOT CONTOURED

?——— 20 - - - - - - ?
CONTOUR LINE OF EQUAL WATER LEVEL ELEVATION IN FEET MEAN SEA LEVEL, DASHED WHERE APPROXIMATE, QUERIED WHERE INFERRED

INDICATES DIRECTION OF GROUNDWATER FLOW

NOTES: WATER LEVELS MEASURED ON OCTOBER 22-23, 2003

WELL IDENTIFIERS ENDING IN NUMBERS ARE AN ABBREVIATION OF THE STATE WELL NUMBER. WELLS WITH IDENTIFIERS ENDING IN LETTERS HAVE NOT BEEN ASSIGNED A STATE WELL NUMBER, BUT ARE BASED ON A SIMILAR IDENTIFICATION SCHEME.



SAN DIEGUITO GROUNDWATER BASIN

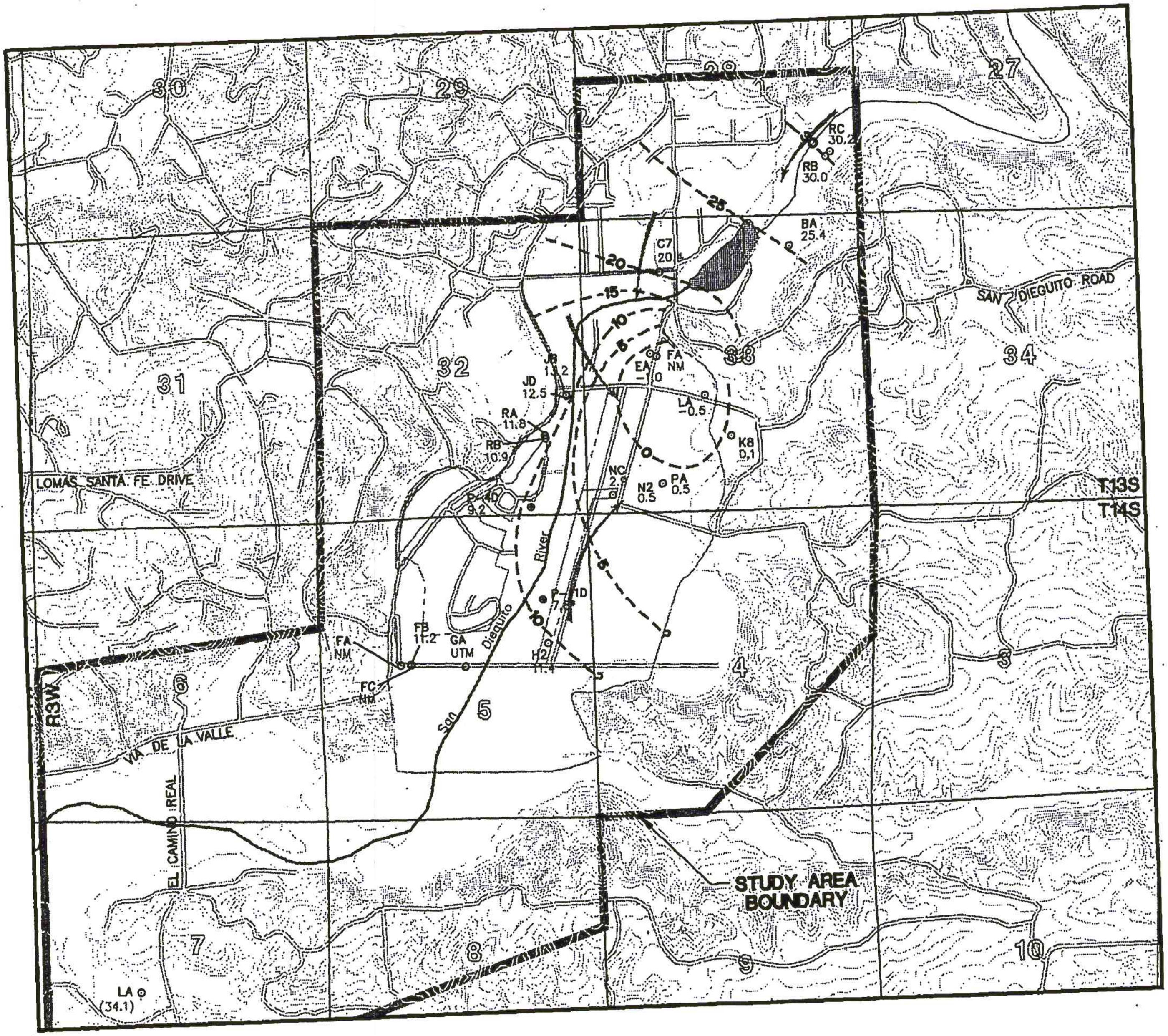
WATER TABLE ELEVATIONS
OCTOBER 2003

HARGIS + ASSOCIATES, INC
Hydrogeology/Engineering

08/04

FIGURE 8

PREP BY GTC REV BY RAN RPT NO. 689.1 220-1493 C



EXPLANATION

P-4D ●	DEEP PIEZOMETER
RC ○	WATER LEVEL MONITORING WELL
30.2	WATER LEVEL ELEVATION, IN FEET MEAN SEA LEVEL
(34.1)	WATER LEVEL ELEVATION NOT CONTOURED
▴	WATER LEVEL RECORDED BY TRANSDUCER
NM	NOT MEASURED

?———— 20 - - - - - - ?

CONTOUR LINE OF EQUAL WATER LEVEL ELEVATION IN FEET MEAN SEA LEVEL, DASHED WHERE APPROXIMATE, QUERIED WHERE INFERRED

INDICATES DIRECTION OF GROUNDWATER FLOW

NOTES: WATER LEVELS MEASURED ON OCTOBER 22-23, 2003

WELL IDENTIFIERS ENDING IN NUMBERS ARE AN ABBREVIATION OF THE STATE WELL NUMBER. WELLS WITH IDENTIFIERS ENDING IN LETTERS HAVE NOT BEEN ASSIGNED A STATE WELL NUMBER, BUT ARE BASED ON A SIMILAR IDENTIFICATION SCHEME.

0 1,800 3,600

FEET

SAN DIEGUITO GROUNDWATER BASIN

DEEP WATER LEVEL ELEVATIONS
OCTOBER 2003

HARGIS+ASSOCIATES, INC
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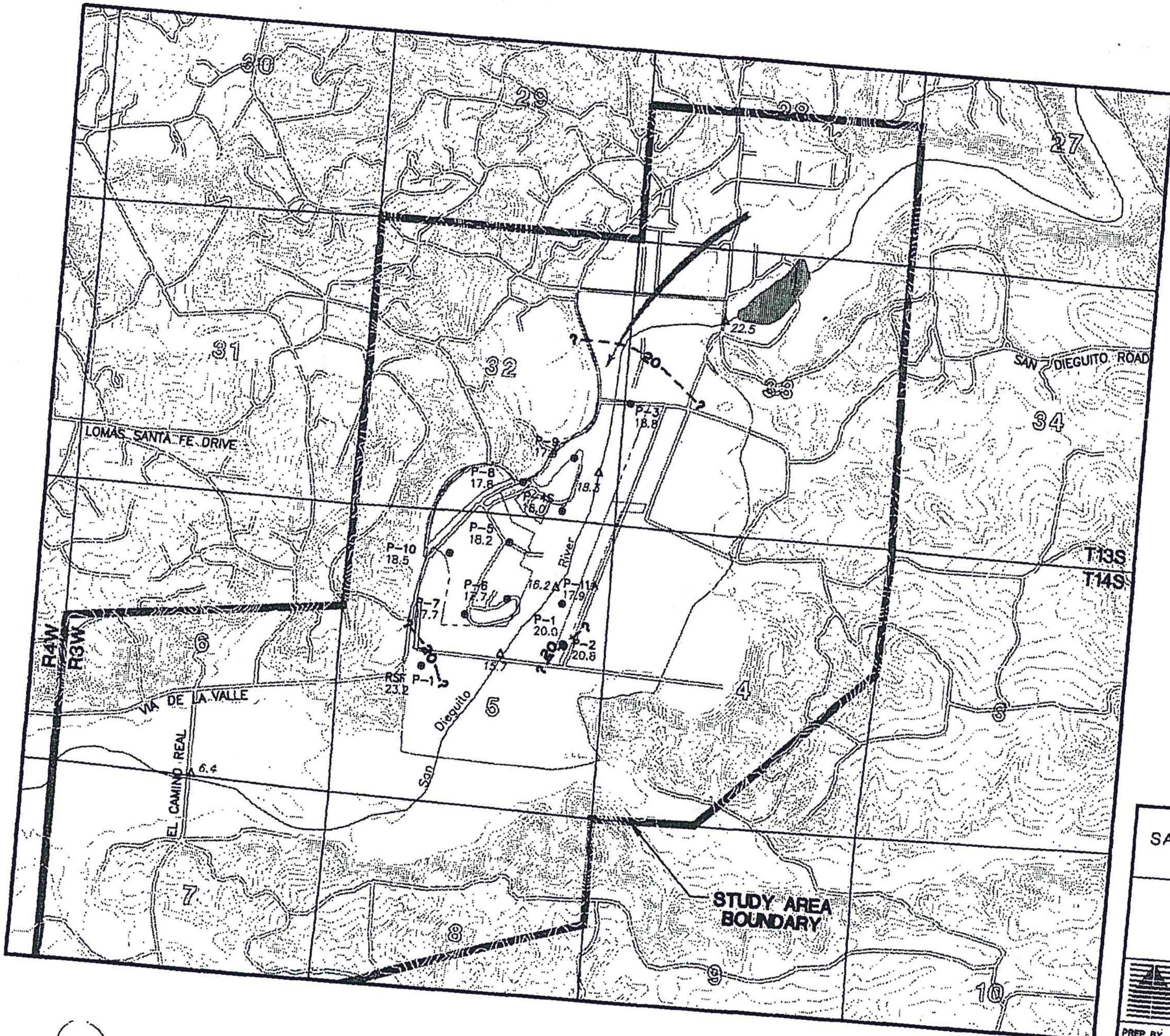
08/04

FIGURE 9

PREP BY GTC REV BY RAN RPT NO. 689.09 220-1496 C



EXPLANATION

15.5 △ SURFACE WATER ELEVATION, SAN DIEGUITO RIVER

P-1 ● SHALLOW PIEZOMETER

20.0 WATER LEVEL ELEVATION, IN FEET MEAN SEA LEVEL

(23.5) WATER LEVEL ELEVATION NOT CONTOURED

?———— 20 – – – – –?
CONTOUR LINE OF EQUAL WATER LEVEL ELEVATION IN FEET MEAN SEA LEVEL, DASHED WHERE APPROXIMATE, QUERIED WHERE INFERRED

INDICATES DIRECTION OF GROUNDWATER FLOW

NOTES: WATER LEVELS MEASURED ON MARCH 11-12, 2004

WELL IDENTIFIERS ENDING IN NUMBERS ARE AN ABBREVIATION OF THE STATE WELL NUMBER. WELLS WITH IDENTIFIERS ENDING IN LETTERS HAVE NOT BEEN ASSIGNED A STATE WELL NUMBER, BUT ARE BASED ON A SIMILAR IDENTIFICATION SCHEME.

0 1,800 3,600
FEET

SAN DIEGUITO GROUNDWATER BASIN

WATER TABLE ELEVATIONS
MARCH 2004

HARGIS+ASSOCIATES, INC
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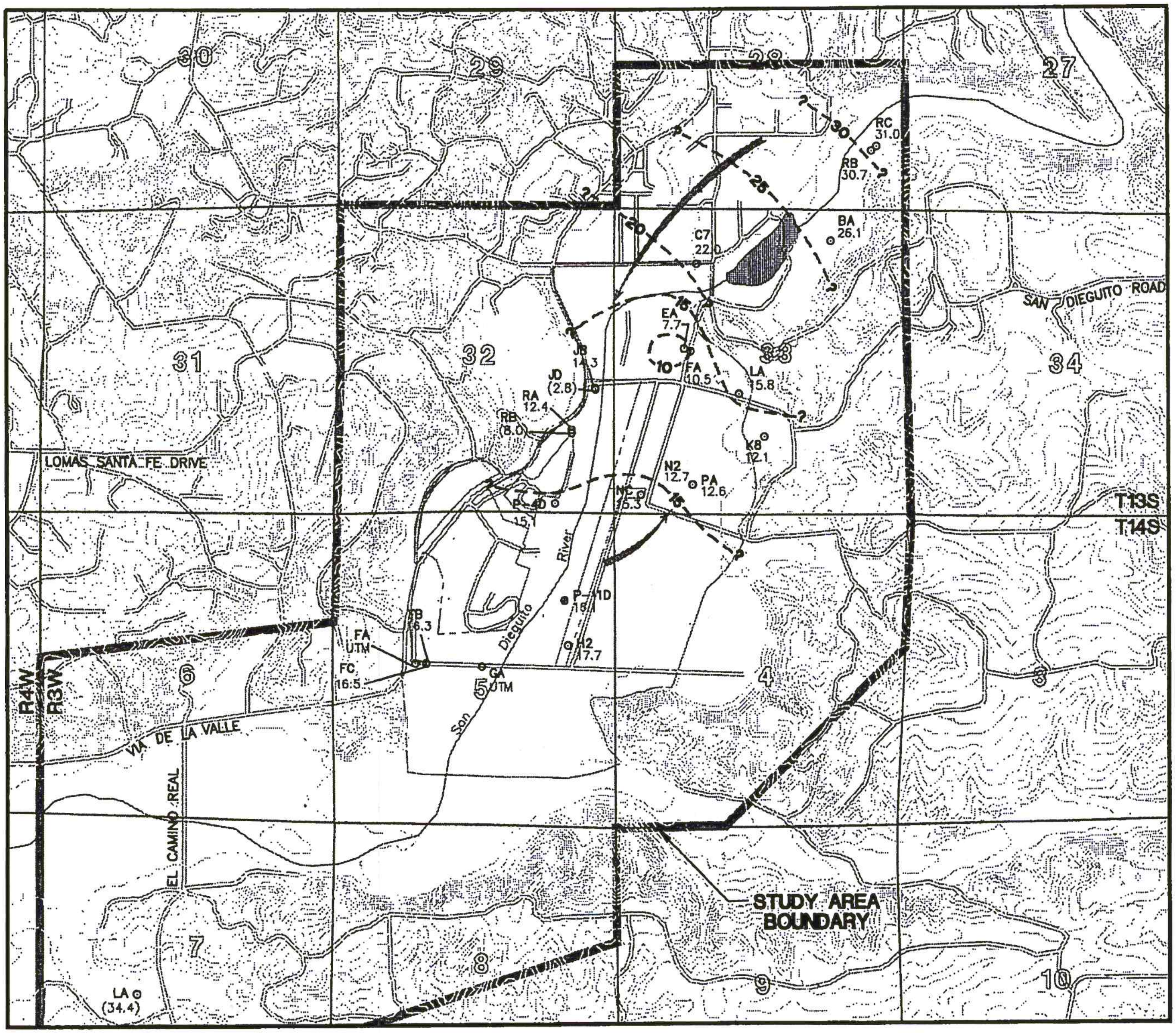
FIGURE 10

