



Geotechnical
Environmental and
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Engineering

Groundwater Storage and Recovery Pilot Project in White Wolf Basin Final Pilot Project Report

Submitted to:
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INTRODUCTION

The final pilot project report summarizes the results of Phases 1 through 6 of the Wheeler Ridge-Maricopa Water Storage District's (WRMWSD) Groundwater Storage and Recovery Pilot Project in the White Wolf Basin and also provides conclusions and recommendations respecting the technical feasibility of a final project. This report satisfies Task 7.2 – Final Project Report as outlined in WRMWSD's Proposition 13 Grant Funding Application to the California Department of Water Resources (Work Plan dated February 16, 2001, Attachment B-2, page B-2-14). A copy of Attachment B-2 of the Work Plan is included as Appendix A.

ACKNOWLEDGEMENTS

This pilot project was planned and executed jointly by the Wheeler Ridge-Maricopa Water Storage District, its consultant, Bookman-Edmonston, a Division of GEI, and the Tejon-Castac Water District.

Major funding for the pilot project was provided by a grant from the California Department of Water Resources (DWR) under the Safe Drinking Water, Clean Water, Watershed Protection and Flood Protection Act (Proposition 13), 2001 funding cycle, in addition to local agency funds expended by WRMWSD and the Tejon-Castac Water District. Mark Meeks, John Woodling, Tracie Billington, Linda Buchanan, and Christina Kuo of the DWR, Department of Planning and Local Assistance (DPLA), ably administered the Proposition 13 grant. Shannon Burns and Dottie Tarleton-Rush, DPLA, administered grant reimbursements. Ralph Svetich, Darby Vickery, and Joseph Chang, DPLA, Conjunctive Water Management Branch, contributed valuable technical review and helped guide the project as it was successfully adapted to actual field conditions.

Tejon Ranch Corporation generously allowed access to their property during field investigations, granting easements and leases for monitor well sites and test ponds. Bakersfield Well & Pump Company and Whitten Pumps, Inc, helped solve numerous technical problems during well drilling. Dr. Kip Solomon of the University of Utah performed tritium water analyses and provided assistance on isotope interpretation. Gary Corbell, Welenco, Inc., assisted with electric log interpretation. Finally, the California Department of Oil, Gas, and Geothermal Resources, Division of Oil and Gas Records, Bakersfield office provided valuable oil well logs and records.

BACKGROUND

The White Wolf Basin is located in the southern San Joaquin Valley and is bounded on the north by the White Wolf fault, on the east by the Springs fault, and on the south by the Tehachapi Mountains. It is comprised of approximately 52,000 acres of land, of which roughly 32,000 acres are actively farmed (Figure 1).

Beginning in the 1950's, agricultural pumping in the White Wolf Basin led to groundwater overdraft. Overdraft was manifested as a consistent lowering of the local water table, which led to increased energy use for pumping and increased pumping costs. Water levels continued to decline until the mid-1970's, several years after the first facilities were completed for importing Central Valley Project (CVP) and State Water Project (SWP) water into the White Wolf Basin. The Arvin-Edison Water Storage District secured a surface water supply from the Friant-Kern Division of the federal Central Valley Project in 1962 and completed initial construction of its project between 1964 and 1968. Deliveries of federal surface water to the White Wolf Basin began in 1966. The Wheeler Ridge-Maricopa Water Storage District was formed in 1959 for the purpose of securing a surface water supply from the Feather River Project (now the State Water Project). The WRMWSD's project was approved by its landowners in 1967 and surface water deliveries began in 1971. The first deliveries of State Project Water to the White Wolf Basin began in 1973. Since 1966, combined State Project and Central Valley Project deliveries to the White Wolf Basin have amounted to more than 2,000,000 acre-feet.

Since the introduction of imported surface water, overdraft in the White Wolf Basin has been corrected and even reversed (Figure 2). Per studies commissioned by the WRMWSD, groundwater levels have generally risen on the order of 50 to 100 feet since the early 1970s. Although many private wells continue to operate in the White Wolf Basin, both WRMWSD and AEWSD pursue a conjunctive use water management strategy that maximizes surface water imports to minimize groundwater pumping.



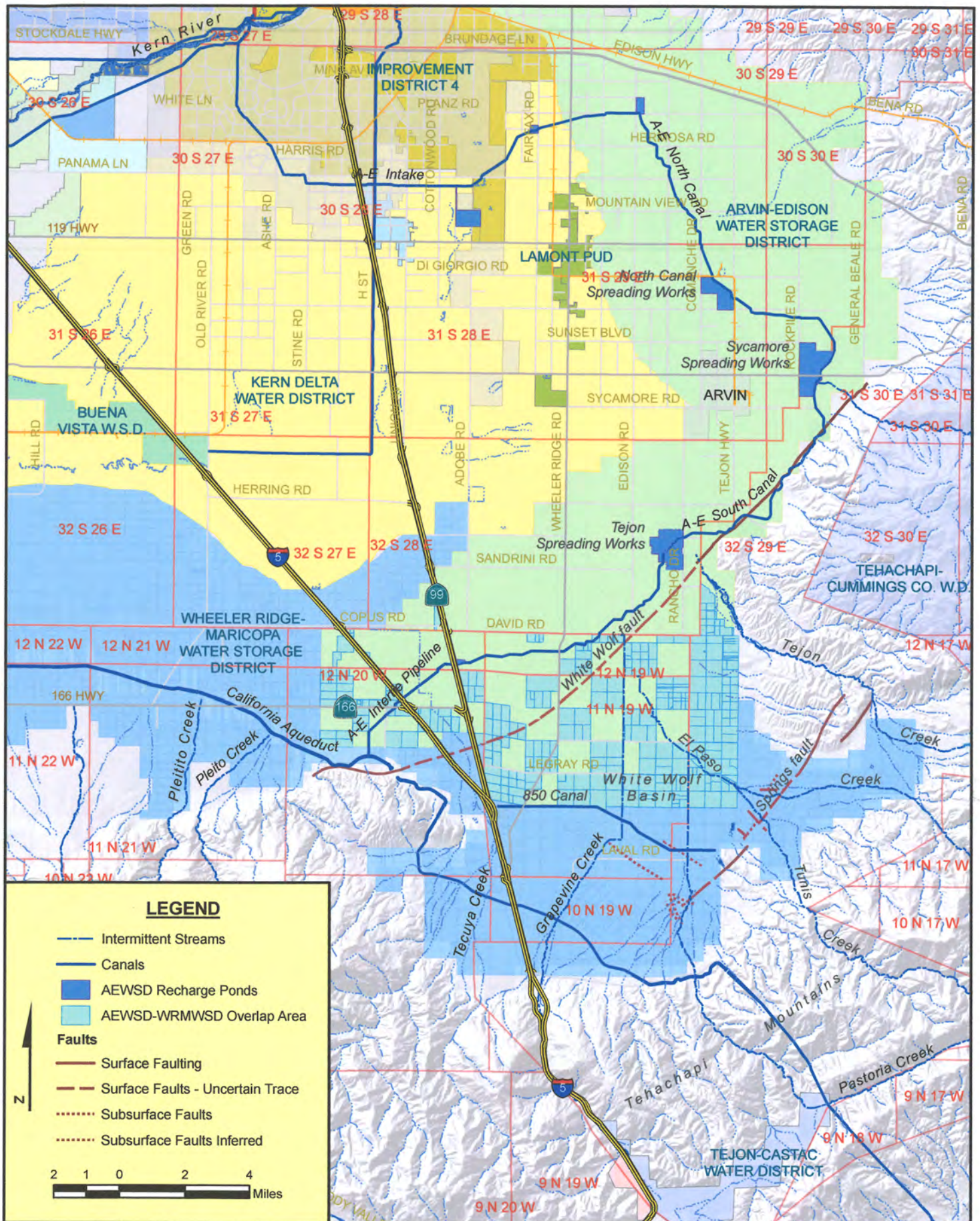
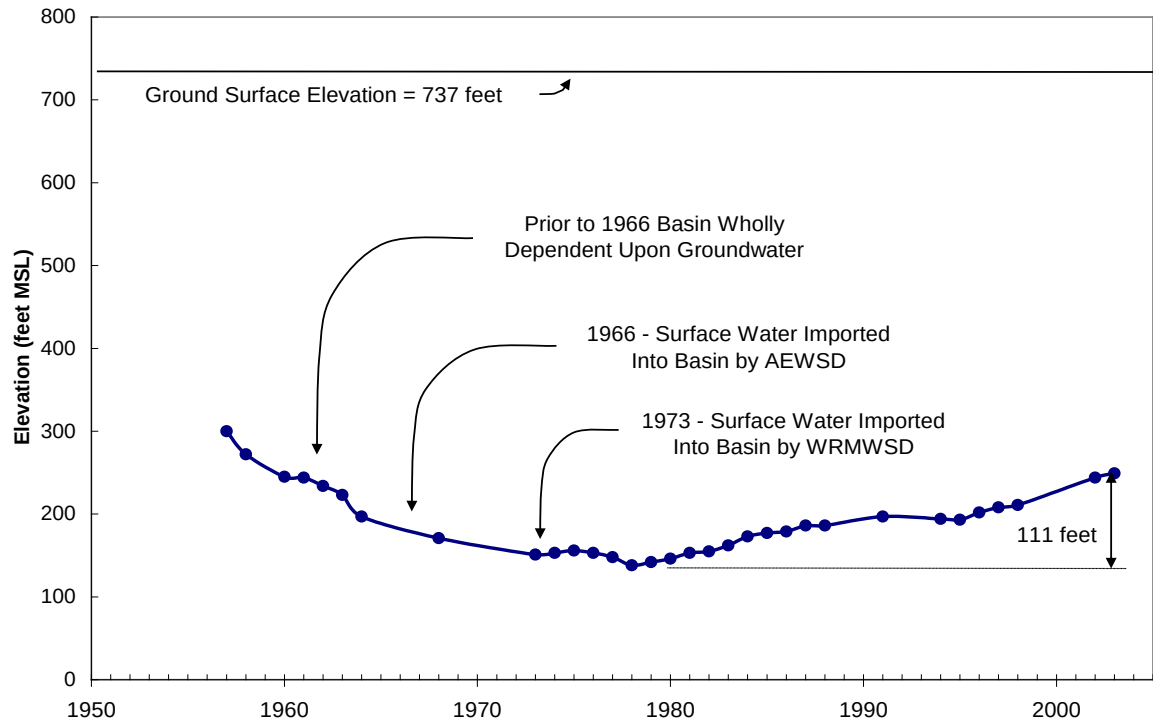


FIGURE 2.
HYDROGRAPH OF WELL 11N19W-24H1 LOCATED IN THE WHITE WOLF BASIN



The AEWS service area comprises roughly 6,490 acres in the northern portion of the White Wolf Basin. Arvin-Edison facilities in or near the White Wolf Basin include two pressurized pipeline systems known respectively as the Tejon System and the White Wolf System. Each year, the AEWS delivers approximately 23,000 acre-feet of surface water into the White Wolf Basin.

The WRMS supplies 14,462 contract acres within the White Wolf Basin through its 850 Canal and WRM10 Pumping Plant (Figure 3). The 850 Canal is a concrete-lined canal, roughly 7 miles long, designed to convey approximately 150-220 cubic feet per second (cfs) from Reach 15 of the California Aqueduct to the eastern extent of the White Wolf Basin. Lands located adjacent to the 850 Canal are generally supplied under pressure by one of five WRMS pumping plants. Some lands located more than one mile north of the 850 Canal are supplied under gravity. The District serves an additional 2,465 contract acres through four Aqueduct turnouts (Pumping Plant WRM15 and gravity turnouts 13A, 13B, and WRM14) located on Reach 16 of the California Aqueduct. Each year, the WRMS delivers approximately 39,000-49,000 acre-feet of State Project Water into the White Wolf Basin.

Beginning in the mid-1970's, the White Wolf Basin has been evaluated by various researchers as a potential location for the development of a groundwater banking program. In an unpublished report entitled *Report on Investigation of Planned Operation and Management of the White Wolf Ground Water Basin* by Bookman-Edmonston Engineering (1975), it was asserted that the White Wolf Basin contains permeable water bearing strata to depths of nearly 2,000 feet. The base of the fresh water was estimated to be approximately 1,250 feet below ground surface in the easterly portion of the basin and the geology was such that relatively rapid infiltration of surface water would be expected. The report noted that existing wells within the White Wolf Basin were productive and yielded water of acceptable quality for irrigation.

In February 1979, Anderson and others prepared a Technical Information Record (TIR) entitled, *Preliminary Evaluation of State Water Project Ground Water Storage Program: White Wolf Basin*. The TIR was prepared to summarize information collected as part of a reconnaissance level study and to estimate the cost of banking and recovering SWP water within the White Wolf Basin for comparison with other areas under evaluation. The report stated that water could be stored and recovered within the subject area, and could be stored by direct (spreading) or in-direct (in-lieu) methods. It further noted that of the estimated 4.0 million acre-feet (ac-ft) of storage capacity within the aquifer, nearly 1.5 million ac-ft of capacity had been dewatered by historic pumping. The TIR recommended three locations that had geologic characteristics that would support rapid infiltration of surface water. These locations are adjacent to Grapevine Creek, Pastoria Creek and El Paso Creek. DWR suggested that recharge facilities consisting of 274 acres at the Grapevine Creek location, 318 acres at the Pastoria Creek location and 66 acres at the El Paso Creek location could be developed to recharge the aquifer. Recovery would be accomplished using either existing wells or constructing new wells.

