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FINAL DRAFT INTERIM MEASURE PHASE 1 ACTIVITIES EVALUATION AND RECOMMENDATIONS REPORT ADDENDUM FOR SITE 11 NSB KINGS BAY GA
4/1/1996
ABB ENVIRONMENTAL

FINAL DRAFT

INTERIM MEASURE PHASE I ACTIVITIES: EVALUATION AND RECOMMENDATIONS REPORT ADDENDUM SITE 11, OLD CAMDEN COUNTY LANDFILL

NAVAL SUBMARINE BASE KINGS BAY, GEORGIA

UNIT IDENTIFICATION CODE: N42237
CONTRACT NO. N62467-89-D-0317/094

APRIL 1996

SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORTH CHARLESTON, SOUTH CAROLINA
29419-9010

FINAL DRAFT

INTERIM MEASURE PHASE I ACTIVITIES: EVALUATION AND RECOMMENDATIONS REPORT ADDENDUM

SITE 11, OLD CAMDEN COUNTY LANDFILL
NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

Unit Identification Code: N42237

Contract No. N62467-89-D-0317/094

Prepared by:

ABB Environmental Services, Inc.
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Naval Facilities Engineering Command
2155 Eagle Drive
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April 1996

This evaluation and recommendations report addendum for the interim measure Phase I activities has been prepared using scientific principles and professional judgment. Recommendations are based upon interpretation of applicable regulatory requirements and guidelines. If conditions are determined to exist that differ from those described, the undersigned geologist should be notified to evaluate the effects of any additional information on the assessment described in this report addendum. This addendum was developed for Site 11, Old Camden County Landfill, Naval Submarine Base in Kings Bay, Georgia, and should not be construed to apply to any other site.

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CERTIFICATION OF TECHNICAL
DATA CONFORMITY (MAY 1987)

The Contractor, ABB Environmental Services, Inc., hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. N62467-89-D-0317/094 are complete, accurate, and comply with all requirements of this contract.

DATE: April 25, 1996

NAME AND TITLE OF CERTIFYING OFFICIAL: Theodore Taylor
Project Manager

NAME AND TITLE OF CERTIFYING OFFICIAL: Kurt Sichelstiel
Project Technical Lead

(DFAR 252.227-7036)

EXECUTIVE SUMMARY

This report provides an overview of the existing interim measure (IM) system at Site 11, Old Camden County Landfill, specifically states the original objectives of the IM system, and discusses the purposes of this addendum to the Interim Measure Phase I Activities: Evaluation and Recommendations Report (ABB Environmental Services, Inc., 1994). The material presented in this report addendum is organized into a data assessment chapter and a conclusions and recommendations chapter.

The purpose of this addendum is to provide additional data review, presentation, and clarification to technical and regulatory issues raised by the Georgia Environmental Protection Division (GEPD) during their initial review of the IM Phase I Activities Evaluations and Recommendations Report. This addendum provides an overview of the process used to estimate the performance of the IM Phase I groundwater extraction (GWE) system. The evaluations and interpretations presented in this addendum are based on available data and are not intended to be conclusive evidence of the GWE system's effects on the contamination at Site 11. Technical issues addressed in this addendum include: (1) possible tidal influences on groundwater flow, (2) effects recharge at the land application system may have on Site 11 groundwater flow, (3) a possible groundwater divide along the east side of the landfill, and (4) air emissions. More quantitative data will be collected over time to more fully define the response of the aquifer and contaminants to remedial efforts.

This addendum presents a preliminary evaluation of the capture zone created by the IM Phase I GWE system using three approaches. The first, a mass balance approach, was used to estimate the approximate width of the capture zone and to analytically validate the empirical and numerical model approaches. A second approach, based on the interpretation of actual hydraulic data collected during Stages 2 and 3 of the Phase I field activities, was used to empirically derive the capture zone. A third approach using a two-dimensional, numerical flow model was used to simulate the IM Phase I GWE system operations and capture zone. These three methods support the initial evaluation of the Phase I GWE system capture zone effectiveness. The estimates provided by these three analyses indicate that the capture zone is approximately 1,000 to 1,100 feet wide. Additional operations and performance monitoring will continue through the IM activities so that the effectiveness of the GWE system can be more fully understood and documented.

Based on the results of this initial evaluation, recommendations are made for Phase II system upgrades and/or improvements, consistent with overall IM objectives. These include the following: (1) existing wells will be redeveloped to increase specific capacity, (2) existing offgas emissions treatment system will continue operation; and (3) an additional recovery well will extract contaminated groundwater from an area of high volatile organic compound concentration within the surficial aquifer and enhance the IM Phase I system capture zone.

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GLOSSARY

ABB-ES	ABB Environmental Services, Inc.
CADD	computer-aided drafting and design
DAT	diffused aeration tank
ft/day	feet per day
ft^2/day	feet squared per day
ft^3/day	cubic feet per day
ft/ft	feet per foot
GEPD	Georgia Environmental Protection Division
gpm	gallons per minute
GWE	groundwater extraction
IM	interim measure
in/yr	inches per year
L	length
LAS	land application system
mlw	mean low water
NSB	Naval Submarine Base
PIW	private irrigation well
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RW	recovery well
USGS	U.S. Geological Survey
VOC	volatile organic compound
WWTF	wastewater treatment facility

1.0 INTRODUCTION

This introduction provides an overview of the existing interim measure (IM) system at Site 11, Old Camden County Landfill, specifically states the original objectives of the IM system, and discusses the purposes of this addendum to the Interim Measure Phase I Activities: Evaluation and Recommendations Report (ABB Environmental Services, Inc. [ABB-ES], 1994a).

The material presented in this report addendum is organized into two chapters: Chapter 2.0, Data Assessment, presents the trend analysis of groundwater levels, groundwater divide considerations related to eastern flow-head boundary conditions, and estimation of the capture zone associated with the IM Phase I groundwater extraction (GWE) system using (1) a mass balance approach, (2) an empirical approach, and (3) a two-dimensional numerical flow modeling approach. Chapter 3.0, Conclusions and Recommendations, presents recommendations for additional well development to increase the recovery well efficiencies and Phase II system upgrades.

1.1 OVERVIEW OF SITE 11 INTERIM MEASURE SYSTEM. The first phase of the IM which was designed to extract and treat a specific area of contaminated groundwater on the western side of Site 11 has been in operation since March 1994. A brief overview of the landfill (the source) and type of contaminants is presented below to provide project background information.

Site 11, the Old Camden County Landfill, is the site of an inactive municipal landfill consisting of approximately 26 acres along the northwest boundary of the Naval Submarine Base (NSB) at Kings Bay, Georgia. The landfill was operated by Camden County from 1974 to 1981 and reportedly received no hazardous waste. Burning of wastes before burial was allowed during the first year the landfill operated; however, this practice was disallowed after 1975. Operation of the landfill ceased in October 1981 and was covered with 2 feet of fill. The landfill surface is currently vegetated with grasses, weeds, and pine saplings.

Groundwater samples collected from beneath the site contained volatile organic compounds (VOCs) within the surficial aquifer. Primary VOC contaminants include chlorinated solvents such as trichloroethene, vinyl chloride, cis-1,2-dichloroethene, nonchlorinated solvents, and fuel-related VOCs. The contaminants have migrated within the groundwater to the west affecting water quality under the nearby Crooked River Plantation Subdivision.

The Phase I GWE system includes five recovery wells at four locations positioned in the areas of highest contamination along the western side of the landfill and right-of-way of Spur 40. Locations of these recovery wells, piezometers, and the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) monitoring wells are shown on Figure 1-1. Recovered groundwater is conveyed to an equalization tank for treatment in an air sparging unit (a diffused aeration tank [DAT]) to reduce groundwater to maximum contaminant levels. Treated effluent is then discharged to the NSB wastewater treatment facility (WWTF) at Kings Bay.

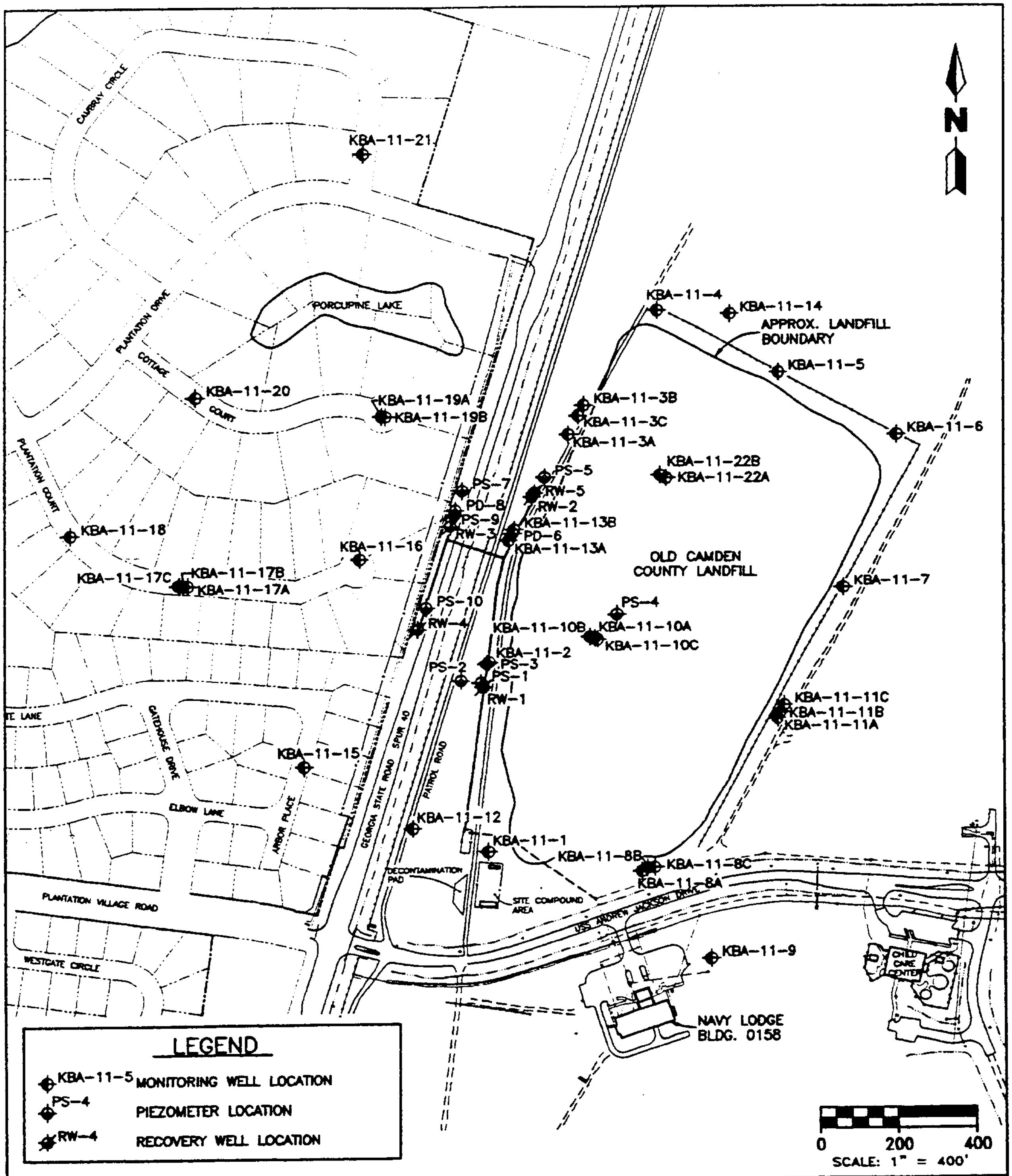

FIGURE 1-1

MONITORING WELL, PIEZOMETER AND RECOVERY WELL LOCATIONS

IM PHASE I ACTIVITIES EVALUATIONS AND RECOMMENDATIONS REPORT ADDENDUM
SITE 11, OLD CAMDEN COUNTY LANDFILL
NAVAL SUBMARINE BASE KINGS BAY, GEORGIA

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1.2 OBJECTIVES OF THE INTERIM MEASURE. As stated above, the Navy discovered that groundwater contaminants have been migrating beyond the Base boundary and impacting the water quality within the surficial aquifer. During the spring of 1993, a focused approach was developed to begin remediation of a specific area of groundwater where the highest concentrations of VOCs had been detected. This focused approach, an interim measure, was developed to control further migration of this area of contamination. The ongoing RCRA corrective action program will ultimately address (final) corrective measures for Site 11. This effort was designed to operate concurrently with the ongoing RFI and corrective measure study efforts. The RFI activities and the forthcoming supplemental RFI report more fully characterize site conditions, describe the extent of the plume, and provide a mechanism for the Navy and the Georgia Environmental Protection Division (GEPD) to establish cleanup standards. The extent of groundwater remedial efforts cannot be determined until cleanup standards have been finalized. The IM was used as a means of addressing a particular area of contamination that was fairly concentrated relative to other areas where concentrations of contaminants are much lower.

The overall objective of the IM is to hydraulically control movement of the most contaminated part of the VOC plume within the surficial aquifer using a GWE system and phased approach. Phase I was implemented in the fall of 1993. Subsequent phases will be used to augment the Phase I system to achieve the overall objective of the IM. The initial part of Phase I included a background monitoring period and three stages of pumping. Stage 1 included pumping from recovery well (RW) 2. Stage 2 included pumping from RW-2 and RW-5. Stage 3 included pumping from all five recovery wells. The objective of the first phase was to collect site-specific data such as the following:

- head response due to a pumping stress;
- hydraulic conductivity estimates;
- water quality (treatability parameters and contaminants); and
- well yields and specific capacity, and operational variances.

These site-specific data will be used to support the decision-making process for long-term corrective measures, while actively extracting VOC-contaminated groundwater from areas of highest contamination.

1.3 PURPOSE OF THE ADDENDUM. The purpose of this addendum to the IM Phase I Activities: Evaluation and Recommendations Report is to provide additional data review, presentation, and clarification to technical and regulatory issues raised by the GEPD during their initial review of the IM Phase I Activities Evaluations and Recommendations Report. This addendum provides an overview of the process used to estimate the performance of the IM Phase I GWE system. Some of the hydraulic data were reevaluated. Specifically, drawdown due to pumping stress was corrected for regional recession. This focused reevaluation included reassessment of the vertical influence of the GWE system and estimation of the Phase I GWE systems capture zone within the surficial aquifer. The evaluations and interpretations presented in this addendum are based on available data and are not intended to be conclusive evidence of the GWE system's effects on the contamination at Site 11. More quantitative data will be collected over time to more fully define the response of the aquifer and contaminants to remedial efforts.

Other issues raised by the U.S. Geological Survey (USGS) and GEPD, such as (1) possible tidal influences on groundwater flow, (2) effects recharge at the land application system may have on Site 11 groundwater flow, (3) a possible groundwater divide along the east side of the landfill, and (4) air emissions, are addressed in this addendum.

The following subsections provide a brief summary of the data analyses performed and the subsequent interpretations and findings of the data evaluation process. More detail is provided in Chapters 2.0 and 3.0 of this report addendum.

<u>1.3.1 Additional Data Evaluation</u> Additional data evaluation have been performed on existing hydraulic data. Much of these data had been provided in raw format in Appendix F, included in the Interim Measure Phase I Activities: Evaluation and Recommendations Report for Site 11, Old Camden County Landfill, Naval Submarine Base, Kings Bay, Georgia (ABB-ES, 1994a). Evaluation of these hydraulic data was facilitated through the use of spreadsheet software with graphic capabilities. Hydrographs of water level elevations for selected wells are presented and discussed in Chapter 2.0 of this evaluation and recommendation report addendum. Additional information (rainfall data, barometric pressure data, well recessional factors, and distance versus drawdown plots) is also presented. Analysis of the natural and GWE system pumping-stress-induced water-level changes are included in this addendum.

<u>1.3.2 GWE System Drawdowns</u> GWE system drawdowns are based on a comparison of natural, prepumping water levels and pumping-stress-induced water levels. Drawdown data were corrected for regional recession of the aquifer and residual drawdown effects from Stage 2 pumping. With this correction, steady-state conditions were achieved at approximately 9,000 minutes (6.25 days) into the Stage 3 pumping test. Approximately 60 to 97 percent of corrected drawdown occurred within 700 minutes (12 hours) of the start of the Stage 3 pumping test. The influence of the corrected drawdown values relative to a GWE system capture zone were evaluated and are discussed in Chapter 2.0.

<u>1.3.3 Capture Zone</u> A preliminary evaluation of the capture zone created by the IM Phase I GWE system was conducted using three approaches. The first, a mass balance approach, was used to estimate the approximate width of the capture zone and to analytically validate the empirical and numerical model approaches. This method of analysis is discussed in greater detail in Section 2.3. A second approach, based on the interpretation of actual hydraulic data collected during Stages 2 and 3 of the Phase I field activities, was used to empirically derive the capture zone. Both width and shape of the capture zone can be interpreted by this method. A third approach using a two-dimensional, numerical flow model was also used to simulate the IM Phase I GWE system operations and capture zone. These three methods support the initial evaluation of the Phase I GWE system capture zone effectiveness. The numerical flow model was also used as a tool to simulate Phase II GWE system operation with an additional recovery well. Additional operations and performance monitoring will continue through the IM activities so that the effectiveness of the GWE system can be more fully understood and documented.

<u>1.3.4 Recommendations</u> Based on the results of this initial evaluation, recommendations are made for Phase II system upgrades and/or improvements, consistent with overall IM objectives. These include the following:

- Well Redevelopment – Existing wells will be redeveloped to increase specific capacity and well efficiency. Initially, RW-1 will be redeveloped to evaluate the procedures; refinement of the procedure to site-specific conditions will be done, if necessary. The remainder of the Phase I wells will be redeveloped using the refined procedures. The Phase II recovery well will be developed using the refined procedures.

- Treatment System Offgas Emissions – The existing offgas emissions treatment system will continue operation.

- Additional GWE Well – A location is recommended for installation of an additional recovery well. This well will extract contaminated groundwater from an area of high VOC concentration within the surficial aquifer and enhance the IM Phase I system capture zone. This recovery well will be installed between RW-1 and RW-2. Additional flow from this proposed Phase II well is estimated to be a total of 10 gallons per minute (gpm), based on preliminary modeling.

2.0 DATA ASSESSMENT

Additional data evaluation has been performed on existing hydraulic data from the Site 11 IM Phase I system operations. These evaluation activities used available data to begin a process of developing a more thorough understanding of the aquifer and the capture zone created by the existing GWE system. As more data become available in the future, the site conceptual model may be redefined to accommodate new information.

Specific steps in the data evaluation process are provided in Appendix A. ABB-ES and USGS are currently conducting focused field studies to support continued evaluation of the GWE system performance. These activities address groundwater flow in the subregional area surrounding Site 11. The USGS will provide additional data and analysis of aquifer flow, recharge, and response conditions at a later date. If necessary, findings from these analyses can be used to optimize Phase II operations of the IM GWE system or be incorporated into the corrective action implementation.

2.1 GROUNDWATER LEVEL TREND ANALYSIS. The groundwater-level-trend analysis presented herein focused on changes in water levels within each of three layers or aquifer units within the surficial aquifer which include: (1) the shallow unit, (2) the intermediate unit, and (3) the deep unit. These units do not represent discrete aquifers within the surficial aquifer, but are zones defined for purposes of evaluating the chemical and physical data collected from the site. They are discussed in previous Site 11 Resource Conservation and Recovery Act facility investigation reports (ABB-ES, 1994b). Wells representing the shallow unit are completed in the elevation range of 30 to 5 feet above mean low water (mlw). Wells representing the intermediate unit are completed in the elevation range of 5 feet above to 20 feet below mlw, and wells representing the deep unit are completed in the elevation range of 20 to 60 feet below mlw. Details regarding well completion elevations and relative position (distance from recovery wells) of the 50 wells (monitoring wells, piezometers, and recovery wells) surrounding Site 11 are provided in Table 2-1.

Hydrographs of water levels for 43 wells monitored during Phase I operations were generated for the background monitoring period and three operational (pumping) stages. The background period and system operational stages commenced on February 28, 1994, and continued through May 12, 1994. Hydrographs representing water levels within each of the three aquifer units were generated to evaluate external influences and support trend analysis within the full saturated thickness of the surficial aquifer during this period. Hydrographs for the 43 wells and piezometers were prepared and a group of hydrographs were selected for inclusion in this addendum to facilitate the discussion. Other hydrographs can be made available if needed in the future. External influences that may affect the aquifer or impact GWE operations and the trend analysis of water levels are discussed below. Selected hydrographs are provided in the text to represent typical conditions or aquifer response.

The scale of some of the hydrographs presented herein was reduced to focus on particular elements pertinent to the discussion. When the scale is reduced, a jagged line is formed by the water level measurements recorded by the pressure transducer. This is a characteristic of the combined effects of processing the

Table 2-1
Well Construction Data

Interim Measure Phase I Activities:
Evaluation and Recommendations Report
Site 11, Old Camden County Landfill
Naval Submarine Base
Kings Bay, Georgia

Monitoring Well No.	Elevation TOC (feet mlw)	Screened Interval Elevation (feet mlw)	Well Radial Distance from RW-1 (feet)	Well Radial Distance from RW-2 (feet)	Well Radial Distance from RW-3 (feet)	Well Radial Distance from RW-4 (feet)	Well Radial Distance from RW-5 (feet)
Shallow wells (mean screen depth between 30 and 5 feet mlw)							
KBA-11-1	36.66	31.66 to 21.66	435	NM	NM	621	NM
KBA-11-2	36.02	30.32 to 20.32	70	454	378	207	465
KBA-11-3A	34.63	29.43 to 19.43	399	191	392	648	179
KBA-11-4	35.15	29.35 to 19.35	NM	593	786	809	581
KBA-11-5	36.03	30.03 to 20.03	NM	NM	NM	NM	NM
KBA-11-6	37.43	31.63 to 21.63	1,260	966	1,189	1,351	958
KBA-11-7	37.38	31.28 to 21.28	NM	NM	NM	NM	NM
KBA-11-8A	37.48	31.76 to 21.76	NM	NM	NM	NM	NM
KBA-11-9	34.66	29.06 to 19.06	NM	NM	NM	NM	NM
KBA-11-10A	35.42	25.82 to 15.82	319	411	483	463	418
KBA-11-11A	35.85	8.95 to -1.05	NM	876	1,001	972	878
KBA-11-14	34.54	7.84 to -2.16	NM	NM	NM	NM	NM
KBA-11-19A	25.95	16.05 to 6.05	NM	451	345	576	452
KBA-11-22A	36.18	23.38 to 13.38	735	357	580	766	349
RW-5	30.27	25.27 to 4.25	NM	NM	NM	NM	NM
Intermediate depth wells (mean screen depth between 5 and -20 feet mlw)							
KBA-11-3B	33.49	-4.61 to -14.61	NM	278	473	735	267
KBA-11-8B	38.20	4.60 to -5.40	NM	NM	NM	NM	NM

See notes at end of table.

Table 2-1 (Continued)
Well Construction Data

Interim Measure Phase I Activities:
Evaluation and Recommendations Report
Site 11, Old Camden County Landfill
Naval Submarine Base
Kings Bay, Georgia

Monitoring Well No.	Elevation TOC (feet mlw)	Screened Interval Elevation (feet mlw)	Well Radial Distance from RW-1 (feet)	Well Radial Distance from RW-2 (feet)	Well Radial Distance from RW-3 (feet)	Well Radial Distance from RW-4 (feet)	Well Radial Distance from RW-5 (feet)
KBA-11-8C	37.91	-14.83 to -24.83	NM	NM	NM	NM	NM
KBA-11-10B	38.03	-3.67 to -13.67	310	403	471	451	410
KBA-11-11B	35.94	-10.66 to -20.66	NM	872	1,000	976	874
KBA-11-12	35.72	5.22 to -4.78	414	NM	NM	529	NM
KBA-11-13A	34.20	1.70 to -8.30	399	130	157	334	142
KBA-11-15	28.49	-0.51 to -10.51	NM	932	745	472	944
KBA-11-16	28.66	-6.24 to -16.24	NM	480	254	243	489
KBA-11-17A	25.71	5.71 to -4.29	NM	932	707	617	941
KBA-11-17B	25.41	-9.39 to -19.39	NM	943	718	628	951
KBA-11-18	22.81	-12.99 to -22.99	NM	1,207	990	941	1,214
KBA-11-20	23.07	-6.93 to -16.93	NM	924	755	853	927
KBA-11-21	23.56	-6.84 to -16.84	NM	1,016	1,015	1,271	1,010
KBA-11-22B	36.13	-6.47 to -16.47	NM	342	566	NM	334
PS-1	33.02	3.02 to -1.98	14	513	427	220	524
PS-2	33.59	-0.06 to -5.08	63	528	419	181	540
PS-3	34.49	3.04 to -1.97	64	460	381	204	471
PS-4	36.91	6.85 to 1.84	400	330	449	498	335
PS-5	33.37	4.15 to -0.85	583	62	278	521	50
PS-7	28.20	6.20 to 1.20	528	183	98	385	189
PD-8	28.53	-17.97 to -22.97	480	203	44	331	211

See notes at end of table.

Table 2-1 (Continued)
Well Construction Data

Interim Measure Phase I Activities:
Evaluation and Recommendations Report
Site 11, Old Camden County Landfill
Naval Submarine Base
Kings Bay, Georgia

Monitoring Well No.	Elevation TOC (feet mlw)	Screened Interval Elevation (feet mlw)	Well Radial Distance from RW-1 (feet)	Well Radial Distance from RW-2 (feet)	Well Radial Distance from RW-3 (feet)	Well Radial Distance from RW-4 (feet)	Well Radial Distance from RW-5 (feet)
PS-9	28.72	1.27 to -3.73	468	208	31	318	216
PS-10	30.54	4.54 to -0.46	262	402	226	62	414
RW-1	32.47	12.47 to -27.53	NM	NM	NM	NM	NM
RW-2	30.49	10.49 to -39.51	NM	NM	NM	NM	NM
RW-3	27.70	7.70 to -42.30	NM	NM	NM	NM	NM
RW-4	28.89	3.89 to -36.11	NM	NM	NM	NM	NM
Deep wells (mean screen depth between -20 and -60 feet mlw)							
KBA-11-3C	33.88	-53.32 to -63.32	NM	247	443	704	235
KBA-11-10C	38.28	-41.72 to -51.72	326	418	NM	472	425
KBA-11-11C	36.00	-34.70 to -44.70	NM	870	1,000	982	869
KBA-11-13B	34.86	-45.84 to -55.84	430	98	167	365	109
KBA-11-17C	24.86	-49.94 to -59.94	NM	953	728	639	961
KBA-11-19B	26.15	-34.05 to -44.05	NM	441	338	573	442
PD-6	33.35	-27.67 to -32.67	419	109	164	354	121

Notes: TOC = top of casing.
mlw = mean low water.
RW = recovery well.
NM = not measured.

data (digitizing) in the data logger and small fluctuations in pressure, such as would be caused by vehicles operating in the vicinity of the well.

2.1.1 Tidal Influence Site 11 is located approximately 3,300 feet from the nearest tidal estuary. Tidal data for 1994 are not currently available for this estuary but is expected to be available in the near future. However, based on an analysis of 1992 and 1995 Kings Bay tidal data for the same time periods (February 25 through March 19), the average tidal period (time between tide extremes) is approximately 6 hours with an average water level change of 6.9 feet. This is not expected to vary significantly from year to year. Thus, tidal influences within the aquifer would be indicated by a cyclic-fluctuation pattern with a period of approximately 6 hours and a magnitude proportional to tide height. Representative hydrographs selected from each of the aquifer units during a 48-hour portion of the background monitoring period are shown on Figures 2-1 through 2-3. The 48-hour interval shown on these figures was chosen to minimize the effects of other influences (rainfall, regional recession, and barometric pressure) on the aquifer. Also shown on these figures is a typical tide fluctuation in Kings Bay (lower graph) for the same time period during 1995. This tidal information is not meant to be directly compared to the hydrograph data, rather it is presented to give the reader a general feeling for the tidal period and range. Based on an analysis of the hydrographs on Figures 2-1 through 2-3, no cyclic-fluctuation pattern with a period of approximately 6 hours is observed. Thus, Site 11 appears to be beyond the areal limits of tidal influence.

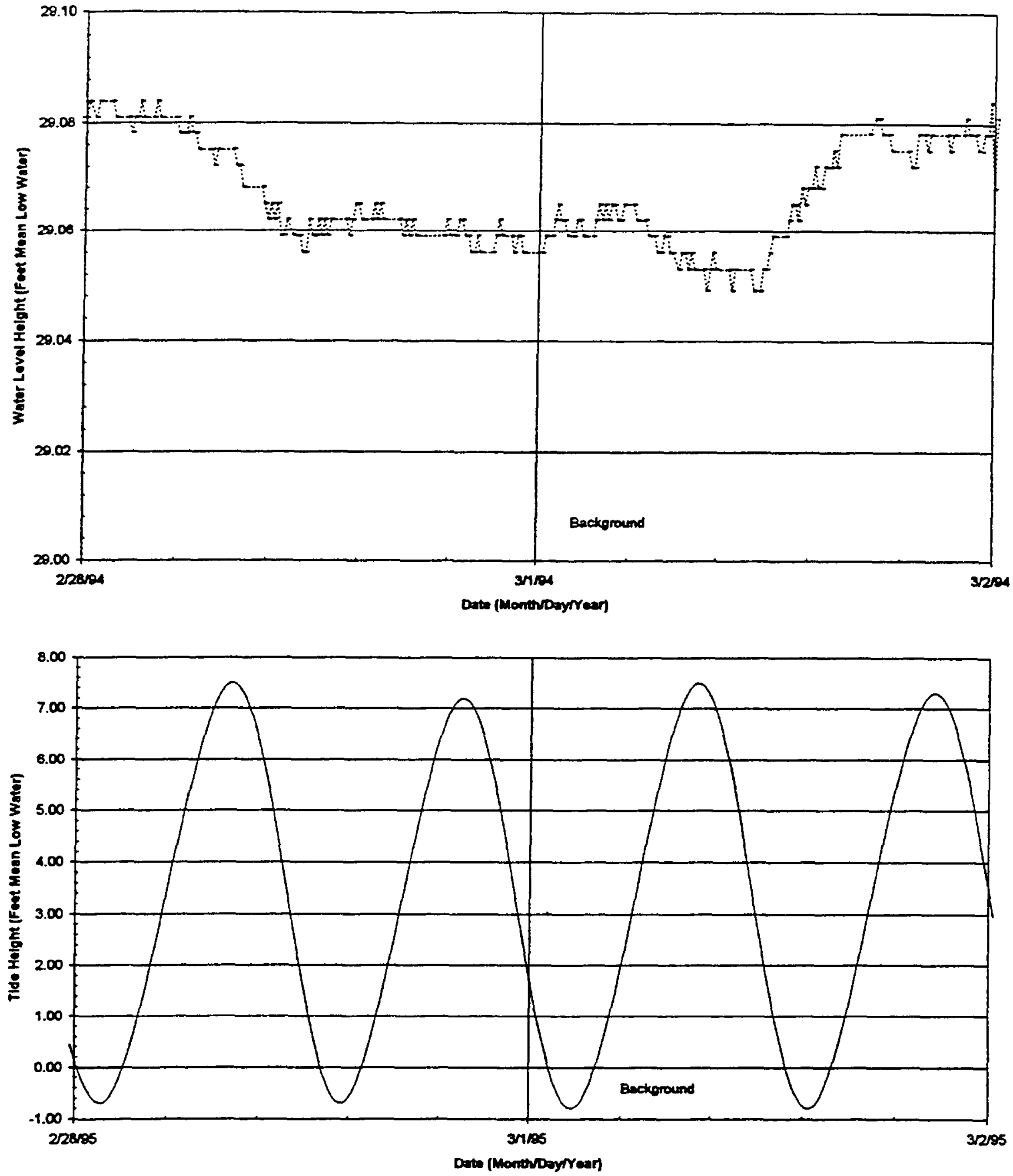
2.1.2 Recharge and Discharge Effects

Land Application System. Site 11 is located approximately 5,000 feet from the base's WWTF land application system (LAS). An operational response within the aquifer units would be indicated by an hourly or daily pattern (shift of water levels) mimicking LAS operational periods. No significant operational-type responses were observed as shown on the hydrographs on Figures 2-1 through 2-3. The slight fluctuation in water level is due to barometric pressure shifts discussed in Subsection 2.1.3. Apparently, the site is beyond the areal limits of any significant LAS (aquifer recharge) influence.