PREP BY GTC REV BY RAN RPT NO. 689.1 220-1473 C



EXPLANATION

P-11D ⊕	DEEP PIEZOMETER
EA ⊙	WATER LEVEL MONITORING WELL
7.7	WATER LEVEL ELEVATION, IN FEET MEAN SEA LEVEL
UTM	UNABLE TO MEASURE
(8.0)	WATER LEVEL ELEVATION NOT CONTOURED

?———— 20 - - - - - - ?
CONTOUR LINE OF EQUAL WATER LEVEL ELEVATION IN FEET MEAN SEA LEVEL, DASHED WHERE APPROXIMATE, QUERIED WHERE INFERRED

INDICATES DIRECTION OF GROUNDWATER FLOW

NOTES: WATER LEVELS MEASURED ON MARCH 11-12, 2004

WELL IDENTIFIERS ENDING IN NUMBERS ARE AN ABBREVIATION OF THE STATE WELL NUMBER. WELLS WITH IDENTIFIERS ENDING IN LETTERS HAVE NOT BEEN ASSIGNED A STATE WELL NUMBER, BUT ARE BASED ON A SIMILAR IDENTIFICATION SCHEME.

0 1,800 3,600
FEET

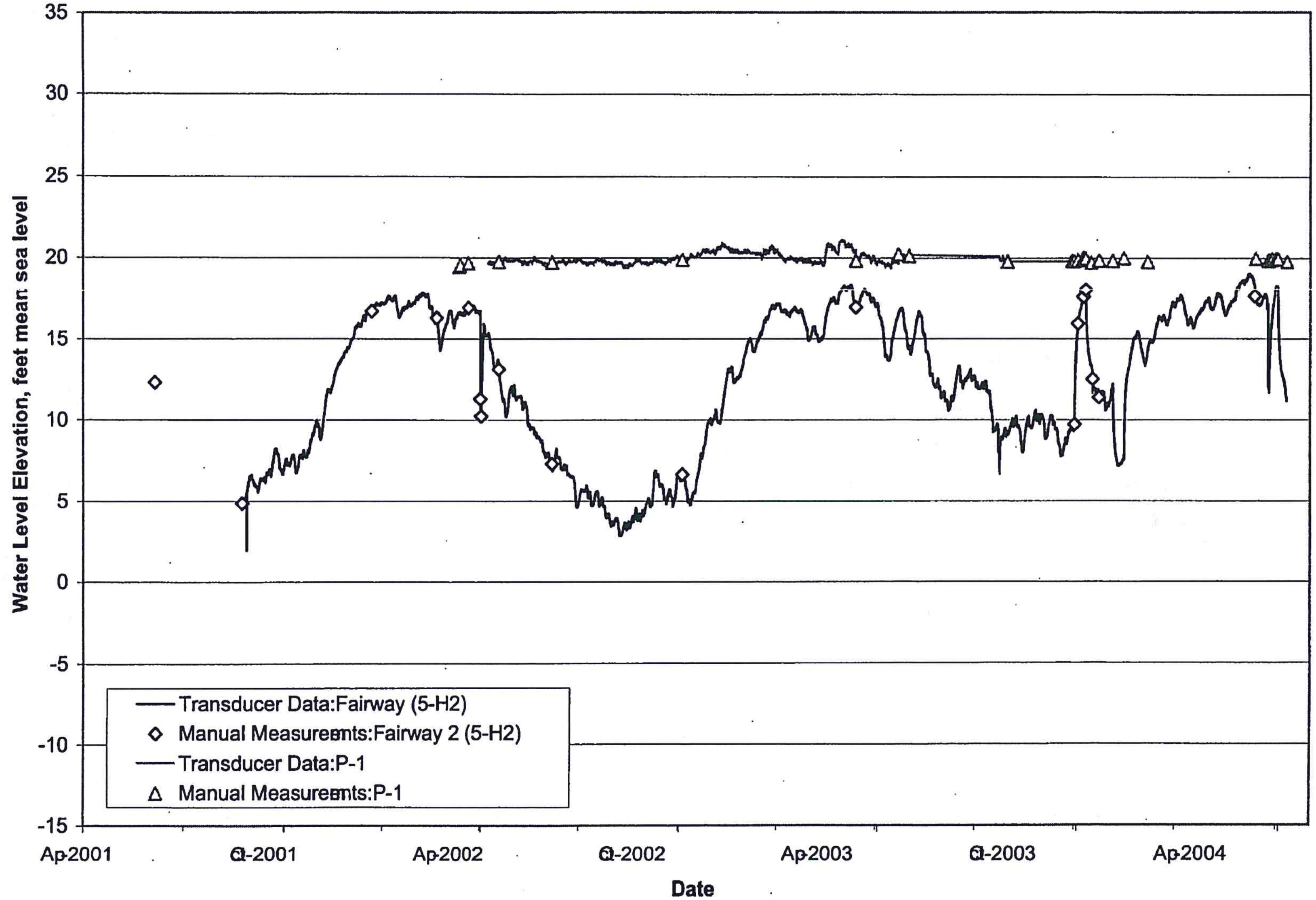
SAN DIEGUITO GROUNDWATER BASIN

DEEP WATER LEVEL ELEVATIONS
MARCH 2004

HARGIS+ASSOCIATES, INC.
Hydrogeology/Engineering
08/04

FIGURE 11

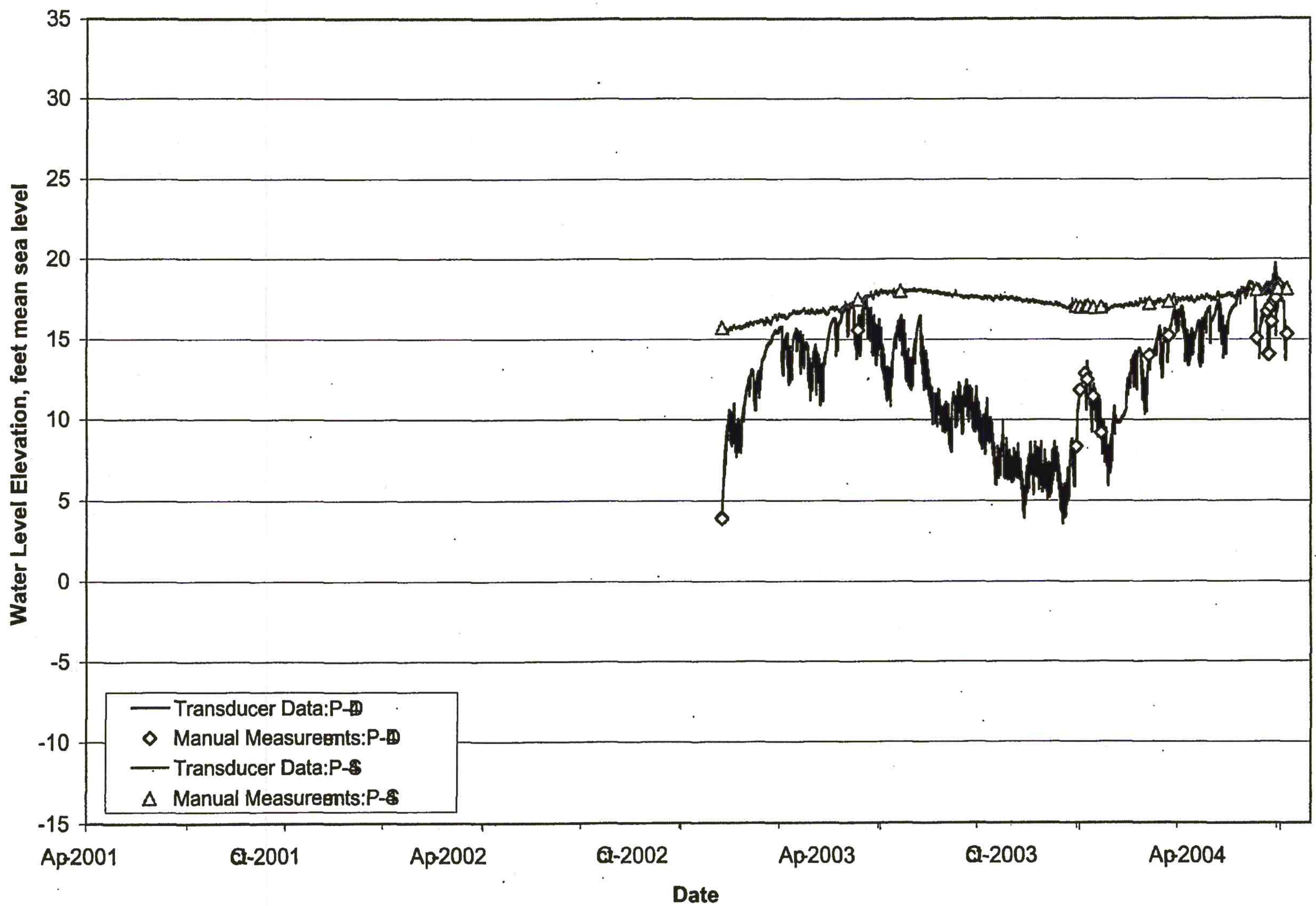
PREP BY GTC REV BY RAN RPT NO. 889.1 | 220-1474 | C



69Rp20041 Fig 12
08/17/04

FIGURE 12: WATER LEVEL HYDROGRAPH, 5-H2 AND MORGAN RUN P-1

HARGIS + ASSOCIATES, INC.