Until the late 1980's and early 1990's, WRMWSD found the SWP water supplies to be reliable for their demands. Several factors, however, changed WRMWSD's outlook towards SWP water supply reliability:

- the 1991 drought, which resulted in no SWP water being available for agriculture in 1991
- the federal government's concern over water quality in the Delta
- the concern over the protection of endangered species in the Delta and other tributaries

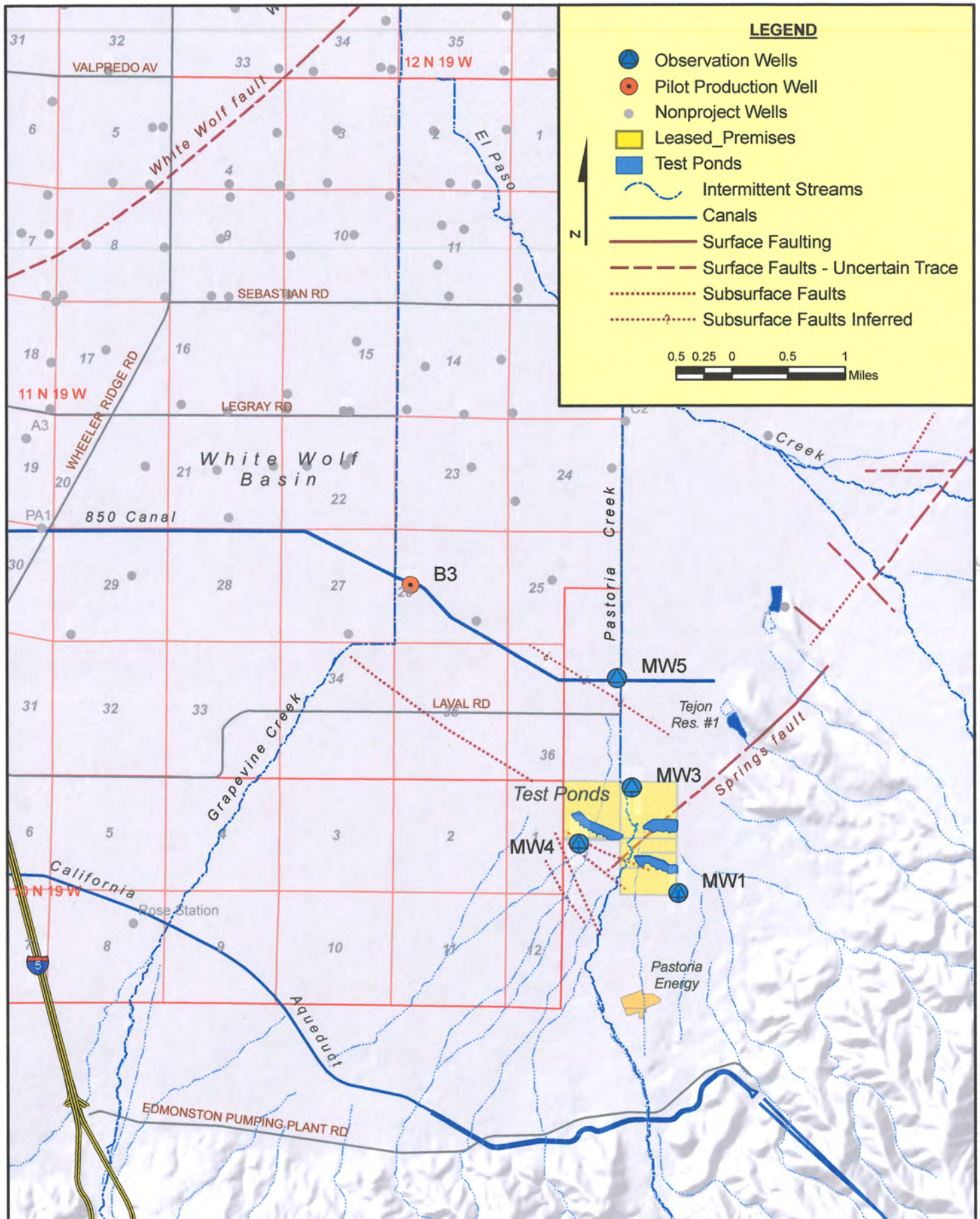
These events resulted in the loss of water to San Joaquin Valley agriculture and caused WRMWSD to reevaluate the reliability of its water supply and take steps to improve reliability for its customers.

In order to protect and regulate its water supply, WRMWSD has participated in the Monterey Agreement amendments to the State Water Contracts and has been involved in

the development of the Kern Water Bank, the Pioneer Project, and the Berrenda Mesa water-banking project on the Kern River Fan. These projects now enable WRMWSD to acquire surplus water and store it for dry-year use and store its own SWP entitlements for future use during years of higher than normal precipitation. In addition to these activities, since 1991 WRMWSD has acquired or drilled eighteen water wells, fourteen of which are located in the White Wolf Basin.

The current Groundwater Storage and Recovery Pilot Project in the White Wolf Basin was introduced as part of a joint Science Applications International Corporation (SAIC) and Bookman-Edmonston Engineering (B-E) study entitled *Technical Memorandum Appraisal-Level Investigation Joint Water Banking and Exchange Program for Wheeler Ridge-Maricopa Water Storage District and Tejon-Castaic Water District* (October 1999). Two groundwater banking scenarios were developed for the appraisal level study: a 5,100 acre-foot per year (AFY) groundwater extraction/15,300 AFY groundwater recharge operation (Phase 1 scenario) and a 45,900 AFY groundwater extraction and recharge operation (Phase 2 scenario). The Phase 1 scenario was developed to provide cooling and other water for a proposed power plant, the 750-megawatt Pastoria Energy Facility (PEF). The estimated annual water demands for the power plant were subsequently increased to 6,200 AFY and the Phase 1 scenario was revised upward to 6,200 AFY extraction/25,000 AFY recharge. The Phase 2 scenario was intended to provide water for the PEF as well as for agricultural, municipal and industrial use by the WRMWSD. For purposes of rounding, the Phase 2 scenario was also revised upward to 50,000 AFY recharge and extraction. To date, water demands at the PEF have been met with direct deliveries of State Water Project (SWP) water delivered by the WRMWSD through new and existing water distribution facilities.

As initially conceived, the groundwater banking operation was expected to consist of a 340-acre recharge facility and four production wells located near Pastoria Creek directly south of the 850 Canal. The groundwater banking operation was designed to include an additional 14 production wells for a total of 18 wells in a second construction phase. The recharge facility was designed to operate from 90 to 270 days or more per year. The total amount of annual recharge was initially estimated based on historic infiltration rates of about 0.5 feet per day (ft/day) at the nearby Arvin-Edison Water Storage District's (AEWSD) Tejon Spreading Grounds (Figure 3). In 1999, three percolation ponds were constructed at the Pastoria Creek site and a pilot infiltration rate test was conducted from August through November 1999 using SWP water delivered through existing WRMWSD water conveyance facilities (Figure 4). The pilot test found that short-term infiltration rates were higher than the initial estimate, ranging between 0.6 and 2.5 ft/day. However, long-term percolation rates were projected to be approximately 0.5 ft/day (WRMWSD, 2000).



Following the overall success of the pilot infiltration test, WRMWSD, with the assistance of B-E, submitted a Proposition 13 grant application, dated February 16, 2001, to the DWR for funding of the Groundwater Storage and Recovery Pilot Project in White Wolf Basin. The project was approved for grant funding in January 2002. The Work Plan in the application included nine phases consisting of one or more tasks. For brevity, only the phases and the title of each phase are listed below:

- Phase 1- Preliminary Data Review and Evaluation
- Phase 2 – Field Exploration and Analysis
- Phase 3 – Groundwater Exploration and Analysis
- Phase 4 – Groundwater Modeling
- Phase 5 – Reverse Flow Hydraulic Modeling of the 850 Canal
- Phase 6 – Prepare Conceptual Project Layout and Cost Estimate
- Phase 7 – Report Preparation
- Phase 8 – Meetings
- Phase 9 – Project Management

The following sections present brief summaries of the work performed in Phases 1 – 6 as well as overall project conclusions and recommendations for further work. The technical memoranda produced for each of the six phases are included in separate appendices at the end of this report.

PHASE 1 - PRELIMINARY DATA REVIEW AND EVALUATION

Phase 1 consisted of six tasks:

- Task 1.1 – Literature review
- Task 1.2 – Oil, Gas and Water Well Data Evaluation
- Task 1.3 - SWP and Groundwater Quality Data Review
- Task 1.4 – Test Recharge Basin Data Evaluation

- Task 1.5 - CEQA Documentation for Field Work
- Task 1.6 – Data Review Technical Memorandum

As part of the Phase 1 scope of work, considerable published and unpublished data were collected and reviewed to gain a better understanding of the geology, hydrogeology, and groundwater quality conditions of the water-bearing sediments in the White Wolf Basin and more specifically in the vicinity of the Pastoria Creek and Grapevine Creek areas. Because of the general lack of water wells in the Pastoria Creek area, oil and gas well logs in the Tejon Oil Field were reviewed to characterize the subsurface geology. These combined data were invaluable in identifying the stratigraphy of the underlying oil- and gas-bearing deposits as well as the structural geology of the area. These data, however, did not provide sufficient detail to determine the thickness or hydraulic character of the Quaternary alluvium and underlying Chanac formation sediments, which represent the principal water-bearing materials underlying the Pastoria Creek site. Although very limited surface water quality data were available for Pastoria Creek and groundwater quality data were available for areas to the west and north of the proposed Pastoria Creek site, there were no groundwater quality data in the project area. Based on the generally favorable geologic conditions noted by others and the success of the pilot recharge program in 1999, further study was recommended in the Phase 1 Data Review Technical Memorandum (TM). A copy of this TM is included as Appendix B.

PHASE 2 – FIELD EXPLORATION AND ANALYSIS

Phase 2 consisted of two tasks:

- Task 2.1 – Subsurface Geotechnical Exploration
- Task 2.2 – Subsurface Geotechnical Exploration Technical Memorandum

Phase 2 entailed a preliminary geotechnical evaluation of the percolation capacity and soil conditions in the upper portion of the unsaturated zone in the vicinity of the proposed Pastoria Creek recharge facilities. As part of this effort, three soil borings were drilled and soil samples collected for geotechnical analysis including laboratory permeability, sieve analysis, moisture content and density determination. Drilling, soil sampling and geotechnical soil testing were performed by Krazan & Associates of Modesto, California as a subcontractor to B-E. Drilling and soil sampling occurred over the period October 7 through 10, 2002. Geotechnical soil testing included the performance of eight (8) permeability tests, 17 sieve analyses, and 17 moisture content and density determinations. The three soil borings were drilled to depths of 37, 59 and 97 feet and were terminated due to auger refusal at those depths. Coarse grained soils were encountered in the three soil borings and consisted of silty sand, sand and gravelly sand or sandy gravel. Vertical permeability ranged between 0.04 ft/day in silty sand to as much as 19.3 ft/day in a silty

sand/sand mixed soil. The complete results of the geotechnical work are presented in the Phase 2 Subsurface Geotechnical Technical Memorandum, which is included as Appendix C.

PHASE 3 – GROUNDWATER EXPLORATION AND ANALYSIS

The Phase 3 work effort consisted of exploration borehole drilling, monitoring and production well construction and testing, long-term aquifer testing, surface water and groundwater sampling and testing, and isotopic tritium (^3H) laboratory analytical work. The following paragraphs summarize the work performed by task. Phase 3 consisted of four tasks:

- Task 3.1 – Exploratory Hole/Monitoring Well and Production Well Construction and Testing
- Task 3.2 – Long-term Aquifer Testing
- Task 3.3 – Tritium Analysis of Surface Water and Groundwater
- Task 3.4 – Groundwater Exploration Technical Memorandum

Monitoring and Production Well Construction

Four exploratory holes/monitoring wells and one production well were constructed at the proposed Pastoria Creek project site to characterize the geology and to quantify, to the extent possible, the hydraulic character of the underlying aquifers (Figure 4). The first monitoring well (MW5) was located adjacent to the 850 Canal west of Rancho Road in the northwest quarter of Section 36, Township 11 North, Range 19 West (T11NR19W), San Bernardino Base & Meridian (SBBM). The remaining three monitoring wells (MW1, MW3, and MW4) were located in Section 1, T10NR19W, SBBM, and Section 6, T10NR18W, SBBM. The production well (B3) was located adjacent to the 850 Canal immediately east of the Grapevine Creek siphon in the northwest quarter of Section 26, T11NR19W, SBBM.

The four monitoring wells were drilled and constructed by Whitten Pumps, Inc. of Delano, California from October 21, 2002 to March 5, 2003 (Tables 1 and 2). Geologic logging and sampling were performed in alternating shifts by staff from WRMWSD and B-E. After completion of drilling to total depth, geophysical logging of the pilot holes was performed to confirm the results of the soils logging, to further characterize the underlying geologic materials, and to evaluate the potential for saline groundwater at depth.