Residential and Private Irrigation Wells. The IM GWE system is located approximately 400 feet and greater from private irrigation wells (PIWs) within the subdivision. No significant water-level response(s) were observed on the hydrographs on Figures 2-1 through 2-3 (and elsewhere in this report) that would be suspected of being related to PIW use. PIWs within the subdivision apparently have little significant impact on groundwater levels at Site 11. These wells apparently were either (1) not operational or (2) operational on short-term schedules and did not significantly impact the potentiometric surface during Phase I operations.

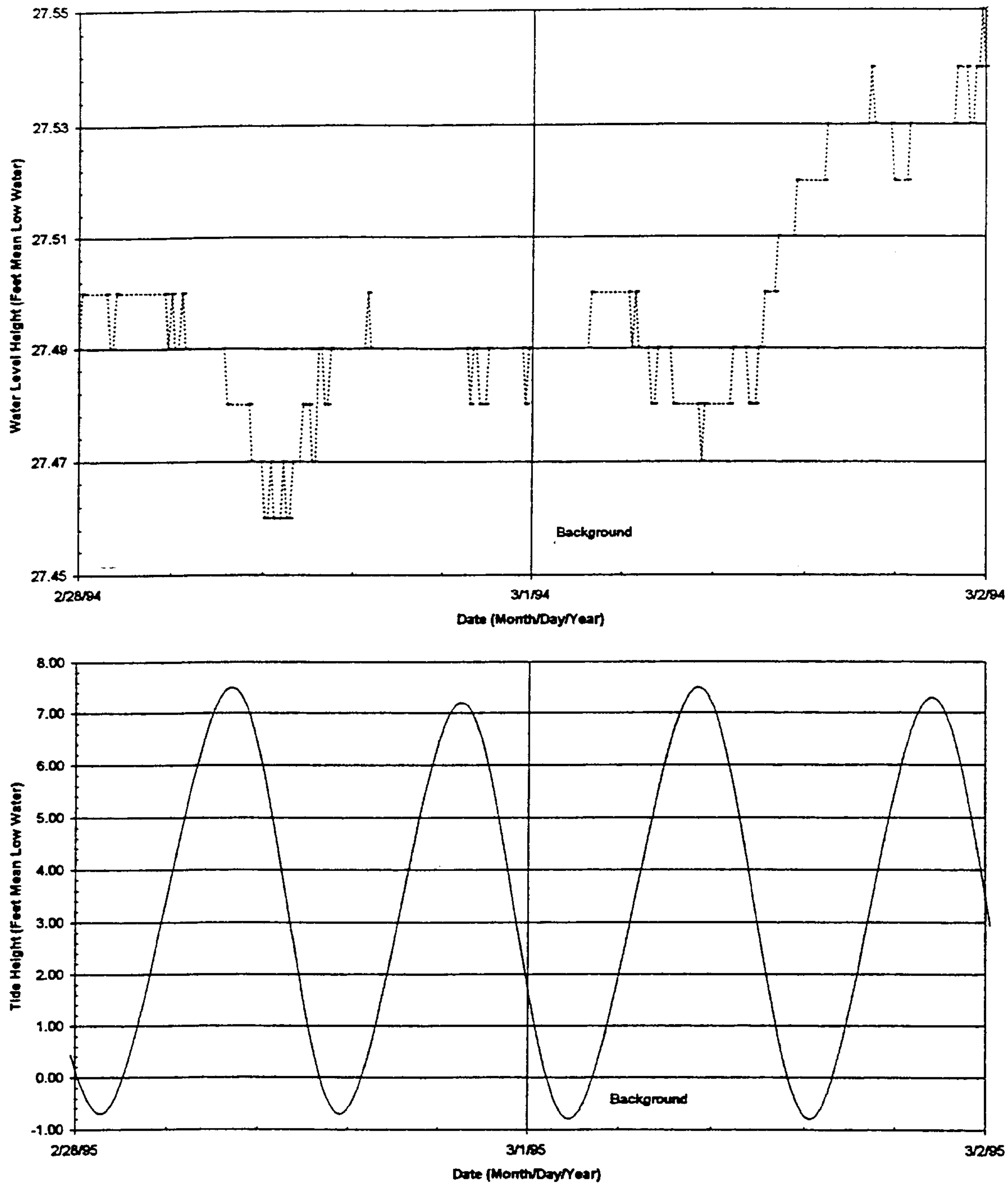
2.1.3 Ambient Weather Effects

Barometric Effects. A discussion of barometric effects on the surficial aquifer units is provided in the IM Phase I Activities: Evaluation and Recommendations Report (ABB-ES, 1994a) in more detail. For this discussion, three hydrographs were selected to present water level fluctuation relative to barometric pressure change during the background monitoring period. Figures 2-4 through 2-6 are



Note: Kings Bay 1995 tidal ranges and periods are shown; 1994 data is unavailable.

FIGURE 2-1 KBA-11-2 (SHALLOW UNIT WELL) WATER LEVEL ELEVATION AND TIDE HEIGHT VERSUS DATE	IM PHASE I ACTIVITIES EVALUATIONS AND RECOMMENDATIONS REPORT ADDENDUM SITE 11, OLD CAMDEN COUNTY LANDFILL NAVAL SUBMARINE BASE KINGS BAY, GEORGIA



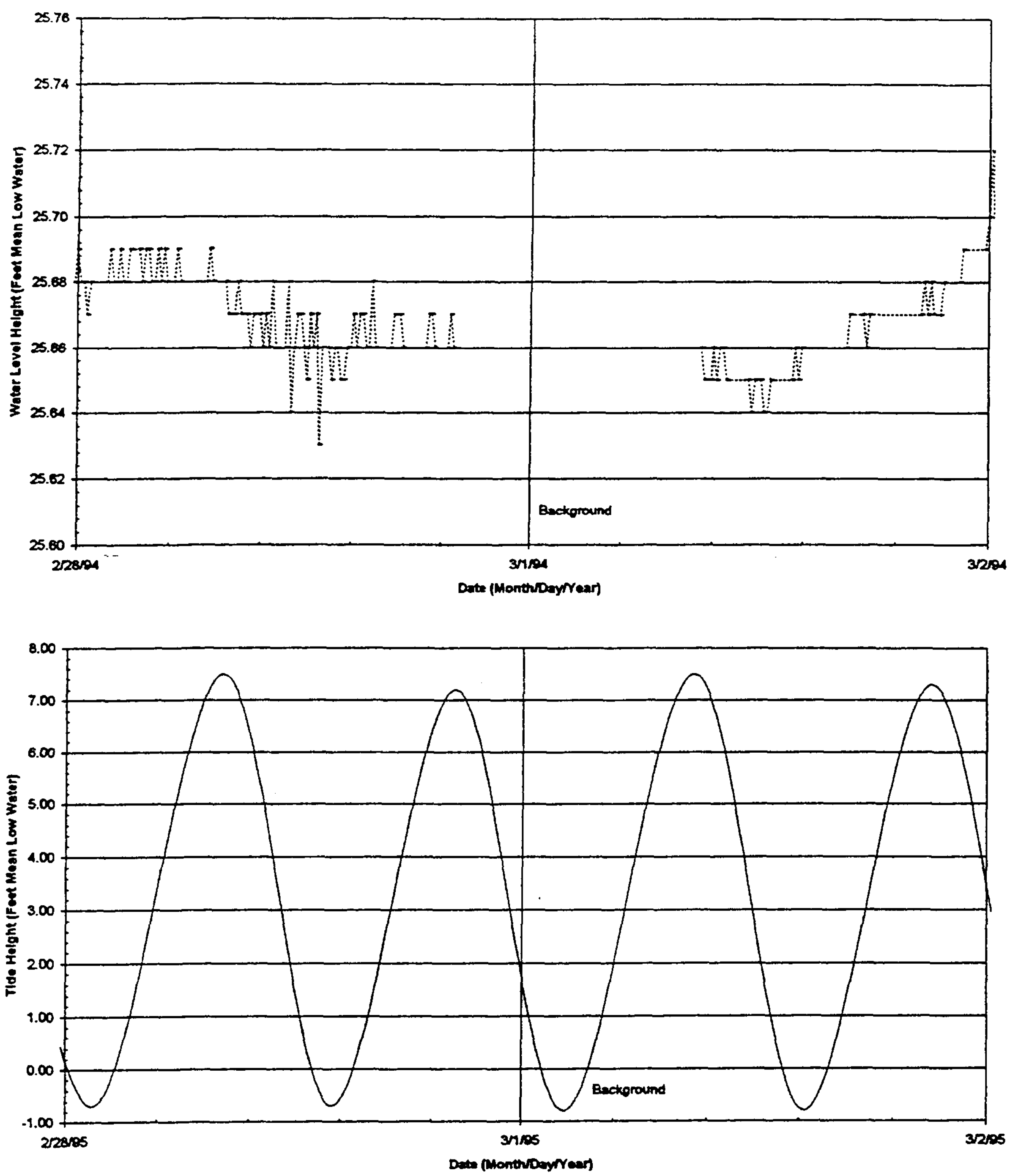
Note: Kings Bay 1995 tidal ranges and periods are shown; 1994 data is unavailable.

FIGURE 2-2

PS-3 (INTERMEDIATE UNIT WELL)
WATER LEVEL ELEVATION AND TIDE HEIGHT VERSUS DATE

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
SITE 11, OLD CAMDEN
COUNTY LANDFILL

NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA



Note: Kings Bay 1995 tidal ranges and periods are shown; 1994 data is currently unavailable.

FIGURE 2-3

PD-6 (DEEP UNIT WELL)
WATER LEVEL ELEVATION AND TIDE HEIGHT
VERSUS DATE

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
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COUNTY LANDFILL

NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

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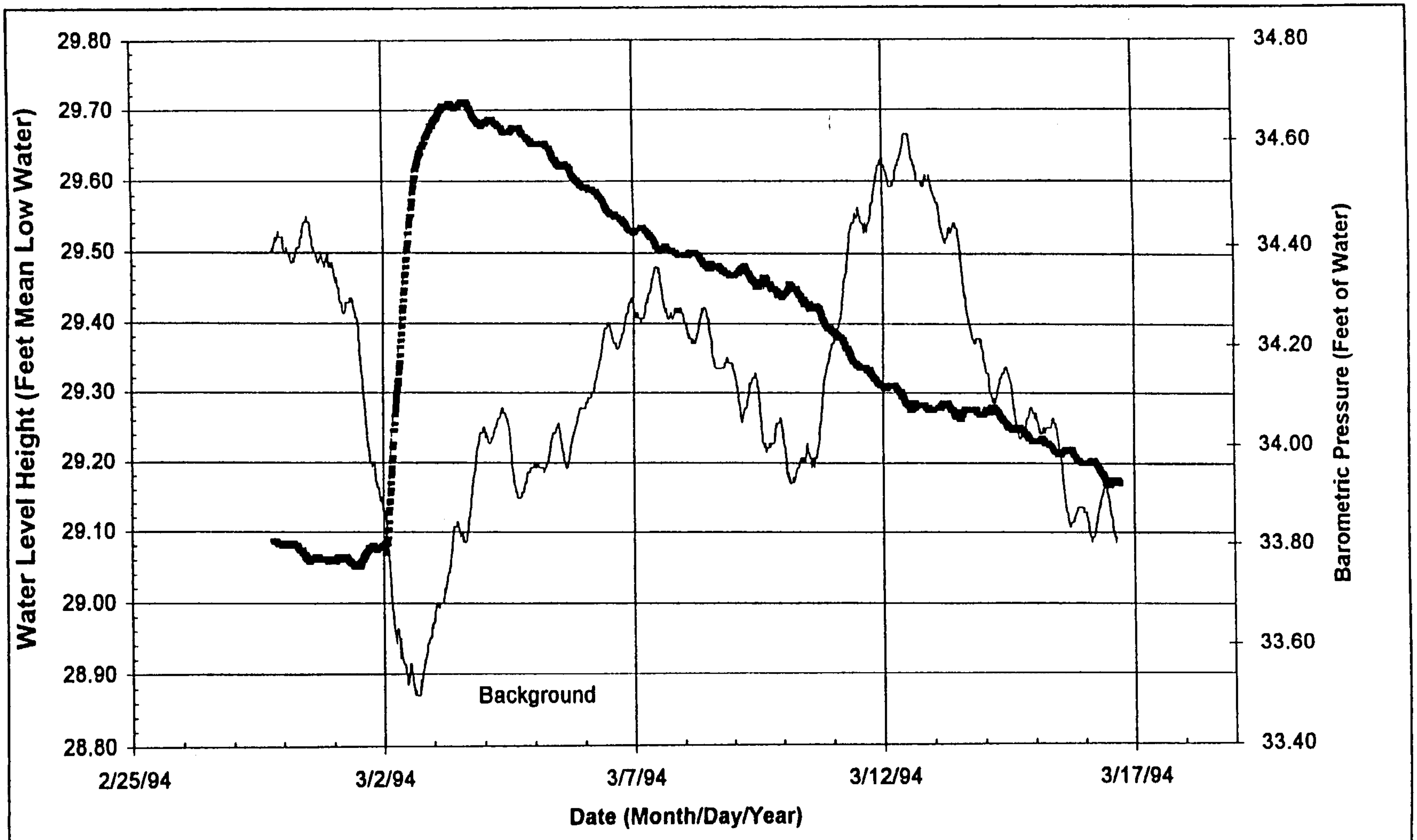

Water Level
Barometric Pressure

FIGURE 2-4

KBA-11-2 (SHALLOW UNIT WELL)
WATER LEVEL ELEVATION AND BAROMETRIC
PRESSURE VERSUS DATE

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
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NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

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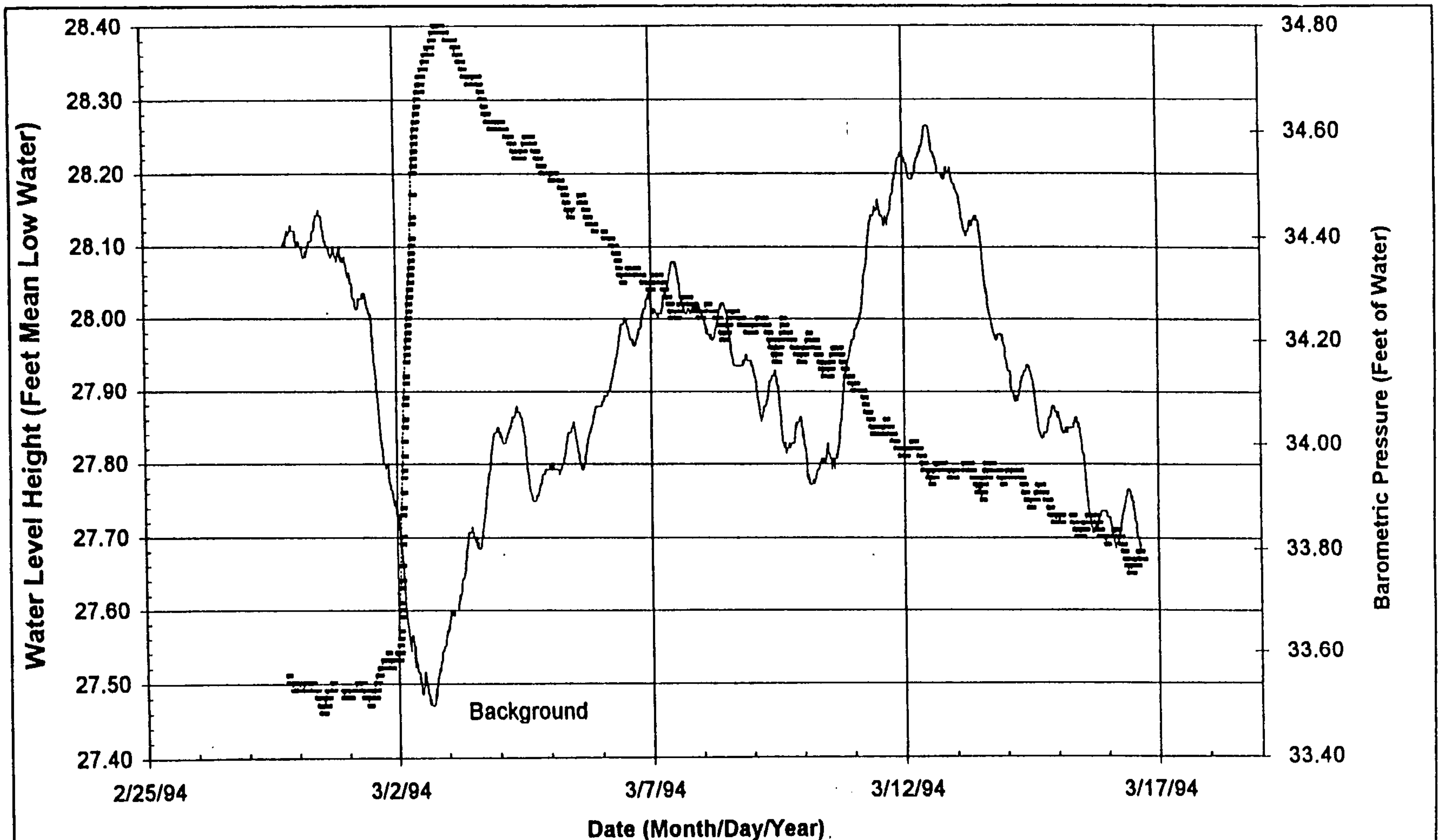

Water Level

Barometric Pressure

FIGURE 2-5

PS-3 (INTERMEDIATE UNIT WELL)
WATER LEVEL ELEVATION AND BAROMETRIC
PRESSURE VERSUS DATE

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
SITE 11, OLD CAMDEN
COUNTY LANDFILL
NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

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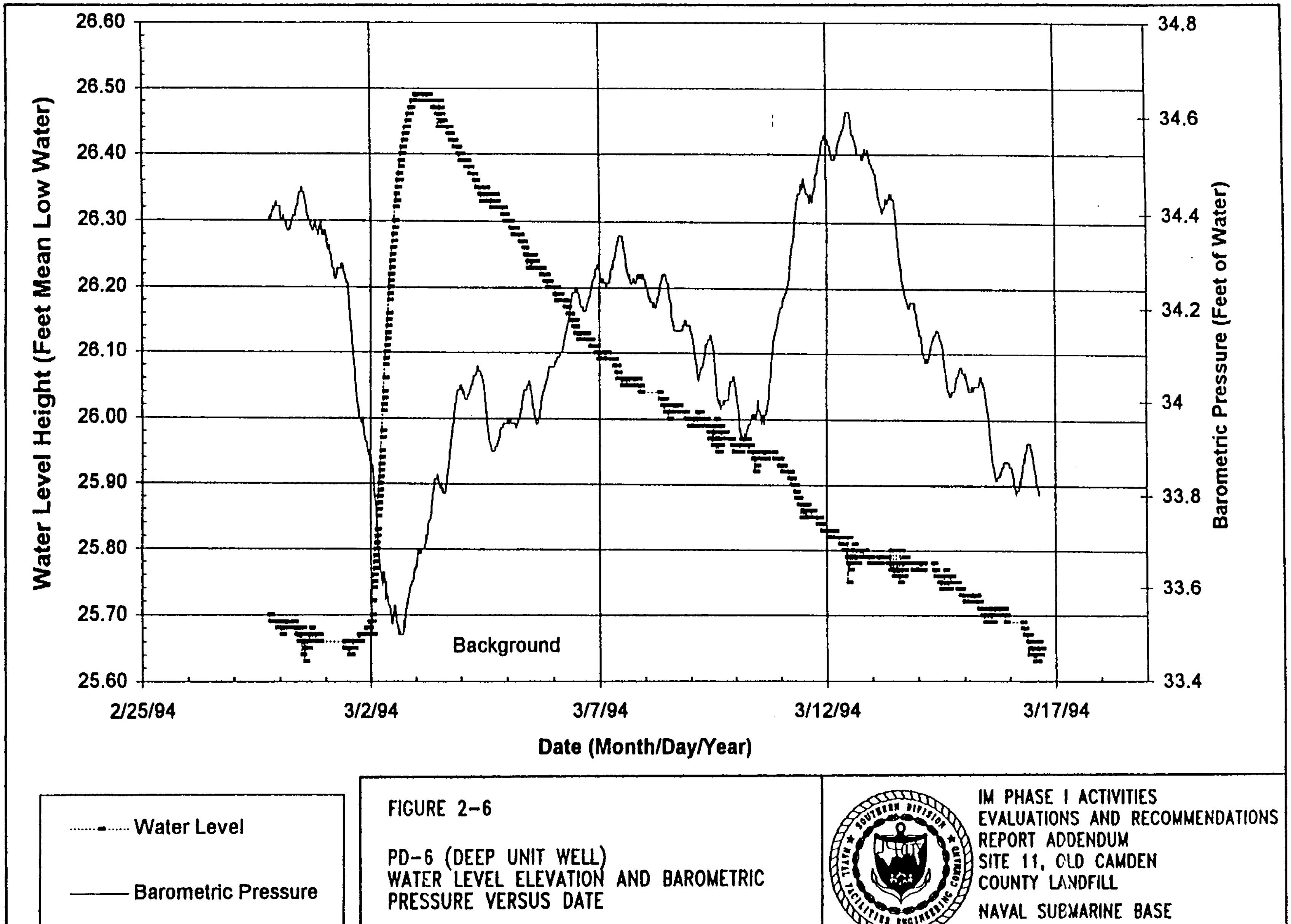

FIGURE 2-6

PD-6 (DEEP UNIT WELL)
WATER LEVEL ELEVATION AND BAROMETRIC PRESSURE VERSUS DATE

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
SITE 11, OLD CAMDEN
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hydrographs for the period March 12 through 16, 1994. A time period between March 12 and 16, 1994, was selected for demonstrating barometric effects on water levels because barometric pressure change is likely to be the only factor influencing groundwater level fluctuations. Other time periods may be equally suited to demonstrate the effects of barometric pressure changes on water level fluctuations. These hydrographs represent aquifer response in the three surficial aquifer units. Water levels in all three units rise slightly as the barometric pressure decreases; levels drop slightly as the barometric pressure increases. A daily pattern develops due to these changes.

As discussed in the evaluation and recommendations report (ABB-ES, 1994a), barometric efficiencies were calculated from data during this period, and the resulting estimates are as follows:

- the shallow unit barometric efficiency is approximately 10 percent,
- the intermediate unit barometric efficiency is approximately 25 percent, and
- the deep unit barometric efficiency is also approximately 25 percent.

As stated in the IM Phase I Activities: Evaluation and Recommendations Report (ABB-ES, 1994a), fluctuation of atmospheric pressure has a small influence on water-levels within the aquifer; however, these natural fluctuations do not appear to significantly affect the GWE system's operation.

Precipitation - Net Recharge. Precipitation during Phase I background and system operations (73 days from February 28, 1994, through May 12, 1994) totalled 5.02 inches. A graph of daily rainfall quantities is provided in Appendix B.

The surficial soils in the Site 11 area are well-drained, fine-grained sands, and, therefore, net recharge does have a significant short-term impact on water levels. Three hydrographs representing water level fluctuation relative to precipitation during the background monitoring period are provided as Figures 2-7 through 2-9. These hydrographs represent aquifer response in the three surficial aquifer units. Water levels in all three units rise significantly after a significant (greater than 1.6 inches) rainfall event on March 2, 1994. During this significant rainfall event, water levels rose to peak levels within approximately 24 hours and then receded under the influence of regional recession. No significant response was observed for the rainfall event (less than 0.2 inches) on March 10, 1994. Less significant rainfall contributed to slower, less significant increases in water levels.

ABB-ES and the USGS are currently conducting focused field studies and will provide more data and analysis of these rainfall and aquifer-response conditions to support the continued operations and performance monitoring of the GWE system.

2.2 EAST BOUNDARY FLOW. Groundwater beneath Site 11 flows generally westward from the eastern side of the landfill where potentiometric levels are approximately 28 plus mlw, as shown on Figure 2-10. This potentiometric surface, under

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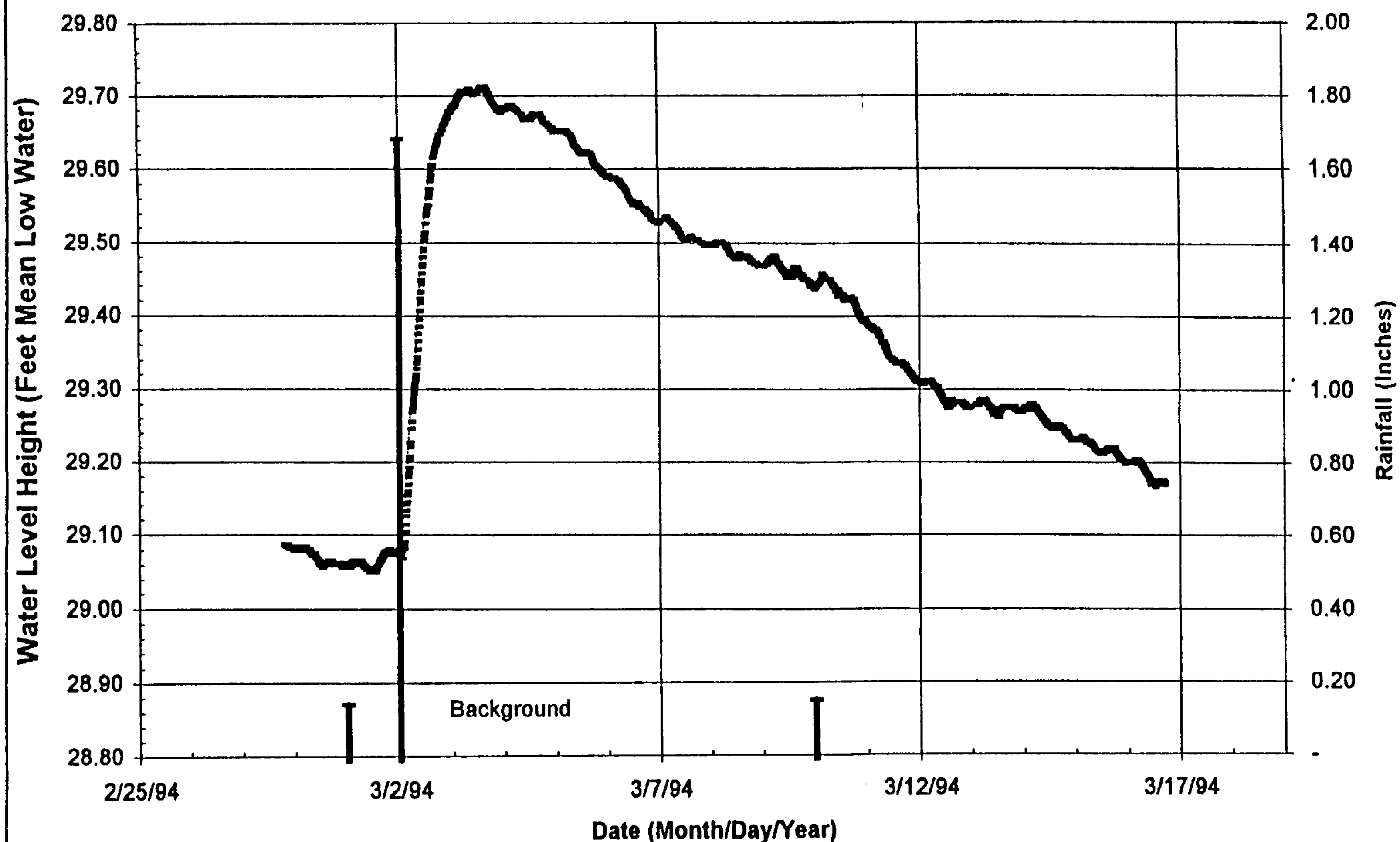

FIGURE 2-7

KBA-11-2 (SHALLOW UNIT WELL)
WATER LEVEL ELEVATION AND
RAINFALL VERSUS DATE

IM PHASE I ACTIVITIES
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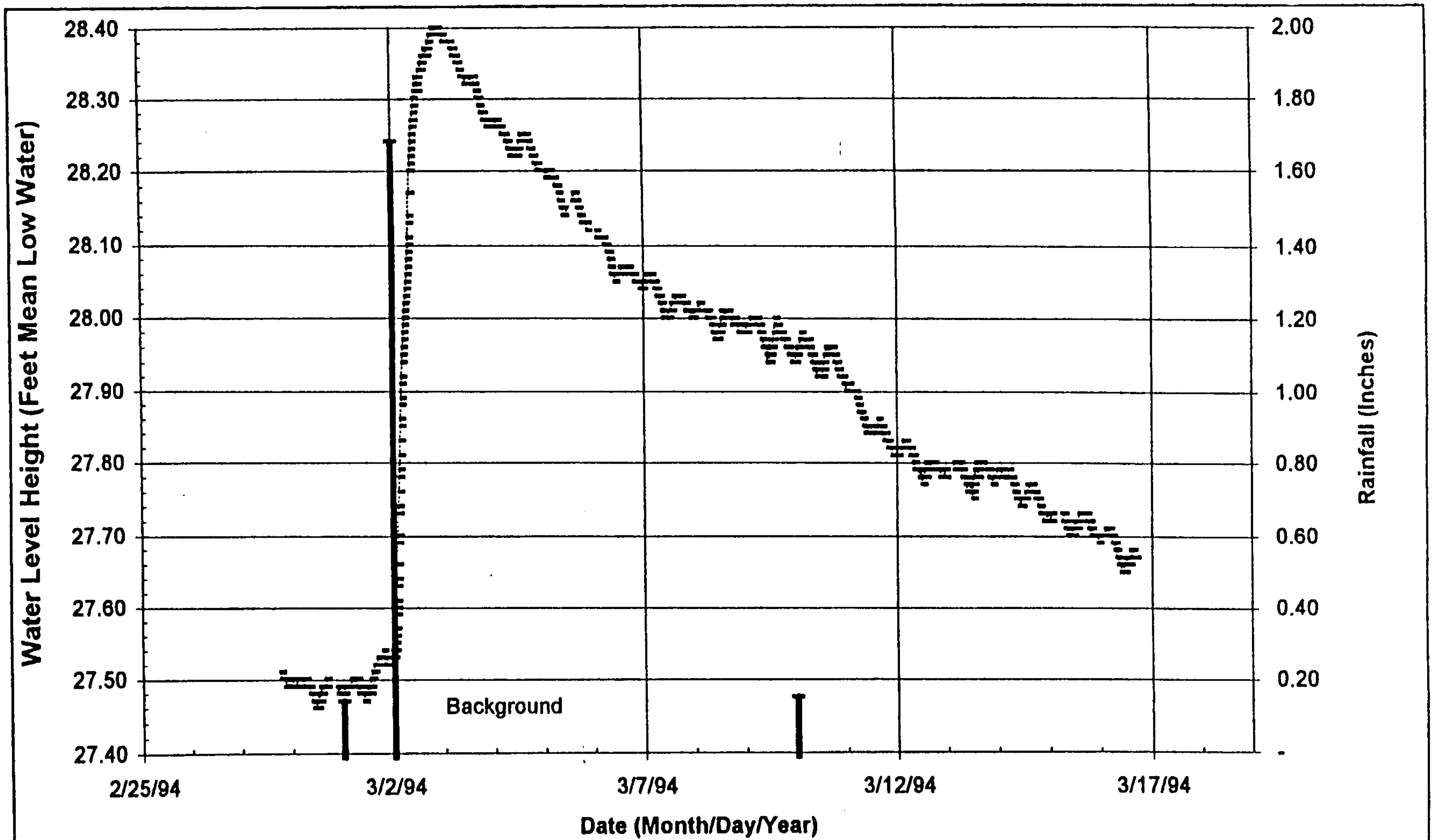