69Rp2004 Fig 13
08/17/04

FIGURE 13: WATER LEVEL HYDROGRAPH, MORGAN RUN P-4S AND P-4D

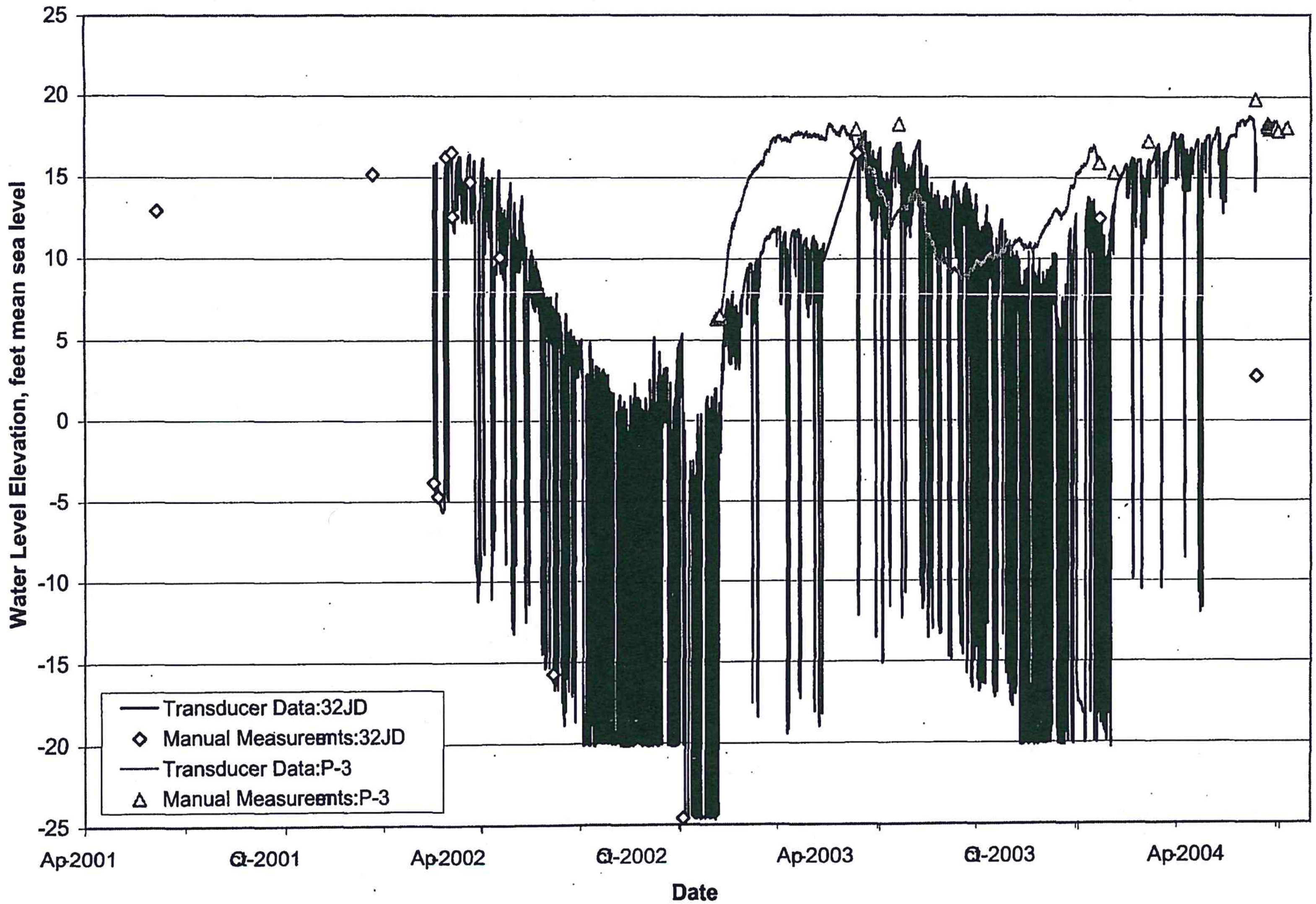
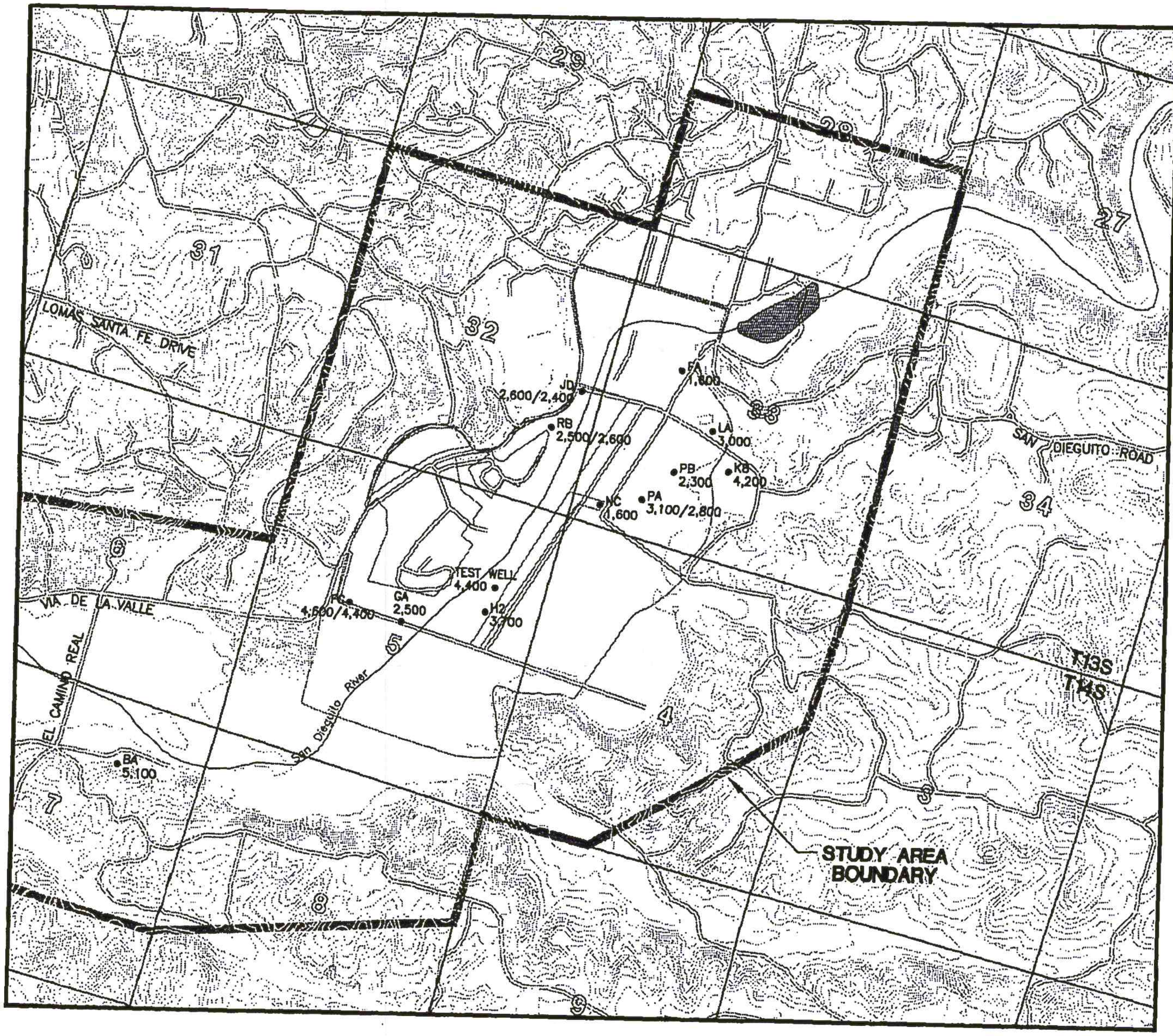


FIGURE 14: WATER LEVEL HYDROGRAPH, 32-JD AND MORGAN RUN P-3



EXPLANATION

H2 ● 3,700 — GROUNDWATER TDS CONCENTRATION IN MILLIGRAMS PER LITER (mg/l)

NOTE: GROUNDWATER SAMPLES COLLECTED AUGUST-SEPTEMBER 2001/FEBRUARY-APRIL 2002 EXCEPT TEST WELL WHICH WAS CONSTRUCTED. AND SAMPLED IN 2003

TDS = TOTAL DISSOLVED SOLIDS

NOTE: WELL IDENTIFIERS ENDING IN NUMBERS ARE AN ABBREVIATION OF THE STATE WELL NUMBER. WELLS WITH IDENTIFIERS ENDING IN LETTERS HAVE NOT BEEN ASSIGNED A STATE WELL NUMBER, BUT ARE BASED ON A SIMILAR IDENTIFICATION SCHEME.

0 1,800 3,600
FEET

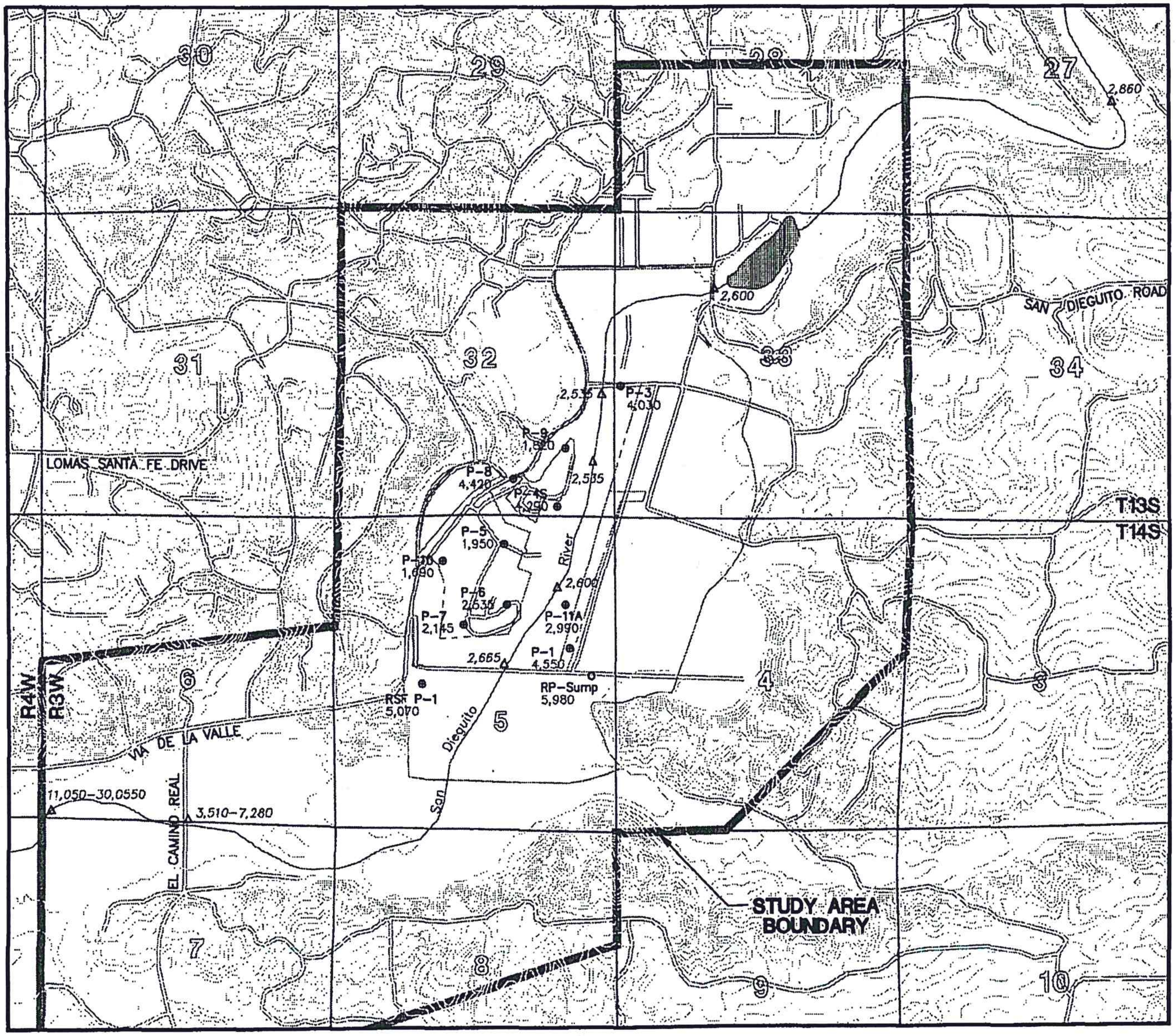
SAN DIEGUITO GROUNDWATER BASIN

TOTAL DISSOLVED SOLIDS 2001/2002

HARGIS+ASSOCIATES, INC
Hydrogeology/Engineering
08/04

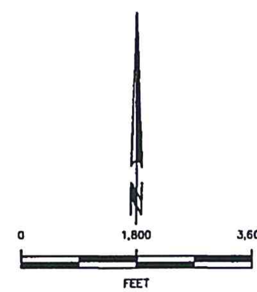
FIGURE 15

PREP BY MAP REV BY RAN RPT NO. 689.20 | 210-2322 | B



EXPLANATION

Δ	SURFACE WATER MONITORING LOCATION SAN DIEGUITO RIVER
P-1 ⊕	SHALLOW PIEZOMETER
o	SUMP
1,775	TDS IN MILLIGRAMS PER LITER ESTIMATED FROM EC MEASUREMENT, SAMPLES COLLECTED IN 2003



SAN DIEGUITO GROUNDWATER BASIN

ESTIMATED TOTAL DISSOLVED SOLIDS SHALLOW ZONE AND SURFACE WATER, 2003

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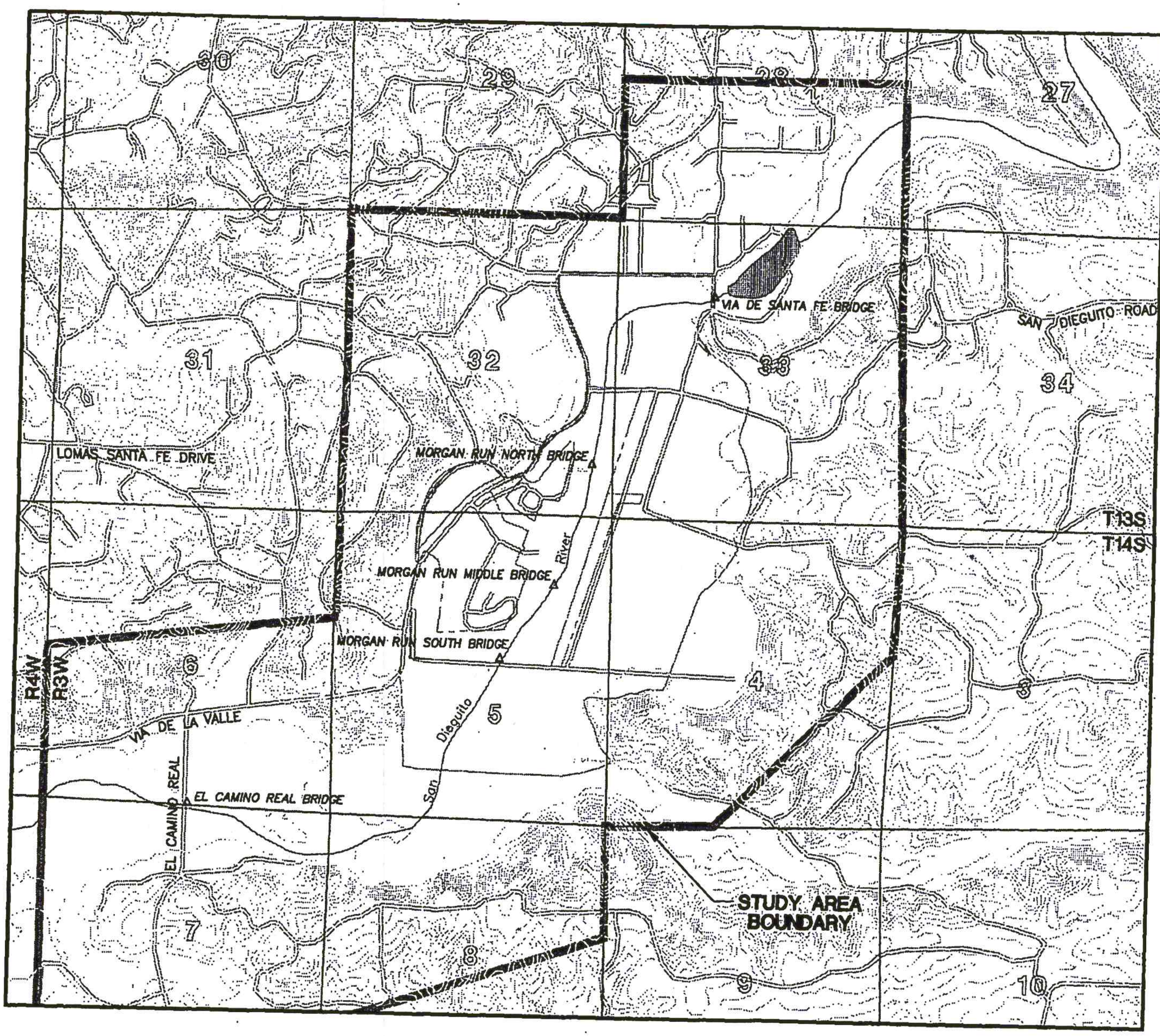
08/04