**TABLE 1
WELL CONSTRUCTION DATES AND DEPTHS**

Well Construction Data					
Hole Number	Well Construction Dates		Total Depth (ft)	Completed (ft)	Depth to Static Water Level on March 6, 2003 (ft)
	From	To			
MW1	12/5/02	1/7/03	1023	990	157
MW3A	1/8/03	2/5/03	1740	840	180
MW3B				1160	167.4
MW4A	2/6/03	3/5/03	1370	460	84
MW4B				1000	97
MW5	10/21/02	12/2/02	1530	1000	413.3
#B3	9/3/03	11/14/03	1511	1290	625

**TABLE 2
SUMMARY OF WELL CONSTRUCTION**

Well Construction Materials Summary															
Hole Number	Depth From Surface (ft)	Bore-hole Diameter (inches)	CASING							Depth From Surface (ft)	Annular Material				
			Type				Material	Internal Diameter (Inches)	Wall Thickness (Inches)		Slot Size (Inches)	Type			Filter Pack (type/size)
			Conductor	Blank	Screen	Fill & Sounding Tubes						Cement	Bentonite	Gravel Fill	
MW1	0-50	22	X				Mild Steel (a)	15.5	0.25		0-50	X			
	0-920	14.75		X			Mild Steel (a)	6.125	0.25		50-920			X	4x8
	920-990	14.75			X		Mild Steel (a)	6.125	0.25	0.03	920-990			X	4x8
MW3											990-1023			X	
	0-50	22	X				Mild Steel (a)	15.5	0.25		0-50	X			
	0-720	14.75		X			Mild Steel (a)	2			0-680	X			
	720-820	14.75			X		Mild Steel (a)	2		0.03	680-700		X		
	820-840	14.75		X			Mild Steel (a)	2			700-870			X	12x20
	0-1060	14.75		X			Mild Steel (a)	6.125	0.25		870-1040		X		
	1060-1140	14.75			X		Mild Steel (a)	6.125	0.25	0.063	1040-1170			X	4x8
	1140-1160	14.75		X			Mild Steel (a)	6.125	0.25		1170-1740			X	1/4" Gravel
MW4		0-50	22	X			Mild Steel (a)	15.5	0.25		0-50	X			
	0-420	14.75		X			Mild Steel (a)	6.125	0.25		0-380	X			
	420-440	14.75			X		Mild Steel (a)	6.125	0.25	0.03	380-400		X		
	440-460	14.75		X			Mild Steel (a)	6.125	0.25		400-460			X	12x20
	0-900	14.75		X			Mild Steel (a)	2			460-860	X			
	900-990	14.75			X		Mild Steel (a)	2		0.03	860-880		X		
	990-1000	14.75		X			Mild Steel (a)	2			880-1000			X	12x20
MW5											1000-1030		X		
											1030-1370			X	1/4" Gravel
	0-50	22	X				Mild Steel (a)	15.5	0.25		0-50	X			
MW5	0-960	14.75		X			Mild Steel (a)	6.125	0.25		50-900	X			
	960-1000	14.75			X		Mild Steel (a)	6.125	0.25	0.03	900-1030			X	10x20
											1030-1400	X			
#B3	0-55	42	X				Mild Steel (a)	32	0.375		0-55	X			
	0-760	30		X			Mild Steel (a)	17.125	0.375		55-1300			X	8x14
	760-1270	30			X		Mild Steel (a)	17.375	0.3125	0.05	1300-1511			X	
	1270-1290	30		X			Mild Steel (a)	17.125	0.375						
	+2-750	30				S	Mild Steel (a)	2							
	+2-55	30				F	Mild Steel (a)	3							

(a) ASTM A53 Grade B Threaded Steel Well Casing

Bakersfield Well & Pump Company began drilling production well B3 on September 3, 2003 and completed all well construction work on November 14, 2003 (Tables 1 and 2). A raised earthen pad was constructed at the well site by WRMWSD immediately prior to commencement of well construction activities to minimize the potential for flooding from nearby Grapevine Creek and provide sufficient room for the drilling equipment to operate. Geologic logging and sampling were performed in alternating shifts by staff from WRMWSD and B-E. After completion of drilling to total depth, geophysical logging of the pilot hole was performed to confirm the results of the soils logging, to further characterize the underlying geologic materials, and to evaluate the potential for saline groundwater at depth. Lithologic logs, geophysical logs, and construction details are presented in the Phase 3 Technical Memorandum, which is included as Appendix D.

Isolation Zone Sampling

Isolation zone tests were performed to assess groundwater quality at discrete depths in the water bearing zones. Groundwater samples were analyzed for general minerals, general physical parameters, Langelier index, aggressiveness index, selected trace metals including total and hexavalent chromium, arsenic, trivalent and pentavalent arsenic, and total recoverable petroleum hydrocarbons (TRPH). Petroleum hydrocarbons were analyzed using EPA Method 418.1 at BC Laboratories, Inc of Bakersfield and/or FGL Environmental of Santa Paula, both California-certified laboratories. TRPH analyses were performed to evaluate the existence of crude oil in the groundwater due to natural seepage from oil-bearing strata or leakage from nearby oil and/or gas wells. Groundwater quality test results, including unedited analytical laboratory testing reports, are presented in the Phase 3 Technical Memorandum.

Pumping Tests

Performance testing of monitoring wells and production Well B3 was conducted in order to quantify the hydraulic characteristics of the underlying aquifers. Following development, Whitten Pumps, Inc. installed a temporary submersible pump and motor in each monitoring well to conduct the aquifer pumping tests. Testing of monitoring wells MW1 and MW3 consisted of a 12-hour step-drawdown test and a 24-hour constant rate pumping test. Due to low well yields, shorter term aquifer testing was conducted at wells MW4 and MW5. Twenty-four-hour discharge rates were 5.7 gallons per minute (gpm) at MW-1 and 15 gpm at MW-3. At Well B3, Bakersfield Well & Pump Company installed a temporary vertical turbine pump and motor with portable diesel engine to conduct the 12-hour step-drawdown and 24 hour constant rate pumping tests. The discharge rate at Well B3 during the constant rate test was 1800 gpm.

Aquifer hydraulic parameters were estimated from the pumping tests. The transmissivities calculated from the monitoring well pumping tests were low, ranging from 78.5 gallons per day per foot (gpd/ft) at MW-3 to 109-329 gpd/ft at MW-1. The Theis method of analysis for confined aquifers was used to calculate the pumping test data for the confined lower portion of the Chanac formation aquifer (MW-1) and the confined Santa Margarita

formation aquifer (MW-3). The transmissivity and hydraulic conductivity from the Well B3 pumping test were calculated using the Neuman method of analysis for anisotropic unconfined aquifers. Transmissivity and horizontal hydraulic conductivity of the alluvial aquifer tested were 1,050,000 gpd/ft and 217 ft/day, respectively. A specific yield of 21.1% was calculated from observation well T11N/R19W-26F01 during the pumping test at Well B3. A somewhat lower specific yield of 10.4 % was calculated from observation Well B3 during a subsequent pumping test at Well PB1.

Long-Term Aquifer Testing

B-E and WRMWSD conducted three long-term constant rate aquifer tests during the period April 18 through June 4, 2003 to estimate hydraulic parameters of the alluvial aquifer north of the 850 Canal and the Pastoria Creek recharge site. Pumping tests were conducted at wells 11N/18W-19D01, 11N/19W-28G01 and 11N/19W-24M01. Additionally, wells 11N/18W-18M01 and 11N/19W-24H01 were used as observation wells to record groundwater level changes associated with the pumping at nearby irrigation well 11N/19W-13J01. Based on the Neuman method of analysis for the long-term pumping tests, the estimated transmissivity in the alluvial aquifer north of the 850 Canal ranged from 232,000 to 1,030,000 gpd/ft, and averaged 685,000 gpd/ft. The calculated specific yield ranged between 2.2% and 10.6% and averaged 6.5%. A more detailed description of the various pumping tests conducted and the results calculated therein are presented in the Phase 3 Technical Memorandum.

Tritium Analysis of Surface Water and Groundwater

Isotopic tritium analyses were performed to determine whether Pastoria Creek has recharged the underlying water bearing units since approximately 1952 and to help interpret the relative ages of water in the Santa Margarita and Chanac formations. Split samples were obtained from isolation zone sampling of monitoring well boreholes and submitted to the University of Utah for analysis. Surface water samples from Pastoria Creek were also collected and submitted for tritium analyses. Laboratory analytical results indicated that recharge has occurred locally within the past 50 years in the Santa Margarita formation but not in the overlying Chanac formation. The results of the tritium analyses are presented in the Phase 3 Technical Memorandum.

Data obtained from the construction and testing of Well B3 and the long-term pumping tests led to the selection of an alternative project site farther to the northwest in the Grapevine Creek area. Subsequent studies and analyses conducted as part of Phases 4, 5 and 6 (discussed below) were focused in this new area.

PHASE 4 – GROUNDWATER MODELING

Phase 4 consisted of three tasks:

- Task 4.1 – Develop Preliminary Groundwater Model
- Task 4.2 – Design monitor Well network
- Task 4.3 – Preliminary Groundwater Model Technical Memorandum

Phase 4 consisted of the development of a three-dimensional groundwater flow model using the United States Geological Survey's (USGS) MODFLOW program to estimate the hydraulic impacts of groundwater recharge and discharge as part of the newly proposed Grapevine Creek groundwater banking operation. The initial phase of groundwater model development included the estimation of aquifer hydraulic parameters based on available published and unpublished data together with new data obtained during Phase 3 activities. Aquifer boundaries were established based on existing geologic data and the results of subsurface exploration performed in Phase 3. The model area was bounded by the Tehachapi Mountains on the east and southeast, the San Emigdio Mountains on the southwest, Wheeler Ridge on the west, and the White Wolf fault on the north (Figure 5). The geologic units along the east, south and west boundaries are the elevated bedrock hills. A no-flow boundary condition was assigned to these boundaries. The boundary condition on the north side of the model area is defined by the White Wolf fault.

In the model calibration process, basin-wide recharge and pumping were estimated from the water balance from 1971 through 1990. Observed groundwater elevations at six representative wells were compared to predicted groundwater elevations from the model (Figure 5). Following model calibration, WRMWSD, in concert with B-E, developed several possible operating scenarios for recharge and recovery, which were grouped collectively under Scenario 1 and Scenario 2. The groundwater flow model was then used to determine the potential effects of recharge and recovery on groundwater levels in the White Wolf Basin. In each case, the model represented a 30-year period starting in 2003. Following are descriptions of the model scenarios.

Scenario 1

Scenario 1A entailed recharge and recovery of about 25,000 acre-feet per year (ac-ft/yr). In this scenario, recharge of SWP water was simulated at spreading grounds located adjacent to and north of WRMWSD's 850 Canal (Figure 15). The simulated spreading grounds area was net 190 acres. Groundwater recovery was simulated at 12 extraction wells completed in the alluvial aquifer. This scenario was run for a 30-year period made up of three 10-year cycles. The sequence of recharge and extraction in Scenario 1A was three years of recharge, followed by a four-year resting period, followed by three years of extraction from the recovery wells.

LEGEND

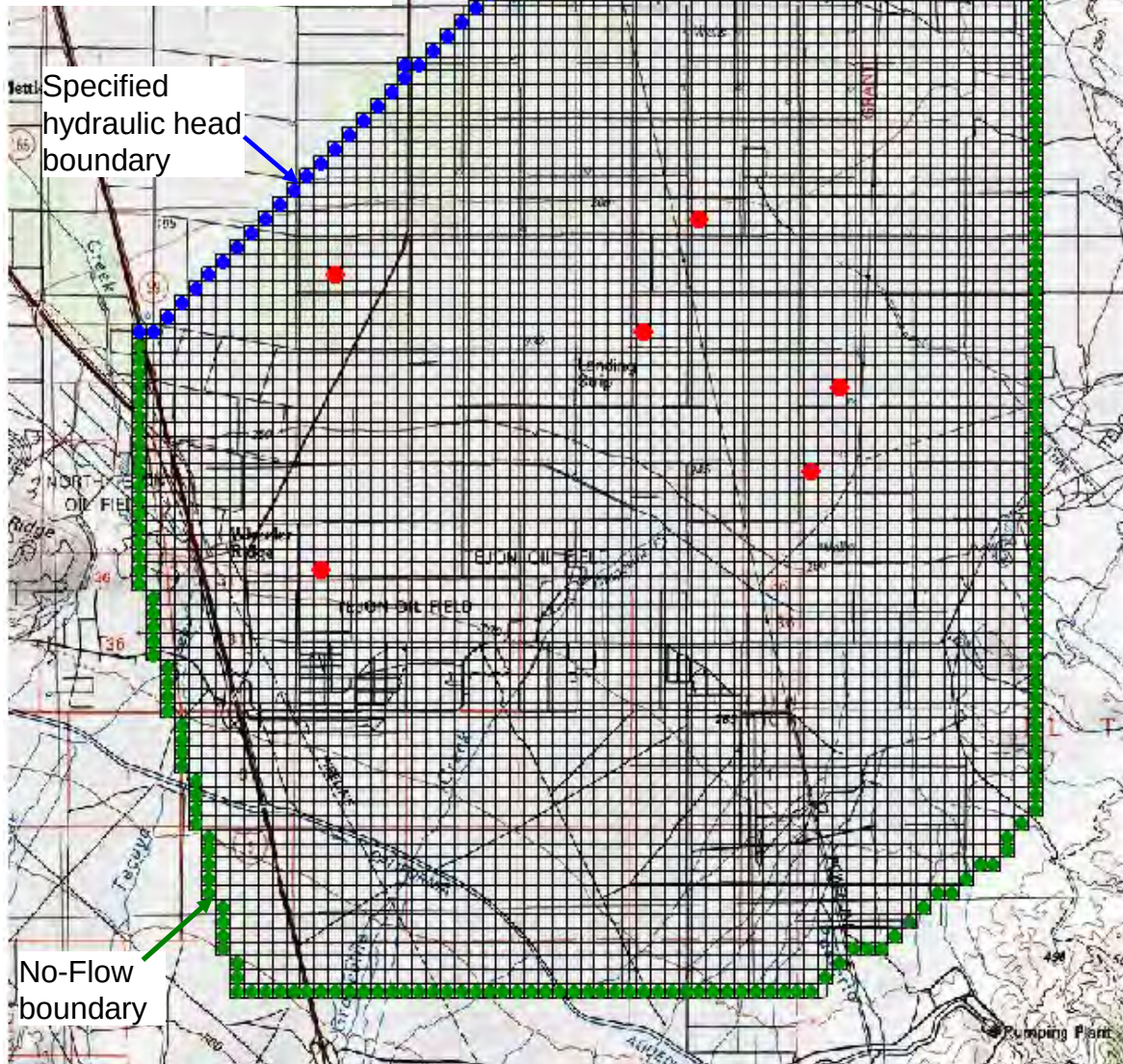
● Specified hydraulic head boundary

● No-Flow boundary

● Calibration Target Well

Model grid

0 0.5 1 mile



Scenario 1B had the same physical conditions as Scenario 1A (i.e., same layout of spreading grounds and recovery wells, same proposed annual project recharge and extraction rates). The only difference between Scenario 1B and Scenario 1A was the sequence of recharge and recovery. The sequence of recharge and recovery in Scenario 1B was three years of recharge to the spreading grounds, followed by a three-year resting period, followed by *three years* of extraction from the recovery wells, plus a final one-year resting period.