FIGURE 2-8

PS-3 (INTERMEDIATE UNIT WELL)
WATER LEVEL ELEVATION AND
RAINFALL VERSUS DATE

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
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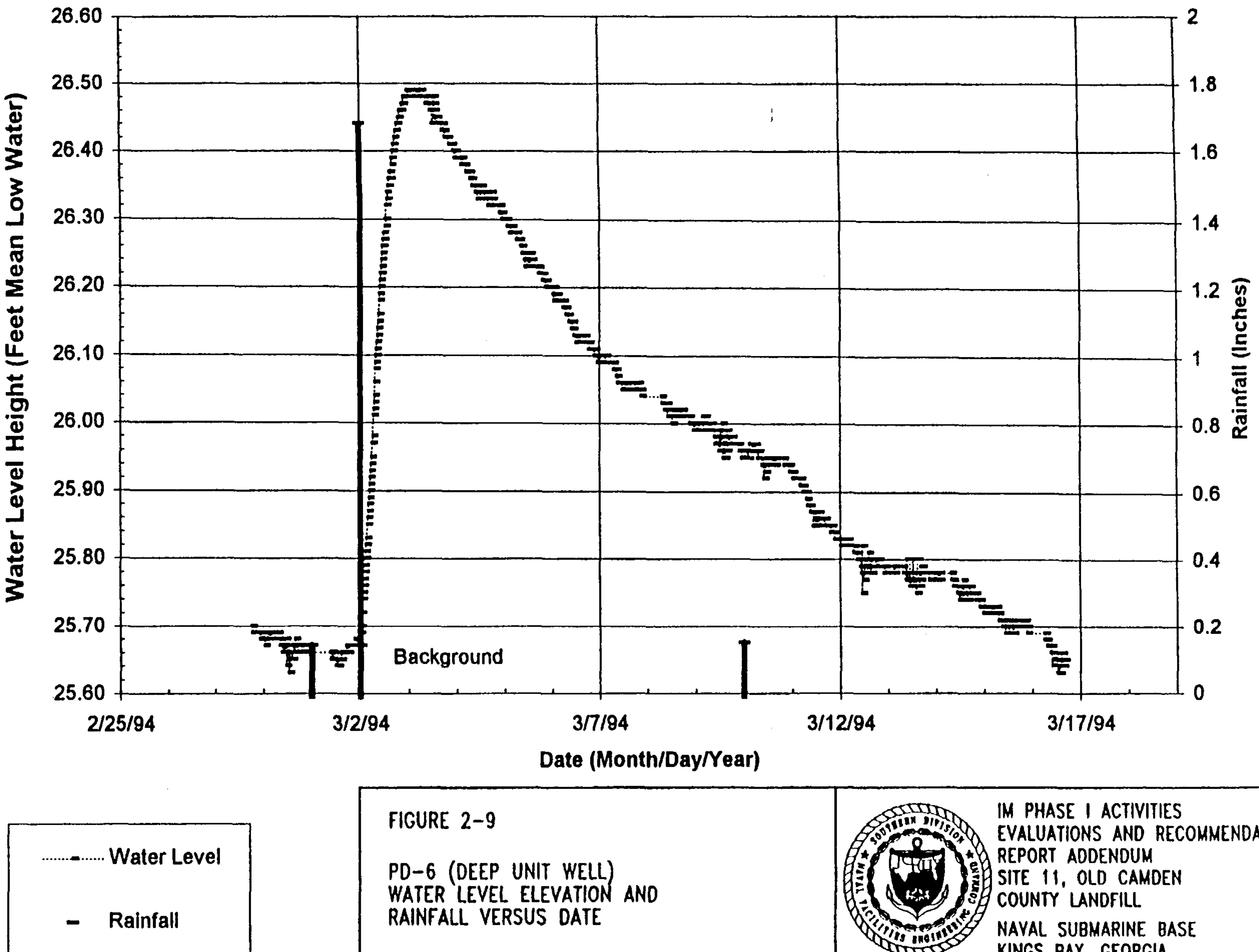

FIGURE 2-9

PD-6 (DEEP UNIT WELL)
WATER LEVEL ELEVATION AND
RAINFALL VERSUS DATE

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
SITE 11, OLD CAMDEN
COUNTY LANDFILL

NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

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natural flow (no pumping stress) conditions, was generated from April 4, 1994, water-level elevations. A groundwater divide may exist under the east side of the landfill or perhaps within the range of 500 to 600 feet further east. If the divide is 500 to 600 feet further east of the landfill, groundwater flow beneath the site would flow westward as stated above. If the divide exists within the limits of the landfill, an easterly component of groundwater flow may also exist. A conservative assumption was used to address this unknown. This approach is justified based on adherence to the IM objectives, to hydraulically control contaminated groundwater in a specific area west of Site 11 and migrating beyond the Base boundary to the subdivision. This conservative assumption was used to focus capture zone analysis to the area west of the source area. (In both the analytical and numerical models used for capture zone analysis, groundwater was assumed to flow from the west side of the landfill to the east.)? However, as stated above, ABB-ES and USGS are conducting focused field studies to support GWE system performance monitoring activities. Additional data regarding the proximity of the groundwater divide to the landfill and potential flow directions other than to the west will be provided by ABB-ES and USGS as part of the system's continued operations.

2.3 CAPTURE ZONE ANALYSIS. This section includes assessment of the Phase I capture zone through the use of (1) a mass balance approach, (2) actual GWE system performance data to empirically derive the capture zone, and (3) a two-dimensional, numerical model – FLOWPATH™. The first approach is based on the theory of mass conservation. The second approach is based on the application of interpretive skills to derive the capture zone from hydraulic head data. The third approach is based on the application of groundwater flow principles and mathematical equations. These three approaches are described in the following three subsections. All three approaches provide estimates of the potential affect that the GWE system has on the surficial aquifer and capture of contaminated groundwater. More quantitative data will be collected over time to more fully document changes in groundwater quality.

2.3.1 Mass Balance Approach to Capture Zone Analysis In this section the concept of a capture zone will be demonstrated through the use of a mass balance (conservation of mass) approach. This approach provides an alternative method to verify the size of the capture zone predicted by the numerical modeling in Subsection 2.3.3. A conceptual sketch of the capture zone produced by a recovery well is presented on Figure 2-11.

The mass balance approach requires that outflow must equal inflow for a steady-state flow system. In other words, the volume rate of groundwater flow extracted from the aquifer within the capture zone must equal the volume rate of groundwater flowing into the capture zone. The inflow to the capture zone is provided by two sources: (1) the regional groundwater flow crossing the upgradient side of the capture zone and (2) the net recharge from precipitation entering the areal footprint of the capture zone. Because the capture zone, by definition, is bounded on all other sides by flow lines, these two inflow values must be balanced by the recovery well extraction rate. The following equation expresses the mass balance:

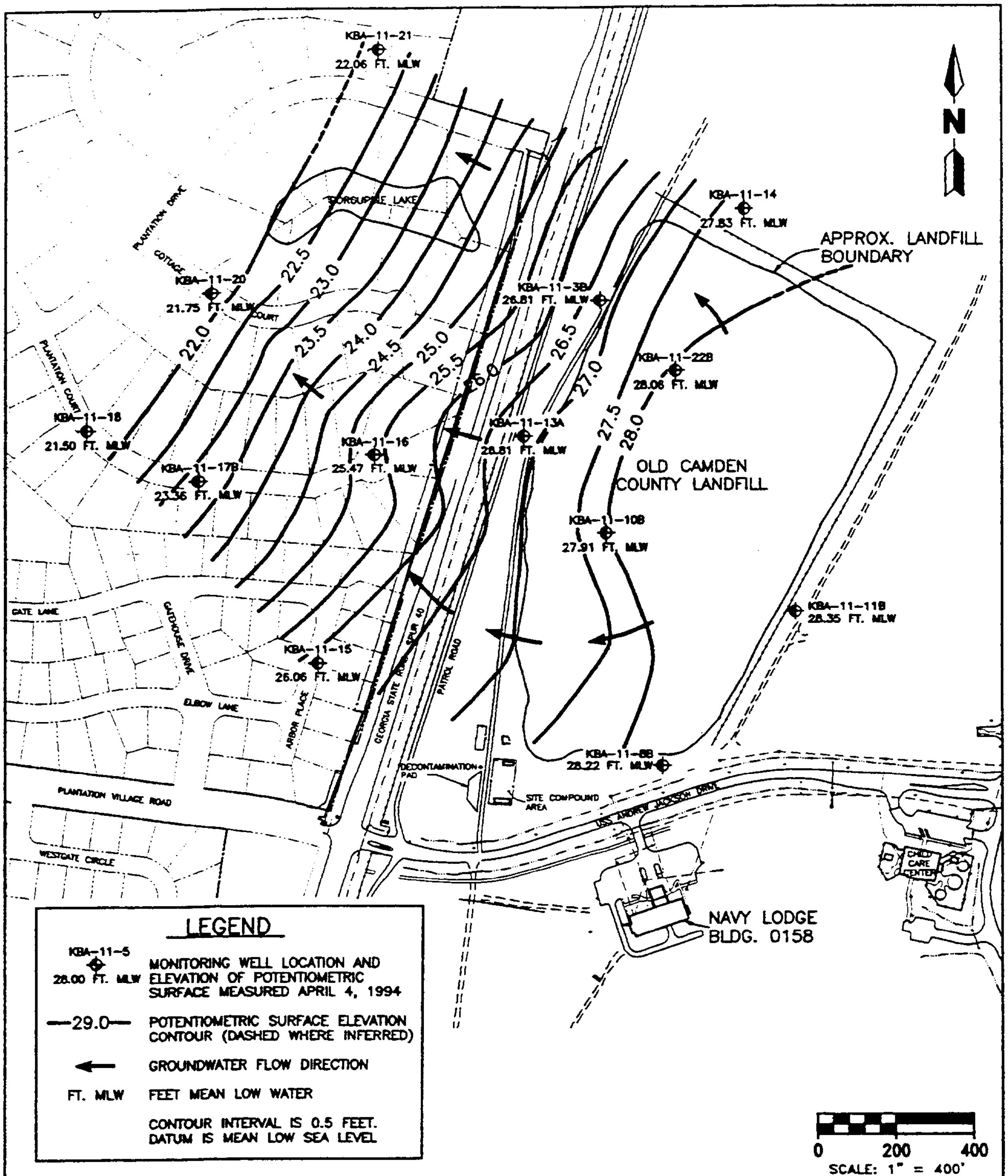

FIGURE 2-10

POTENTIOMETRIC SURFACE MAP, GROUNDWATER EXTRACTION SYSTEM NOT OPERATING (APRIL 4, 1994 WATER LEVELS)

IM PHASE I ACTIVITIES EVALUATIONS AND RECOMMENDATIONS REPORT ADDENDUM
SITE 11, OLD CAMDEN COUNTY LANDFILL

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KINGS BAY, GEORGIA

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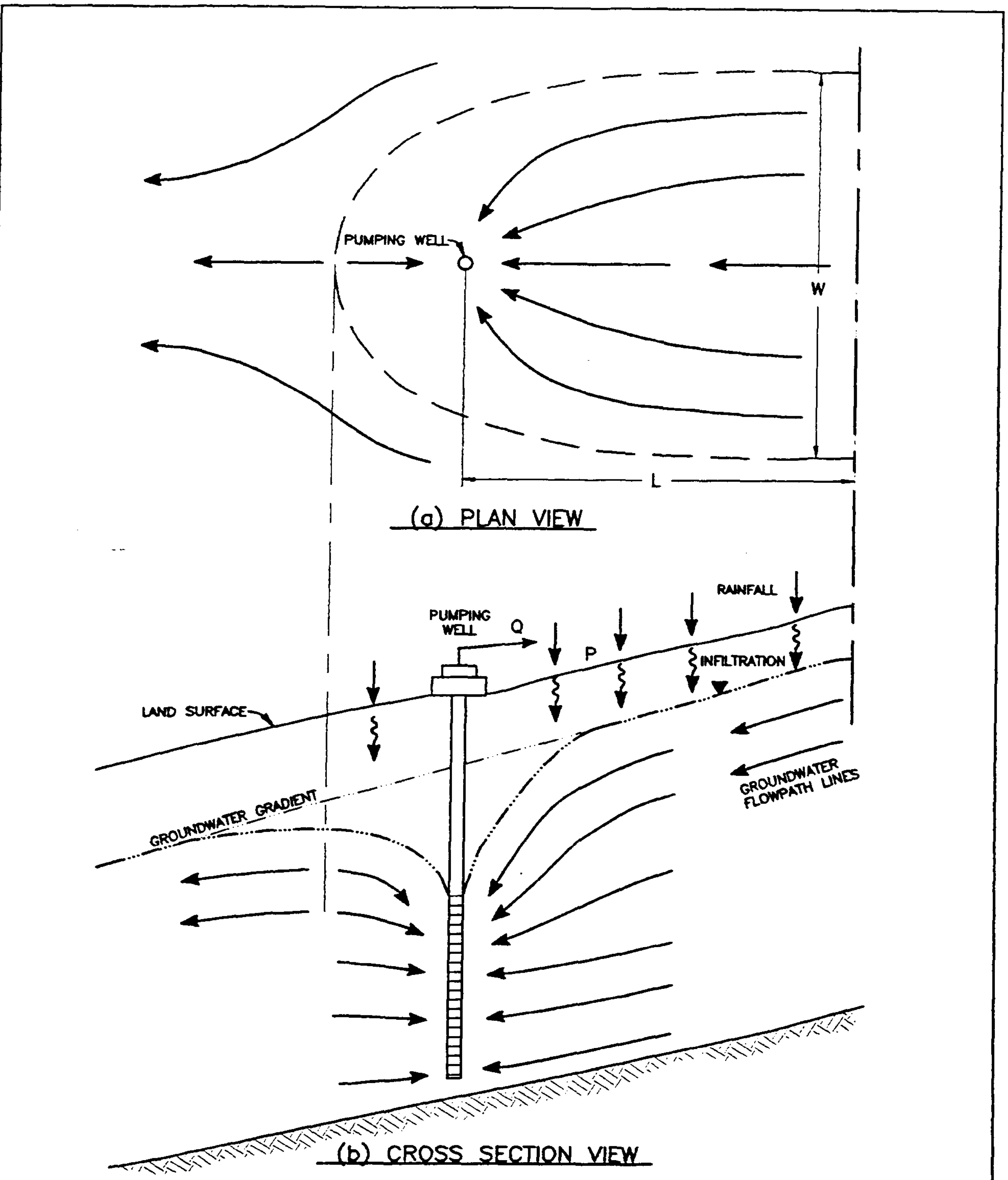

FIGURE 2-11

CONCEPTUAL CAPTURE ZONE, MASS BALANCE APPROACH

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EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
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COUNTY LANDFILL

NAVAL SUBMARINE BASE
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$$Q_w = p \cdot L \cdot W + T \cdot i \cdot W \tag{1}$$

where

Q_w = recovery well discharge rate, cubic feet per day (ft^3/day)
p = net infiltration rate over the capture zone, feet per day (ft/day)
L = length of the capture zone upgradient from the recovery well (feet)
W = width of the capture zone at the upgradient side (feet)
T = transmissivity of the aquifer, feet squared per day (ft^2/day)
i = hydraulic gradient at upgradient side of capture zone, feet per foot (ft/ft)

The above equation can be used to calculate the width of the capture zone given the other parameters in the equation. The recovery well discharge is known from flow meter records, the transmissivity was estimated from aquifer tests analyzed by ABB-ES and USGS, the hydraulic gradient is measured from contour maps of piezometric surface. The length (L) is the distance from the recovery well to the upgradient side (east side) of the landfill. Net recharge is estimated from annual precipitation minus both runoff and annual evapotranspiration. Precipitation data were obtained from the National Climatic Center and evaporation estimates were developed from the "Thomas abcd Method" (Gupta, 1989). Therefore, the width of the capture zone based on these mass balance considerations can be calculated.

The following parameter values are applicable to the recovery wells at Site 11:

Q_w = 8 gpm = 1,540 ft^3/day (typical for one recovery well)
T = 1,110 ft^2/day (average value from Stage 3 testing)
i = 2.2×10^{-3} ft/ft (at eastern to western edge of landfill) (elevation 28.35 feet - 26.5 feet)/850 feet
p = 19.9 inches per year = 4.54×10^{-3} ft/day
L = 850 feet

The calculated width of the capture zone is

$$W = \frac{Q_w}{(p \cdot L + T \cdot i)} = \frac{1,540}{(4.54x10^{-3})(850) + (2.2x10^{-3})(1,110)} = 244\ ft \tag{2}$$

This capture width is for a single recovery well extracting groundwater at a volumetric rate of 8 gpm. Since we actually have five wells extracting a total volumetric rate of approximately 36 gpm, the total capture zone width would be approximately 244×(36/8) = 1,100 feet. This value can be compared with the capture zone width predicted by the numerical model, which is described in Subsection 2.3.3.

<u>2.3.2 Empirical Capture Zone</u> In this section, the capture zone is derived empirically based on hydraulic head data collected during GWE system operations. This approach provides a method to estimate the size and shape of the capture zone based on interpretation of actual data as well as verify the modeling results. This evaluation generally follows the empirical approach used in the original IM Phase I Activities: Evaluation and Recommendations Report. However, this approach has been refined, and drawdown data have been revised. Specific procedural steps were followed to account for regional recession trends that were

not accounted for in the original evaluations and recommendations report. Uncorrected, apparent drawdowns based on April 4, 1994, (static) water levels and April 19, 1994, (pumping stress) water levels used to generate the interpreted capture zone are included in Table 2-2. These apparent drawdown values are larger than the corrected drawdowns generated through the more conservative approach discussed below. The refined process by which data were reevaluated and the capture zone was reinterpreted is provided as procedural steps in Appendix A. An overview of the process is described in the discussion below.

Regional Recession Analysis. To determine regional trends in groundwater recession, water-level elevations were plotted with respect to time. Based on the relatively steady decline in water levels during Phase I, slopes were calculated to establish regional recession trends for various time periods. This trend analysis was performed on three wells selected to represent the three aquifer units. These control wells were selected based on their large radial distance from the GWE wells because drawdown due to pumping would be very minimal, if any at all. Increasing the distance from the pumping stress minimizes the magnitude of the stress response (i.e., drawdown). For the trend analysis, wells KBA-11-6, KBA-11-18, and KBA-11-11C, which are distant from the recovery wells, were selected as control wells to represent the shallow, intermediate, and deep units, respectively. Regional recession factors for each of the shallow, intermediate, and deep units were estimated based on the slope of the line fitted to water levels from the three wells. Figures 2-12 through 2-14 show hydrographs for each of the control wells during the period April 1 to May 8, 1994. The slope of the line fitted to the data defines a unit rate change in water levels due to regional recession. Commercially available computer software was used to fit the lines to the data and calculate slopes according to the principles of linear regression. As shown on the graphs on Figures 2-12 through 2-14, the regional recession factors are 0.032, 0.031, and 0.035 ft/day for the shallow, intermediate, and deep units of the surficial aquifer, respectively.

Drawdown Correction. Drawdowns were corrected for regional recession using the recession factors discussed in the preceding paragraph. Apparent and corrected drawdown data, corrected for regional recession are provided in Table 2-2. The regional recession factor multiplied by the number of days (to the hour) between April 4, 1994 (noon), and April 19, 1994 (0600 hours), defines the amount of decline of water levels caused by regional recession and not pumping stress. The remaining decline of water levels is drawdown caused by pumping stress.

The effects of residual drawdown, after Stage 2 pumping stopped, were observed in most wells. Stage 3 was to have commenced immediately after completion of Stage 2; however, plans for start up of Stage 3 were altered to allow cleaning and minor maintenance of the IM treatment system over a 10-hour shutdown period. Upon start up of Stage 3, water levels in most wells had not fully recovered from Stage 2 pumping. Static and/or reference (April 4, 1994) water levels used to calculate drawdown predate Stage 2 pumping, so that no residual drawdown from Stage 2 affect the evaluations presented herein.

Four graphs of drawdown versus elapsed time are provided as Figures 2-15 through 2-18 for 11 wells. These graphs provide drawdown corrected for regional recession based on values obtained from each of the three control wells. Plots of drawdown are shown for selected paired, or clustered wells and piezometers. As indicated on Figure 2-16, the water level in PS-3 fully recovered (drawdown

Table 2-2
Water Level Elevation Data: Apparent and Corrected Drawdown

Interim Measure Phase I Activities:
Evaluation and Recommendations Report
Site 11, Old Camden County Landfill
Naval Submarine Base
Kings Bay, Georgia

Monitoring Well No.	April 4, 1994, Static Water Level Elevation (ft/mlw)	April 19, 1994, Water Level Elevation	Apparent Drawdown at Steady-State Conditions (feet)[1]	Regional Recession Factor (ft/day)[2]	Corrected Drawdown at Steady-State Conditions (feet)[3]	Corrected Water Level Elevation at Steady-State Conditions (ft/mlw)
Shallow wells (mean screen depth between 30 and 5 feet mlw)						
KBA-11-1	29.58	29.15	0.43	0.032	-0.04	29.62
KBA-11-2	28.70	28.09	0.61	0.032	0.14	28.56
KBA-11-3A	27.48	26.66	0.82	0.032	0.35	27.13
KBA-11-4	27.97	27.44	0.53	0.032	0.06	27.91
KBA-11-5	28.83	NM	NM	NM	NM	NM
KBA-11-6	29.27	28.79	0.48	0.032	0.01	29.26
KBA-11-7	29.59	NM	NM	NM	NM	NM
KBA-11-8A	29.14	NM	NM	NM	NM	NM
KBA-11-9	29.06	NM	NM	NM	NM	NM
KBA-11-10A	29.29	28.73	0.56	0.032	0.09	29.20
KBA-11-11A	28.49	27.84	0.65	0.032	0.18	28.31
KBA-11-14	27.83	NM	NM	NM	NM	NM
KBA-11-19A	24.60	23.91	0.69	0.032	0.22	24.38
KBA-11-22A	28.82	28.25	0.57	0.032	0.10	28.72
RW-5	27.54	17.74	9.80	0.032	9.33	18.21

See notes at end of table.

Table 2-2 (Continued)
Water Level Elevation Data: Apparent and Corrected Drawdown

Interim Measure Phase I Activities:
Evaluation and Recommendations Report
Site 11, Old Camden County Landfill
Naval Submarine Base
Kings Bay, Georgia

Monitoring Well No.	April 4, 1994, Static Water Level Elevation (ft/mlw)	April 19, 1994, Water Level Elevation	Apparent Drawdown at Steady-State Conditions (feet)[1]	Regional Recession Factor (ft/day)[2]	Corrected Drawdown at Steady-State Conditions (feet)[3]	Corrected Water Level Elevation at Steady-State Conditions (ft/mlw)
Intermediate depth wells (mean screen depth between 5 and -20 feet mlw)						
KBA-11-3B	26.81	25.93	0.88	0.031	0.43	26.38
KBA-11-8B	28.22	NM	NM	NM	NM	NM
KBA-11-8C	28.19	NM	NM	NM	NM	NM
KBA-11-10B	27.91	26.88	1.03	0.031	0.58	27.33
KBA-11-11B	28.35	27.68	0.67	0.031	0.22	28.13
KBA-11-12	27.10	26.21	0.89	0.031	0.44	26.66
KBA-11-13A	26.81	25.12	1.69	0.031	1.24	25.57
KBA-11-15	26.06	25.28	0.78	0.031	0.33	25.73
KBA-11-16	25.47	24.40	1.07	0.031	0.62	24.85
KBA-11-17A	23.63	22.95	0.68	0.031	0.23	23.40
KBA-11-17B	23.36	22.83	0.53	0.031	0.08	23.28
KBA-11-18	21.50	20.90	0.60	0.031	0.15	21.35
KBA-11-20	21.75	21.18	0.57	0.031	0.12	21.63

See notes at end of table.

Table 2-2 (Continued)
Water Level Elevation Data: Apparent and Corrected Drawdown

Interim Measure Phase I Activities:
Evaluation and Recommendations Report
Site 11, Old Camden County Landfill
Naval Submarine Base
Kings Bay, Georgia

Monitoring Well No.	April 4, 1994, Static Water Level Elevation (ft/mlw)	April 19, 1994, Water Level Elevation	Apparent Drawdown at Steady-State Conditions (feet)[1]	Regional Recession Factor (ft/day)[2]	Corrected Drawdown at Steady-State Conditions (feet)[3]	Corrected Water Level Elevation at Steady-State Conditions (ft/mlw)
KBA-11-21	22.06	21.51	0.55	0.031	0.10	21.96
KBA-11-22B	28.06	27.25	0.81	0.031	0.36	27.70
PS-1	27.17	25.24	1.93	0.031	1.47	25.69
PS-2	26.97	25.36	1.61	0.031	1.16	25.81
PS-3	26.98	25.45	1.53	0.031	1.07	25.91
PS-4	NA	NA	NA	NA	NA	NA
PS-5	27.09	25.65	1.44	0.031	0.99	26.10
PS-7	26.14	24.56	1.58	0.031	1.13	25.01
PD-8	26.12	24.31	1.81	0.031	1.35	24.76
PS-9	26.26	24.25	2.01	0.031	1.56	24.70
PS-10	26.44	24.66	1.78	0.031	1.33	25.11
RW-1	27.05	13.70	13.35	0.031	12.89	14.15
RW-2	27.26	16.40	10.86	0.031	10.40	16.85
RW-3	26.07	8.59	17.48	0.031	17.03	9.04
RW-4	26.14	9.65	16.49	0.031	16.03	10.10

See notes at end of table.

Table 2-2 (Continued)
Water Level Elevation Data: Apparent and Corrected Drawdown

Interim Measure Phase I Activities:
Evaluation and Recommendations Report
Site 11, Old Camden County Landfill
Naval Submarine Base
Kings Bay, Georgia

Monitoring Well No.	April 4, 1994, Static Water Level Elevation (ft/mlw)	April 19, 1994, Water Level Elevation	Apparent Drawdown at Steady-State Conditions (feet)[1]	Regional Recession Factor (ft/day)[2]	Corrected Drawdown at Steady-State Conditions (feet)[3]	Corrected Water Level Elevation at Steady-State Conditions (ft/mlw)
Deep wells (mean screen depth between -20 and -60 feet mlw)						
KBA-11-3C	21.35	20.52	0.83	0.035	0.31	21.04
KBA-11-10C	24.79	23.85	0.94	0.035	0.42	24.37
KBA-11-11C	26.26	25.55	0.71	0.035	0.19	26.07
KBA-11-13B	23.22	22.24	0.98	0.035	0.47	22.75
KBA-11-17C	21.03	20.40	0.63	0.035	0.11	20.92
KBA-11-19B	21.87	21.13	0.74	0.035	0.22	21.65
PD-6	25.31	24.02	1.29	0.035	0.77	24.54

[1] Apparent drawdowns are based on differences in water level elevation, April 4 through April 13, 1994, (15-day period, not corrected for regional recession trend).
[2] Regional recession factors calculated from selected control wells KBA-11-6, KBA-11-18, and KBA-11-11C and represent the shallow, intermediate, and deep aquifer units, respectively.
[3] Steady-state conditions achieved in intermediate and deep aquifer units. Shallow units continue to drawdown due to drainage to lower aquifer units; however, groundwater elevations in the shallow wells were selected at the time that intermediate and deep units achieve steady state.

Notes: ft/mlw = feet mean low water.
mlw = mean low water.
NA = not analyzed.
ft/day = feet per day.
NM = not measured.