FIGURE 16

PREP BY SLB REV BY RAN RPT NO. 689.1 | 410-4752 | B



EXPLANATION

△ SURFACE WATER MEASUREMENT LOCATION SAN DIEGUITO RIVER

SAN DIEGUITO GROUNDWATER BASIN

SURFACE WATER MEASUREMENT LOCATIONS

HARGIS + ASSOCIATES, INC
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FIGURE 17

PREP BY GTC REV BY RAN RPT NO. 889.25 | 220-1530 | B

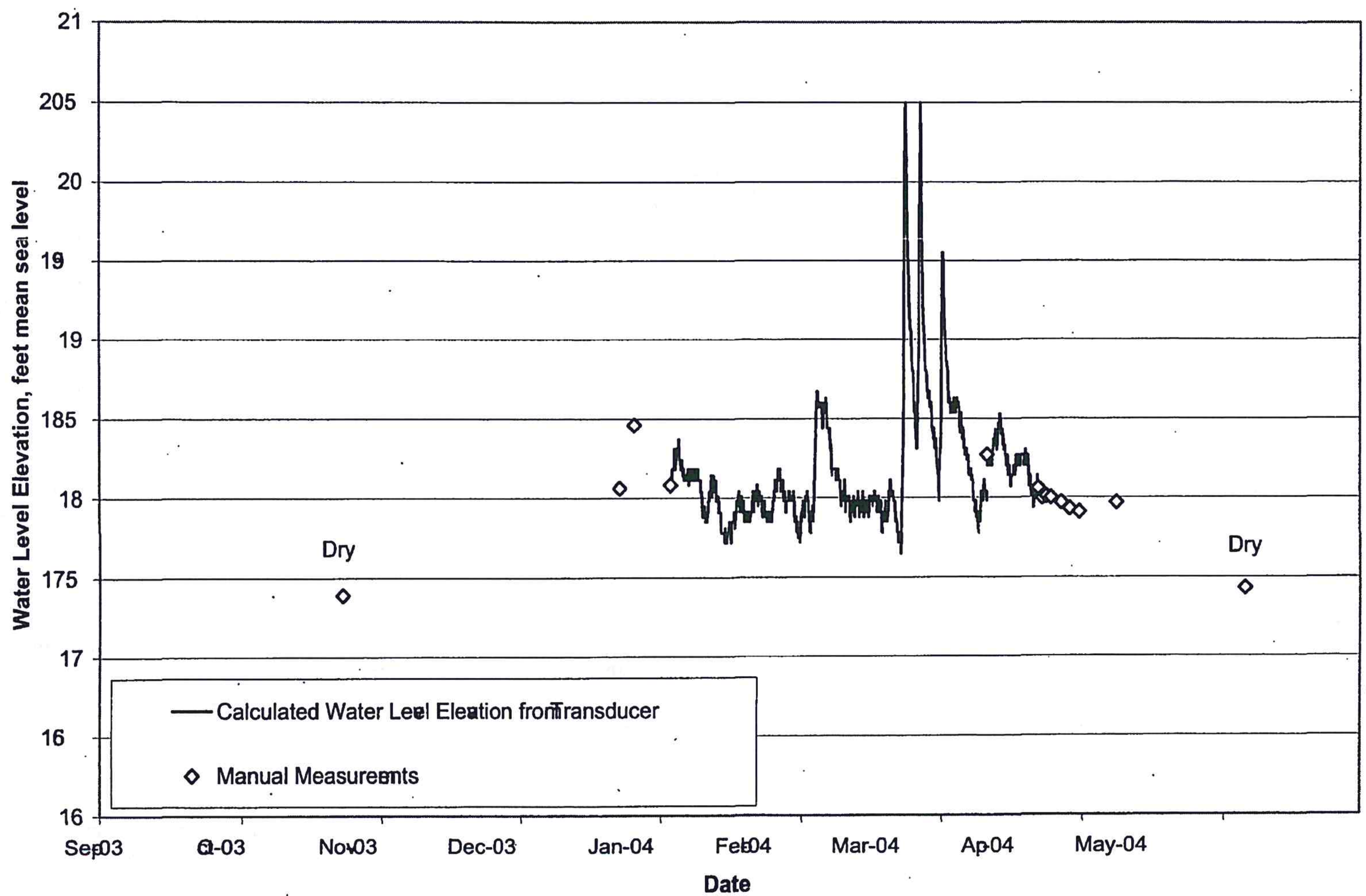


FIGURE 18. WATER LEVEL HYDROGRAPH, MORGAN RUN NORTH BRIDGE

HARGIS + ASSOCIATES, INC.

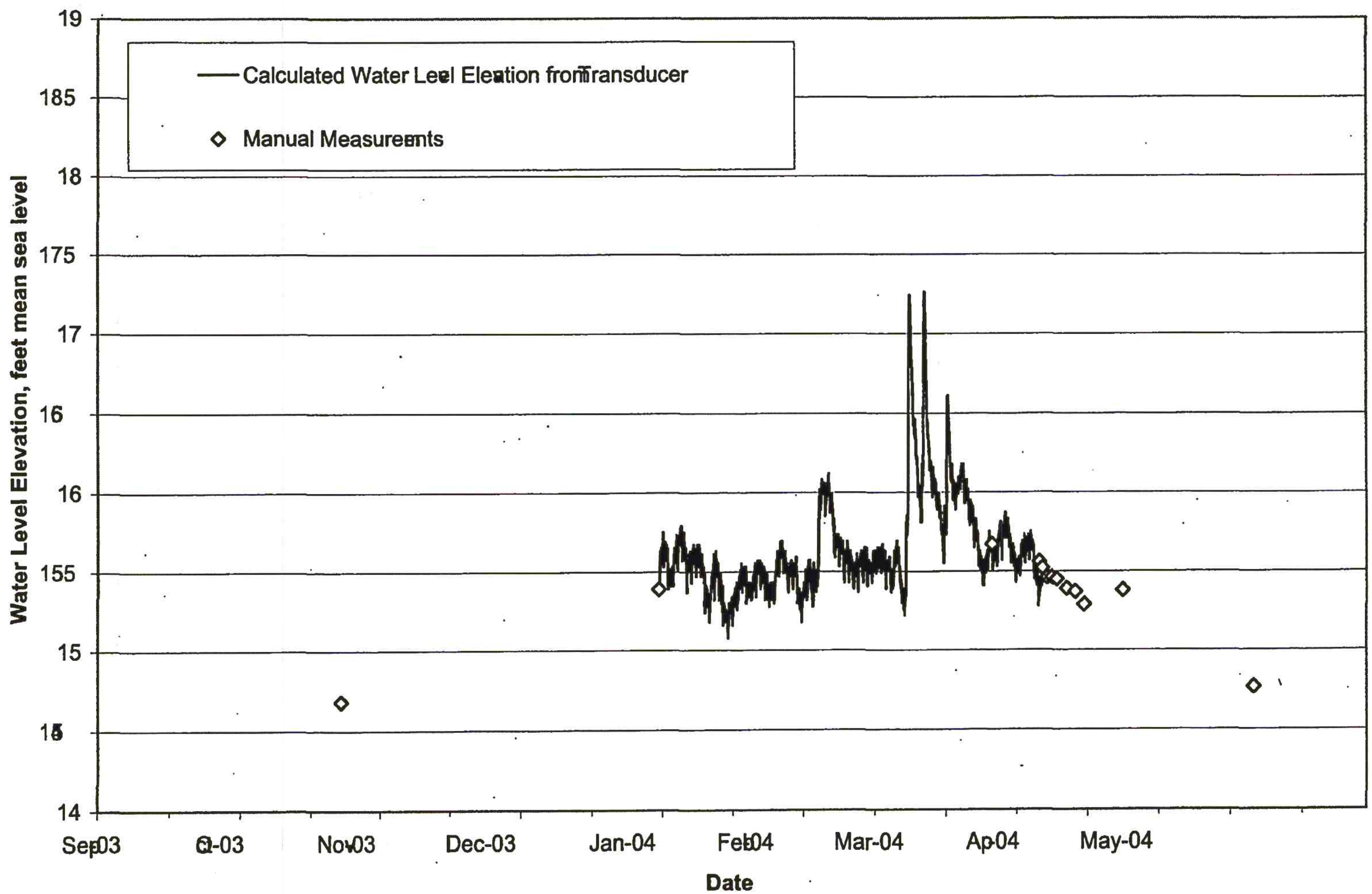
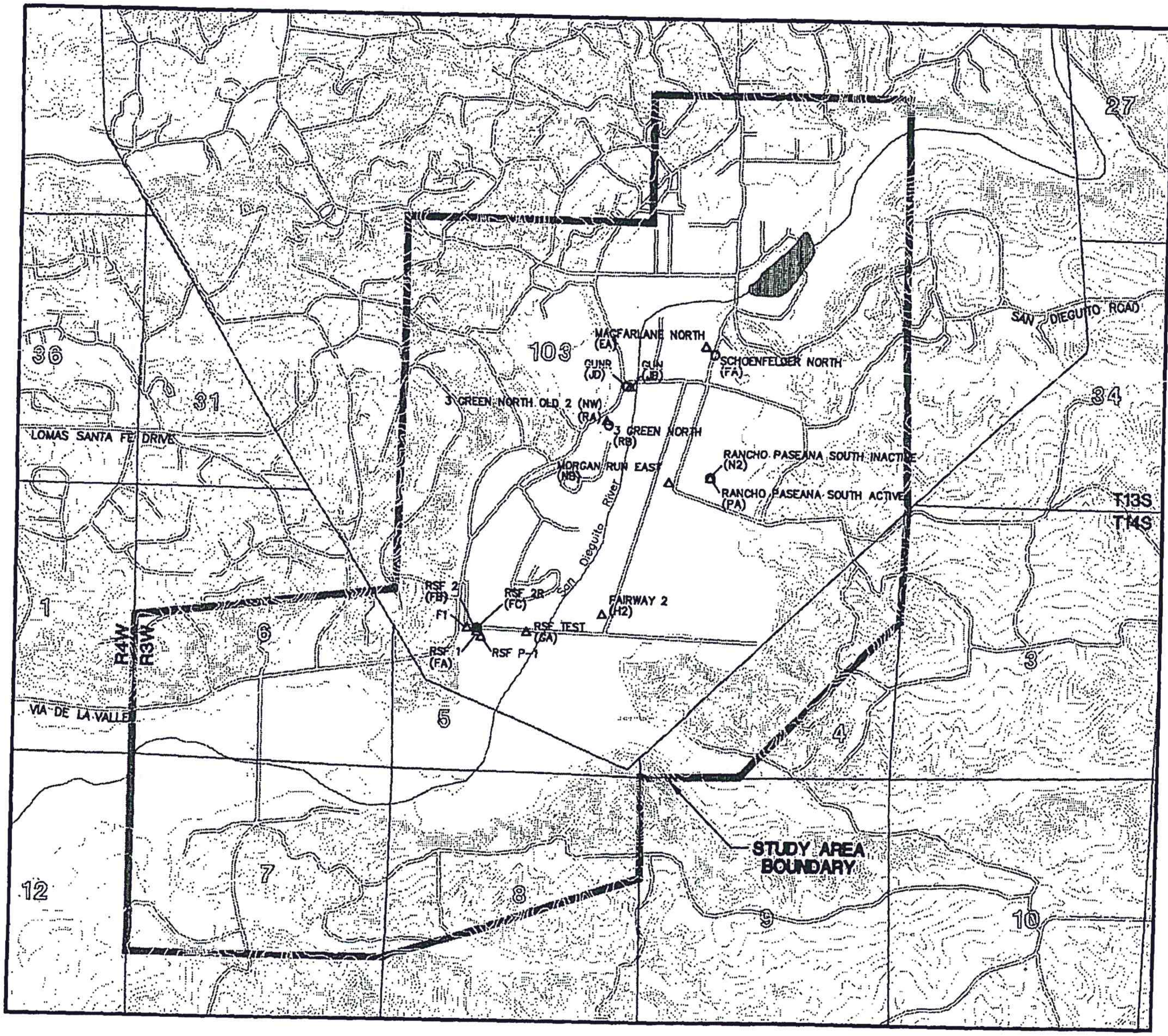


FIGURE 19. WATER LEVEL HYDROGRAPH, MORGAN RUN SOUTH BRIDGE

69Rp20041 Fig 19So Bridge
08/17/04



EXPLANATION

○ PUMPING TEST LOCATION

△ OBSERVATION WELL LOCATION

WELL IDENTIFIERS ENDING IN NUMBERS ARE AN ABBREVIATION OF THE STATE WELL NUMBER. WELLS WITH IDENTIFIERS ENDING IN LETTERS HAVE NOT BEEN ASSIGNED A STATE WELL NUMBER, BUT ARE BASED ON A SIMILAR IDENTIFICATION SCHEME.