Scenario 2

Scenario 2A simulated recharge and recovery at a rate of about 50,000 ac-ft/yr. Simulated recharge facilities consisted of two spreading grounds areas (Figure 16). Here, the simulated spreading grounds located north of the 850 Canal were expanded to 260 acres and a 130-acre spreading grounds area was added south of the 850 Canal, for a total net area of 390 acres. Groundwater recovery was simulated at 25 extraction wells completed in the alluvial aquifer. Scenario 2A was simulated for a 30 year period comprised of three 10-year cycles. The sequence of recharge and extraction was the same as Scenario 1A.

Scenario 2B had the same physical conditions as Scenario 2A (same layout of spreading grounds and recovery wells, same annual recharge and extraction rates) but included a one-year rest period at the end of each 10-year cycle (Table 3).

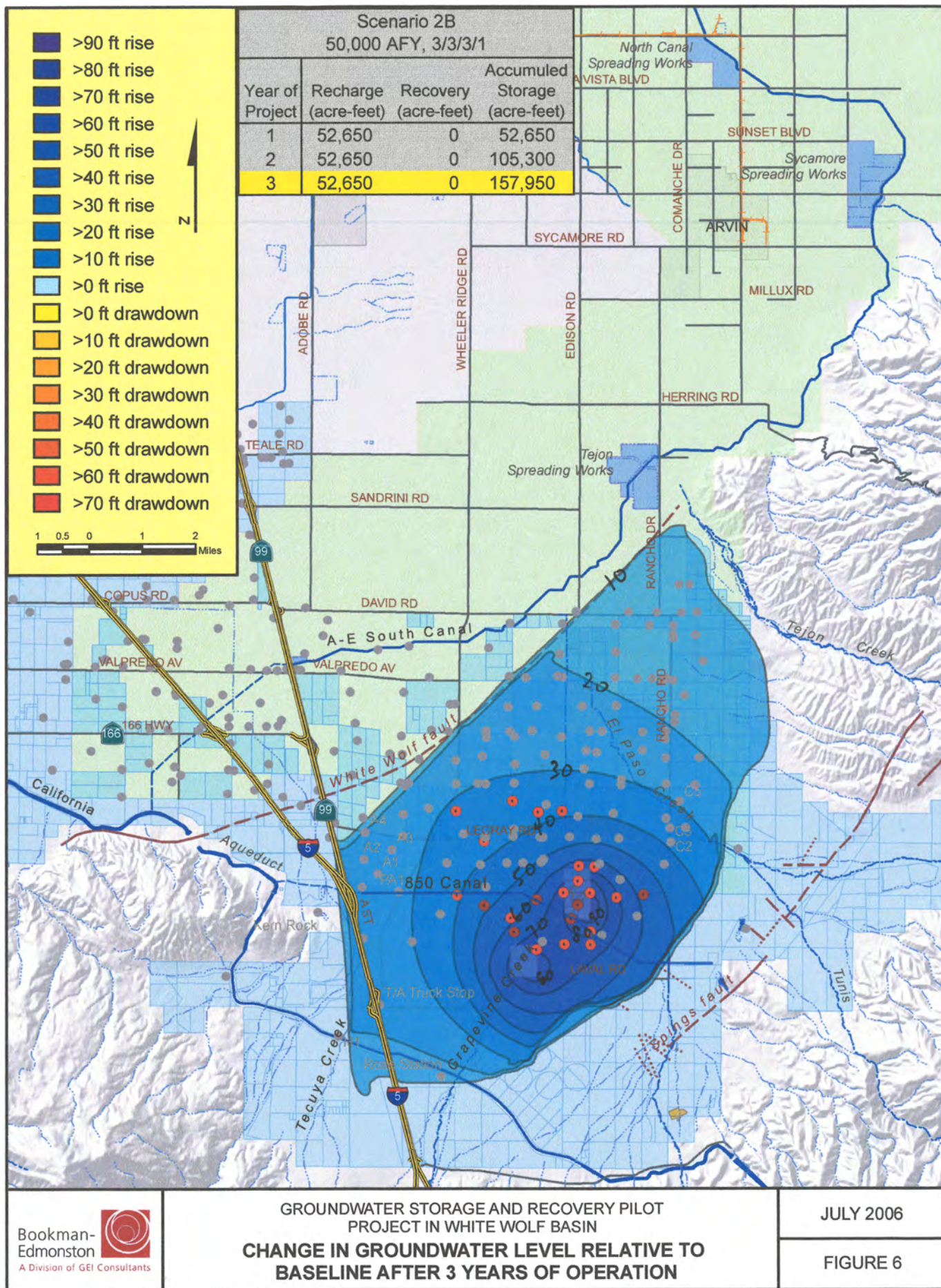
Simulated Changes in Groundwater Levels

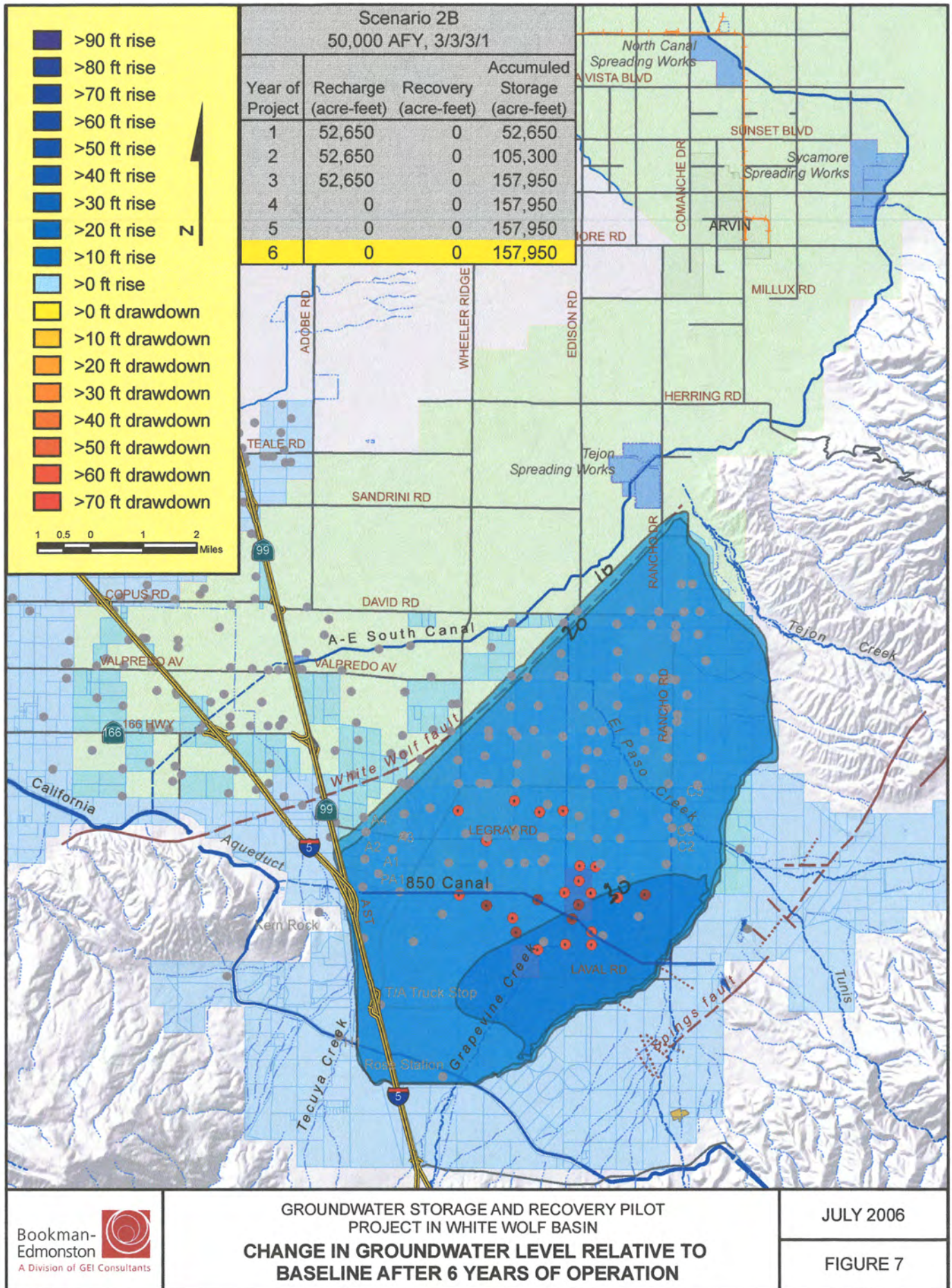
Potential hydraulic impacts of recharge and recovery operations in the above scenarios were evaluated utilizing the MODFLOW groundwater flow model. The model results represent incremental changes to groundwater conditions, which is a common approach to hydraulic impact analysis. In other words, model results do not represent predicted future water levels but instead represent net differences that would superimpose upon actual water levels in the event that a groundwater banking project were operated as described in the White Wolf Basin.

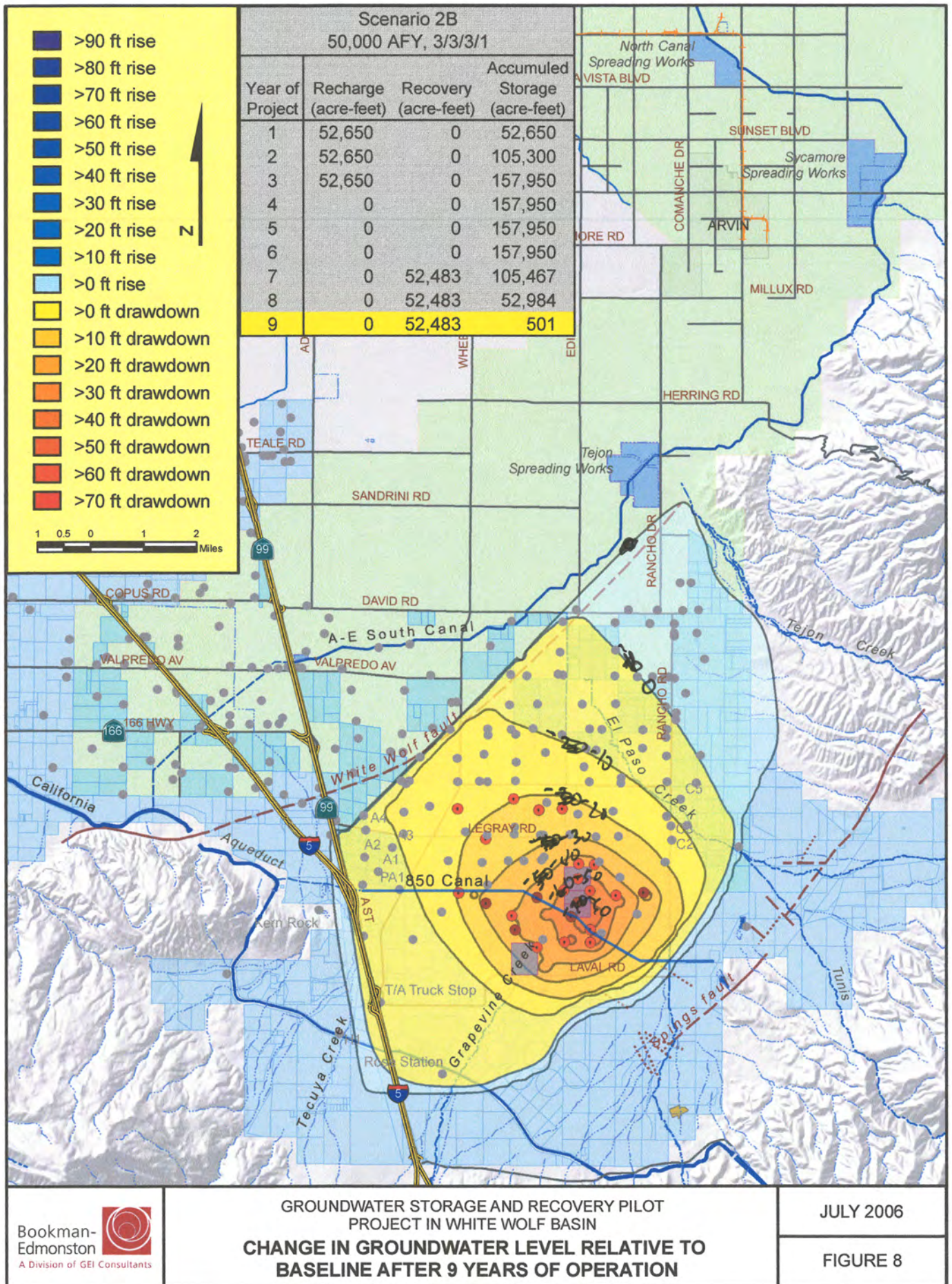
Figures 6-13 illustrate simulated changes in groundwater levels during the first 20 years of recharge and recovery operations under Scenario 2B. Some useful insights were provided by the modeling effort. For example, it was seen that relatively large groundwater mounds were during years of active recharge, but that mounds virtually disappeared as recharge water spread throughout the basin during subsequent years. Moreover, it appeared that relatively steep drawdowns were created during years of consecutive groundwater extraction, but that drawdowns moderated in subsequent years and pumping depressions spread generally throughout the basin. This can be attributed to the relatively high transmissivities that were assigned to model layers in accordance with lessons learned during the subsurface investigation phase of this project.