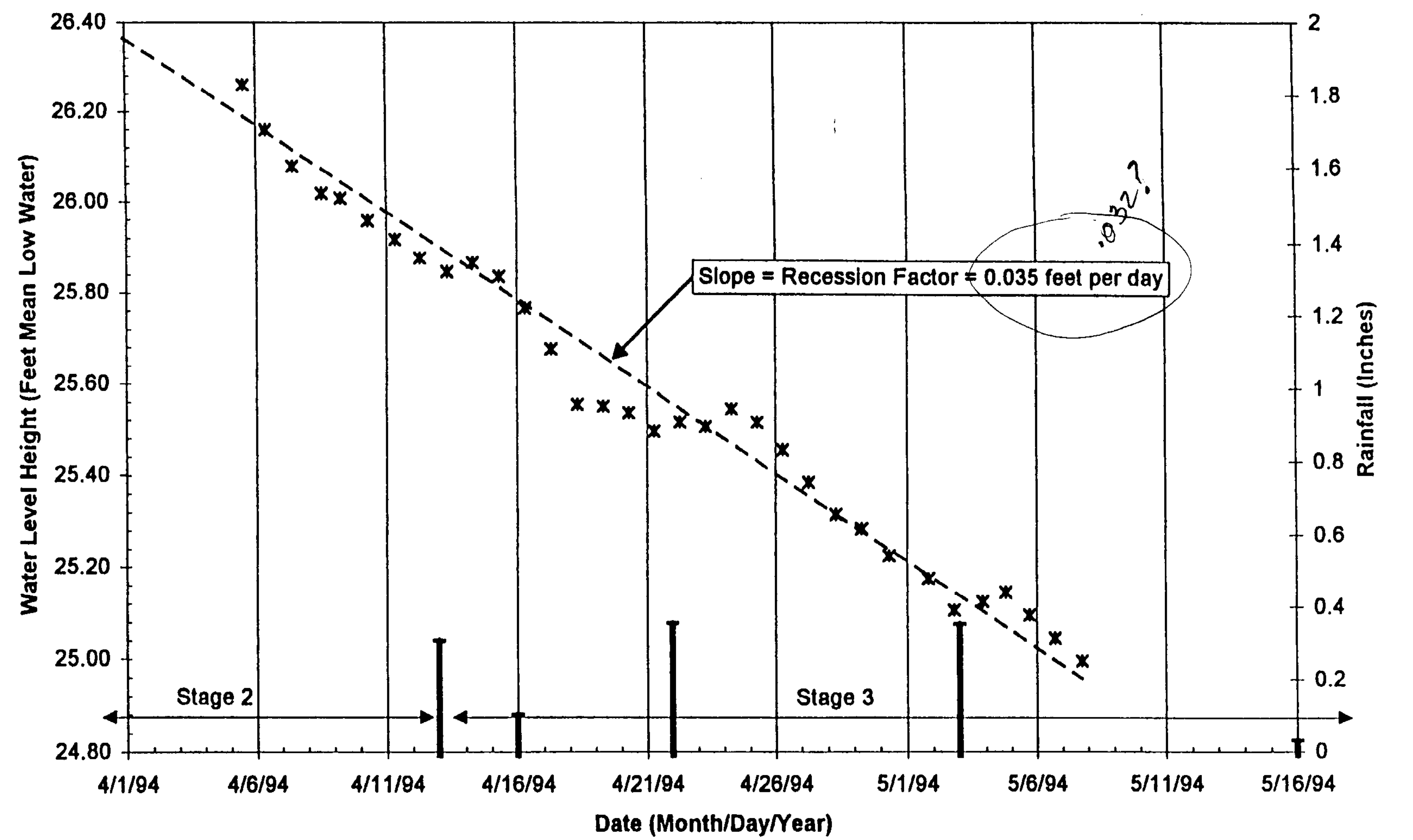

FIGURE 2-12

KBA-11-6 (SHALLOW UNIT WELL)
WATER LEVEL ELEVATION VERSUS DATE,
REGIONAL RECESSION TREND ANALYSIS,
STAGES 2 AND 3

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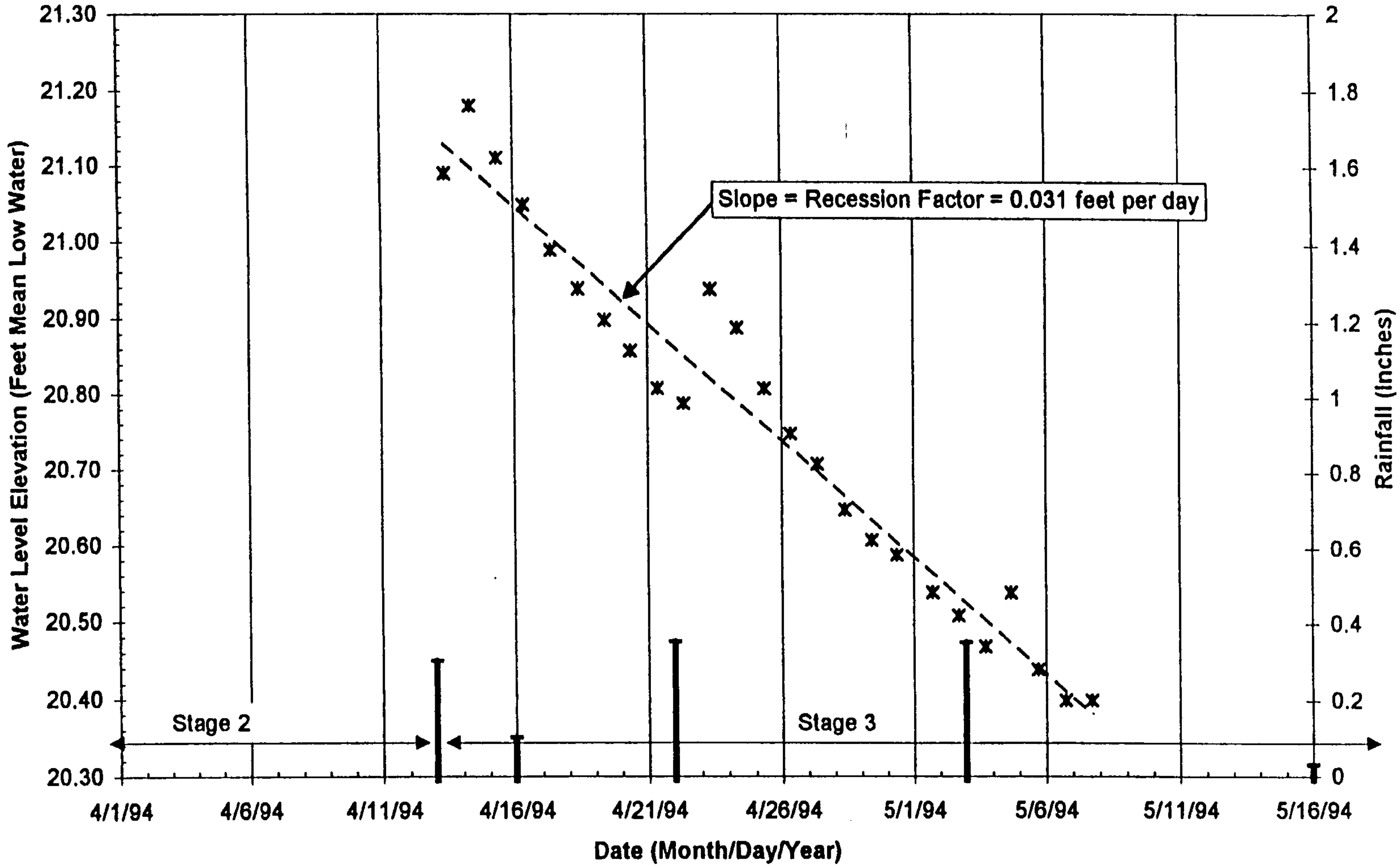

FIGURE 2-13

KBA-11-18 (INTERMEDIATE UNIT WELL) WATER LEVEL ELEVATION VERSUS DATE, REGIONAL RECESSION TREND ANALYSIS, STAGES 2 AND 3

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KINGS BAY, GEORGIA

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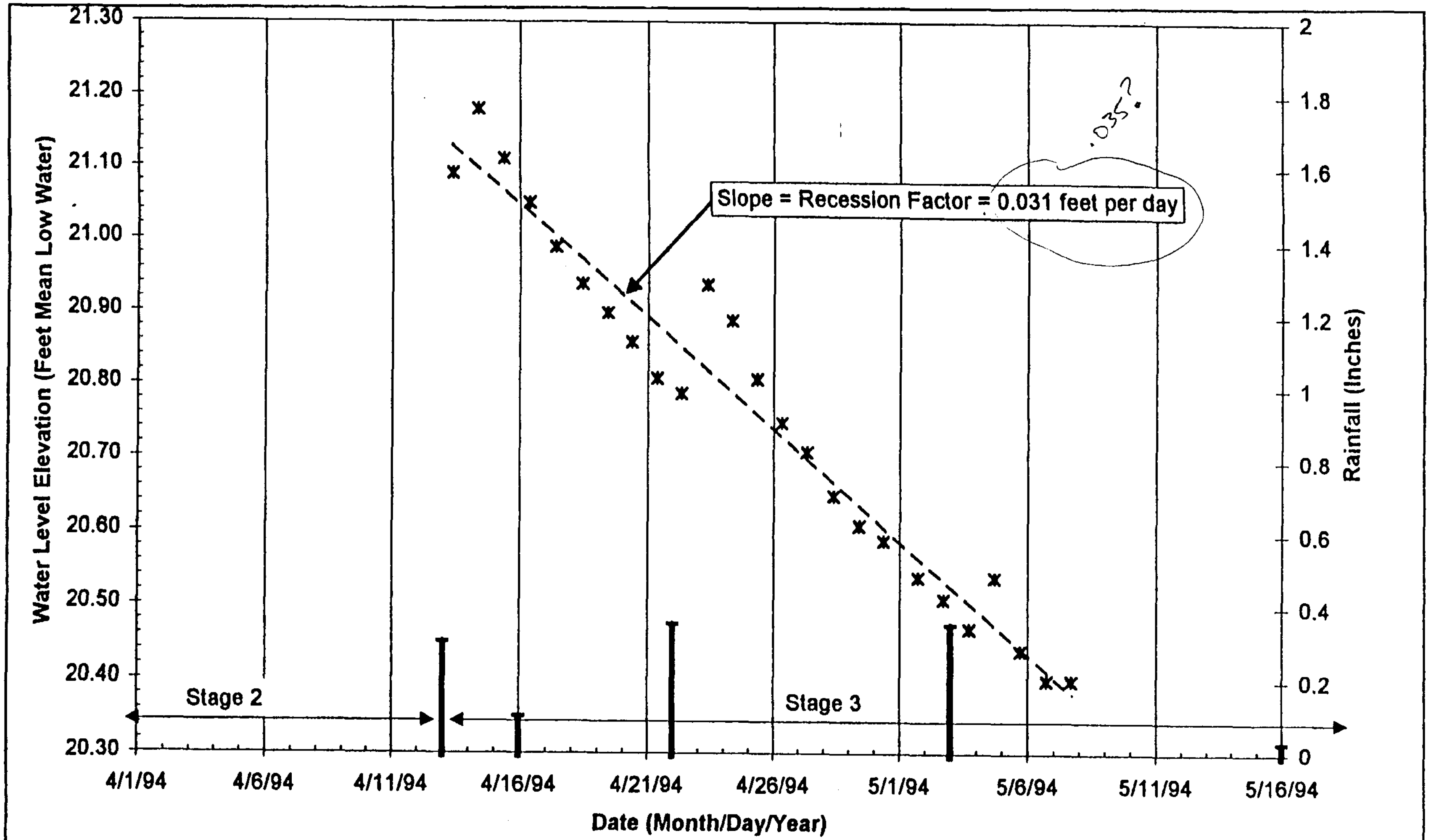

FIGURE 2-14

KBA-11-11C (DEEP UNIT WELL)
WATER LEVEL ELEVATION VERSUS DATE,
REGIONAL RECESSION TREND ANALYSIS,
STAGES 2 AND 3

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
SITE 11, OLD CAMDEN
COUNTY LANDFILL

NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

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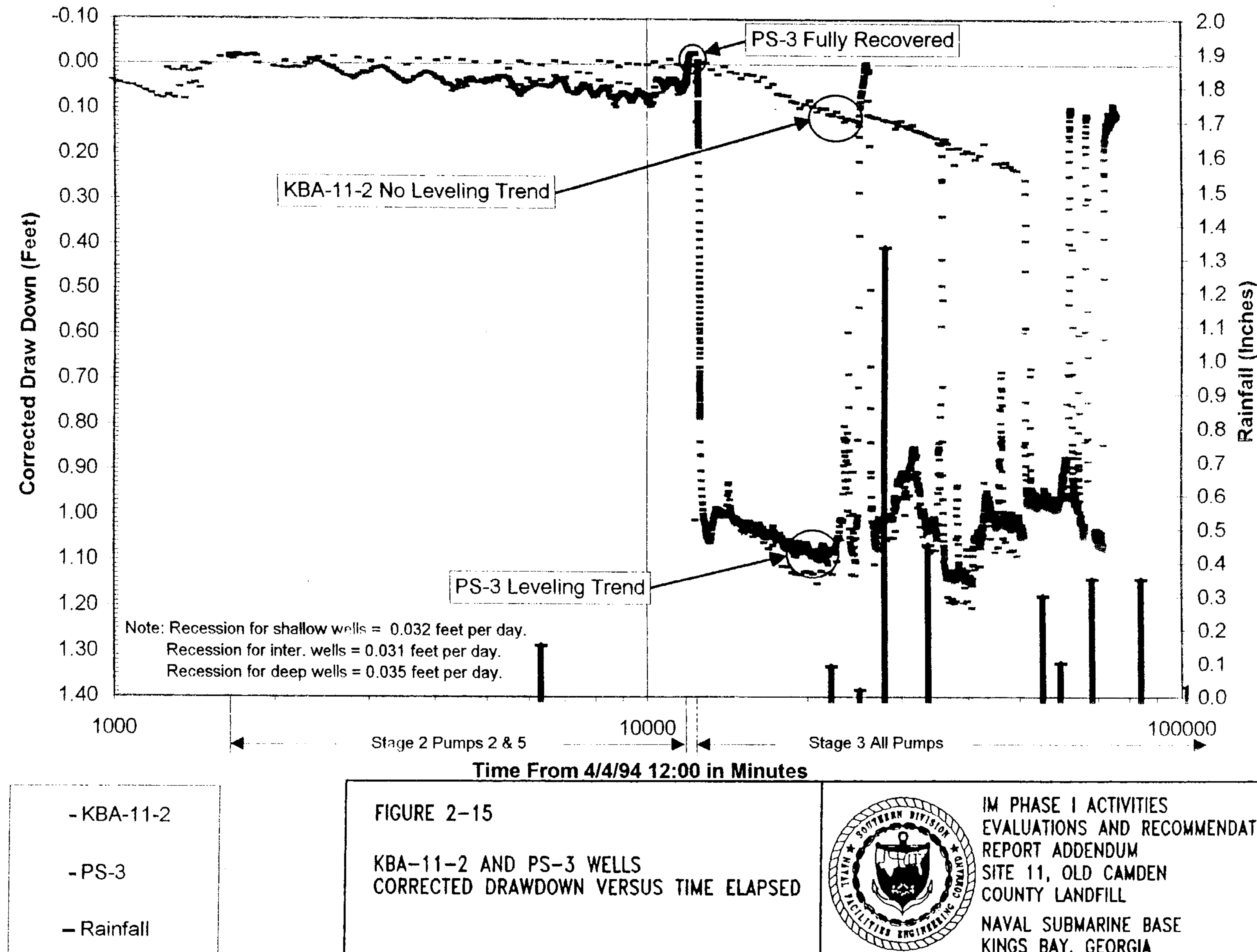

FIGURE 2-15

KBA-11-2 AND PS-3 WELLS
CORRECTED DRAWDOWN VERSUS TIME ELAPSED

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
SITE 11, OLD CAMDEN
COUNTY LANDFILL
NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

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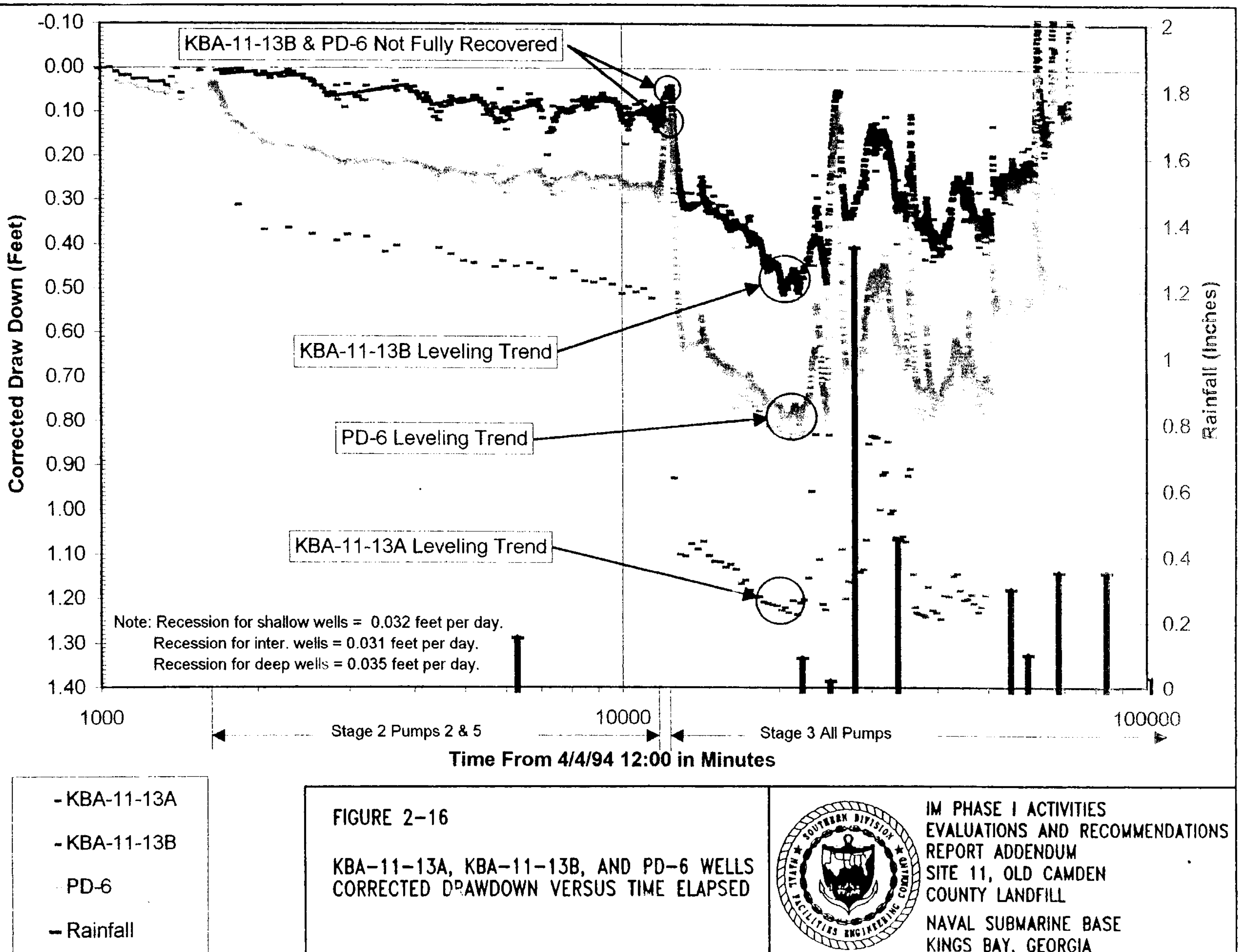

FIGURE 2-16

KBA-11-13A, KBA-11-13B, AND PD-6 WELLS CORRECTED DRAWDOWN VERSUS TIME ELAPSED

IM PHASE I ACTIVITIES EVALUATIONS AND RECOMMENDATIONS REPORT ADDENDUM
SITE 11, OLD CAMDEN COUNTY LANDFILL

NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

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equals 0.0 foot) after Stage 2 was shut down and prior to Stage 3 start up. Other wells, such as those shown on Figures 2-16 through 2-18 had not fully recovered at the end of Stage 2. KBA-11-13A, KBA-11-13B, and PD-6 were within 0.15 foot of equilibrium; KBA-11-11A, KBA-11-11B, and KBA-11-11C were within 0.09 foot of equilibrium; and KBA-11-10B and KBA-11-10C were within 0.06 foot of equilibrium at the start of Stage 3.

The 11 representative wells were chosen for the hydrographs on Figures 2-13 through 2-16 based on their relative position vertically within the aquifer. Three wells, KBA-11-6, KBA-11-22A, and KBA-11-2, represent the shallow unit at varying radial distances from the recovery wells. Five wells, KBA-11-3B, KBA-11-10B, KBA-11-16, KBA-11-13A, and PS-3, represent the intermediate unit at varying radial distances. Three wells, KBA-11-11C, KBA-11-13B, and PD-6, represent the deep unit at varying distances. Distances from each of the recovery wells are provided in Table 2-1.

Drawdown contours were generated from corrected drawdown values shown in Table 2-2. These drawdown values are based on a comparison of natural, prepumping water levels measured on April 4, 1994, and pumping-stress-induced water levels at steady-state conditions. April 4, 1994, was chosen for static water levels because this predated Stages 2 and 3 pumping and coincided with an RFI groundwater sampling event when field crews were onsite and collected water level measurements. Steady-state conditions were achieved within the intermediate and deep aquifer units approximately 9,000 minutes (approximately 6.25 days) into Stage 3 on April 19, 1994. Drawdown versus elapsed time on Figures 2-15 through 2-18 show this leveling trend at approximately 19,000 minutes from the start of Stage 2 (approximately 9,000 minutes into Stage 3). However, approximately 85 to 95 percent of the total corrected drawdown observed in the intermediate aquifer unit occurs within the first 12 hours of the start of the (Stage 3) test. Approximately 60 to 70 percent of the total corrected drawdown observed in the deep aquifer unit occurs within the first 12 hours of the start of the test. Apparently, steady-state conditions are not established in the shallow unit as no leveling trend is observed on the hydrographs for KBA-11-2 and KBA-11-10A (Figures 2-15 and 2-17). Water levels within this shallow unit continue to drop throughout the course of the test, as shown on Figures 2-15 and 2-17. This may be drainage from the shallow unit into the underlying aquifer units.

Based on corrected drawdowns discussed below, the GWE Phase I system is interpreted to be influencing all three of the aquifer units. As shown in Table 2-2, corrected drawdown values range from -0.04 to 0.35 feet within the shallow aquifer unit at distances ranging from 435 feet to 70 feet from the closest recovery well(s) (distances are provided in Table 2-1). Corrected drawdowns range from 0.10 to 1.56 feet within the intermediate aquifer unit with radial distances ranging from 1,000 feet to 31 feet. Corrected drawdowns range from 0.11 to 0.77 feet within the deep unit at distances ranging from 639 to 109 feet.

A drawdown map of the Phase I GWE system at steady-state conditions is provided as Figure 2-19. This drawdown map is based on corrected drawdown within the intermediate unit. The drawdown map was developed by plotting the corrected drawdown values listed in Table 2-2 on a scaled map. Contours of equal drawdown were drawn using a process similar to that used to develop a potentiometric contour map. The drawdown versus distance graphs in Appendix B facilitated the interpretation of the contours. The drawdown contour map is an estimate of the change in potentiometric head that may be expected to occur in the intermediate

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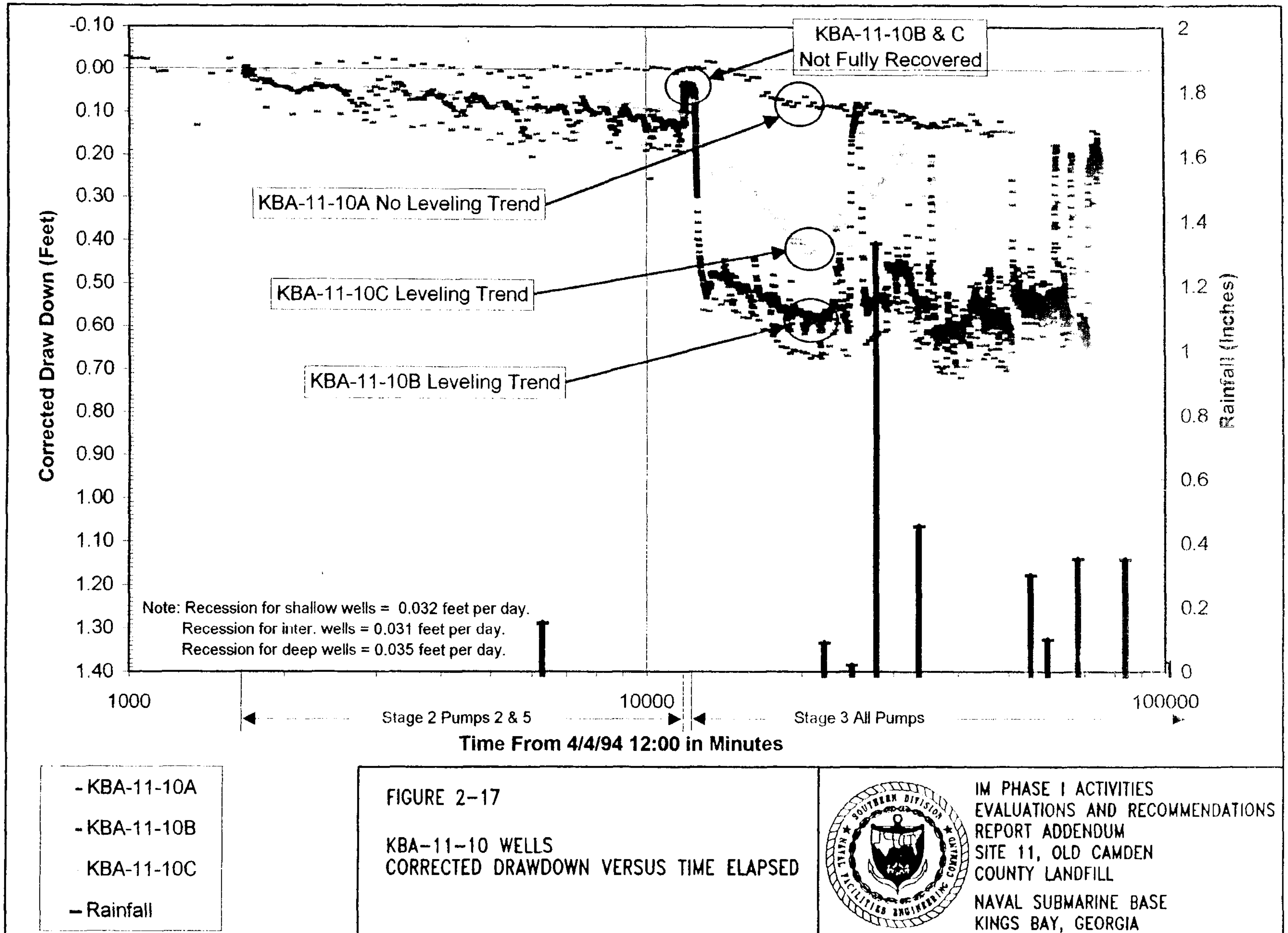

FIGURE 2-17

KBA-11-10 WELLS
CORRECTED DRAWDOWN VERSUS TIME ELAPSED

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
SITE 11, OLD CAMDEN
COUNTY LANDFILL

NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

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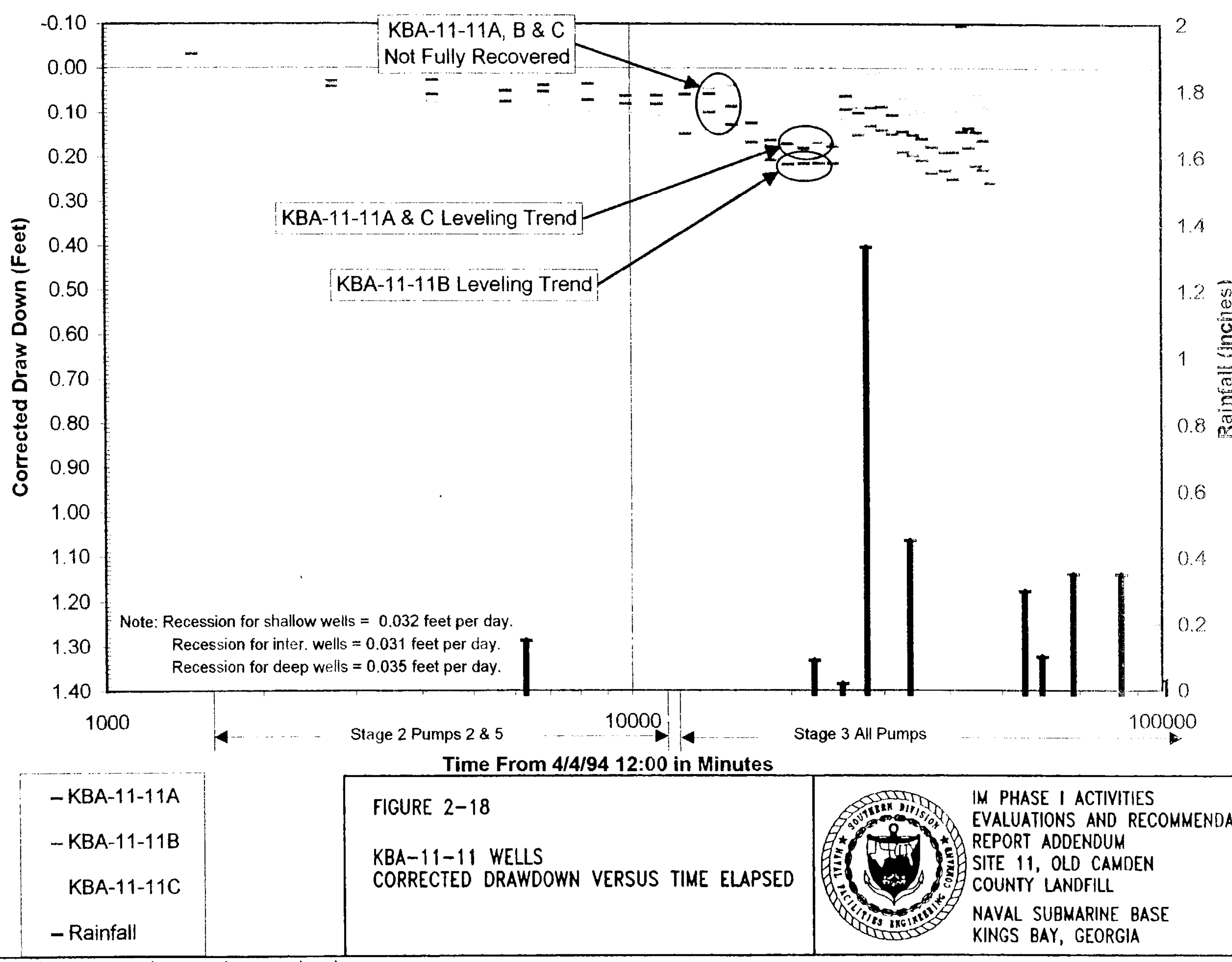

FIGURE 2-18

KBA-11-11 WELLS
CORRECTED DRAWDOWN VERSUS TIME ELAPSED

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
SITE 11, OLD CAMDEN
COUNTY LANDFILL
NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

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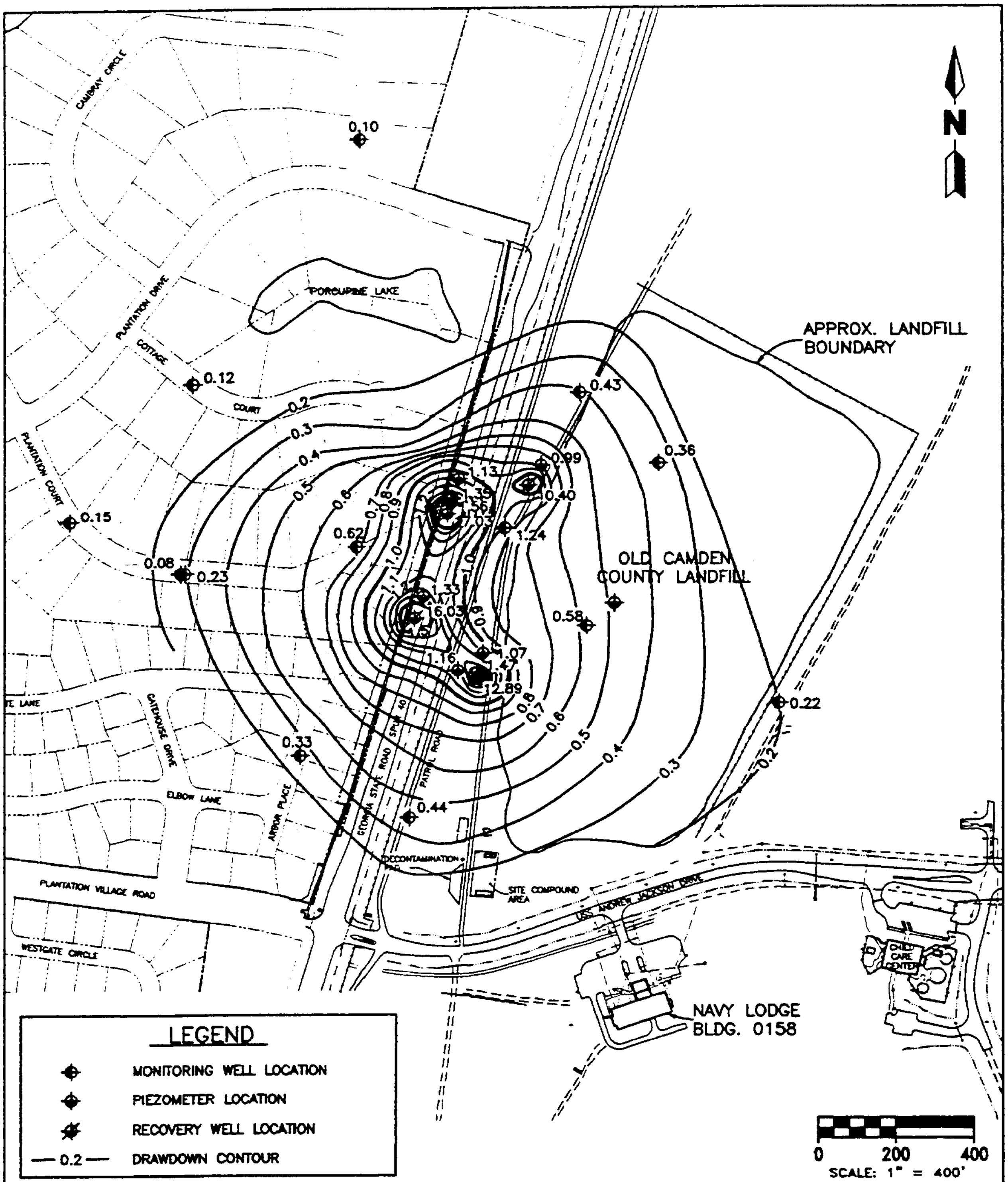

FIGURE 2-19

DRAWDOWN BETWEEN 4/4/94 AND 4/19/94
CORRECTED FOR REGIONAL RECESSION;
INTERMEDIATE UNIT

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
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SITE 11, OLD CAMDEN
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D:\DWG\ABB\08523-24\EVAL_REC\FIG_DD4\DMF\960324 zone of the surficial aquifer as a result of pumping stresses and at steady-state conditions.