SAN DIEGUITO GROUNDWATER BASIN

AQUIFER TEST LOCATIONS

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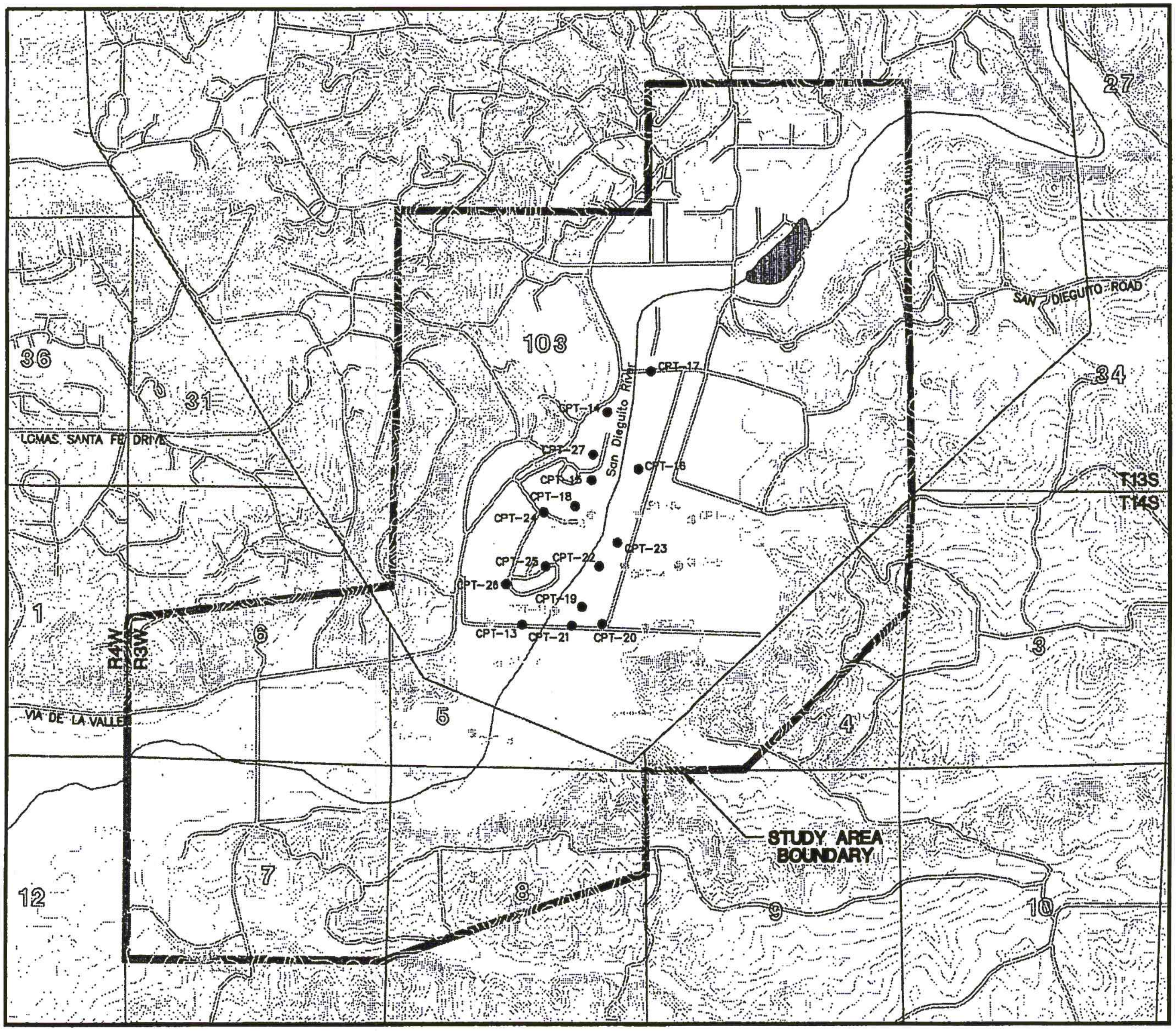
FIGURE 20

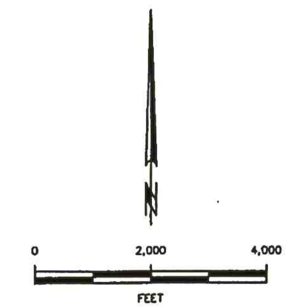
PREP BY SLB REV BY RAN RPT NO. 689.20 | 410-4754 | B



EXPLANATION

- ROUND I CPT LOCATION
- ROUND II CPT LOCATION

CPT = CONE PENETROMETER TESTING



SAN DIEGUITO GROUNDWATER BASIN

CPT LOCATIONS

HARGIS+ASSOCIATES, INC.
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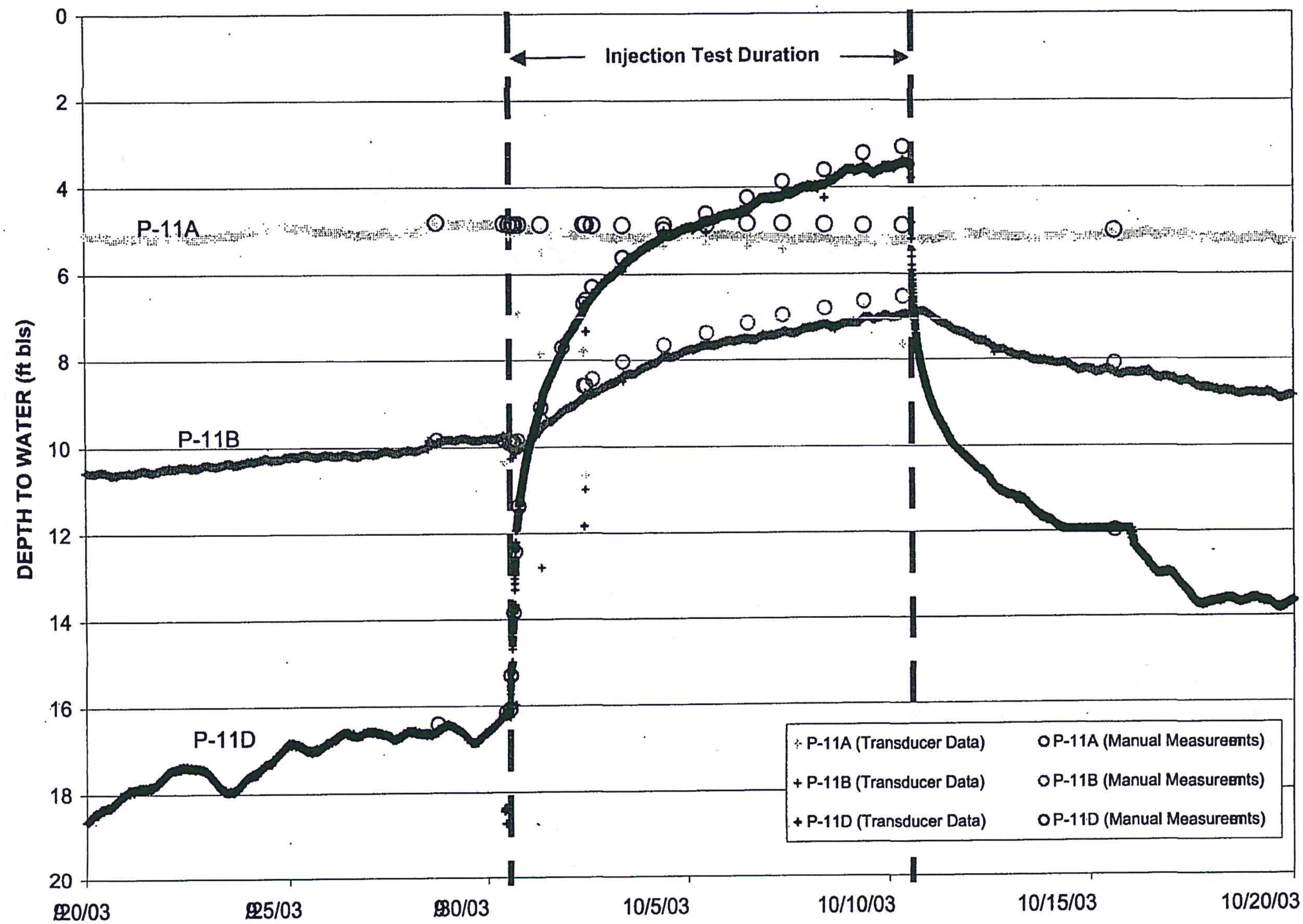
FIGURE 21

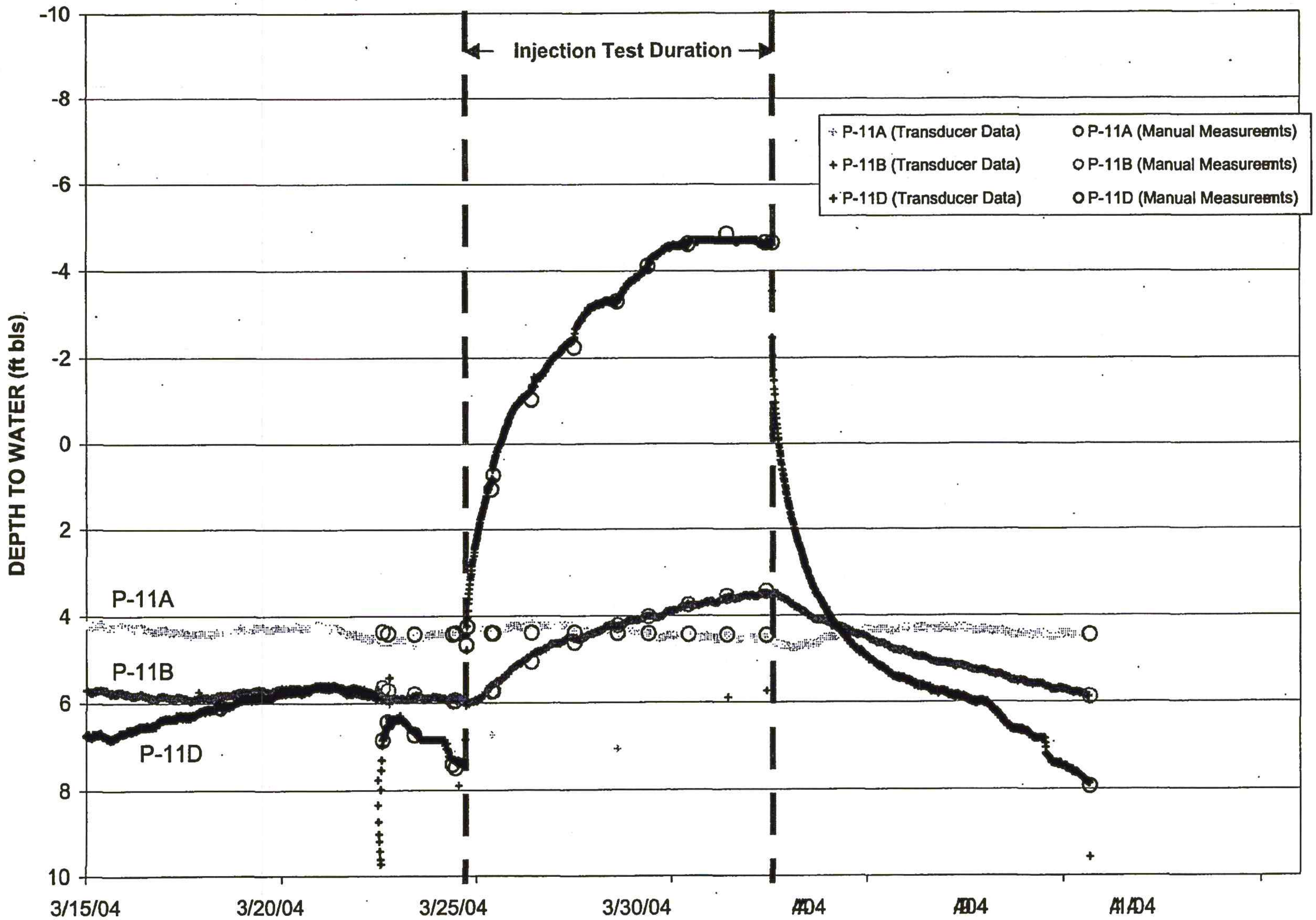
PREP BY SLB REV BY RAN RPT NO. 689.20 | 410-4756 | B



69Rp2004l Fig 22
08/17/04

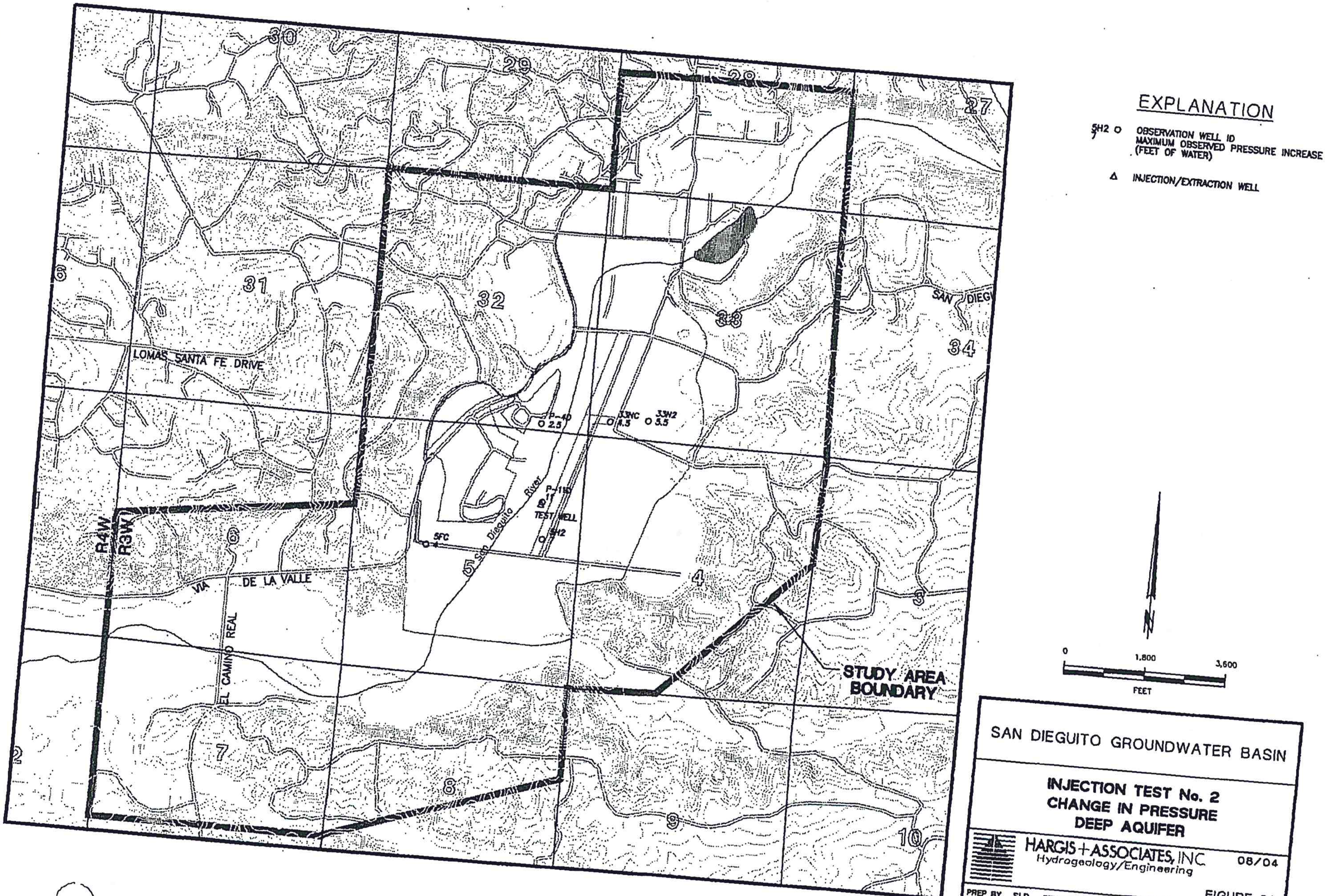
FIGURE 22: INJECTION TEST NO. 1 WATER LEVELS, PIEZOMETER CLUSTER P-11

HARGIS + ASSOCIATES, INC.