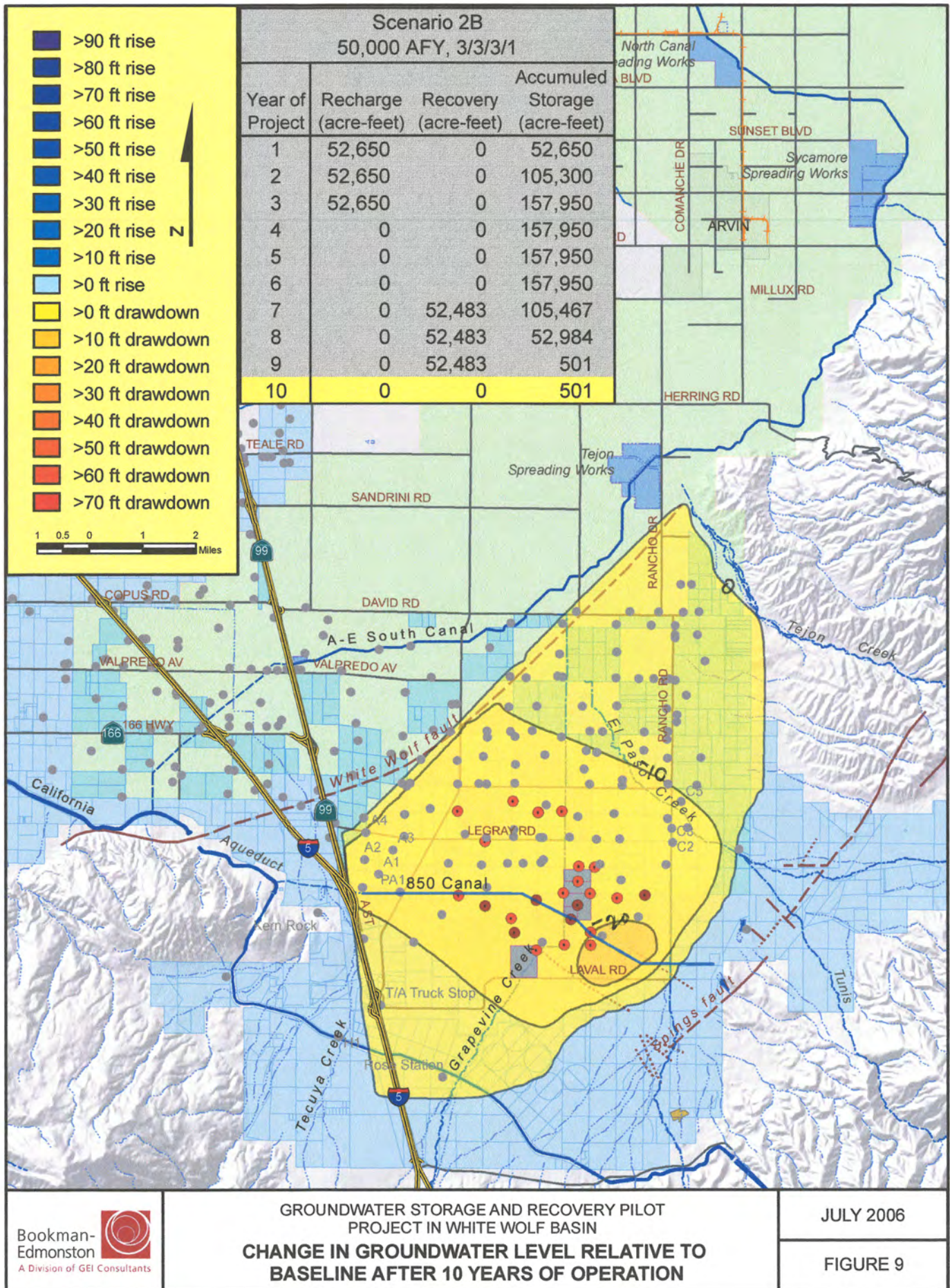
TABLE 3
SUMMARY OF RECHARGE AND RECOVERY OPERATIONS FOR
SCENARIO 2B DURING THE FIRST 20 YEARS OF OPERATION

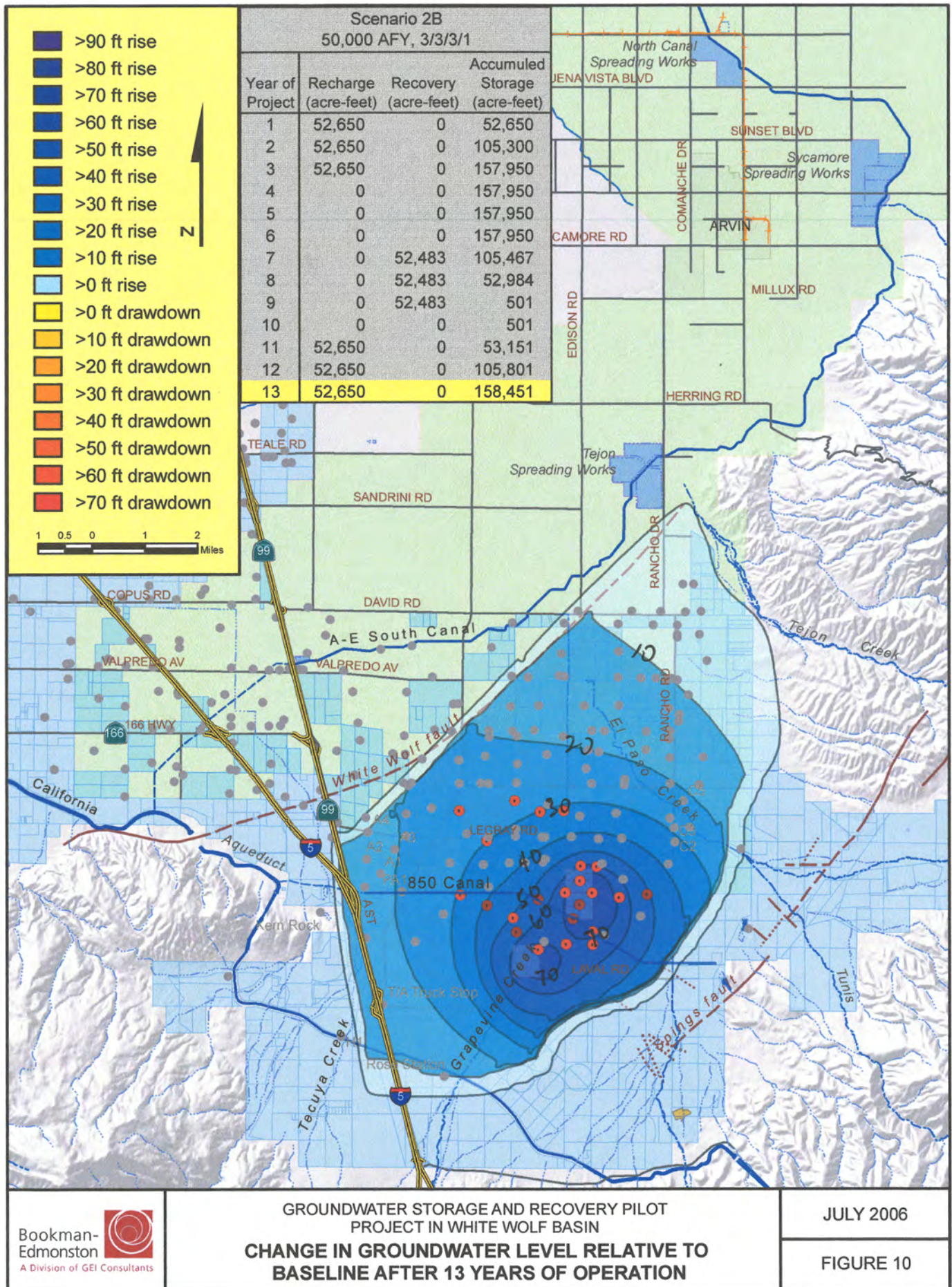
Scenario 2B 50,000 AFY, 3/3/3/1						
Year of Project	Simulated Recharge (acre-feet)	Simulated Recovery (acre-feet)	Water in Storage (acre-feet)	Total Accumulated Recharge (acre-feet)	Accumulated Leakage Across White Wolf Fault (acre-feet)	Leakage as a Percent of Total Recharge
1	52,650	0	52,650	52,650		
2	52,650	0	105,300	105,300		
3	52,650	0	157,950	157,950		
4	0	0	157,950	157,950		
5	0	0	157,950	157,950		
6	0	0	157,950	157,950	30,100	19%
7	0	52,483	105,467	157,950		
8	0	52,483	52,984	157,950		
9	0	52,483	501	157,950		
10	0	0	501	157,950		
11	52,650	0	53,151	210,600		
12	52,650	0	105,801	263,250		
13	52,650	0	158,451	315,900		
14	0	0	158,451	315,900		
15	0	0	158,451	315,900		
16	0	0	158,451	315,900	49,000	16%
17	0	52,483	105,968	315,900		
18	0	52,483	53,485	315,900		
19	0	52,483	1,002	315,900		
20	0	0	1,002	315,900		