Vertical Influence. Vertical influence of the Phase I GWE system is exhibited by similar head response in paired and clustered wells completed within the intermediate and deep units. Table 2-3 provides a comparison of drawdowns from clustered wells relative to vertical position (elevation mlw) within each aquifer unit. GWE influence in the shallow unit is limited by design. Contaminant concentrations of greatest concern are below the shallow unit (ABB-ES, 1992). Four of the recovery wells are screened in the intermediate to deep units. Screened intervals transect these units from elevations 12.5 mlw to -42.3 mlw, as indicated in Table 2-1. These 40- to 50-foot screened recovery wells were placed in zones of known contamination (previous RFI cone penetrometer testing/ HydroCone studies) (ABB-ES, 1992). These wells penetrate approximately 90 to 95 percent of the aquifer, so partial penetration effects of these pumping wells are minimal.

The empirically derived capture zone was based on measured water levels and corrected drawdowns within the intermediate aquifer unit. This horizon of the surficial aquifer, between 5 feet mlw to elevation -20 feet mlw, is the primary horizon of VOC contaminant transport (ABB-ES, 1992 and 1994b). The capture zone was generated using equipotential contours based on corrected water levels and superimposition of the drawdown map on the unstressed, potentiometric surface map (Figure 2-20).

If water level measurements from the existing wells and piezometers are used to develop a potentiometric map, the data points are too sparse to show the head changes that occur over relatively small distances (in plan view) in the vicinity of the recovery wells. Superimposing a potentiometric map based on unstressed water level data, such as April 4, 1994, onto the corrected drawdown map, enables an interpreted, stressed potentiometric surface to be developed. At each node where an unstressed potentiometric contour crosses a drawdown contour, an interpreted value is plotted. The interpreted values are more numerous than the measured values that can be obtained by measuring water levels in the available wells and piezometers. Although interpretive, the larger number of values are useful to allow the resulting interpreted equipotential map to show contours at a level of detail sufficient to estimate flow directed towards recovery wells.

This superimposition process provides increased resolution, through an interpretive approach, within the area surrounding the recovery wells. The superimposition process includes the following steps:

- Head potential at nodes created from the intersection of the drawdown contours with the (unstressed) potentiometric contours interpreted and plotted.
- These interpreted values are then contoured.
- The capture zone is interpreted by generating flowlines normal to equipotential contours.
- Flowlines leading to the recovery wells form the shape and width of the interpreted capture zone.

Table 2-3
Summary of Corrected Drawdown by Well Cluster

Interim Measure Phase I Activities:
Evaluation and Recommendations Report
Site 11, Old Camden County Landfill
Naval Submarine Base
Kings Bay, Georgia

Well Clusters	Screen Elevation (feet mlw)	Aquifer Unit	Corrected Drawdown (feet)
KBA-11-2	30.32 to 20.32	Shallow	[1]0.14
PS-3	3.04 to -1.97	Intermediate	1.07
PS-9	1.27 to -3.73	Intermediate	1.56
PD-8	-17.97 to -22.97	Intermediate	1.35
KBA-11-3A	29.43 to 19.43	Shallow	[1]0.35
KBA-11-3B	-4.61 to -14.61	Intermediate	0.43
KBA-11-3C	-53.32 to -63.32	Deep	0.31
KBA-11-10A	25.82 to 15.82	Shallow	[1]0.09
KBA-11-10B	-3.67 to -13.67	Intermediate	0.58
KBA-11-10C	-41.72 to -51.72	Deep	0.42
KBA-11-11A	8.95 to -1.05	Shallow	[1]0.18
KBA-11-11B	-10.66 to -20.66	Intermediate	0.22
KBA-11-11C	-34.70 to -44.70	Deep	0.19
KBA-11-13A	1.70 to -8.30	Intermediate	1.24
PD-6	-27.67 to -32.67	Deep	0.77
KBA-11-13B	-45.84 to -55.84	Deep	0.47
KBA-11-17A	5.71 to -4.29	Intermediate	0.23
KBA-11-17B	-9.39 to -19.39	Intermediate	0.08
KBA-11-17C	-49.94 to -59.94	Deep	0.11
KBA-11-19A	16.05 to 6.05	Shallow	[1]0.22
KBA-11-19B	-34.05 to -44.05	Deep	0.22
KBA-11-22A	23.38 to 13.38	Shallow	[1]0.10
KBA-11-22B	-6.47 to -16.47	Intermediate	0.36

[1] Steady-state conditions achieved in intermediate and deep aquifer units. Shallow unit continues to draw down due to drainage to lower aquifer units. Corrected drawdowns of these shallow aquifer unit wells represent drawdowns at the time that intermediate and deep units achieve steady-state conditions. Actual corrected drawdowns continue to drop and may be closer to intermediate and deep unit(s) drawdown values.

Note: mlw = mean low water.

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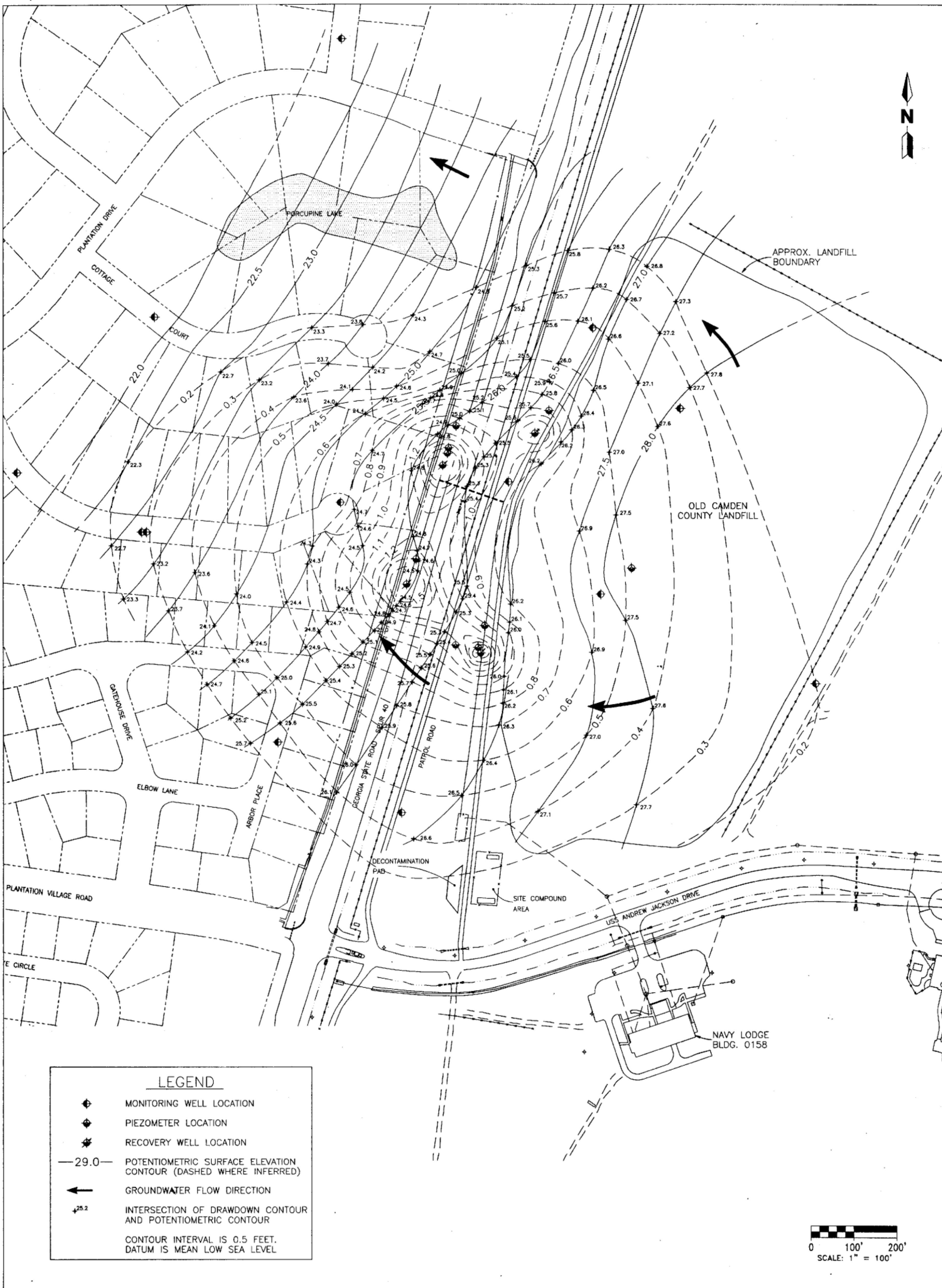

FIGURE 2-20

SUPERIMPOSITION BASE MAP,
DRAWDOWN SUPERIMPOSED ON UNSTRESSED
POTENTIOMETRIC SURFACE

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
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This empirically derived capture zone is shown on Figure 2-21. The corrected water level elevations listed in Table 2-2 for intermediate depth wells and piezometers are posted on Figure 2-21. Of the 21 monitoring wells and piezometers posted, two values (KBA-11-12 and KBA-11-16) do not fit the contours drawn using the superimposition node values. This may be due to external causes, such as PIW or city water usage near KBA-11-16, or may be error associated with the data evaluation process. Overall, the corrected elevations fit the expected head distribution interpreted from the superimposition map. The width of this capture zone is approximately 1,130 feet. Flowlines sweep northwestward and westward toward recovery wells RW-1 and RW-4, as well as southwestward and westward toward RW-2, RW-5, and RW-3 to form the shape of the capture zone. The interpreted flowlines provide an estimate of what the flow regime may look like in the intermediate unit during IM operation. Follow-on activities are being planned to collect chemical data that will enable a more quantitative evaluation of the effects the IM system has on contaminant migration, flow rates, and concentration trends.

2.3.3 Numerical Modeling Capture Zone Analysis This provides a brief overview of the two-dimensional, numerical groundwater flow model, model domain and grid setup, modeling assumptions and input parameters, and the Phase I capture zone results. The model was used as a third means of estimating the capture zone created by the GWE system.

Model Setup. A capture zone model for the Phase I GWE system was created using FLOWPATH™ (developed by Waterloo Hydrologic Software, Inc.), a finite difference model for two-dimensional, steady-state flow through a heterogeneous, saturated, anisotropic, porous medium.

The model domain developed for this evaluation is 3,000 by 3,000 feet. The size of the model domain was selected to provide a focus on Site 11 and allow constant head boundaries to be set outside of the GWE well(s) radius of influence. A computer-aided drafting and design (CADD) drawing of Site 11 and the surrounding area was imported into FLOWPATH™ and rotated 25 degrees counterclockwise so that model no-flow boundaries were parallel to the general direction of flow as it is currently understood. New information that may show the flow at the model boundaries is different than currently understood has not been adequately evaluated to incorporate into these interpretations. The landfill is centrally located in the model domain. A rectangular grid was superimposed over the CADD drawing, forming 957 (29 by 33) grid cells. Figure 2-22 shows the location of the Site 11 landfill, GWE wells, and the model grid.

FLOWPATH™ uses a block-centered finite difference scheme so that aquifer properties for this unconfined aquifer are defined for each block. Aquifer parameters were based on site-specific data collected during the Phase I GWE installation and operation activities. Hydraulic conductivity and effective porosity were set as constants throughout the model domain. Constant heads were set 550 feet east of the site boundary to simulate the potentiometric contour pattern(s) within the landfill. If a groundwater divide exists either within the limits of the landfill or along the eastern boundary (discussed in Section 2.2, creating a constant head boundary provides a more conservative analysis because (1) constant-head produces a steeper hydraulic gradient across the landfill than no-flow and (2) a steeper hydraulic gradient produces a smaller capture zone width. Constant heads were set at elevation 28.75 to 29.5 feet mlw, along the

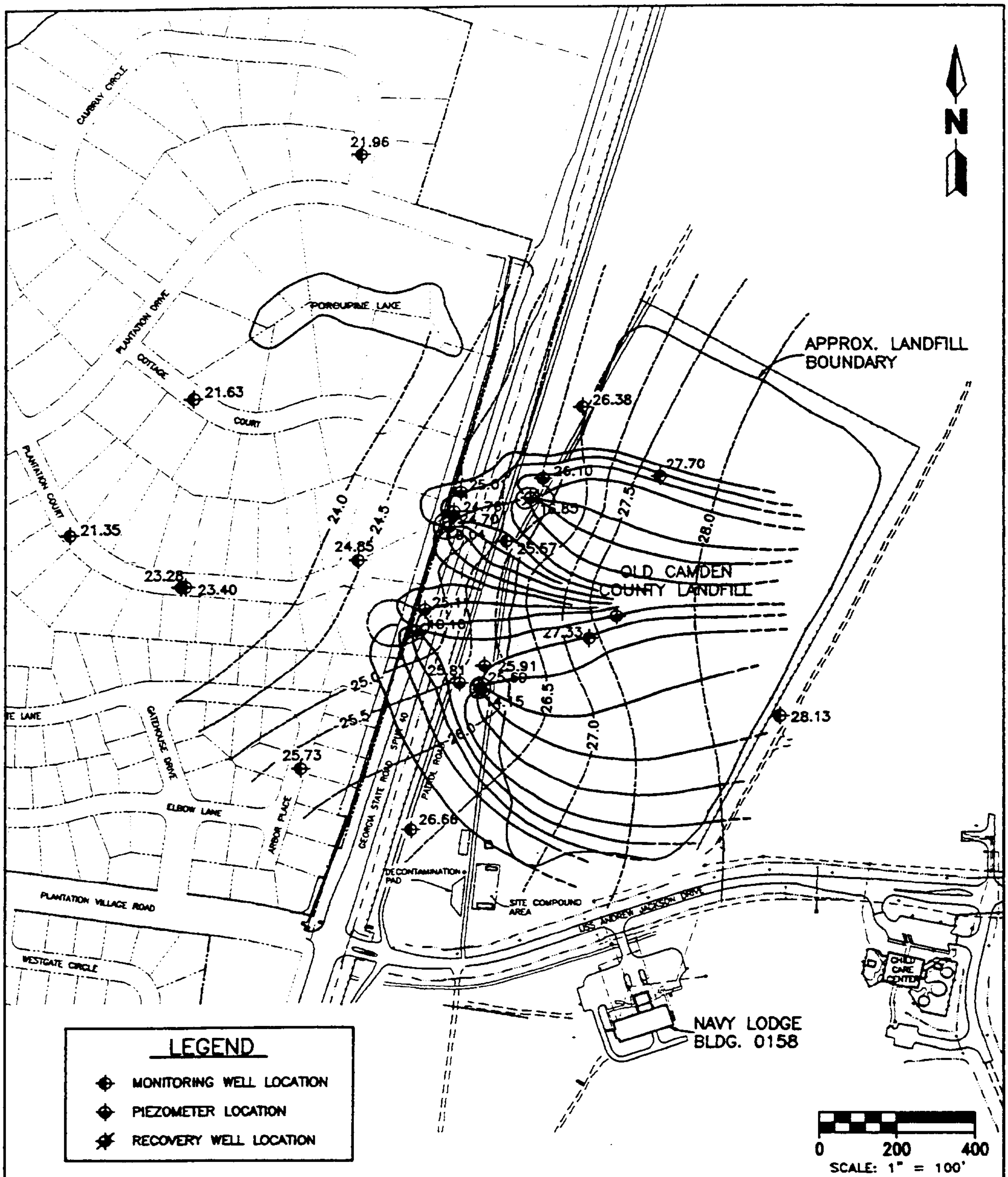

FIGURE 2-21

INTERPRETED CAPTURE ZONE, INTERMEDIATE AQUIFER UNIT 5 TO -20 FEET MLW

IM PHASE I ACTIVITIES EVALUATIONS AND RECOMMENDATIONS REPORT ADDENDUM
SITE 11, OLD CAMDEN COUNTY LANDFILL
NAVAL SUBMARINE BASE KINGS BAY, GEORGIA

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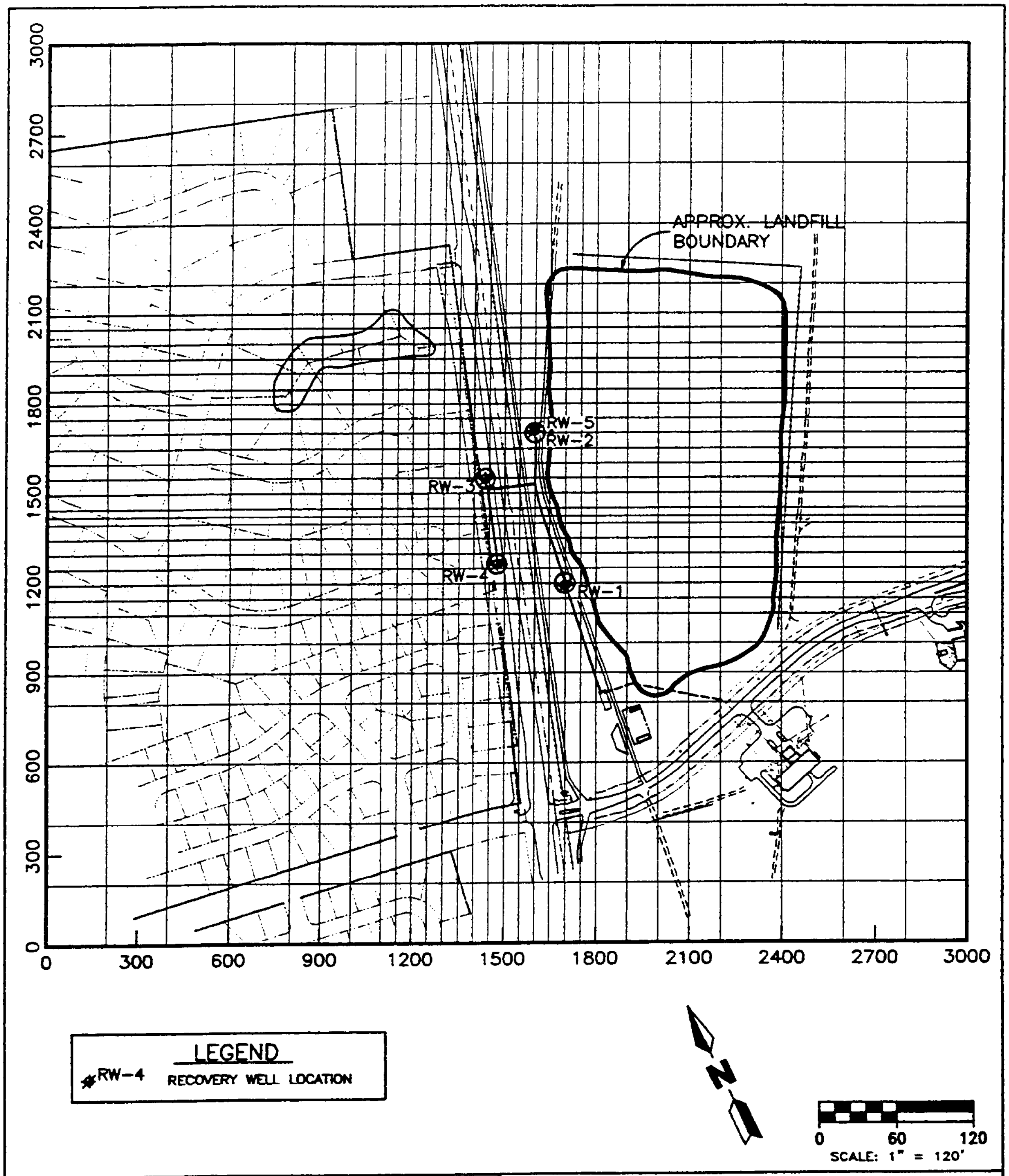

FIGURE 2-22

FLOWPATH™ MODEL GRID WITH PHASE I WELL LOCATIONS

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
SITE 11, OLD CAMDEN COUNTY LANDFILL
NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

D:\DWG\ABB\08523-24\EVAL_REC\FIG_GRID\DMF\960322 eastern boundary of the model domain, approximately 550 feet upgradient of the landfill, and 1,300 feet upgradient of the GWE system. Constant heads were set at elevation 18.25 to 20.1 feet mlw, approximately 1,600 feet downgradient of the landfill and 1,400 feet downgradient of the GWE system. Based on geologic logs of borings drilled during the RFI activities, the bottom of the aquifer slopes westward from elevation -45.0 feet mlw at the eastern boundary of the domain to elevation -60.0 feet mlw at the western boundary of the domain. Net recharge was set at several rates based upon infiltration and evapotranspiration values for the various surface materials, topography, and vegetation. Net recharge estimates range from 2.4 inches per year (in/yr) to 19.9 in/yr, with a weighted average of 6.3 in/yr across the model domain. These estimates were developed from the application of runoff coefficients to precipitation data obtained from the National Climatic Center. Evapotranspiration estimates were generated using the "Thomas abcd Method" (Gupta, 1989). Discharge values from the recovery wells range from 7.5 gpm at RW-1 and RW-3 to a combined flow of 13.1 gpm at the RW-2/RW-5 location. Model input and specific information pertaining to the FLOWPATH™ model iterations are provided in Table 2-4.

Model Implementation. FLOWPATH™ model runs were generated for the following three groundwater flow scenarios. The first two scenarios simulate (1) groundwater flow under natural conditions without any pumping and (2) extraction of contaminated groundwater from the aquifer using the Phase I existing recovery wells. The third scenario involved continued extraction of groundwater from the Phase I wells with additional discharge from one Phase II recovery well. This predictive scenario is discussed in Appendix C of this report addendum. Model-generated output from this scenario is also included in this appendix.

Groundwater flow under natural, unstressed, conditions was simulated to calibrate the model. The model closely matches the unstressed conditions. Details on the model calibration are contained in the IM Phase I Activities: Evaluation and Recommendations Report (ABB-ES, 1994a).

Flow within the surficial aquifer is represented by pathlines generated by the model and shown on Figure 2-23 (Scenario 1). These pathlines are normal to the potentiometric contours and represent movement of a particle of groundwater within the aquifer. These particles track direction of groundwater flow as well as distance relative to travel time. Particles were released at key locations within the Site 11 area, near monitoring wells to simulate contaminant movement. The pathlines on this figure represent 7 years of particle movement.

A slight mounding effect, indicated by the westward arc-shaped potentiometric contours, was simulated in the landfill area of the model by increasing the infiltration rate in that specific area. Overall average net recharge in the model domain was 6.3 in/yr; net recharge within the landfill area was set at 19.9 in/yr.

Simulation of groundwater flow by this two-dimensional model is consistent with actual flow within the surficial aquifer in the area monitored during previous RFI and IM activities. Gradients and direction of flow are similar to those interpreted from potentiometric maps developed from the RFI monitoring wells, such as on Figure 2-10.

Table 2-4
Modeling Assumptions and Input Parameters for FLOWPATH™ Model

Interim Measure Phase I Activities:
Evaluation and Recommendations Report Addendum
Site 11, Old Camden County Landfill
Naval Submarine Base
Kings Bay, Georgia

Parameter	Area-Specific Values	Default Values
Hydraulic Conductivity[1] (ft/day)		
Aquifer matrix		14.8
Effective Porosity[2]		
Aquifer matrix		0.25
Constant Heads (feet mlw)		
West northwest: 21 nodes		18.25 to 20.1
East southeast: 17 nodes		28.75 to 29.5
Bottom of Aquifer (feet mlw)		
West northwest to east southeast	-60.0 to -45.0	-52.5
Recharge[3] (ft/day)		
Infiltration		
- residential area	0.01005	0.01005
- forest/wooded	0.00975	
- cultivated/grassland	0.01070	
- landfill area	0.01305	
Evapotranspiration		
- residential area	0.0092	0.0092
- forest/wooded	0.0092	
- cultivated/grassland and landfill	0.0085	
Recovery Well Discharge		
Phase I RW-1	7.5 gpm	
Phase I RW-2/RW-5	13.1 gpm	
Phase I RW-3	7.5 gpm	
Phase I RW-4	7.9 gpm	
Phase II RW-6	9.7 gpm	

1 Hydraulic conductivities are based on aquifer test results.
2 Effective porosity values are assumed, based on typical values for fine-grained sands (Driscoll, 1988).
3 Recharge: infiltration values developed from application of runoff coefficients to precipitation data obtained from National Climatic Center and Evapotranspiration, developed from the "Thomas abcd Method" (Gupta, 1989). Net recharge is equal to the difference of infiltration and evapotranspiration.

Notes: ™ = trademark.
ft/day = feet per day.
mlw = mean low water.
gpm = gallons per minute.

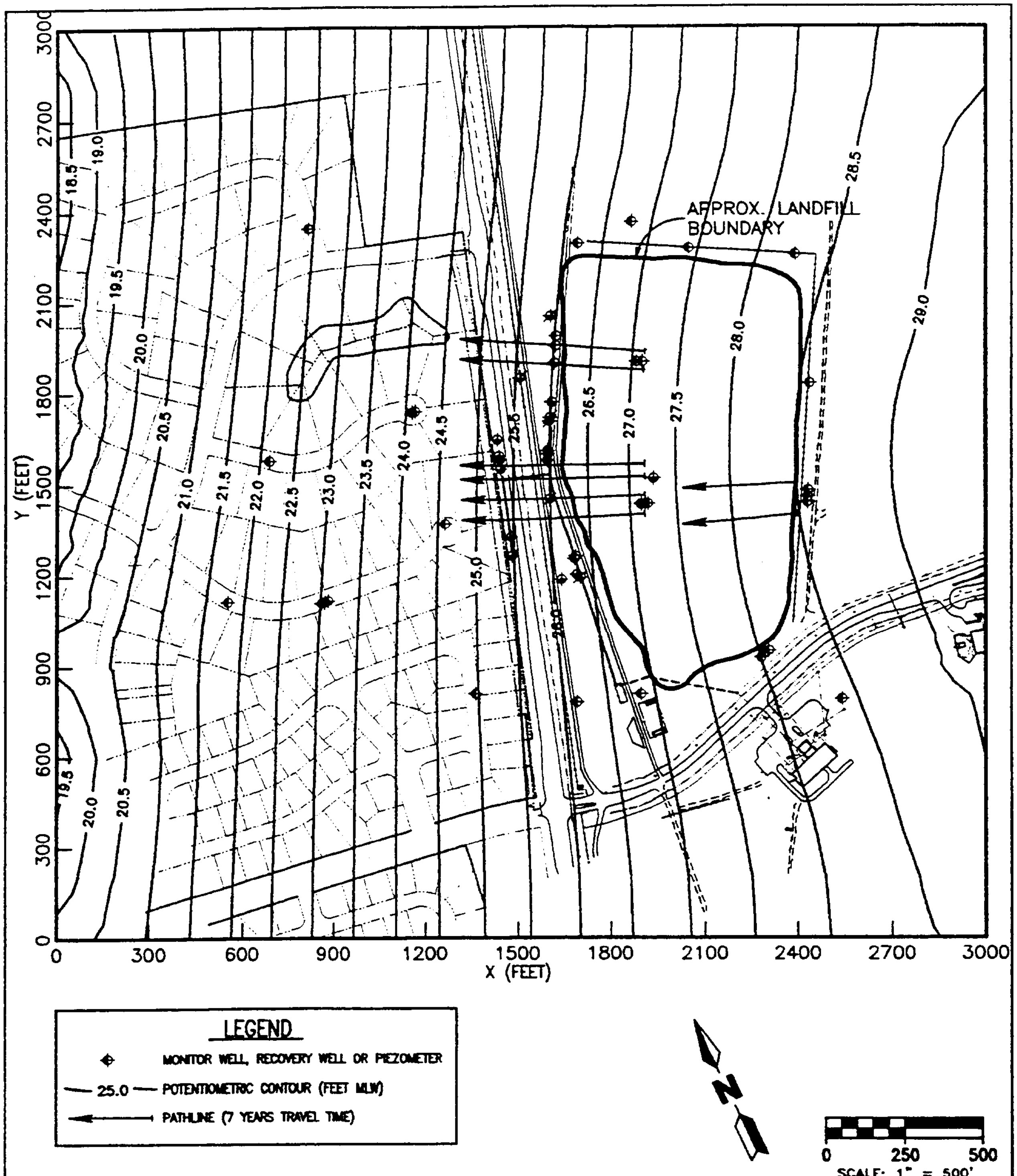

FIGURE 2-23
SCENARIO 1:
SIMULATED POTENTIOMETRIC SURFACE MAP;
NATURAL GROUNDWATER FLOW,
UNSTRESSED CONDITIONS
FLOWPATH™ MODEL FILE: S11NATPO.DXF

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
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The second scenario was generated to simulate groundwater flow under pumping-stressed, steady-state conditions. This simulation provides an interpretation of flow within the surficial aquifer during Phase I GWE system operations. Flow is represented by pathlines and velocity vectors generated by the model and shown on Figure 2-24. This figure also provides contours of drawdown created by the GWE system. Particles were released at the same key locations discussed above. The pathlines on this figure represent 7 years of particle movement.