89Rp20041 Fig 23
08/17/04

FIGURE 23: INJECTION TEST NO. 2 WATER LEVELS, PIEZOMETER CLUSTER P-11



SAN DIEGUITO GROUNDWATER BASIN

INJECTION TEST No. 2
CHANGE IN PRESSURE
DEEP AQUIFER

HARGIS + ASSOCIATES, INC
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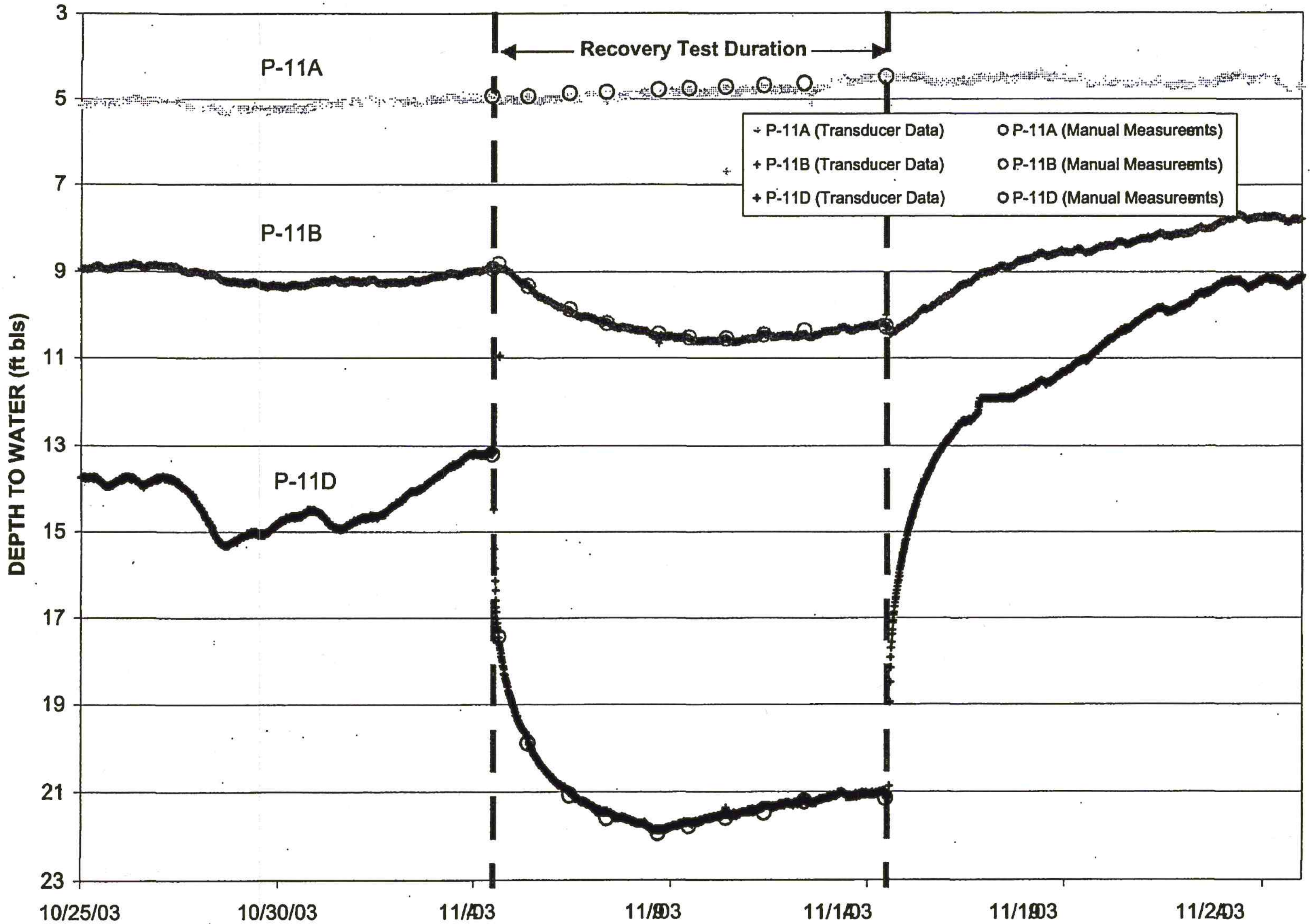
PREP BY SLB REV BY MAP RPT NO. 889.20

FIGURE 24

410-4750 B

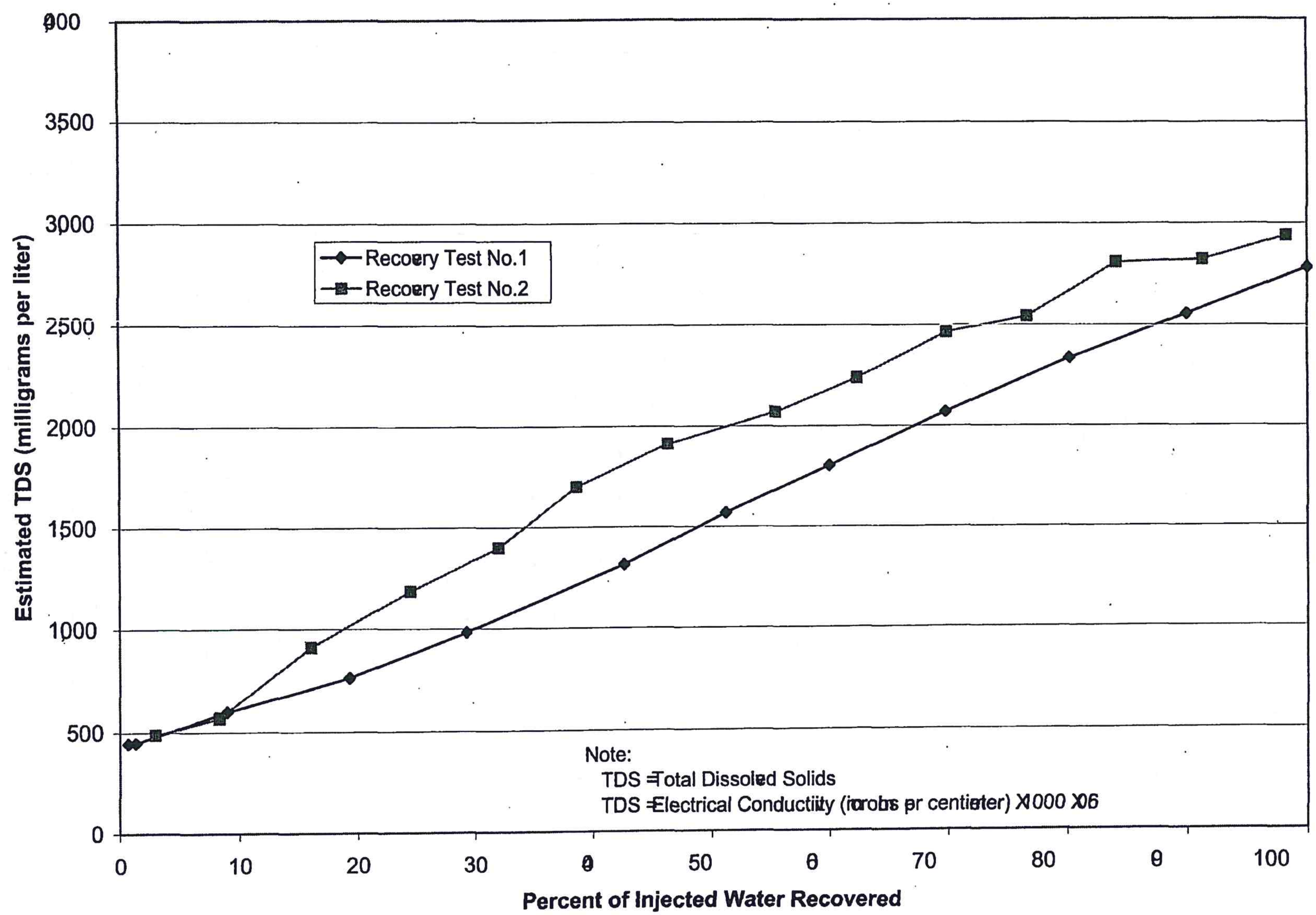
HARGIS + ASSOCIATES, INC.



89Rp2004I Fig 25
08/17/04

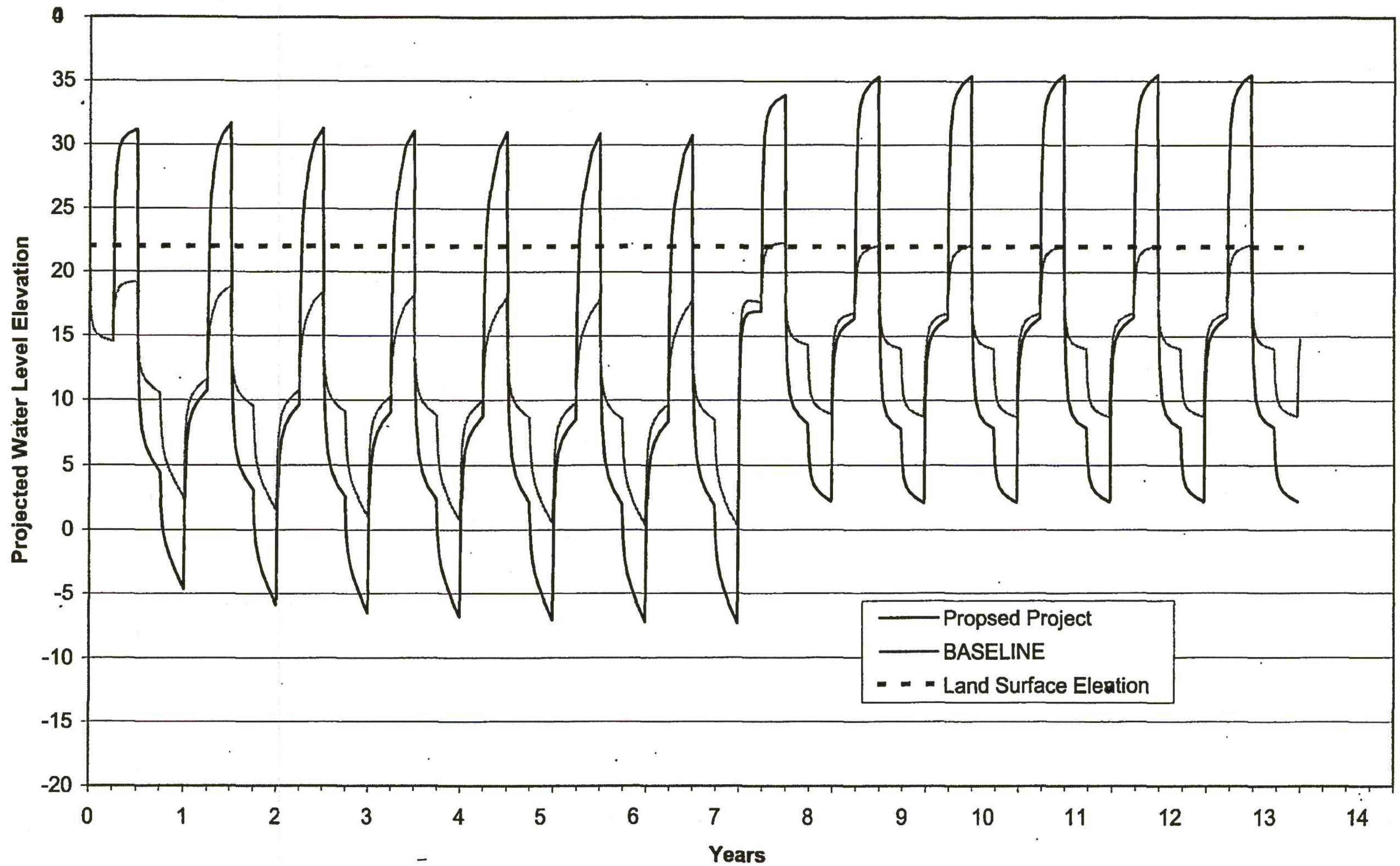
FIGURE 25: RECOVERY TEST NO. 1
WATER LEVELS P-11A, P-11B and P-11D

HARGIS + ASSOCIATES, INC.