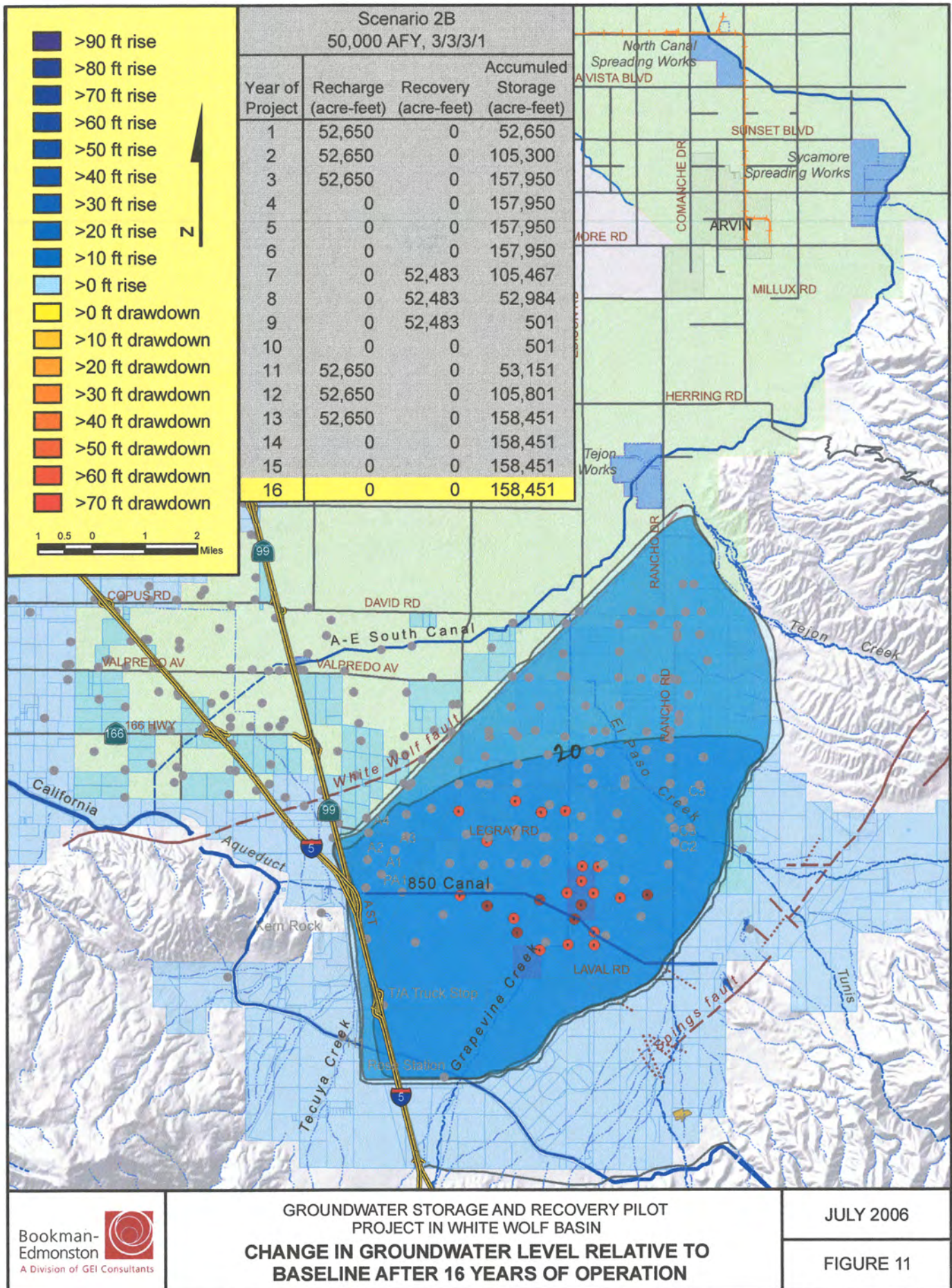


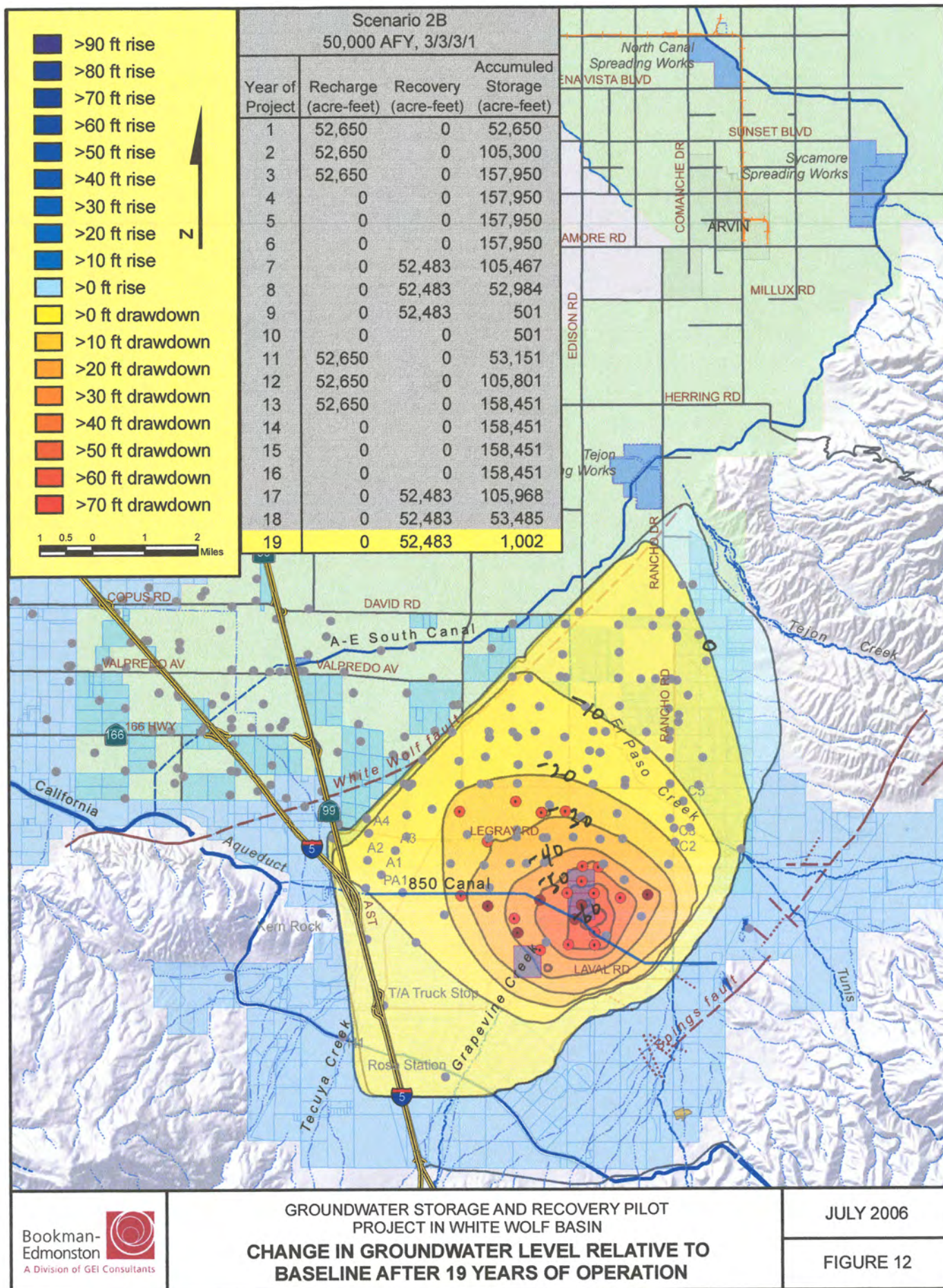


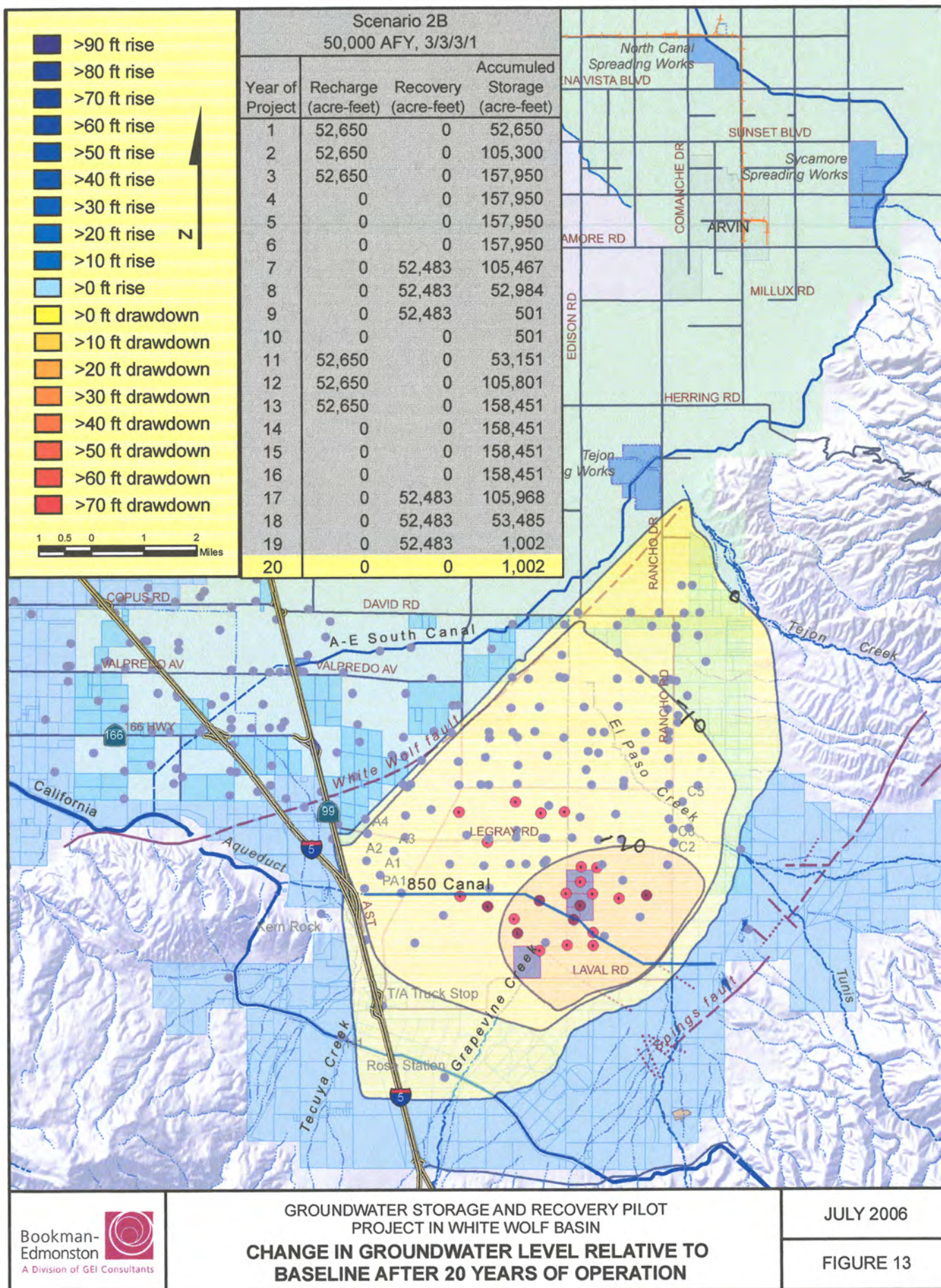












It was also found that simulated groundwater outflows across the White Wolf fault were significant, eventually amounting to 16-19% of the total accumulated recharge after 20 years in Scenario 2B. Here it should be noted that although subsurface outflows would not be recoverable by project wells, they would yet benefit the main San Joaquin Valley aquifer. If not recovered by a cooperative arrangement, however, outflows would affect the economics of the project by making less water available for recovery. In the groundwater model, groundwater recharge was matched closely by groundwater extraction, so that after 20 years of operation, the net accumulated water in storage was only about 1,000 acre-feet. In a final project, one possible operational plan would reduce the amount of water recovered – to approximately 40,000 acre-feet per year in Scenario 2, for example - to account for losses across the White Wolf fault.

A more complete description of the work performed and the results obtained in Phase 4 is presented in the Phase 4 Preliminary Groundwater Model Technical Memorandum, which is included as Appendix E.

PHASE 5 – REVERSE FLOW HYDRAULIC MODELING OF THE 850 CANAL

Phase 5 consisted of two tasks:

- Task 5.1 – Hydraulic Analysis of Reverse Flow in the 850 Canal
- Task 5.2 – Hydraulic Analysis Technical Memorandum

Phase 5 consisted of the development of a surface water hydraulic model and a hydraulic analysis of potential reverse flow conditions in the 850 Canal from the vicinity of turnout PC-1 (WRMWSD service area 850C) westward to turnout PA-1 (WRMWSD service area 850A). The 850 Canal is divided into four sections, or reaches, by three check structures (Figure 14). Reach A extends from the west end of the Canal (Station 8+00) to the check structure located about one mile east of PA-1 (Station 105+25). Reach B extends from the check structure located at Station 105+25 to the check structure located adjacent to PB-1 (Station 185+48). Reach C extends from the check structure at Station 185+48 to the check structure located at the downstream end of the Rancho Road siphon (Station 337+51). Reach D extends from the check structure at Station 337+51 to the end of the canal (Station 380+21).

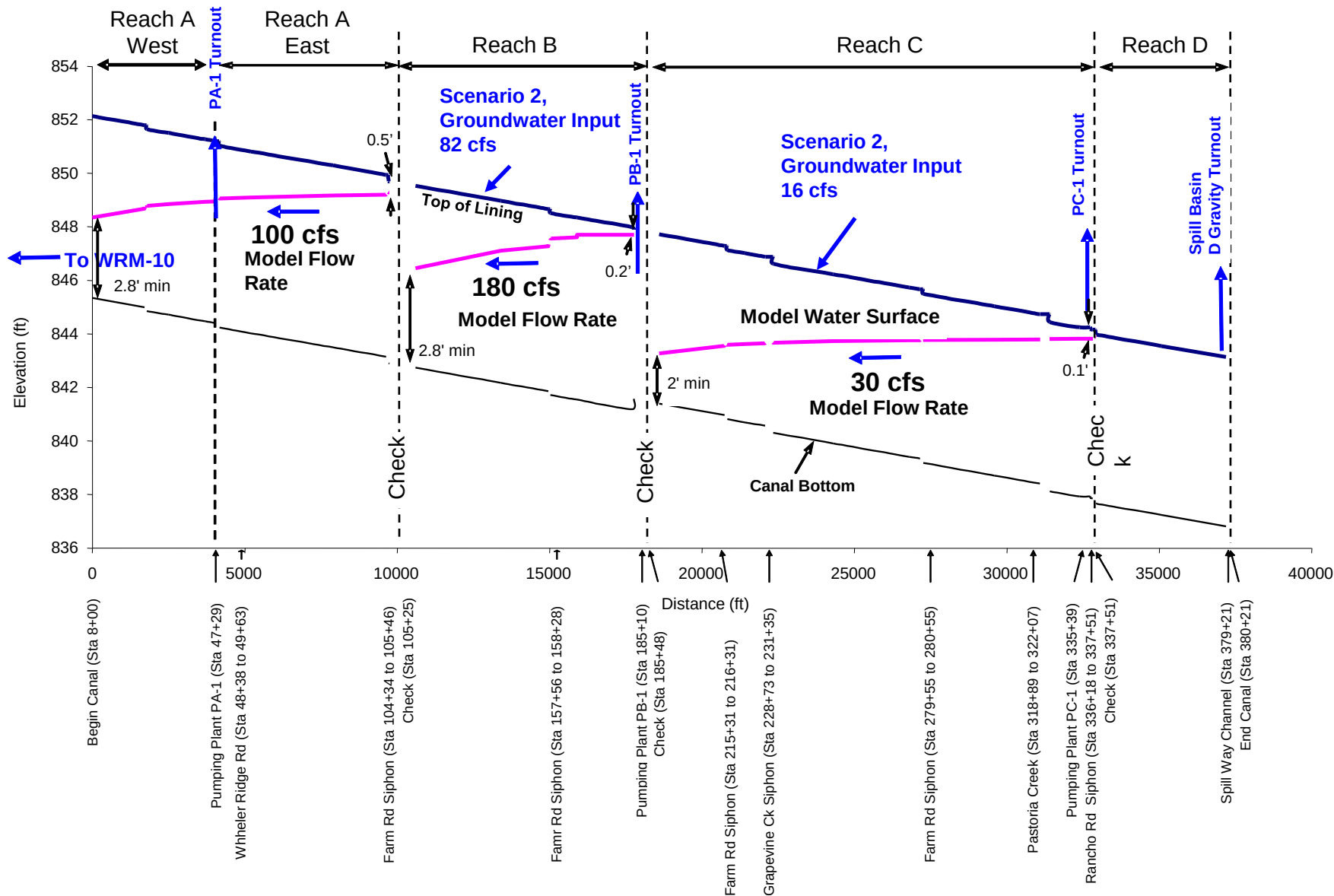
Work performed as part of Phase 5 was principally intended to answer the following questions:

- What is the maximum reverse flow capacity of Reaches A, B, and C?