The velocity vectors represent a relative magnitude of movement (relative to the average linear flow velocity, or seepage velocity and direction). Smaller arrows represent slower movement, and larger arrows represent faster movement. Model output indicates that velocities range from 0.077 ft/day to 0.600 ft/day – an average of 0.204 ft/day within the model domain – during the Phase I GWE system pumping. Under the unstressed, natural flow conditions, the velocities range from 0.058 ft/day to 0.359 ft/day with an average of 0.202 ft/day within the model domain. As indicated by the velocity vectors, groundwater flow is directed toward the Phase I GWE system recovery wells. Flow, as indicated by the vectors between RW-3 and RW-4, is influenced by drawdown (natural gradient is decreased or flattened) and, therefore, flow velocities are decreased, but based on the interpreted flow regime, westward flow between RW-3 and RW-4 is not directed to recovery wells.

Drawdowns ranged from zero feet to 3.0 feet as contoured by the model. The pattern created by these contours is similar to the pattern generated by the interpretation of the corrected drawdowns discussed in Subsection 2.3.2 and shown on Figure 2-21. The greater drawdowns estimated by the model as compared to the interpreted values derived empirically may be associated with differences in pumping duration (7 years as compared to 15 days) and heterogeneities in the aquifer that were not accounted for in the model.

The existing recovery well array does provide an overlapping effect caused by well interference. This phenomenon creates a synergy between wells. Drawdowns are additive because drawdown created by one well is summed with the drawdown created by additional wells within the radii of influence of those pumping wells.

The capture zone generated by this second scenario is approximately 1,000 feet wide and covers most of the lower three fourths of the landfill. A small window of escape is predicted. This capture zone is generated from a reverse-tracking process that releases particles from the pumping well(s) and directs these particles upgradient and normal to equipotential contours. These reverse-track pathlines represent flowlines toward a pumping well(s). Groundwater between the KBA-11-10 series well cluster and north to the KBA-11-22 series flows in the general westerly direction toward recovery wells RW-2, RW-5, and RW-3 as shown on Figure 2-25. Groundwater slightly south of the KBA-11-10 series to a lateral distance of approximately 450 feet flows westerly toward recovery wells RW-2 and RW-4. The model indicates that some pass-through may occur as shown by the gap between the north capture area and the southern capture area. Pathlines emanating from the area just south of the KBA-11-10 series wells are directed through the separated capture zone; however, as discussed above, the groundwater flow velocities are decreased. Due to this potential for contaminant slip-through, an alternative GWE system scenario was evaluated for the IM Phase II and discussed in Subsection 3.3.2 of this addendum.

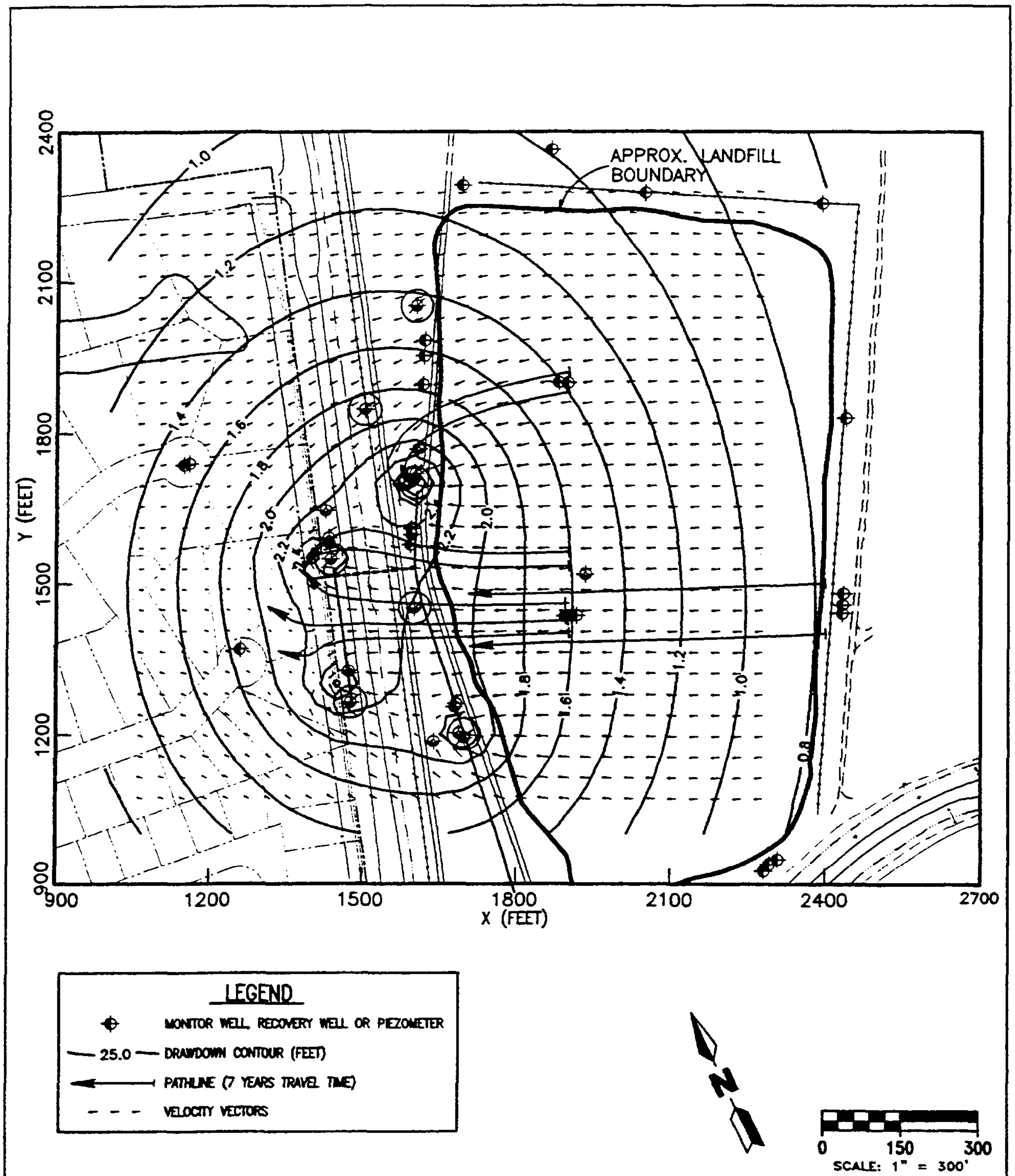

FIGURE 2-24

SCENARIO 2:
SIMULATED DRAWDOWN MAP; PHASE I
GROUND WATER EXTRACTION SYSTEM PUMPING
FLOWPATH™ MODEL FILE: S11CZ1ZD

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
SITE 11, OLD CAMDEN
COUNTY LANDFILL
NAVAL SUBMARINE BASE
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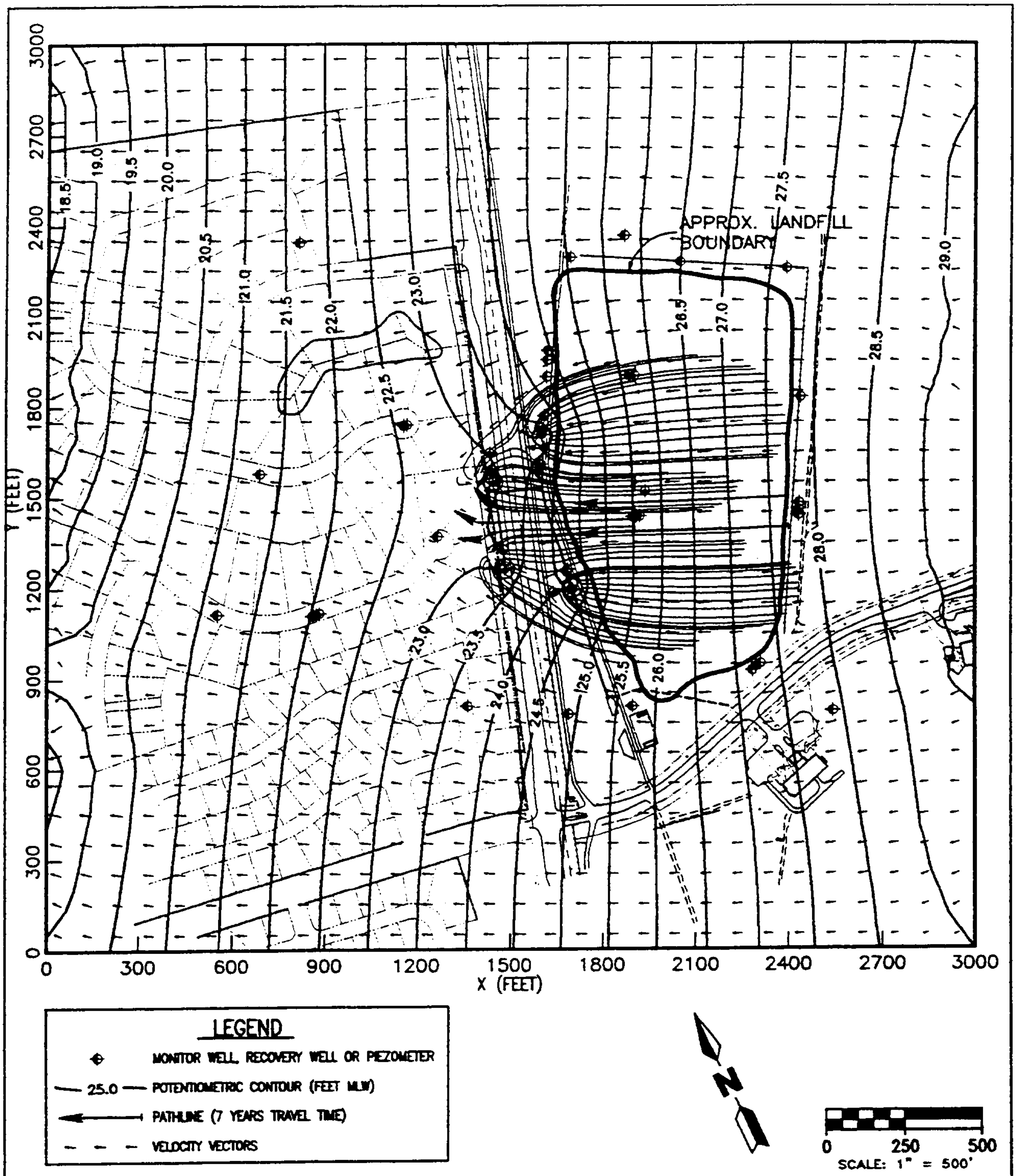

FIGURE 2-25

SIMULATED CAPTURE ZONE; PHASE I GROUND WATER EXTRACTION SYSTEM PUMPING FLOWPATH™ MODEL FILE: S11CZ1PO.DXF

SOUTHERN DIVISION NAVAL FACILITIES ENGINEERING COMMAND

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
REPORT ADDENDUM
SITE 11, OLD CAMDEN
COUNTY LANDFILL

NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

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<u>2.3.4 Capture Zone Analysis Summary</u> Three methods of analysis were used to evaluate capture zone width, each applying a different approach using theory, practical interpretation, or groundwater flow principles and mathematical relationships. The three methods, each deriving capture zone-width estimates from a different approach, predicted a width of 1,100 feet (mass balance), 1,130 feet (empirical), and 1,000 feet (modeled).

3.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter presents conclusions of the additional performance data evaluation Phase I system operation. Recommendations are also included for the continued operation and Phase II system upgrade. These include (1) redevelopment of the existing recovery wells to decrease linear head losses and thereby increase the well efficiencies, (2) treatment of the organic vapors generated by offgases from the DAT unit, and (3) the possibility of additional recovery wells to address regulatory concerns.

3.1 RECOVERY WELL EFFICIENCIES. As discussed in the evaluation and recommendations report (ABB-ES, 1994a), well efficiencies based on the Hantush-Bierschenk Method calculation of linear and nonlinear well losses are relatively high; however, observed drawdowns are significantly greater in the recovery wells than in the surrounding aquifer. This may indicate that the observed inefficiencies are caused by formation linear head losses (formation densification, grain-realignment, and/or well bore wall [skin effect] damage, as discussed in Kruseman and de Ridder [1989]). Because of these uncertainties, existing wells will be redeveloped in a phased approach: (1) an existing recovery well will be redeveloped, (2) procedures will be refined to optimize steps based on site-specific conditions, and (3) the remaining recovery wells will be redeveloped following these refined procedures.

The existing five recovery wells should be redeveloped as part of the Phase II activities. Redevelopment will likely improve well efficiencies, resulting in an increased specific capacity (discharge per foot of drawdown in the well) and better connection to the aquifer. This would allow increased extraction rates which would increase the size of the capture zones. Current plans are to reduce the potential of slip-through by adding one additional recovery well and simply operating the existing recovery wells at the same discharge but increased efficiency during Phase II. The redeveloped wells will have the capacity to allow increased extraction rates should this be desirable in the future.

The well development activities will focus on clearing the well of mineral precipitation, biological growth, and fine-grained material from the formation and any bentonite that may have been left behind from the drilling fluids. These activities will include (1) removing all down-hole equipment and verifying total depth of the well; (2) flushing with an acid to remove mineral buildup and biological growth; (3) flushing with liquid catalyst dispersant to remove biological growth and suspended fine-grained material from the filter pack, the formation, and any bentonite that may have been left behind from drilling; (4) mechanical surging while monitoring pH; and (5) pumping to remove sloughed-off and detrital material from the well. The proposed Phase II recovery well will be developed following these same procedures.

3.2 INTERIM MEASURE TREATMENT SYSTEM - OFFGAS EMISSIONS. An effluent concentration of 0.37 milligram per liter for vinyl chloride was established as the performance criterion for the vapor treatment system. Vinyl chloride was chosen as the indicator compound for compliance due to the toxicity of this compound. This criterion ensures the protection of human health and was approved by GEPD prior to the installation of the IM system. This criterion was developed based on SCREEN modeling, State Ambient Air Concentration determinations (GEPD, 1984), and additional safety factors and represents the most stringent control standard among all applicable State and Federal air control regulations.

Admittedly, the carbon treatment of the air stream is only marginally effective. This was predicted prior to selection of this treatment method. However, historical air sampling data (provided in the 1994 and 1995 Southern Division, Naval Facilities Engineering Command bimonthly reports for the Phase I IM system operation [ABB-ES, 1994c]) confirm that the performance criterion for vinyl chloride has not been exceeded. Furthermore, sampling data also indicate that influent air concentrations have also remained below the performance criteria. Based on this information, an engineering evaluation will be conducted during Phase II design activities to determine the need for continued granular-activated carbon treatment of offgas emissions.

3.3 GROUNDWATER EXTRACTION SYSTEM CAPTURE ZONE RESULTS.

3.3.1 Phase I Groundwater Extraction System The interpreted capture zone widths for the three approaches, or methods of analysis, are very similar and indicate that the GWE system is able to hydraulically control VOC and semivolatile organic compound contaminants migrating from the site in the groundwater. Table 3-1 summarizes the approximate widths of the capture zone.

Table 3-1
Capture Zone Method of Analysis Summary

Interim Measure Phase I Activities:
Evaluation and Recommendations Report Addendum
Site 11, Old Camden County Landfill
Naval Submarine Base
Kings Bay, Georgia

Approach	Approximate Width of Capture Zone
Mass Balance Approach	1,100 feet
Empirical Approach	1,130 feet
Numerical Flow Model	1,000 feet

As shown only by the FLOWPATH™ modeling approach, the existing Phase I recovery well array may allow some slip-through, as shown on Figure 2-23. However, flow velocities are reduced by controlling and altering the gradient.

3.3.2 Phase II Upgrades The overall objective of the proposed Phase II IM activities is to increase the hydraulic containment of the area of the contaminant plume on the western side of Site 11 that is the target area for the IM. The proposed method of control is upgrading the existing GWE IM system with an additional recovery well and engineered enhancements. Until cleanup standards are finalized, the extent of any other future remedial efforts cannot be evaluated. The Phase II upgrades are consistent with the original objectives of the IM.

The addition of the proposed recovery well is designed to provide a continuous capture zone for an area of groundwater known to have high VOC concentrations.

The existing wells are located in the most concentrated portions of the contaminant plume. The proposed new well is also located in an area of high VOC concentrations. This system will control the groundwater gradient and prevent migration of contaminants from high concentration zones along the western boundary of the landfill.

Additional discussion regarding the proposed Phase II GWE and treatment system is provided in the Plan for Interim Measure Phase II Upgrades (ABB-ES, 1996). Other tasks proposed for implementation of the IM Phase II include installation of performance monitoring wells, continued performance monitoring, evaluation of the existing treatment system to accept increased loading, design of treatment system modifications (if required), modification of the LAS discharge permit (if required), and development of a performance monitoring plan. As these activities are planned and implemented, the scope of the cleanup objectives are expected to broaden as the RCRA corrective action program at Site 11 progresses towards final corrective measures for all contaminants and media of potential concern.

REFERENCES

ABB Environmental Services, Inc. (ABB-ES), 1994a, Interim Measure Phase I Activities: Evaluation and Recommendations Report, Site 11, Old Camden County Landfill, Naval Submarine Base, Kings Bay, Georgia: prepared for Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM), Charleston, South Carolina, November.

ABB-ES, 1994b, Resource Conservation and Recovery Act Facility Investigation Report for Sites 5 and 16 and Site History and File Information for Site 12, Naval Installation Restoration Program, Naval Submarine Base, Kings Bay, Georgia: prepared for SOUTHNAVFACENGCOM, Contract No. N63467-89-D-0317.

ABB-ES, 1994c, Bimonthly letter reports for Interim Measure activities at Site 11, Old Camden County Landfill, Naval Submarine Base, Kings Bay, Georgia: prepared for SOUTHNAVFACENGCOM, Contract No. N62467-89-D-0317, refer to letters between April 1994 and November 1995.

ABB-ES, 1996, Plan for Interim Measures, Phase II Upgrades, Site 11, Old Camden County Landfill, Naval Submarine Base, Kings Bay, Georgia: prepared for SOUTHNAVFACENGCOM, Contract No. N63467-89-D-0317, March.

Kruseman and de Ridder, 1989, Analysis and Evaluation of Pumping Test Data, Bulletin 11, International Institute for Land Reclamation and Improvement/ILRI, 4th edition.

Georgia Department of Natural Resources, 1984, Guideline for Ambient Impact Assessment of Toxic Air Pollutant Emissions, July.

Georgia Environmental Protection Division, notice of deficiency letter, June 14, 1995.

APPENDIX A

EVALUATION PROCEDURES

EVALUATION PROCEDURES

1. Uploaded data (converted water levels from feet below top of casing to elevations relative to mean low water [mlw]).

2. Created hydrographs. Showed water-level elevation data graphically versus barometric pressure and date; evaluated barometric effects for significance.

3. Determined that barometric effects were observed but were insignificant when compared to rain, regional recession, and pumping effects.

4. Determined recessional factors for various time frames and wells. Recessional factors are based on trend analyses of the recessional slope(s) on the hydrographs.

5. Determined a representative recessional factor for shallow, intermediate, and deep unit wells using KBA-11-6, KBA-11-11C, and KBA-11-18 as control wells. These wells were selected based on distance from the five recovery wells. A greater distance from the pumping source(s) minimizes pumping-induced stress response (drawdown) at that well.

6. Plotted well drawdown for Stage 3 on semi-log plot.

7. Added recessional factor to Stage 3 semi-log plots; determined that most drawdown values were questionable because water levels had not fully recovered during a 10-hour period between Stage 2 shutdown and Stage 3 start up.

8. Accounted for this residual drawdown by adding Stage 2 data to drawdown semi-log plots. Simply stated: corrected drawdowns are based on difference of water level (at times 'x') referenced static water levels at beginning of Stage 2 (April 5, 1994).

9. Used corrected drawdown plots to determine that steady state occurred approximately 9,000 minutes into the Stage 3 pumping test (April 19, 1994). Steady-state conditions were graphically interpreted from selected well plots (see Figures 2-15 through 2-18). Drawdown values begin to stabilize in the intermediate and deep units at approximately 9,000 minutes.

10. Used April 19, 1994, 6:00 a.m. (or as close to that date and time as available data allowed), as steady-state elevation for well water levels.

11. Determined well drawdown based on difference between above water-level elevations.

12. Corrected actual drawdowns for regional recession to obtain a corrected drawdown due to pumping.

13. Plotted corrected drawdowns from intermediate unit wells and as a function of distance on a base map to create drawdown contours for a site drawdown map.

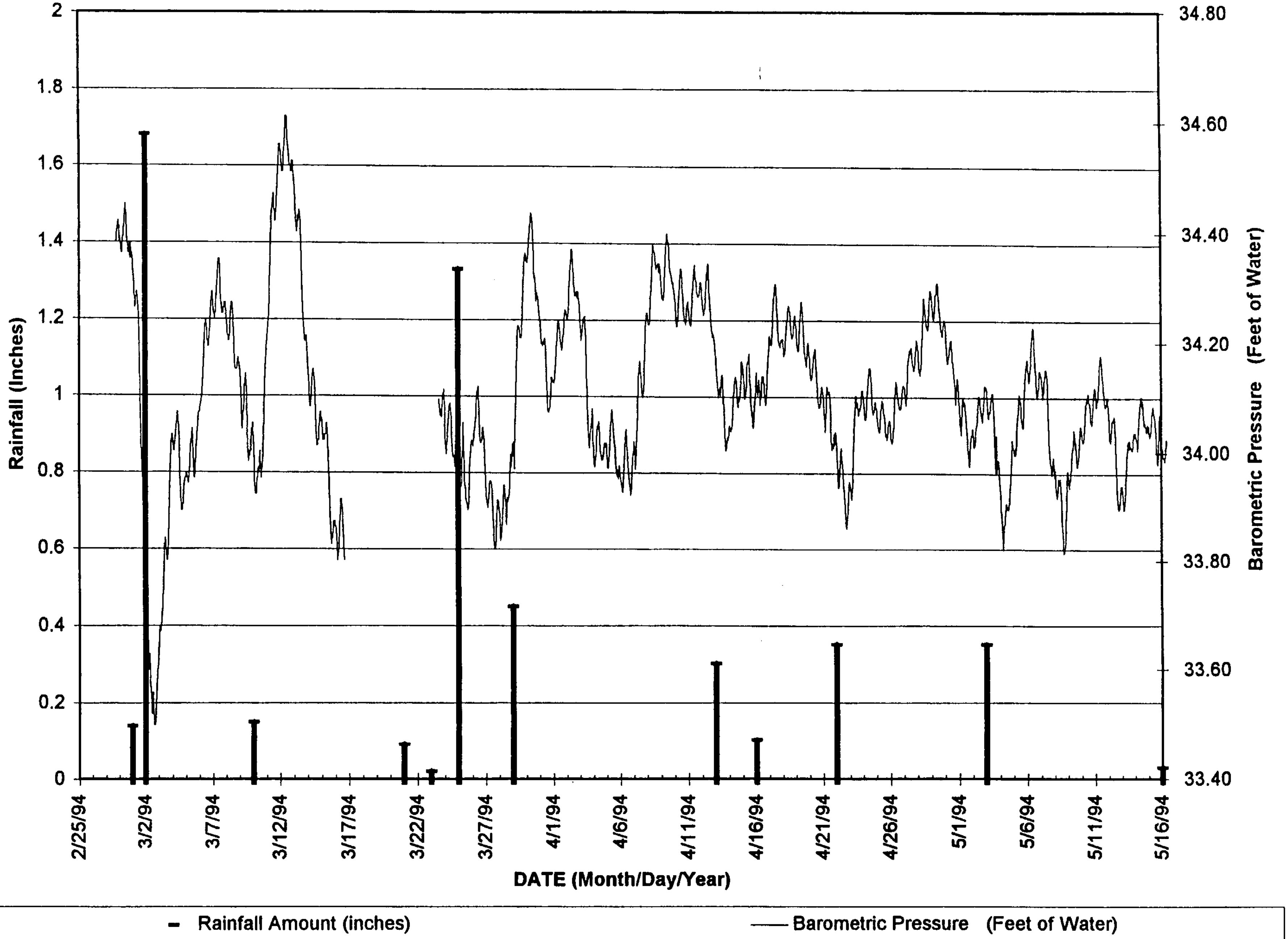
14. The corrected drawdown map was superimposed onto the unstressed (April 5, 1994) potentiometric map and corrected water-level elevations were added to the map at selected well locations (intermediate unit wells). An equipotential contour map of the corrected water-level elevations and the superimposed intersection points (drawdown contours and unstressed potentiometric contours) was generated.

15. Flow lines were generated normal to the equipotential contours. All flow lines that are directed to the recovery well system create an empirical capture zone at steady-state conditions.

APPENDIX B

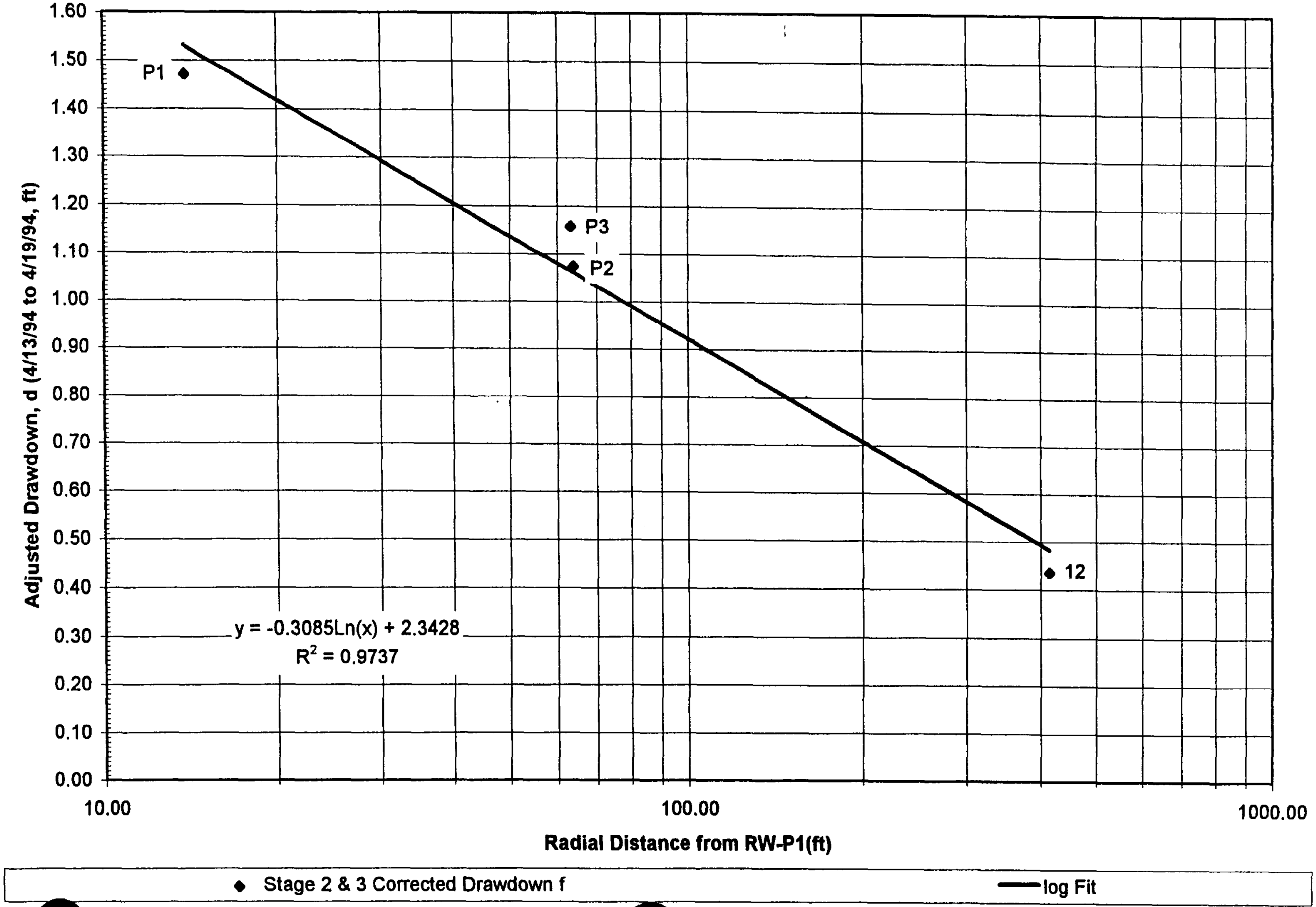
BAROMETRIC PRESSURE AND RAINFALL FOR INTERIM MEASURE PHASE I ACTIVITIES

NSB KINGS BAY, SITE 11
Interim Measure Phase 1 Activities
Daily Rainfall Amounts and Barometric Pressure vs. Date