69Rp20041 Fig 26
08/17/04

FIGURE 26: ESTIMATED TDS OF RECOVERED WATER



69Rp20041 Fig 27 and 29
08/17/04

FIGURE 27. MODEL PROJECTED WATER LEVEL ELEVATIONS, WELL P-11D

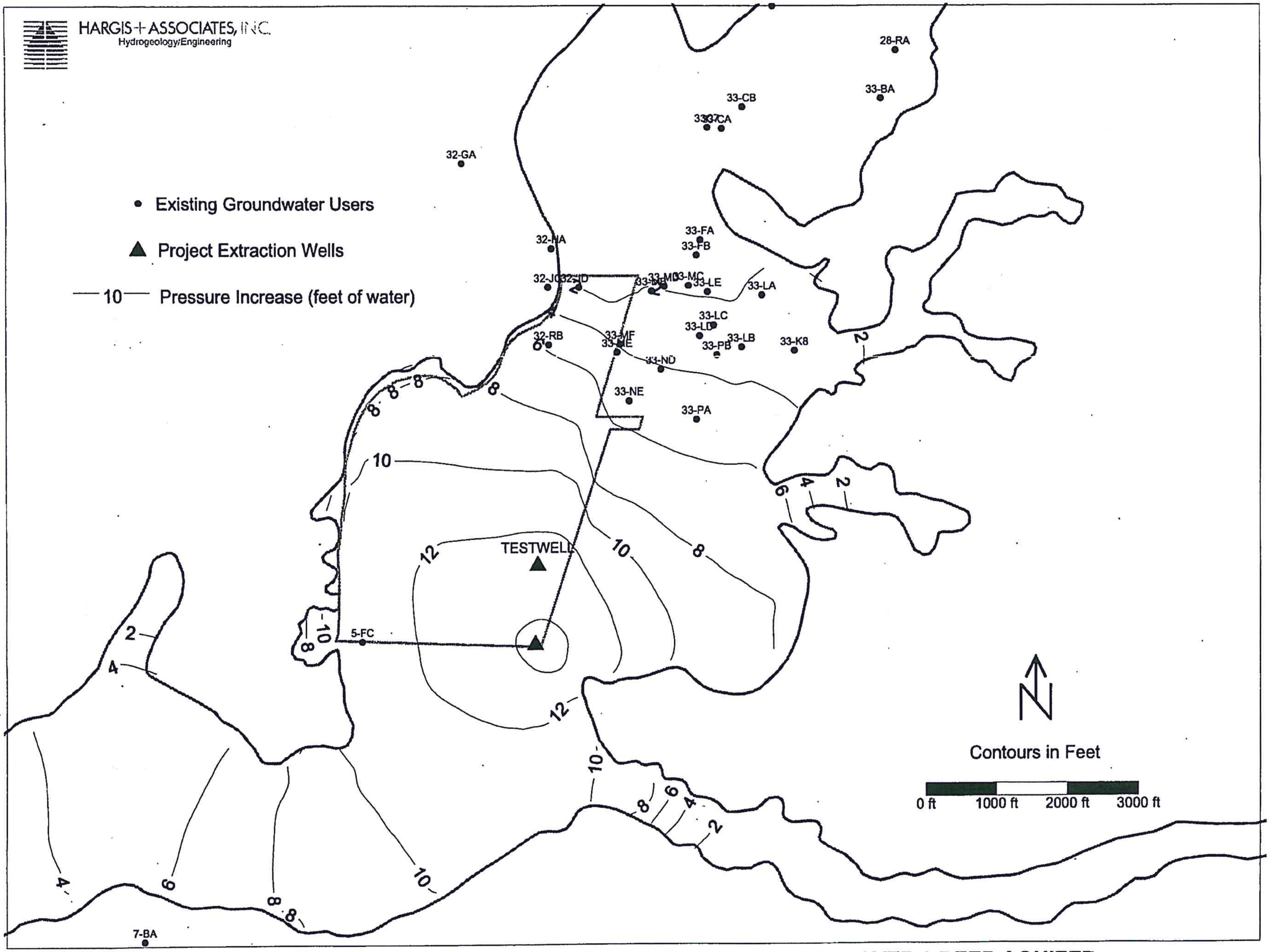
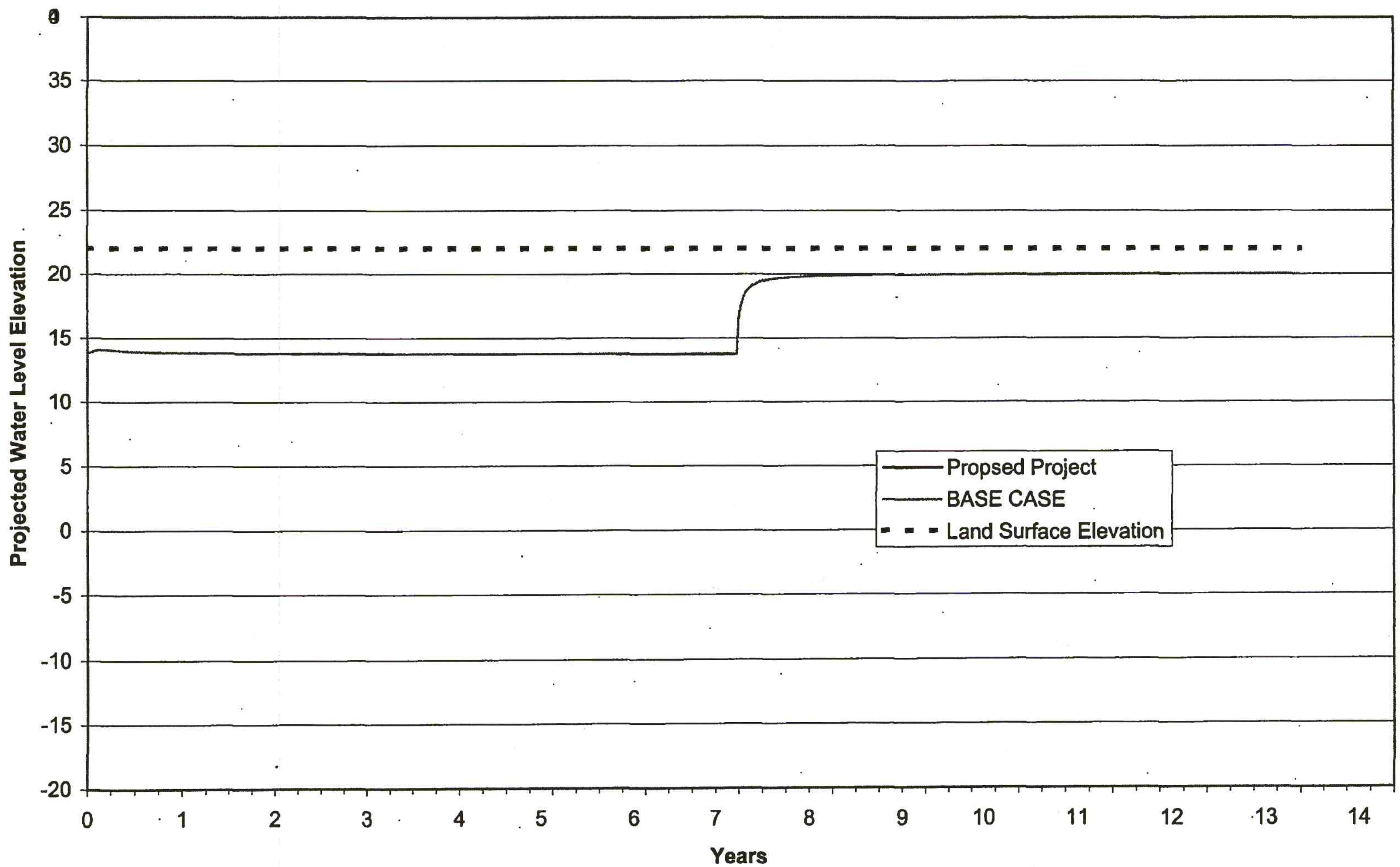