- Is this capacity sufficient to convey recovered water from Reach C to Reach A and thence to Lateral 10P and the California Aqueduct? If not, what canal modifications would be necessary?
- What are the estimated costs to modify the 850 Canal for the reverse flow scenarios selected?

In order to respond to these questions, a separate HEC-RAS hydraulic model simulation was required for each reach of the 850 Canal. The geometry of all canal structures and canal invert elevations was obtained from the as-built drawings. Manning's n and all head loss coefficients were estimated based on the canal design. Year 2003 hourly and monthly delivery data were provided by WRMWSD and were considered to be representative of typical flow conditions. A water depth of 3 feet was assumed at the beginning of the 850 Canal immediately downstream from the WRM 10 Pumping Plant (Figure 14) and at the check structure located east of PA-1 (Station 104+33.60). A water depth of 1.9 foot was assumed at the check structure next to PB-1.

Reverse flow capacity simulations were performed under the conditions that (1) there were no local irrigation demands along the 850 Canal, and (2) there were no modifications to the current canal structure.



In order to increase the reverse flow capacity of Reach C, a check structure was simulated in the lower portion of Reach C at Station 294+00. It was assumed that the gates at this added check structure would be closed when reverse flow occurred and that a “pump-back” pumping station would be located at the downstream end of this check structure. This check structure would separate Reach C into two sections: Reach C East Section and Reach C West.

A separate HEC-RAS model simulation was conducted to estimate the maximum reverse flow rates for Reach C East Section and West Section (Figure 8). A minimum water depth of 2.8 feet was assumed at the check structure (Sta. 185+30) next to PB-1 and 2 feet at the added check structure (Sta. 294+00). Table 4 below summarizes model-simulated reverse flow rates and associated freeboards at Reach C, Reach B, and Reach A.

**TABLE 4
MAXIMUM REVERSE FLOW CAPACITY
SIMULATED FROM THE HEC-RAS MODEL
(WITHOUT ADDED CHECK STRUCTURE)**

Canal Reach	Max. Reverse Flow Rate (cfs)	Minimum Freeboard (ft)	Groundwater Input to Canal per Reach, Scenario 1 (cfs)	Accumulated Groundwater Conveyance in Canal, Scenario 1 (cfs)	Groundwater Input to Canal per Reach, Scenario 2 (cfs)	Accumulated Groundwater Conveyance in Canal, Scenario 2 (cfs)
Reach A (From Sta 8+00 at west end of canal to Sta 105+25)	100	0.5	0	48	0	98
Reach B (From Sta 104+25 to Sta 185+48 near the PB-1 Pumping Plant)	180	0.2	40	48	82	98
Reach C (From Sta 185+48 to Sta 380+21)	30	0.15	8	8	16	16

The analysis indicated that the 850 Canal has sufficient reverse flow capacity to convey all anticipated recovered water from Reach A to Reach C and thence to Lateral 10P and the California Aqueduct without modification.

A more complete description of the work performed and the results obtained in Phase 5 is presented in the Phase 5 Technical Memorandum - 850 Canal Reverse Flow Analysis, which is included as Appendix F.

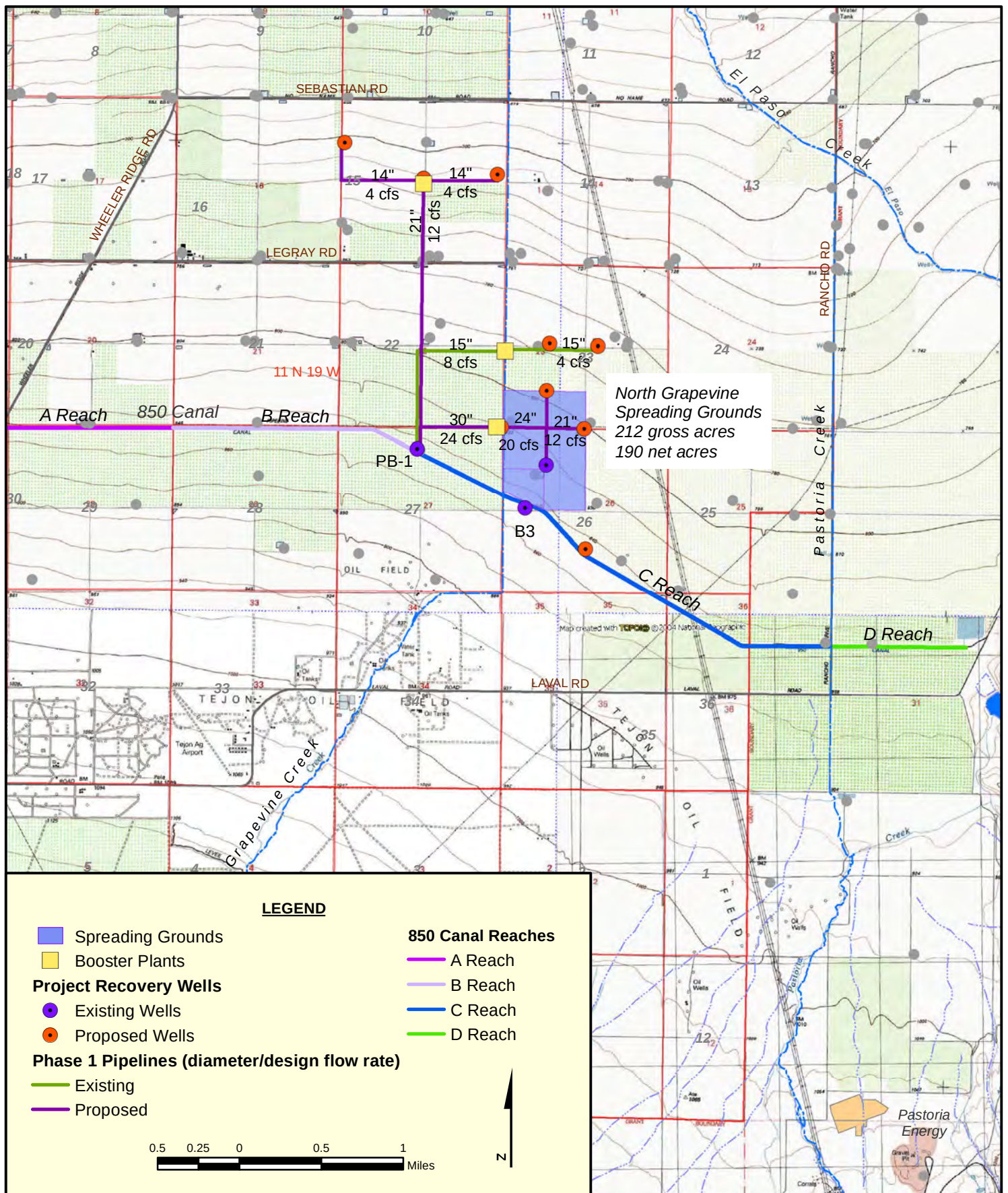
PHASE 6 – PROJECT LAYOUT AND COST ESTIMATE

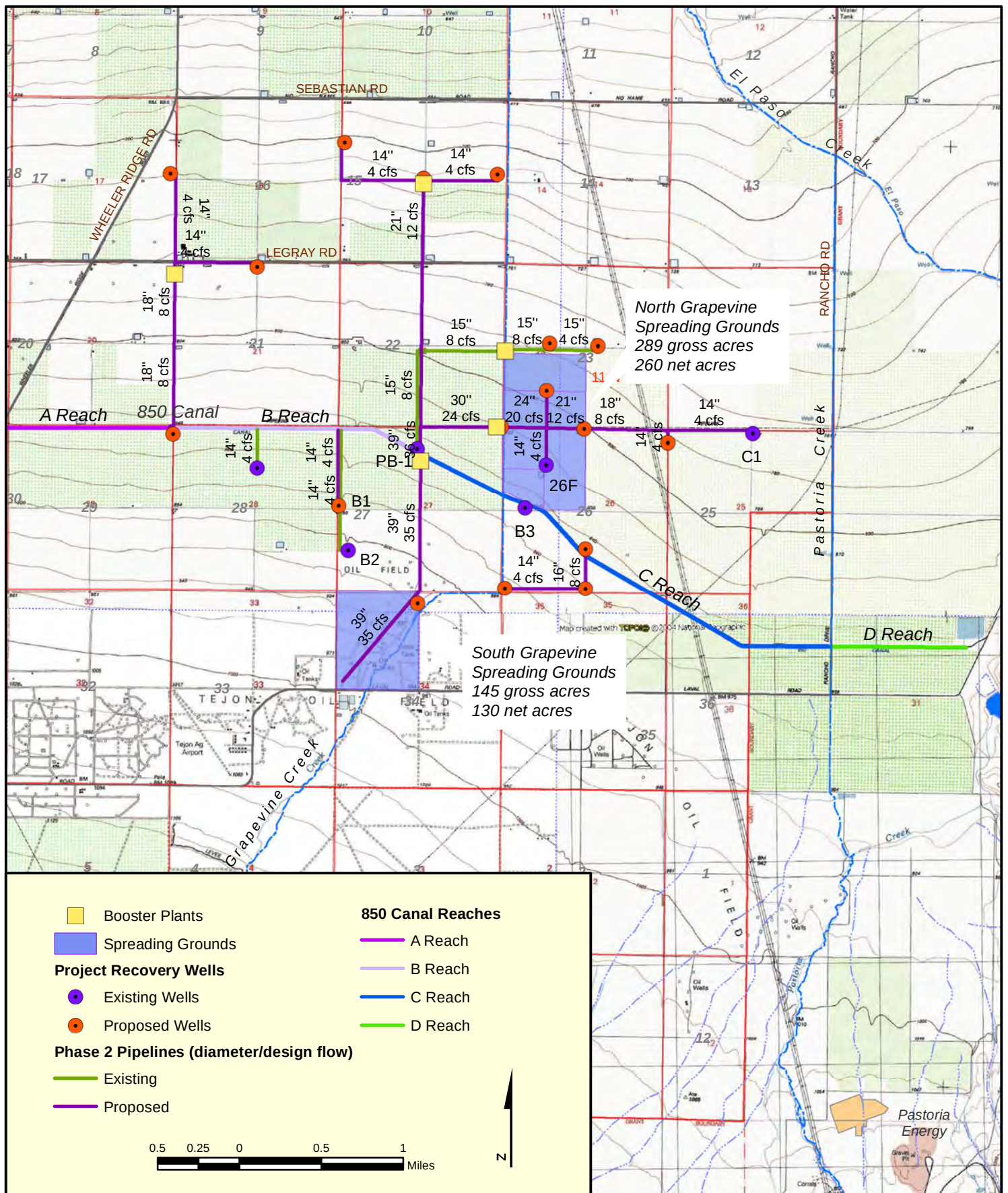
Phase 6 consisted of one task, Task 6.1, Project Layout and Cost Estimate.

Two conceptual project layouts were developed based on Scenarios 1A/1B (Figure 10) and 2A/2B (Figure 11) described previously in Phase 4. Construction costs were estimated for each scenario and a technical memorandum was prepared to describe the project layouts and associated construction cost estimates. The proposed facilities are also shown in Figures 1 and 2 of the Phase 6 Technical Memorandum - Project Layout and Cost Estimate. These are summarized as follows:

TABLE 5
SUMMARY OF FINAL PROJECT FACILITIES

Project Size (AF/year)	Operational Scenario	Gross Spreading Grounds Size (acres)	Net Spreading Grounds Size (acres)	Recharge Flow Rate (cfs)	Recovery Flow Rate (cfs)	Number of Wells
25,000	1A/1B	212	190	50	48	12
50,000	2A/2B	434	390	35 to southern spreading grounds; 65 to northern spreading grounds	98	25





Scenario 1 Facilities (25,000 acre-feet per Year Capacity Project)

Under this scenario, groundwater recharge would be accomplished by diverting water from the 850 Canal to the spreading grounds where it would percolate to the underlying groundwater aquifer. Recharge facilities would consist of a 50 cfs canal turnout and 212 gross acres (190 net acres) of spreading grounds located on the north side of Reach C of the 850 Canal. Recharge water would be conveyed to the spreading grounds by gravity (Figure 15).

Groundwater recovery would be accomplished by 12 extraction wells yielding 48 cfs of recovery capacity. Various water conveyance pipelines and three booster pumping stations would transport recovered groundwater to the 850 Canal. Modifications to the 850 Canal would be required to provide reverse flow capabilities. It was assumed that the 12 extraction wells would be comprised of 10 new wells plus existing well PB-1 (equipped) and existing well B3 (not equipped). It was estimated that the extraction rate from each well would be 4 cfs. Three booster stations together with conveyance pipelines would be utilized to pump extracted groundwater from nine wells to the 850 Canal. Three wells would discharge groundwater directly into the 850 Canal.