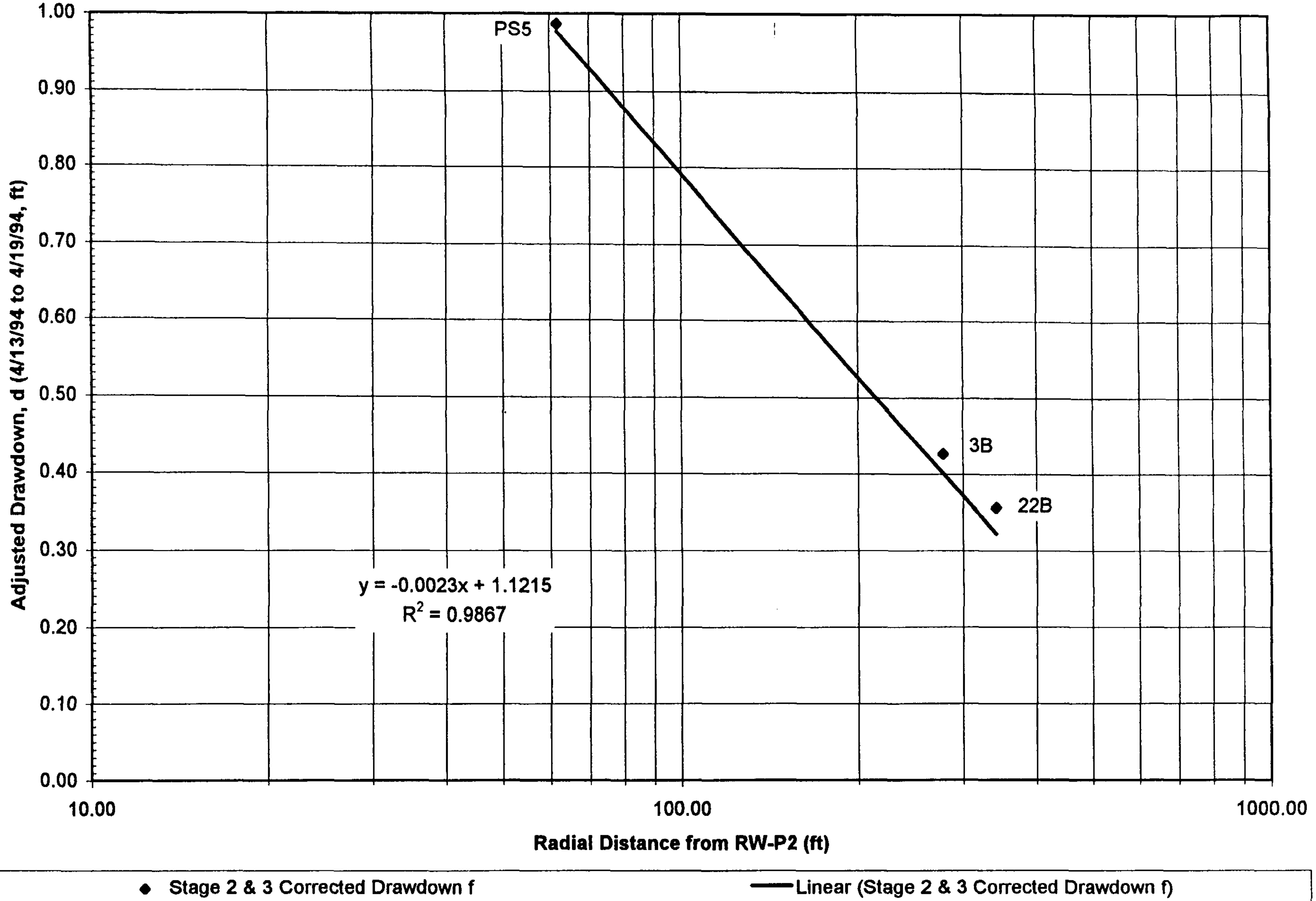


4/10/96 8:16 AM
RAINFALL.XLE:Rainfall & Barometric Pressure

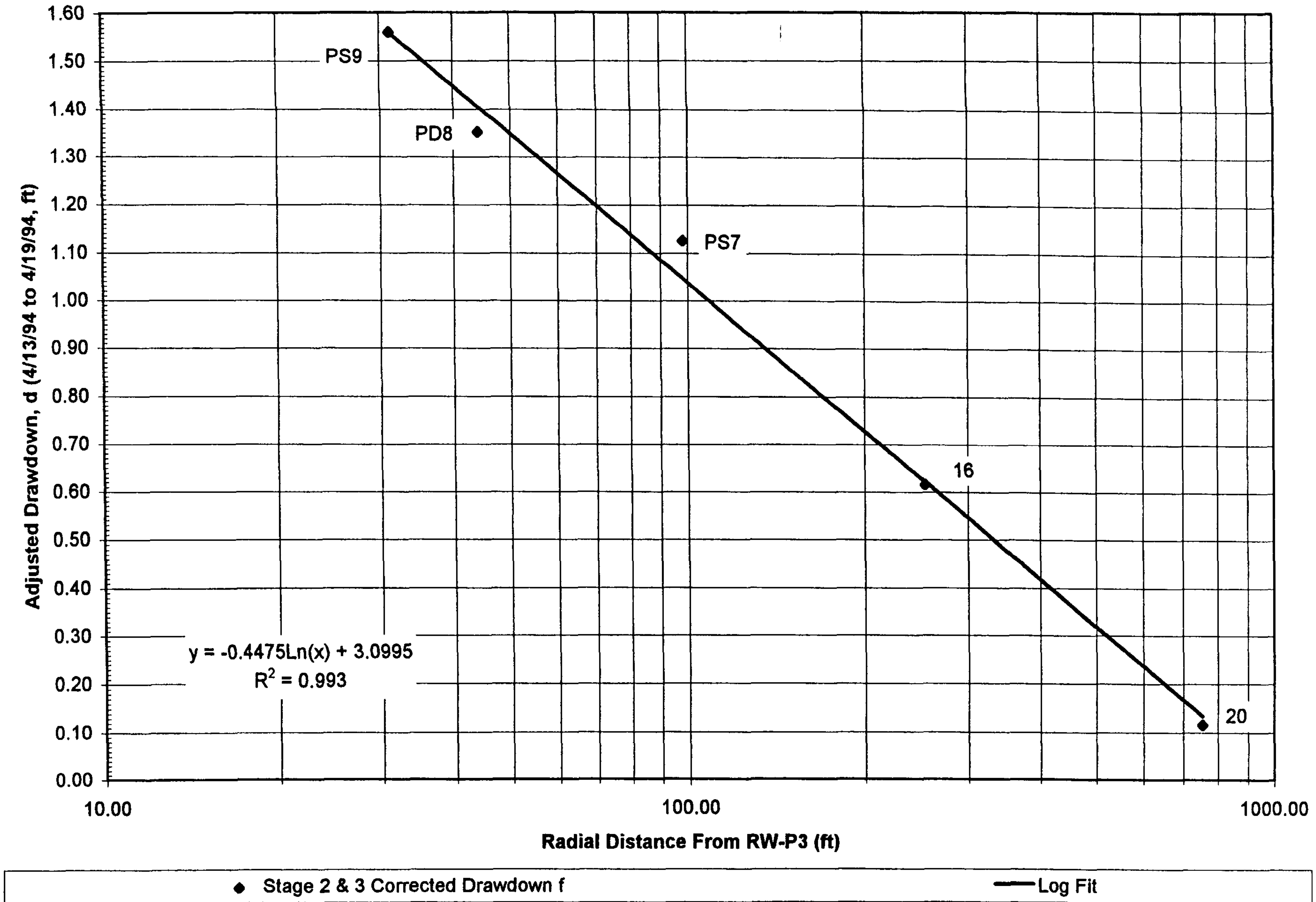
NSB KINGS BAY, SITE 11
Interim Measure Phase 1 Activities
Radial Distance From RW-P1 vs. Adjusted Drawdown



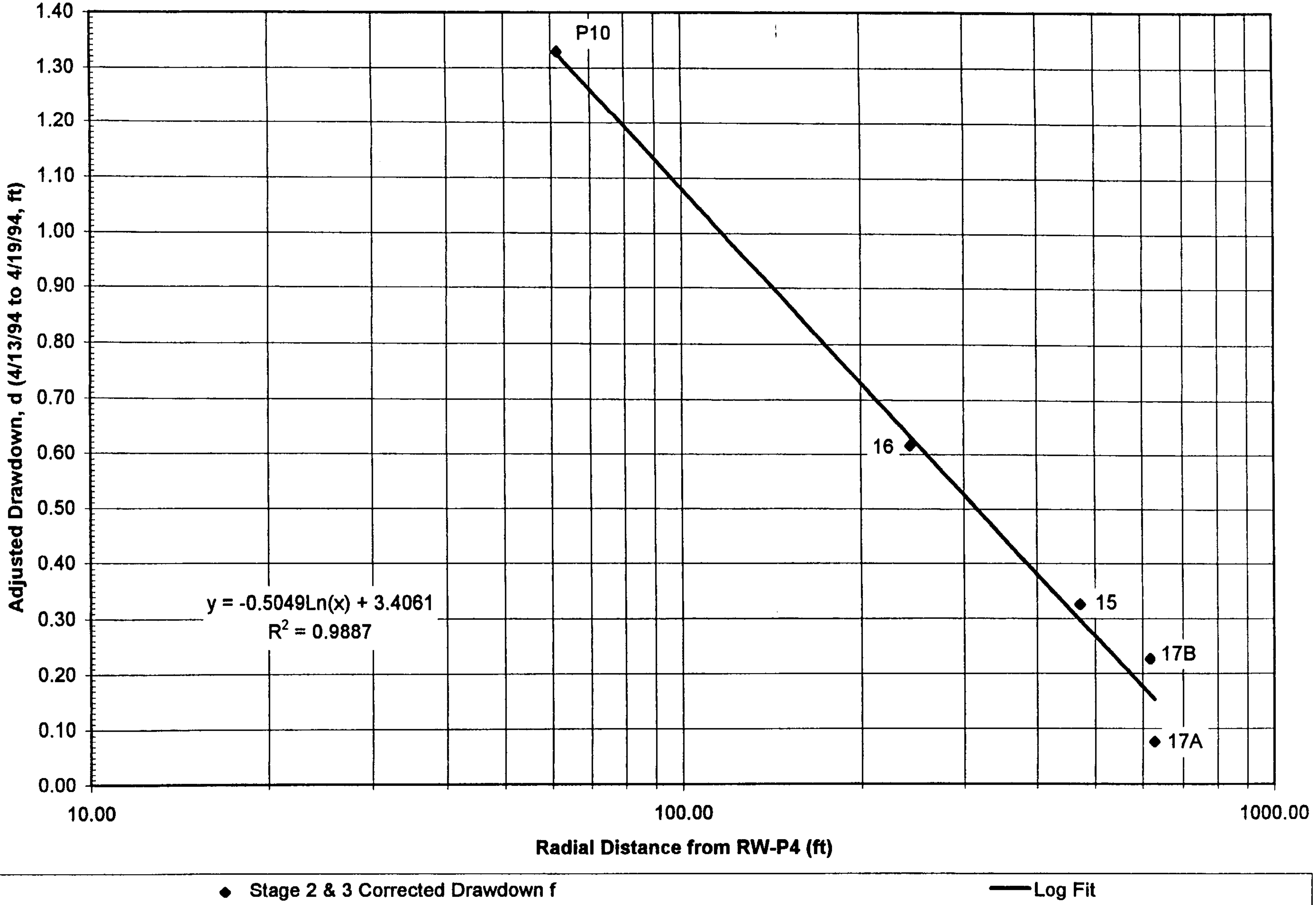
NSB KINGS BAY, SITE 11
Interim Measure Phase 1 Activities
Radial Distance From RW-P2 vs. Adjusted Drawdown



NSB KINGS BAY, SITE 11
Interim Measure Phase 1 Activities
Radial Distance From RW-P3 vs. Adjusted Drawdown



NSB KINGS BAY, SITE 11
Interim Measure Phase 1 Activities
Radial Distance From RW-P4 vs. Adjusted Drawdown



4/10/96 2:59 PM
SUMMARY.XLE:RW-P4

APPENDIX C

FLOWPATH™ DATA

Model Setup. A capture zone model for the Phase I GWE system was created using FLOWPATH™ (developed by Waterloo Hydrologic Software, Inc.), a finite difference model for two-dimensional, steady-state flow through a heterogeneous, saturated, anisotropic, porous medium.

The model domain developed for this evaluation is 3,000 by 3,000 feet. The size of the model domain was selected to provide a focus on Site 11 and allow constant head boundaries to be set outside of the GWE well(s) radius of influence. A rectangular grid was superimposed over the computer-aided drafting and design (CADD) drawing forming 957 (29 by 33) grid cells. The dimensions of each of these rectangular cells were set at 50 and 200 feet long (parallel to the general flow direction) by 50 and 200 feet wide (normal to the general flow direction) (see Figure 2-6). These cells are smaller (50 feet by 50 feet) in the area of the recovery wells to provide better resolution of hydraulic heads and flow characteristics of the modeled extraction system. The intersections of the grids form 30 nodes along the x-axis (east to west direction) and 34 nodes along the y-axis (north to south direction). The resulting model grid (or blocks) is shown on Figure C-1.

FLOWPATH™ uses a block-centered finite difference scheme so that aquifer properties for this unconfined aquifer are defined for each block. Aquifer parameters--were based on site-specific data collected during the Phase I GWE installation and operation activities. These parameters are discussed in Subsection 2.3.3.

Model Implementation. FLOWPATH™ model runs were generated for the following three groundwater flow scenarios: the first two scenarios simulate (1) groundwater flow under natural conditions without any pumping and (2) extraction of contaminated groundwater from the aquifer using the Phase I existing recovery wells. The third scenario involved continued extraction of groundwater from the Phase I wells with additional discharge from one Phase II recovery well. This third scenario is described below. (Note: Scenarios 1 and 2, simulations of Interim Measure (IM) Phase I operations, are described in previous Section 2.3.) Model-generated output from these scenarios are included in this appendix.

Scenario 3: a proposed RW-6 located between RW-3 and RW-4 on the east side of Spur 40 (Figure C-1). This scenario served as a predictive tool for capture zone analysis of a proposed Phase II IM extraction system. The extracted flow is maximized at RW-6 to increase flow toward the center of the capture zone and maintain the lowest pumping elevation in this center area. The capture zone for this proposed model scenario is shown on Figure C-2.

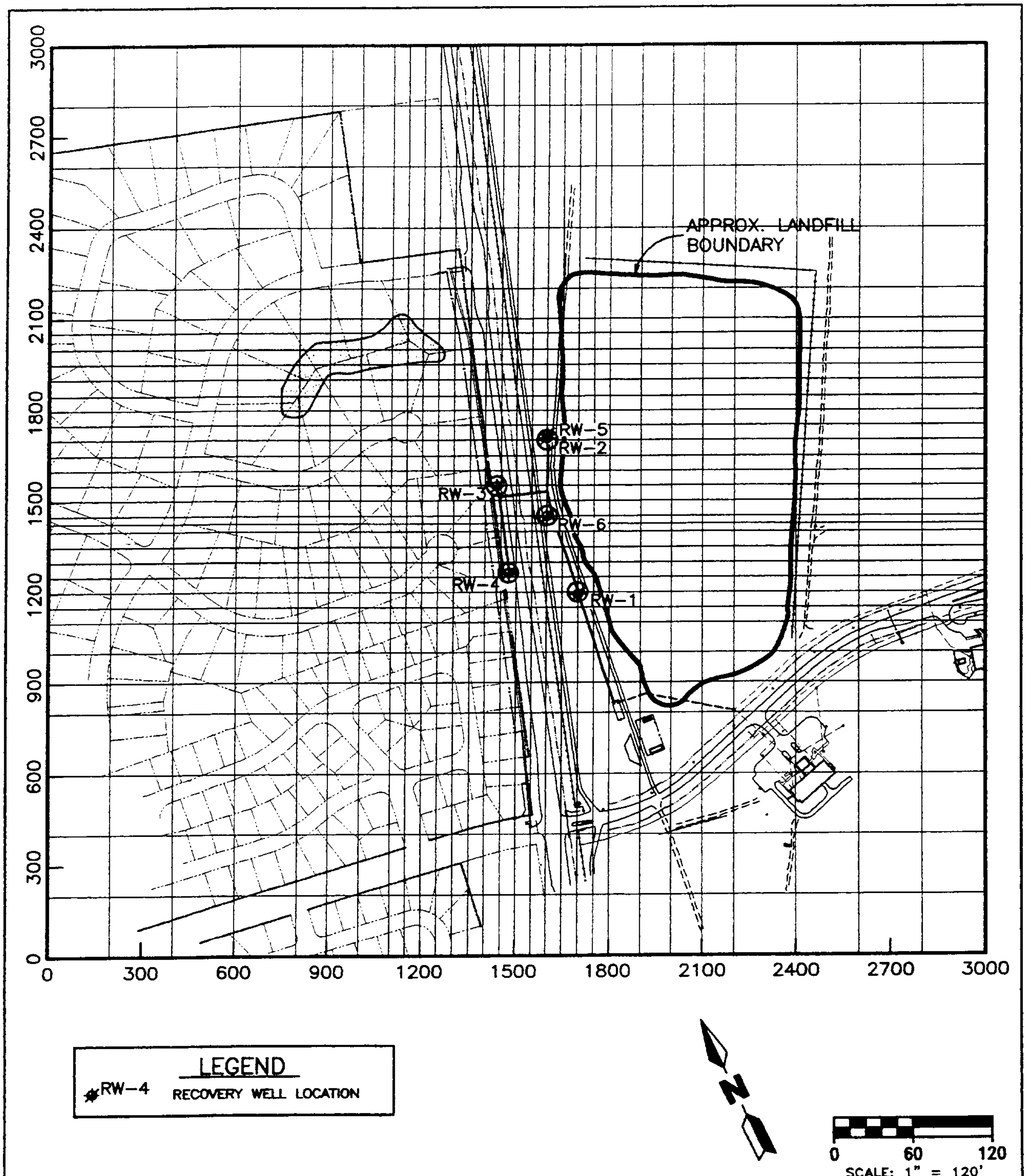


FIGURE C-1

FLOWPATH™ MODEL GRID WITH PHASE I AND PROPOSED PHASE II WELL LOCATIONS

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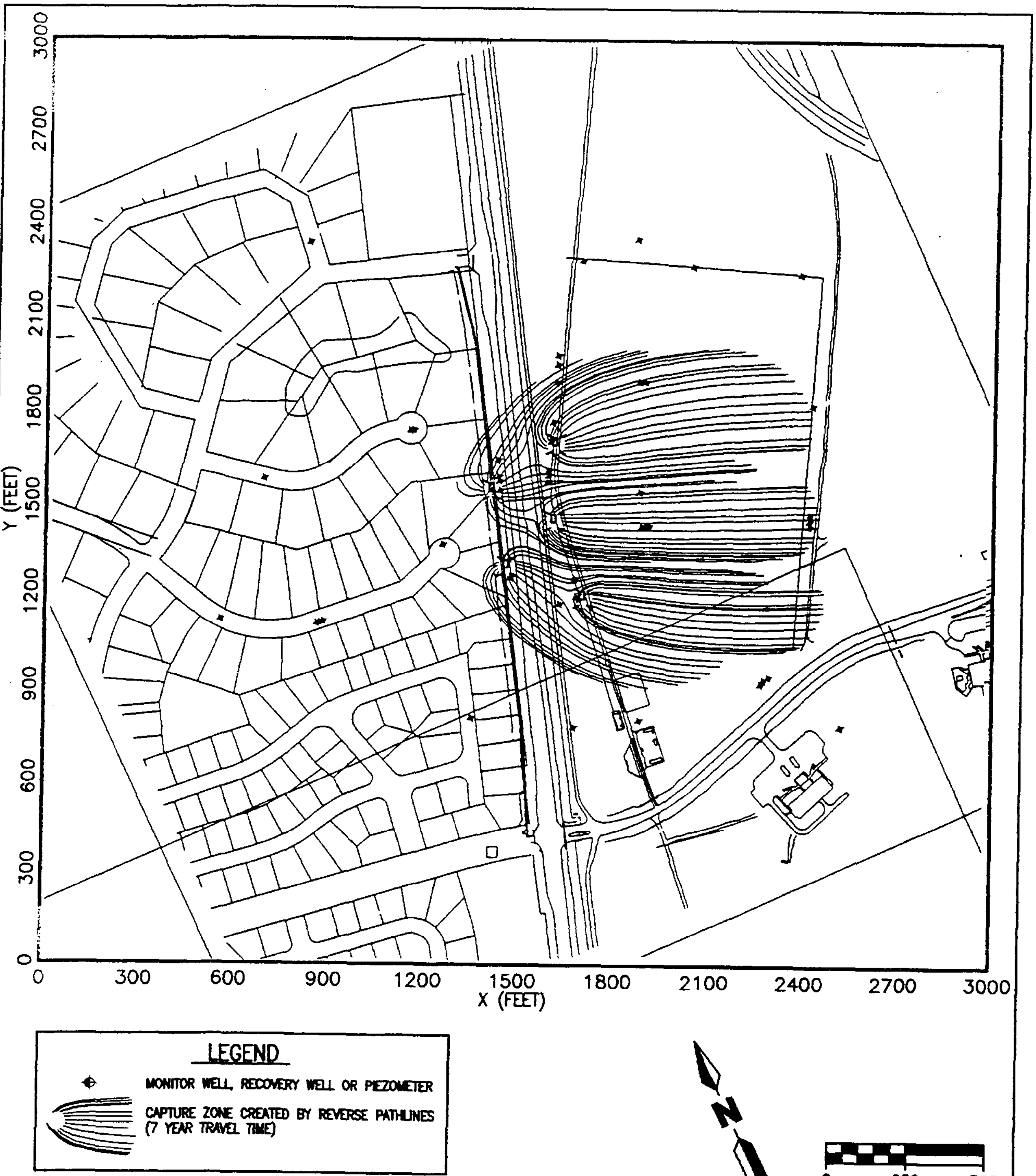

FIGURE C-2

SCENARIO 3:
SIMULATED CAPTURE ZONE IM PHASE II
ONE ADDITIONAL WELL (RW-6)
FLOWPATH™ MODEL FILE: PH2CZ1.DXF

IM PHASE I ACTIVITIES
EVALUATIONS AND RECOMMENDATIONS
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SITE 11, OLD CAMDEN
COUNTY LANDFILL

NAVAL SUBMARINE BASE
KINGS BAY, GEORGIA

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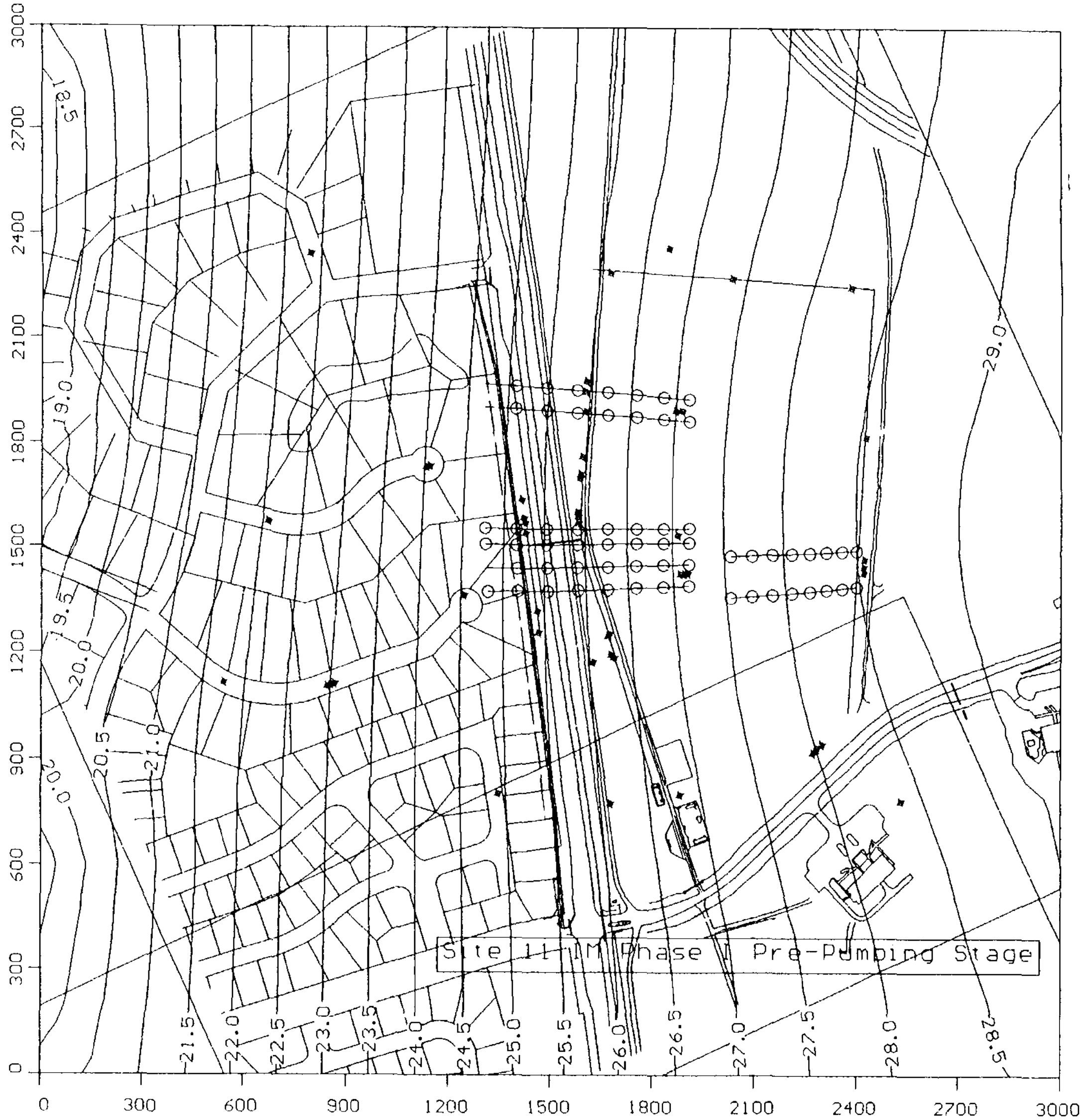
Unstressed, Natural Flow Simulation (Scenario 1)

- Potentiometric Surface
- Potentiometric Surface Simulation, Zoom-in to Landfill
- Velocity Vectors and Pathlines with Time (1 year) Markers, Full View
- Potentiometric Surface Simulation, Zoom-in to Landfill



FLOWPATH 5.11

Model Dimensions

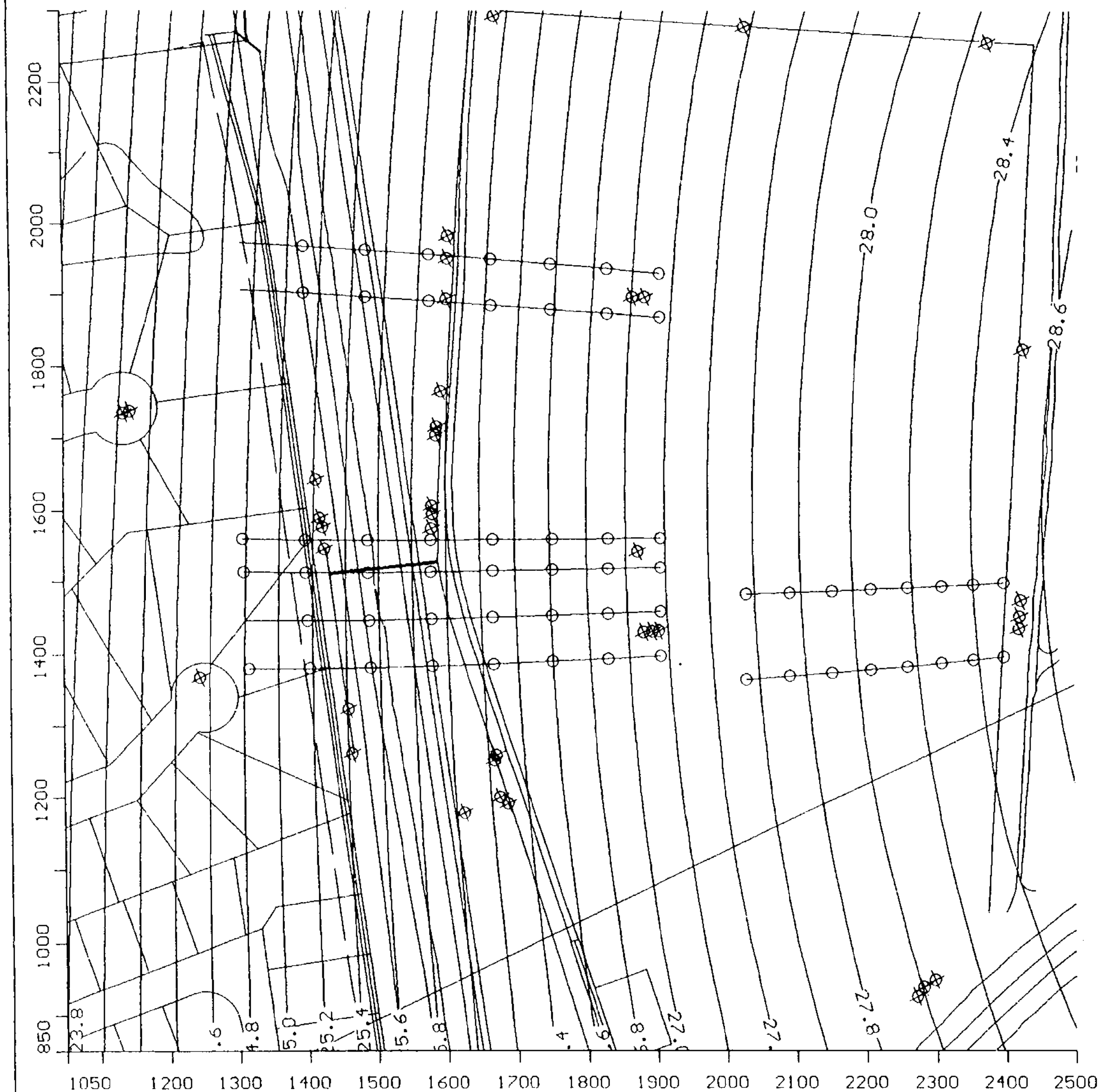
No. rows : 33
No. columns : 30
No. pumps : 0
No. injct : 0
No. const. heads : 38
No. const. flux : 0
No. river nodes : 0
No. drain nodes : 0

Hydraulic Heads (ft)

Min : 18.250
Max : 29.500

Units : [ft][day]

Data Set : S11NAT



FLOWPATH 5.11

Model Dimensions

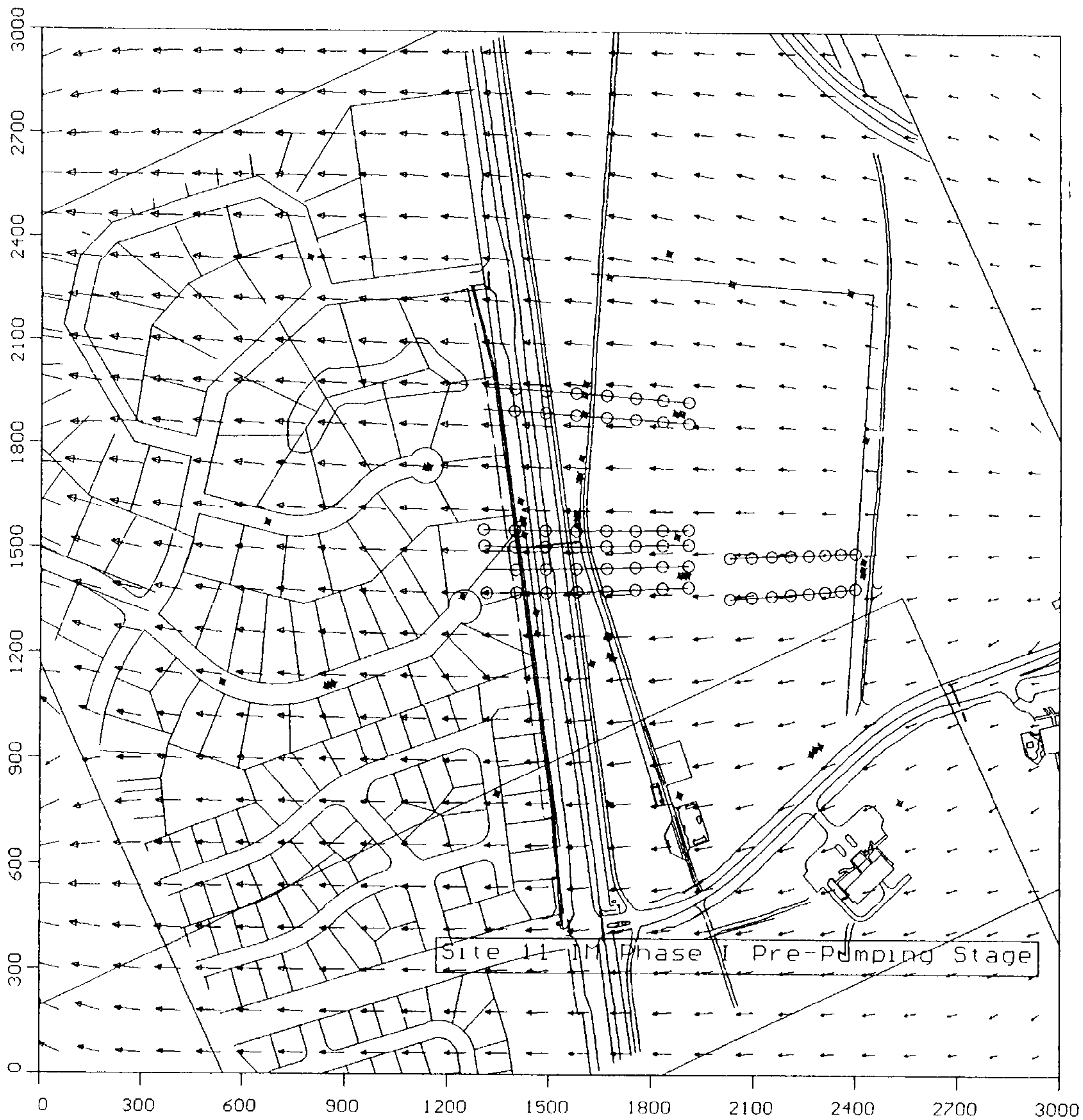
No. rows	: 33
No. columns	: 30
No. pumps	: 0
No. injct	: 0
No. const. heads	: 38
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