FIGURE 28. MODEL PROJECTED MAXIMUM PRESSURE INCREASE - LAYER 3 DEEP AQUIFER



69Rp20041 Fig 27 and 29
08/17/04

FIGURE 29. MODEL PROJECTED WATER LEVEL ELEVATIONS, WELL P-11S

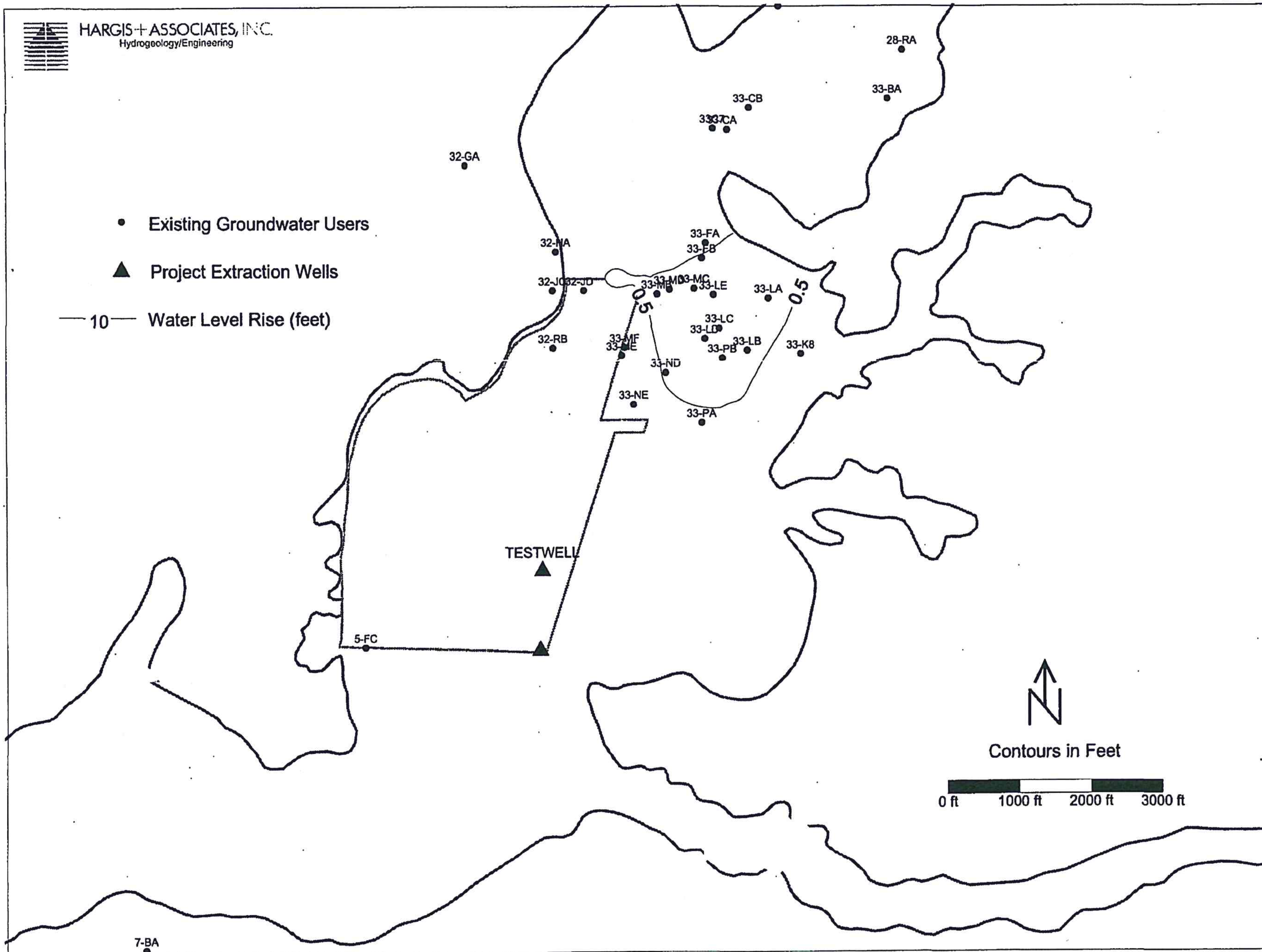


FIGURE 30. MODEL PROJECTED MAXIMUM WATER LEVEL RISE - LAYER 1 SHALLOW ZONE

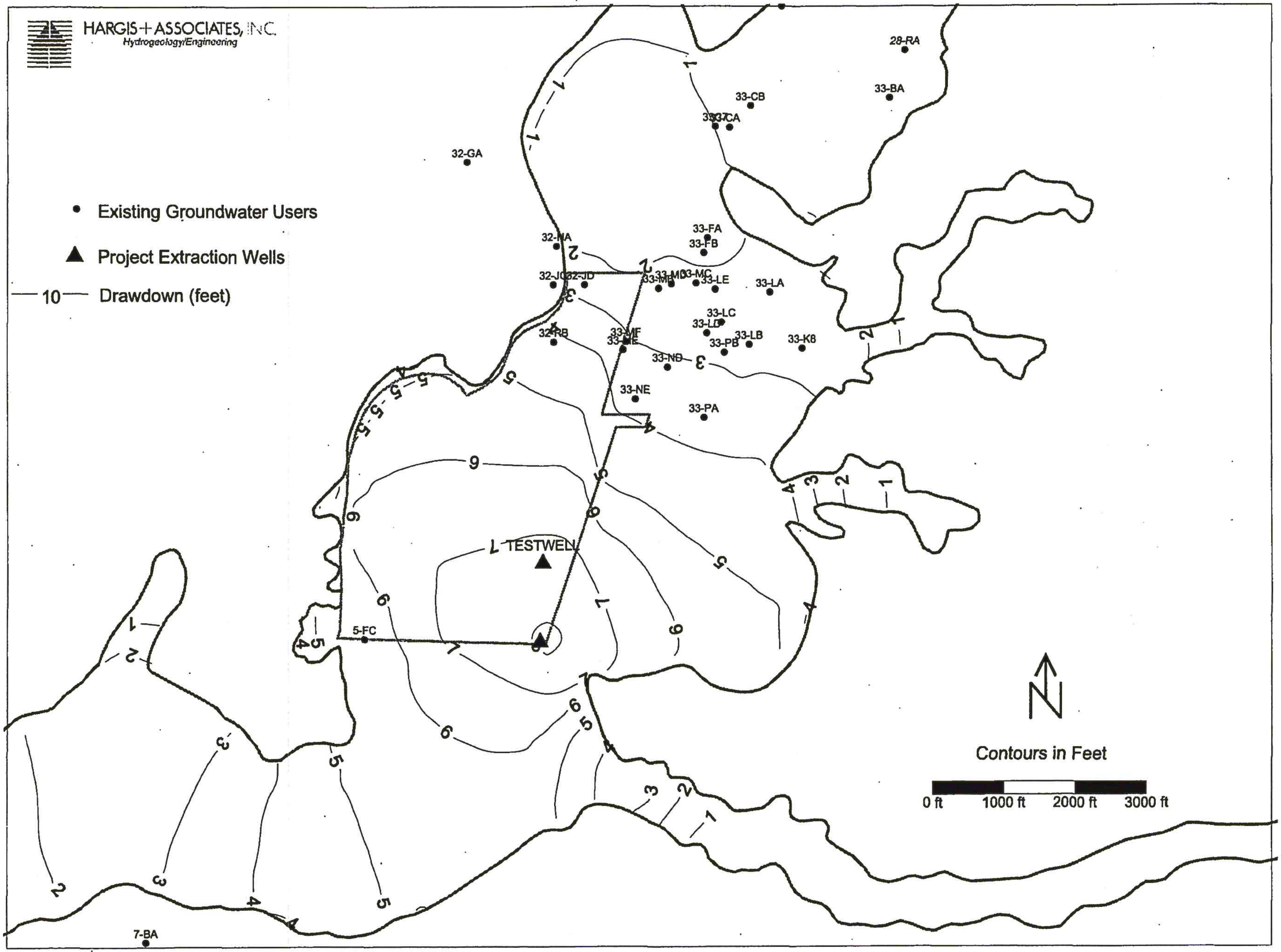
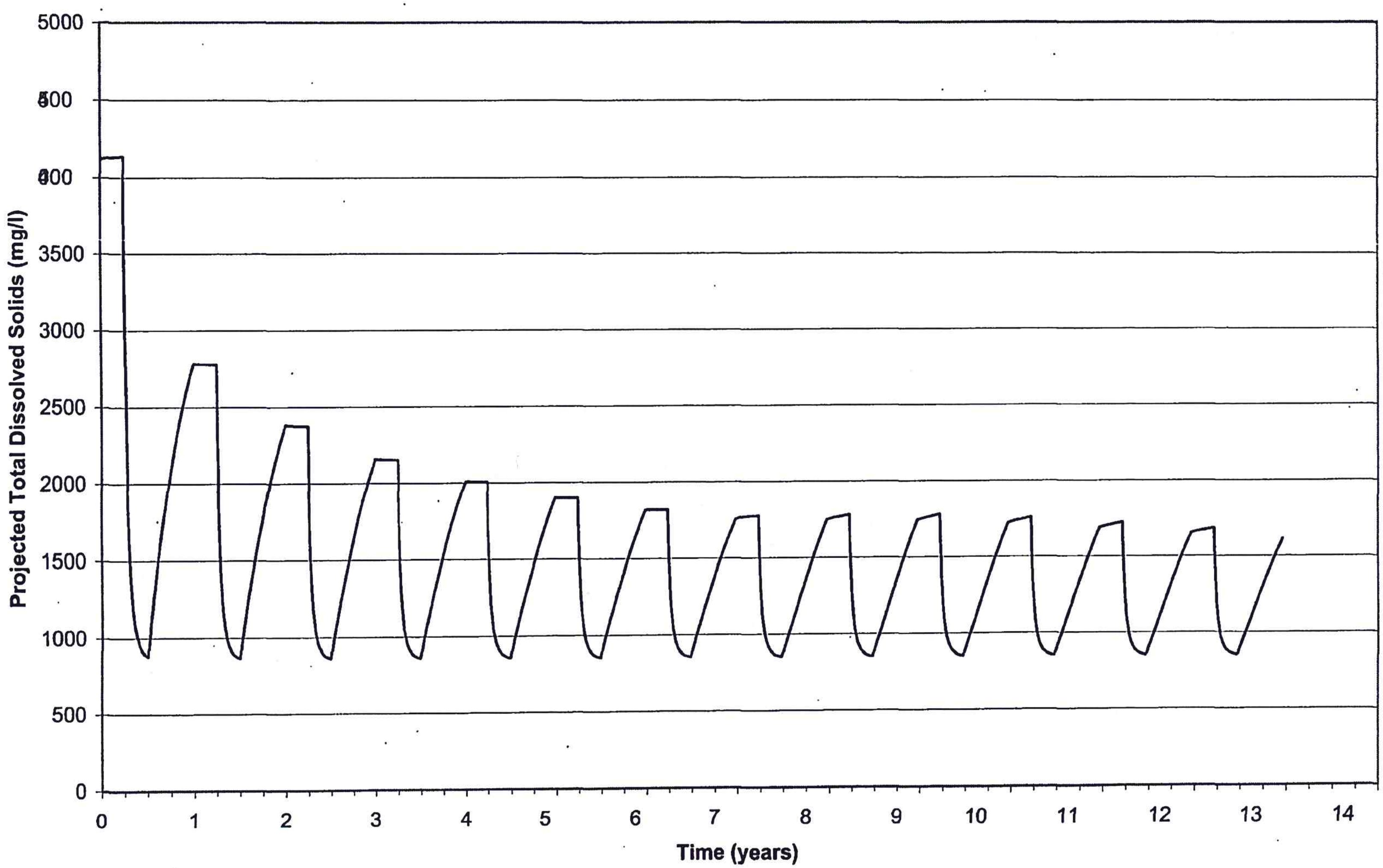


FIGURE 31. MODEL PROJECTED MAXIMUM DRAWDOWN - LAYER 3 DEEP AQUIFER



69Rp20041 Fig 32
08/17/04

FIGURE 32. MODEL PROJECTED TOTAL DISSOLVED SOLIDS - TEST WELL

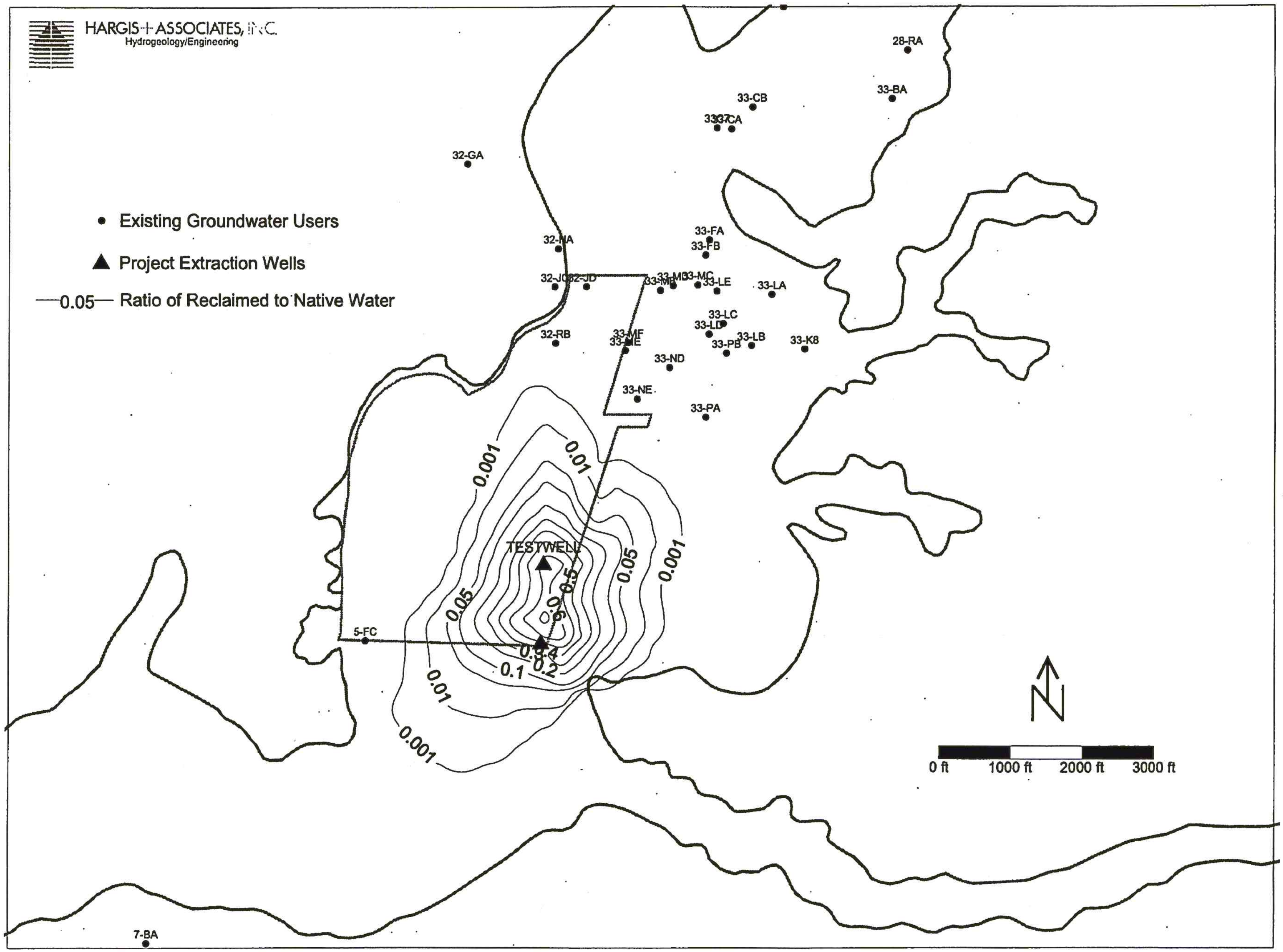


FIGURE 33. PROJECTED RATIO OF RECLAIMED TO NATIVE WATER - 7 YEARS OF INJECTION

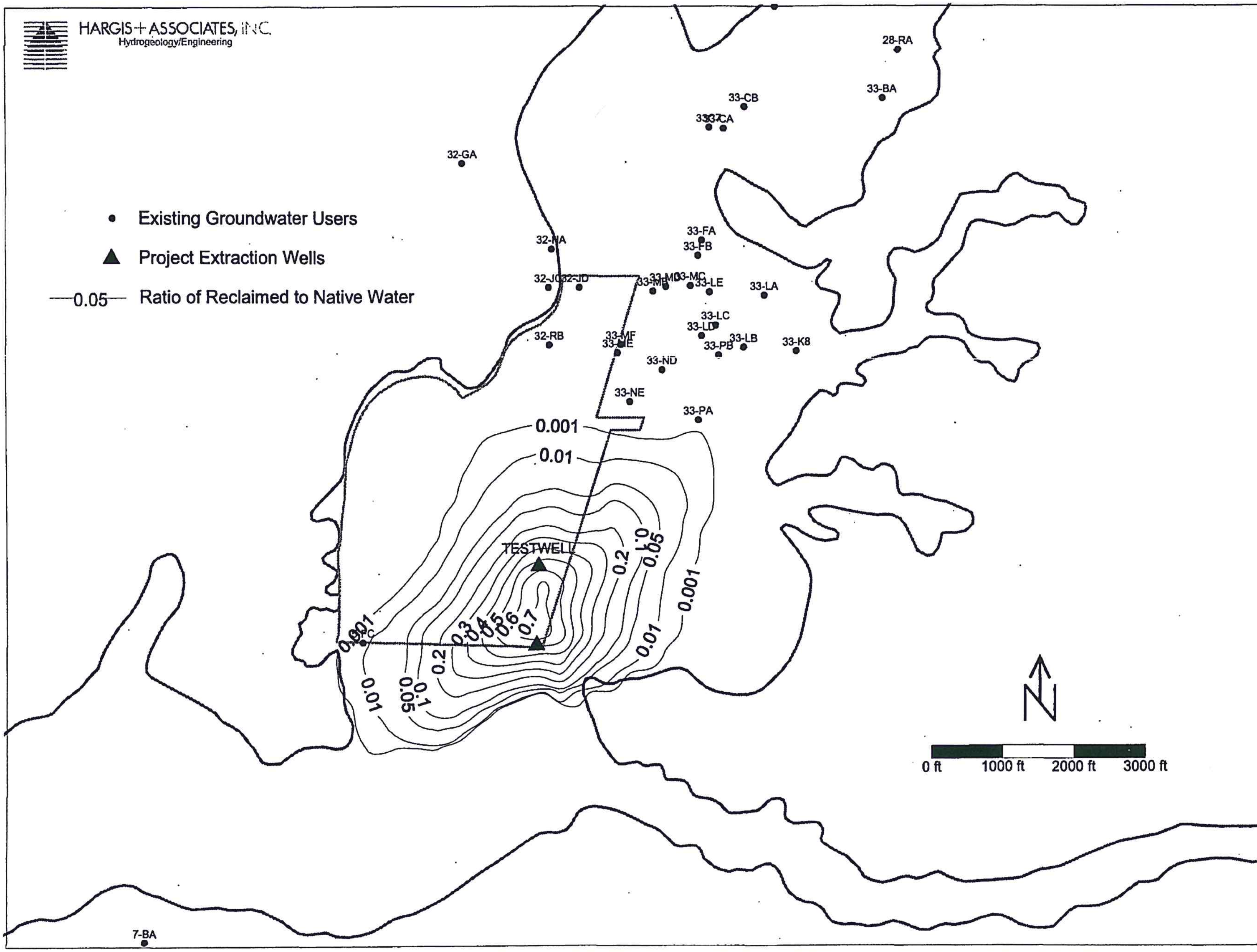


FIGURE 34. PROJECTED RATIO OF RECLAIMED TO NATIVE WATER - 13 YEARS OF INJECTION