Of the 48 cfs pumped into the 850 Canal, 8 cfs would be placed directly into C Reach. Any water not used to meet C Reach and D Reach irrigation demands would be pumped back to Reaches A and B by reverse flow. Another 40 cfs would be placed directly into Reach B. Any water not used to meet local irrigation demands could be delivered to the California Aqueduct by reverse flow through Reach B, Reach A, and Lateral 10P. Modifications at the check structure between Reach A and B would be required to allow for 40 cfs of reverse flow between these two reaches. Modifications to the existing 78-inch diameter Lateral 10P pipeline (from Reach A) at the California Aqueduct could be required to allow for 40 cfs of reverse flow to the California Aqueduct.

Scenario 2 Facilities (50,000 acre-feet per Year Capacity Project)

In this scenario, surface water would be diverted from the 850 Canal to two new spreading grounds where it would percolate to the underlying groundwater aquifer. Recharge facilities would consist of two new turnouts on the 850 Canal, two new areas of spreading grounds, a new booster pumping station, and new water conveyance pipelines to convey SWP water from the 850 Canal to the southern spreading grounds (Figure 16).

Recharge water would be conveyed to the northern spreading grounds (289 gross acres; 260 net acres) by gravity through a 65 cfs turnout. Recharge water would be conveyed to the southern spreading grounds (145 gross acres; 130 net acres) by pumping through a 35 cfs turnout, booster station, and pipeline.

Groundwater recovery would be accomplished using 25 recovery wells with a combined capacity of 98 cfs. Various water conveyance pipelines and four booster pumping stations would transport recovered groundwater to the 850 Canal. Modifications to the 850 Canal

would be required to provide reverse flow capabilities. It was assumed that of the 25 wells required, 5 wells would be existing and 20 wells would be new. Extraction rates were assumed to be 4 cfs per well, except for two existing wells, which were assumed to produce 3 cfs per well. Four booster stations would pump extracted groundwater from 13 wells through conveyance pipelines to the 850 Canal. Eleven wells would discharge groundwater directly into the 850 Canal.

Of the 98 cfs pumped into the 850 Canal, up to 16 cfs would be placed directly in C Reach. Any water not used to meet C Reach and D Reach irrigation demands could be pumped back to Reaches A and B by reverse flow. Another 82 cfs would be placed directly in Reach B. Any water not used to meet local irrigation demands could be delivered to the California Aqueduct by reverse flow through Reach B, Reach A, and Lateral 10P. Modifications to the check structure between Reach A and B would be required to allow for 82 cfs of reverse flow between these two reaches. Modifications to the existing 78-inch diameter Lateral 10P pipeline could be required to allow for 82 cfs of reverse flow to the California Aqueduct.

Estimated Cost of Facilities

Tables 2 and 3 of the Phase 6 Technical Memorandum - Project Layout and Cost Estimate show the estimated costs to construct the various recharge and recovery facilities. In brief, estimated costs were as follows:

- Scenario 1 (25,000 acre-feet per year capacity) \$22,400, 000
- Scenario 2 (50,000 acre-feet per year capacity) \$45,900,000

These estimates were based on the 10% pre-design plans as shown on Figures 10 and 11. The estimated costs were based on 2004 and/or 2005 bid schedules for similar types of work. The estimated costs also include a 25% contingency on bare construction costs, and an additional 15% contingency for engineering, construction management, legal and administrative costs.

A more complete description of the work performed and the results obtained is presented in the Phase 6 Project Layout and Cost Estimate Technical Memorandum, which is included as Appendix G.

RELATIONSHIP TO REGIONAL GROUNDWATER MANAGEMENT

The White Wolf Basin is thought to be favorable for groundwater banking because of its thick gravelly alluvial fan deposits, good ambient water quality, abundant dewatered storage, and proximity to surface water conveyance, among other reasons. Indeed, The Arvin-Edison Water Storage District (AEWSD) has located three groundwater banking

facilities on nearby Tejon Creek, Sycamore Creek, and Caliente Creek alluvial fans for similar reasons. The White Wolf Groundwater Banking Project would extend groundwater banking, already successful on the Kern Fan and on east side of the San Joaquin Valley, to the extreme southern Valley.

The White Wolf Groundwater Banking Project has the potential to provide significant flexibility to other water districts and water purveyors. The primary purposes of groundwater banking in the White Wolf Basin are to assist in the regulation of imported water supplies, provide storage capacity within the District for surplus surface water, and provide a dry-year water supply in the event of shortages or interruptions in the delivery of imported surface water. Each of these expedients is shared by the District's immediate neighbors in the southern San Joaquin Valley, suggesting that the project could benefit the wider San Joaquin Valley through water sales and exchanges. While the project's principal beneficiaries would be the District's agricultural customers, the project area is also an ideal setting for cooperative groundwater banking with other State water contractors. Federal Project contractors, however, could face restrictions if it were not practical to deliver banked federal water to the federal Project place of use.

The Wheeler Ridge-Maricopa Water Storage District and its neighbors in the White Wolf Basin, specifically AEWSD, are mutually affected by groundwater management practices. Under existing conditions, mutual impacts are observed or inferred based on the following:

- AEWSD and WRMWSD district boundaries and surface water service areas overlap within the White Wolf Basin in a region known as the "overlap area".
- Both AEWSD and WRMWSD deliver imported surface water into the White Wolf Basin. Deep percolation of surface water (irrigation return flow) is mutually beneficial.
- AEWSD alternately percolates surface water and extracts groundwater at its banking facilities located on the north side of the White Wolf fault. This alters local groundwater gradients and influences flow across the fault.
- WRMWSD, together with numerous private landowners, produce groundwater on the south side of the White Wolf fault, modifying groundwater gradients and potentially reducing basin outflows across the fault.
- Many landowners in the White Wolf Basin have the option to utilize either imported surface water or well water. Landowner preference for surface water or groundwater is based largely the provisions of landowner water contracts and on the economics of operating a well versus the price of water offered by the water purveyor.

With the introduction of groundwater banking in the White Wolf Basin, new mutual impacts are anticipated based on the following:

- Existing production wells at AEWSD's Tejon Banking Facilities would have the capacity to recover some White Wolf Basin groundwater outflows. For this to occur, however, AEWSD and WRMWSD would have to develop a joint operating agreement.
- It has been shown that in a final project, some recharged water would eventually flow outside District boundaries, especially in the overlap area.
- Recharged water would be subject to extraction by private landowners, both inside and outside of WRMWSD boundaries and both inside and outside the White Wolf Basin.

Following are examples of new opportunities for integrating regional groundwater management in the southern San Joaquin Valley that would be created by a final project:

- Water recovered by AEWSD could potentially be delivered to the WRMWSD either by exchange of surface water entitlement or by pump back to the California Aqueduct through existing AESWD facilities. Water recharged by WRMWSD but recovered at AEWSD facilities located near the South Canal would likely require less pumping lift than if recovered at WRMWSD's 850 Canal. For this to occur, however, AEWSD and WRMWSD would have to develop a joint operating agreement.
- Groundwater banking in the White Wolf Basin could lead to the importation of additional surface water by an out-of-basin banking partner. Each increment of imported water for banking would include a basin enhancement component, which would benefit all overlying landowners and water users in the basin.
- During periods when imported water were stored in the basin, all groundwater producers would benefit to varying degrees from higher water levels and reduced pumping lifts.

A final project should therefore be designed and managed with a view toward facilitating cooperation between WRMWSD, other State and federal water contractors, AEWSD, and private landowners located in the southern San Joaquin Valley.

CONCLUSIONS

Phase 1 Conclusions

Available data reviewed in Phase 1 indicated that the geologic and water quality conditions in the vicinity of the proposed Pastoria Creek recharge site were favorable for continuation

to Phase 2 and Phase 3 studies, although data on the occurrence and movement of groundwater were generally lacking.

Phase 2 Conclusions

Limited geotechnical drilling and testing indicated the soils immediately underlying the proposed Pastoria Creek recharge area to depths of about 97 feet were principally coarse-grained silty sand, sand and gravel mixtures with vertical permeability ranging between 0.04 and 19.3 ft/day.

Phase 3 Conclusions

Combined hydrogeologic and groundwater quality data collected as part of Phase 3 indicate the following:

- The alluvial deposits do not appear to be water-bearing beneath the proposed Pastoria Creek recharge site
- The Chanac formation appears to contain several semi-confined and confined water-bearing units
- The deeper underlying Santa Margarita formation contains a confined aquifer in the vicinity of the study area
- Localized high salinity groundwater occurs in the Chanac formation
- Localized petroleum hydrocarbons (crude oil) and/or gas (possibly methane) occur in the Chanac and Santa Margarita formation aquifers
- The transmissivity of the Chanac and Santa Margarita formations is relatively low and may not yield sufficient supplies of groundwater to wells
- Recharge and available storage in the Chanac formation is limited based on cuttings logs, isotopic tritium data, and aquifer pumping tests
- Recharge in the Santa Margarita formation aquifer occurs primarily from the percolation of stream runoff near the mouth of Pastoria Canyon
- Available storage in the Santa Margarita formation appears to be small due to artesian conditions and limited thickness of the formation
- Based on the observations cited above, it was recommended that alternative recharge-recovery sites be identified for continued study. Alternative sites included a relatively small area below the mouth of Pastoria Canyon (Alternative Site #1; WRMWSD, 2003) and a broad area north of Laval Road extending from Grapevine

Creek on the west to the Tejon Hills on the east (Alternative Site #2; WRMWSD, 2003).

- The hydrogeologic character of the alluvium underlying the Grapevine Creek site (Alternative Site #2) is more favorable than Alternative Site #1.

Phase 4 Conclusions

- The White Wolf Basin groundwater model constructed in this task applied relatively high horizontal transmissivities to alluvial materials. As a result, model simulations showed rapid spreading of both recharge mounding and recovery drawdown throughout the White Wolf basin. High transmissivity had a significant effect on simulated recharge-recovery operations.
- The greatest simulated drawdown attributable to Scenario 1 (25,000 ac-ft/yr recovery) was about 45 feet. The greatest simulated drawdown attributable to Scenario 2 (50,000 ac-ft/yr recovery) was about 100 feet.
- In model simulations, groundwater outflows across the White Wolf fault were significant (10-20% over 30 years of operation). Subsurface outflows from the White Wolf Basin, although nonrecoverable by project wells, would benefit the main San Joaquin Valley aquifer system and would be recoverable by pumpers outside the White Wolf Basin.

Phase 5 Conclusions

- The maximum reverse flow canal prism capacities are:
 - o Reach A 100 cfs
 - o Reach B 180 cfs
 - o Reach C 30 cfs
- The 850 Canal has sufficient reverse flow capacity to convey all anticipated recovered water from Reach C to Reach A and thence to Lateral 10P and the California Aqueduct without modification.

Phase 6 Conclusions

Estimated costs to construct the various recharge and recovery facilities are:

Scenario 1A/1B (25,000 acre-feet per year capacity)	\$22,400,000
Scenario 2A/2B (50,000 acre-feet per year capacity)	\$45,900,000

These costs include some use of existing facilities such as the 850 Canal.

Overall Conclusion

The Groundwater Storage and Recovery Pilot Project in White Wolf Basin demonstrated that groundwater recharge and recovery is technically feasible in the Grapevine Creek area at the investigated capacities of 25,000 and 50,000 acre-feet per year. Investigations suggested, however, that a similar project would not be technically feasible if located in the Pastoria Creek area. Some further analysis and field work are necessary as further described in the Recommendations below.

RECOMMENDATIONS

1. The Pilot Project focused its initial data review on the Pastoria Creek alluvial fan. The proposed facilities, however, are located on the Grapevine Creek alluvial fan. Available electric logs, geologic logs, and oil and gas records should be researched within two miles of the proposed facilities.
2. Geotechnical investigations should be conducted at the proposed spreading grounds to identify any localized geologic layers that could impede recharge. Geotechnical investigations should include 3 to 4 soil borings per site, collection of soil samples at appropriate intervals, and analysis of particle size distribution, permeability, and dry density.
3. The Project Application did not anticipate use of forward flow capacity of the 850 Canal or Lateral 850B for recharge deliveries. Accordingly, the 850 Canal and Lateral 850B should be evaluated to determine their existing available capacity for recharge deliveries.
4. Further investigation should evaluate the acceptability of recovered water quality for placement into the California Aqueduct. This would include sampling approximately 10-20 existing wells for constituents of concern to downstream diverters from the California Aqueduct water districts.
5. Further investigations should be conducted to refine the estimated transmissivity across the White Wolf fault as further described in the Task 4 Technical Memorandum. The groundwater model developed in Task 4 should then be updated and used to evaluate groundwater losses across the fault.
6. The economic feasibility of the Project should be reviewed and updated, expanding on the 1999 SAIC Appraisal Level Study.
7. A final project would lead to new mutual impacts and new opportunities for integrating regional groundwater management. A final project should therefore be designed and managed with a view toward facilitating cooperation between WRMWSD, AEWS, and

private landowners, and other water agencies located in the southern San Joaquin Valley.

8. Water level and water quality monitoring in the basin should be coordinated between the WRMWSD, AEWSD, the DWR, and the KCWA.
9. The preparation of a Groundwater Storage Program Construction Grant Application is recommended after completion of the above Recommendations.

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