Hydraulic Heads (ft)

Min :	18.250
Max :	29.500

Units : [ft][day]

Data Set : S11NAT



FLOWPATH 5.11

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Model Dimensions

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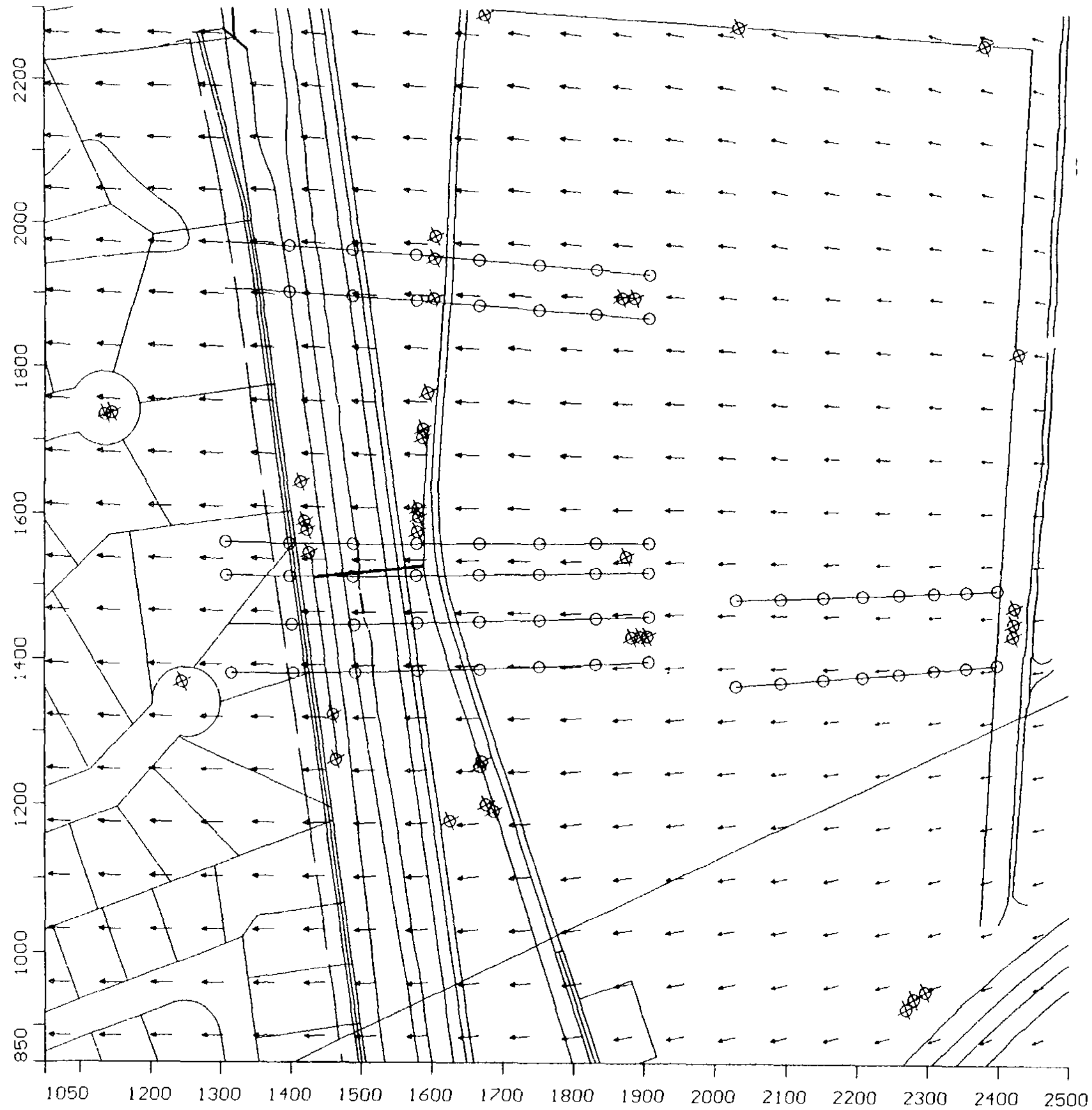
No. columns	:	30
No. pumps	:	0
No. injct	:	0
No. const. heads	:	38
No. const. flux	:	0
No. river nodes	:	0
No. drain nodes	:	0

Velocities (ft/d)

Min :	0.058
Max :	0.359
Avg :	0.202

Units : [ft][day]

Data Set : S11NAT



FLOWPATH 5.11

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software

Model Dimensions

No. rows : 33
No. columns : 30
No. pumps : 0
No. injct : 0
No. const. heads : 38
No. const. flux : 0
No. river nodes : 0
No. drain nodes : 0

Velocities (ft/d)

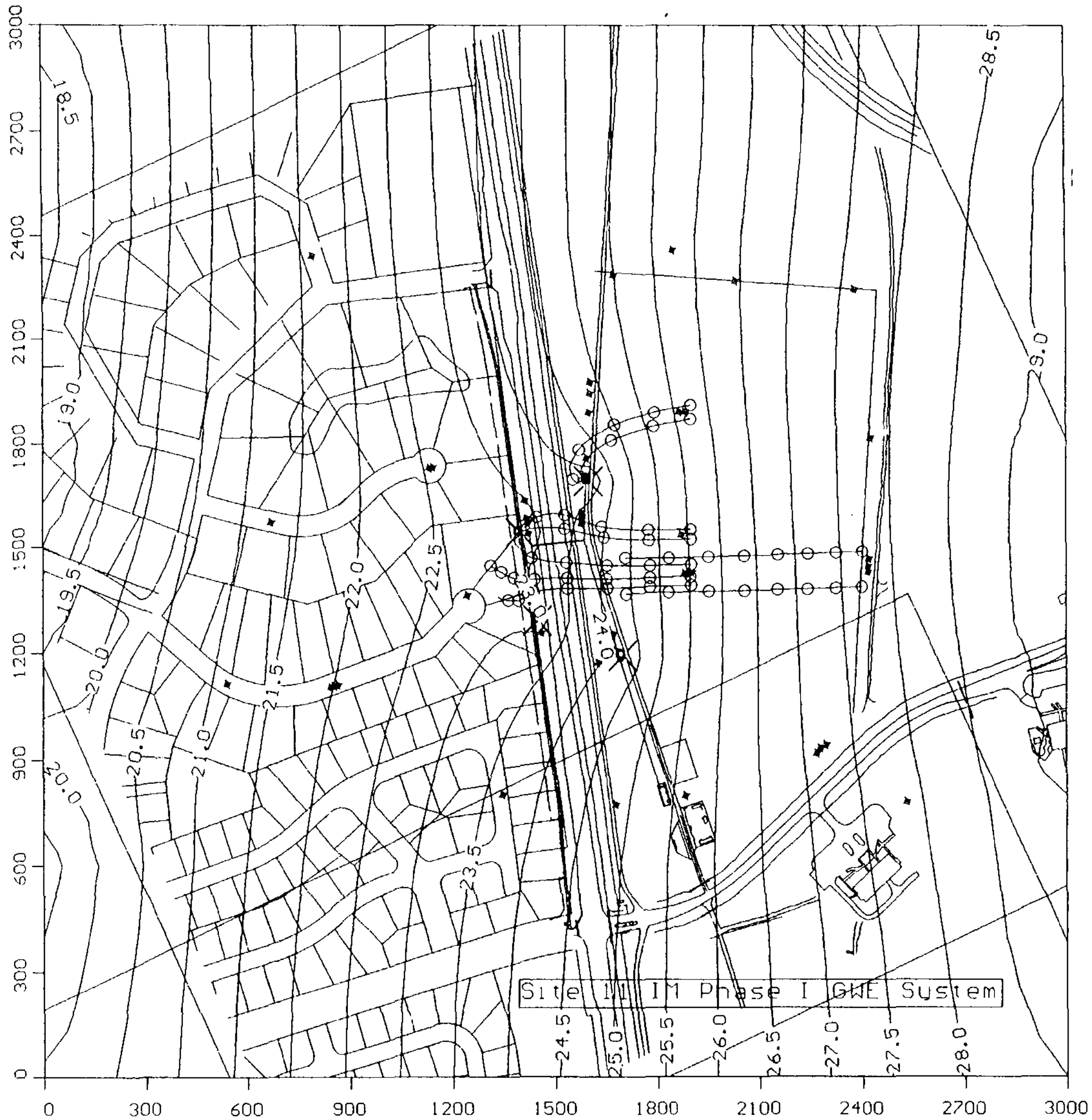
Min : 0.107
Max : 0.259
Avg : 0.202

Units : [ft][day]

Data Set : SIINAT

Phase I Groundwater Extraction (GWE) System Operations Simulation (Scenario 2)

- **Potentiometric Surface Simulation with Pathlines (1-year time markers)**
- **Potentiometric Surface Simulation with Pathlines (1-year time markers), Zoom-in to Landfill**
- **Potentiometric Surface Simulation with Pathlines (1-year time markers), Zoom-in to GWE System Recovery Wells**
- **Simulated Drawdown with Velocity Vectors and Pathlines (1-year time markers), Full View**
- **Simulated Drawdown with Velocity Vectors and Pathlines (1-year time markers), Full View, Zoom-in to Landfill**
- **Simulated Capture Zone with Pathlines (1-year time markers), Full View**
- **Simulated Capture Zone with Pathlines (1-year time markers), Zoom-in to Landfill**



FLOWPATH 5.11

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Model Dimensions

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No. injct	: 0
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No. const. flux	: 0
No. river nodes	: 0
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Hydraulic Heads (ft)

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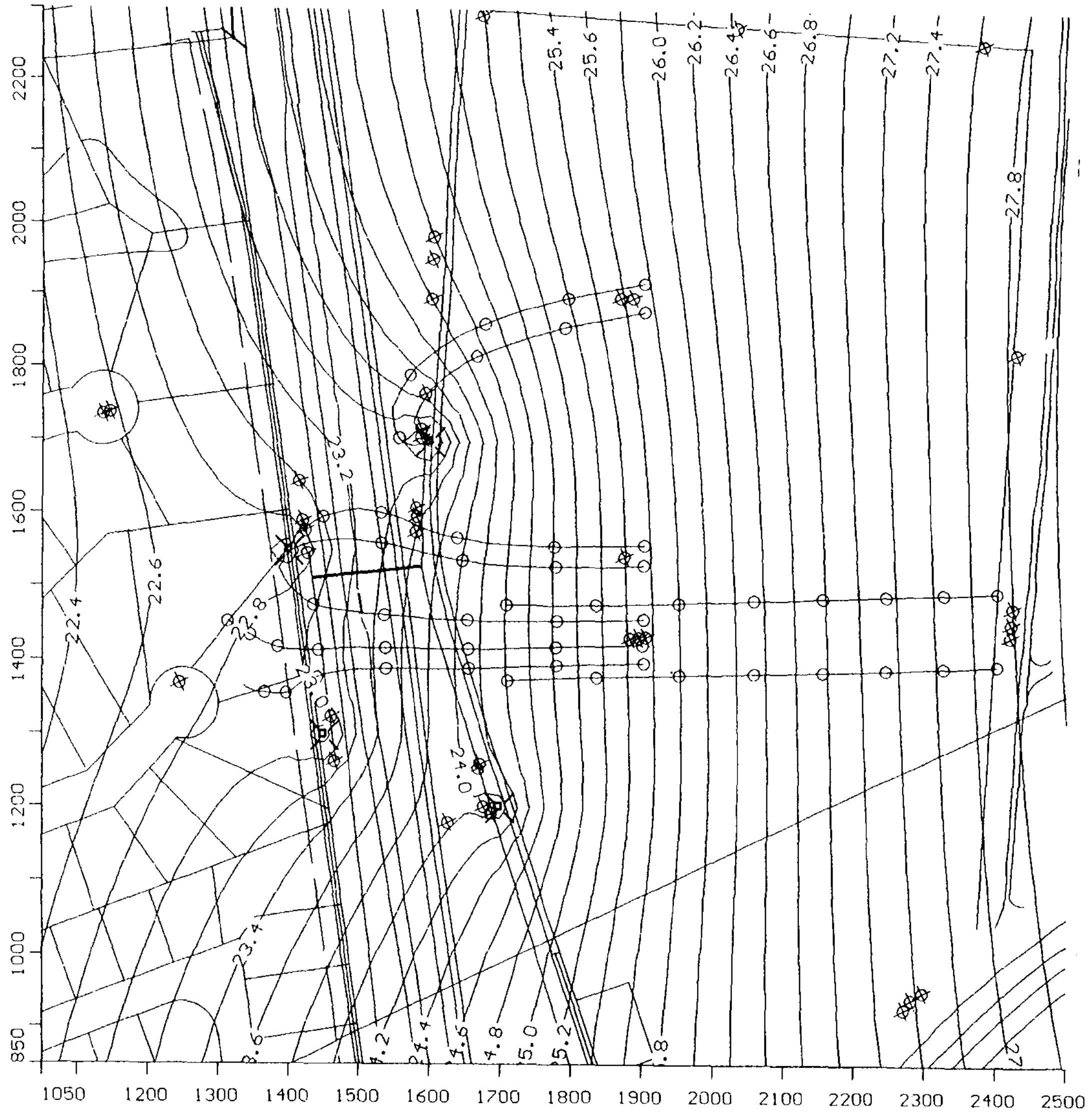
Max :	29.500

Units : [ft][day]

Data Set : S11CZ1



FLOWPATH 5.11

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Model Dimensions

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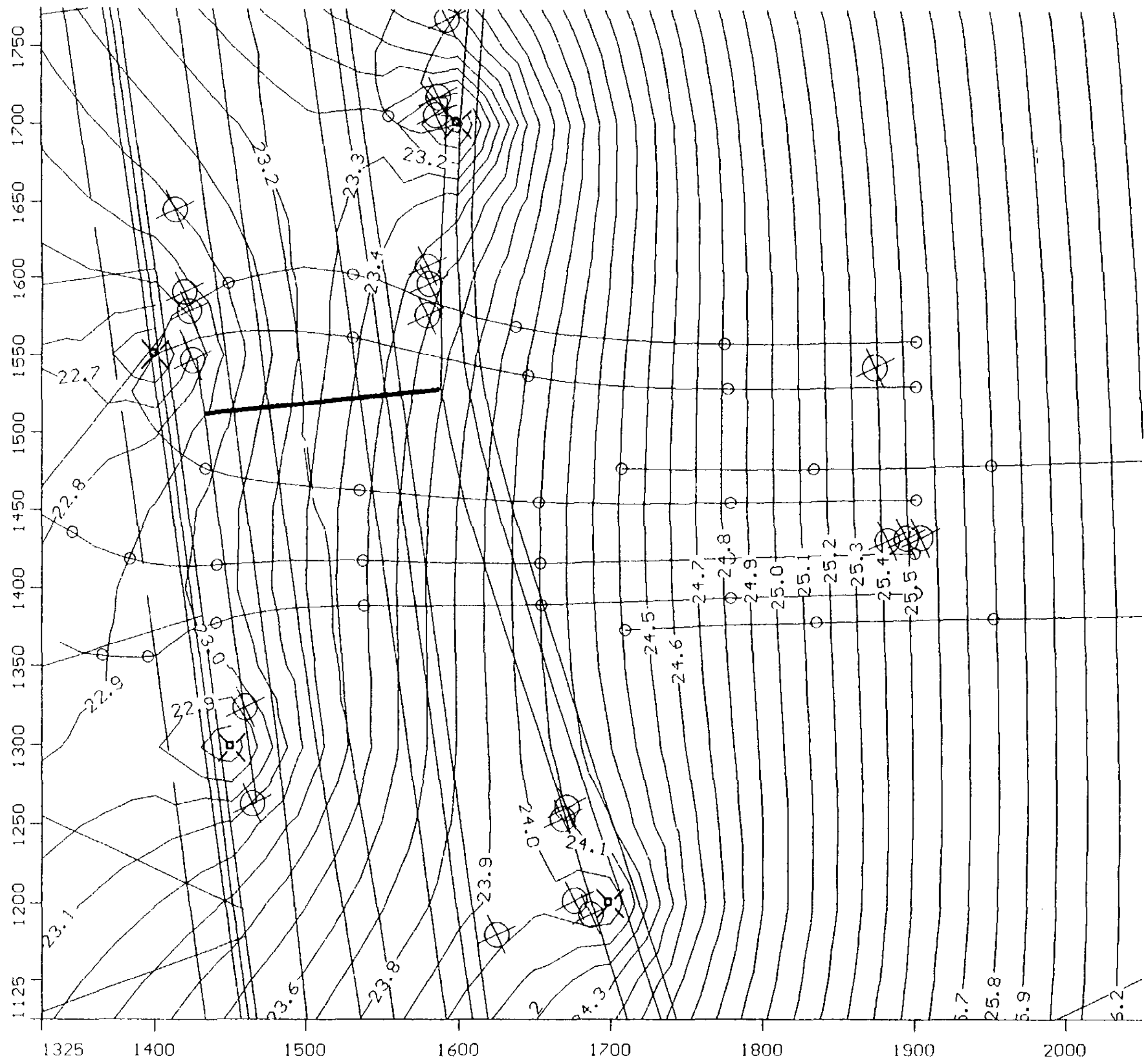
No. columns	: 30
No. pumps	: 4
No. injct	: 0
No. const. heads	: 38
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

Hydraulic Heads (ft)

Min :	18.250
Max :	29.500

Units : [ft][day]

Data Set : S11CZ1



FLOWPATH 5.11

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Model Dimensions

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No. const. flux : 0
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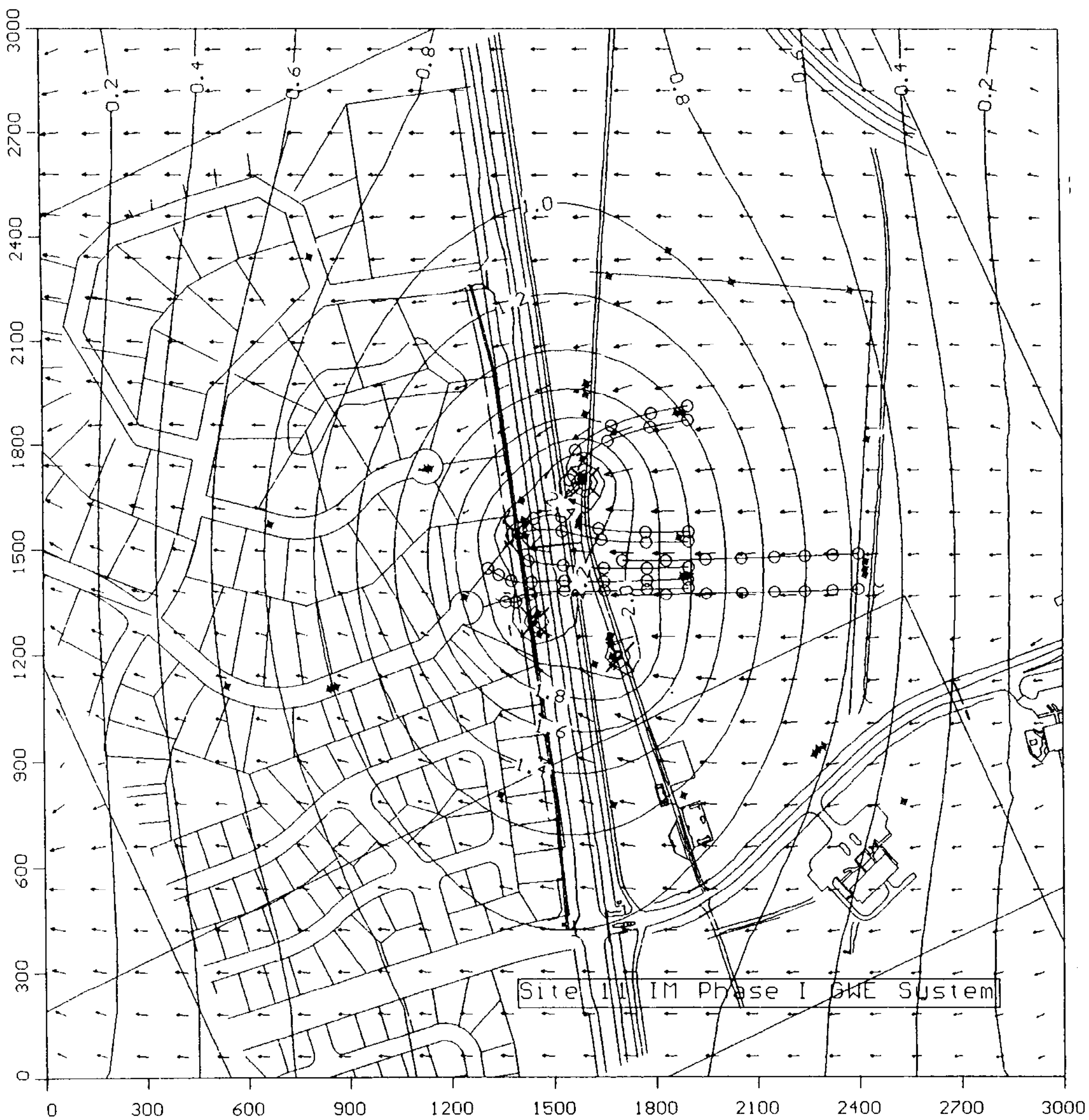
Hydraulic Heads (ft)

Min : 18.250
Max : 29.500

Units : [ft][day]

Data Set : S11C71



FLOWPATH 5.11

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Model Dimensions

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No. columns	:	30
No. pumps	:	4
No. injct	:	0
No. const. heads	:	38
No. const. flux	:	0
No. river nodes	:	0
No. drain nodes	:	0

Drawdown (ft)

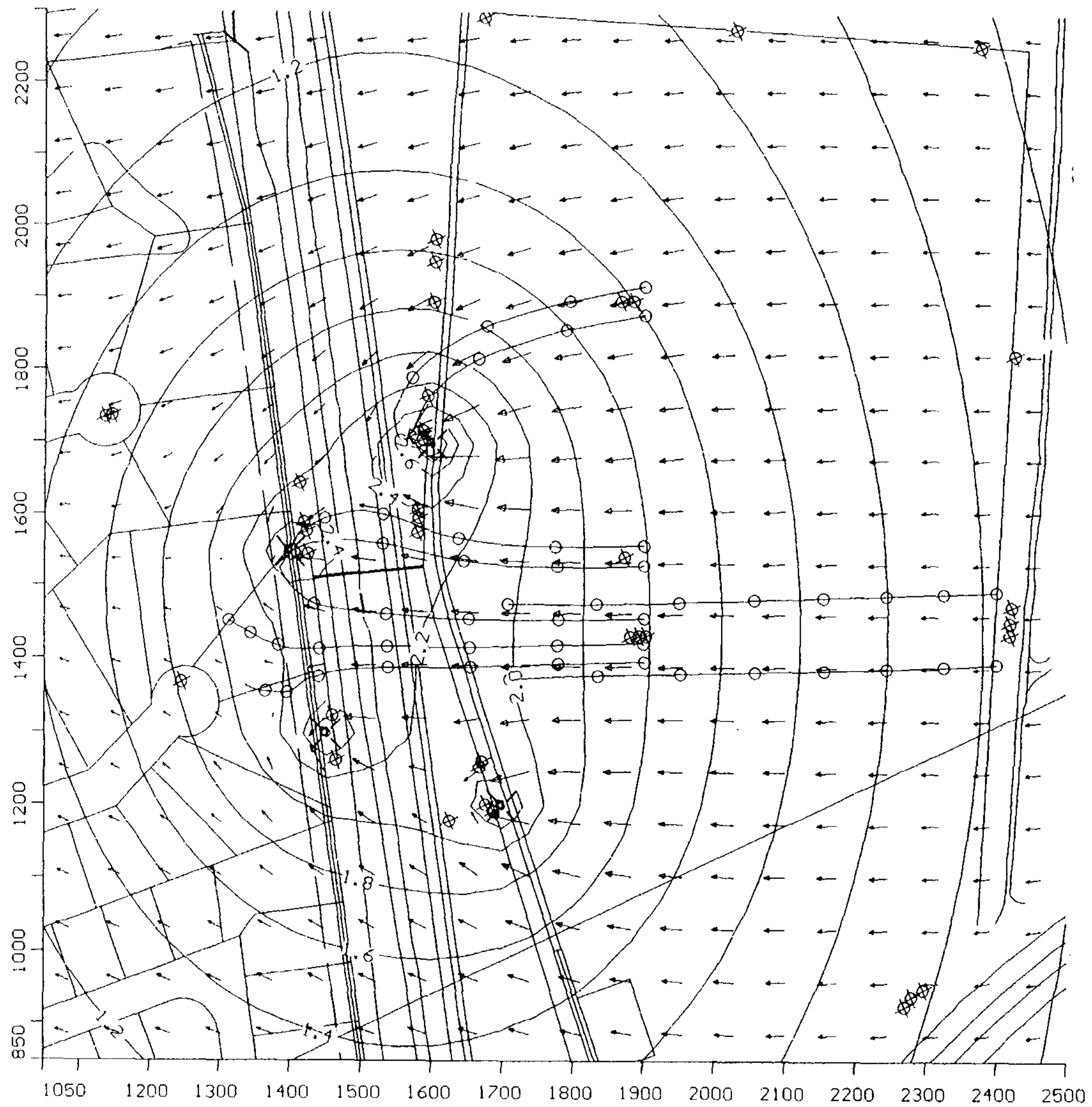
Min	:	-0.000
Max	:	3.050

Velocities (ft/d)

Min	:	0.077
Max	:	0.600
Avg	:	0.204

Units : [ft][day]

Data Set : S11CZ1



FLOWPATH 5.11

Model Dimensions

No. rows : 33
No. columns : 30
No. pumps : 4
No. injct : 0
No. const. heads : 38
No. const. flux : 0
No. river nodes : 0
No. drain nodes : 0

Drawdown (ft)

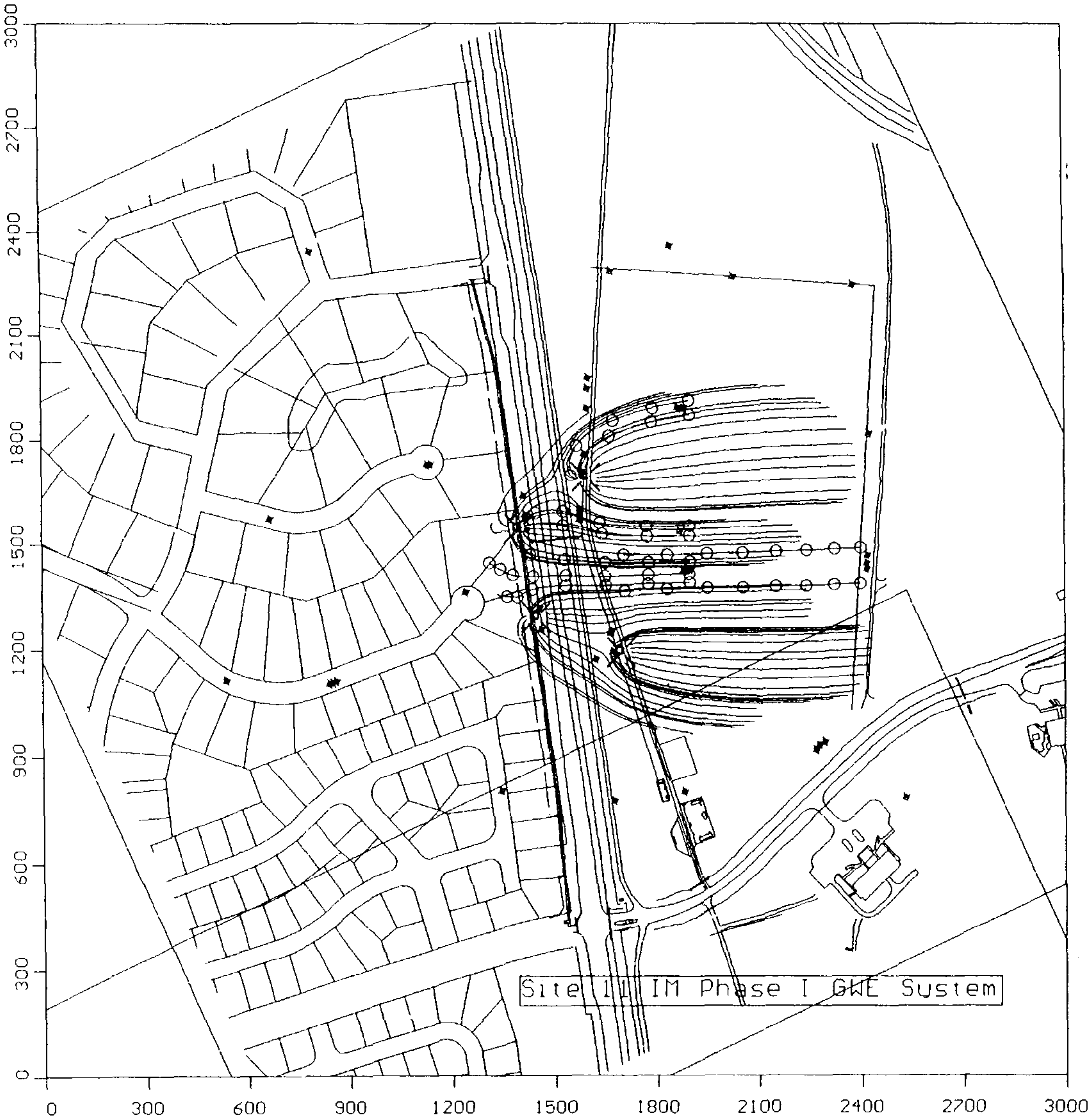
Min : -0.000
Max : 3.050

Velocities (ft/d)

Min : 0.026
Max : 0.619
Avg : 0.237

Units : [ft][day]

Data Set : S11CZ1



FLOWPATH 5.11

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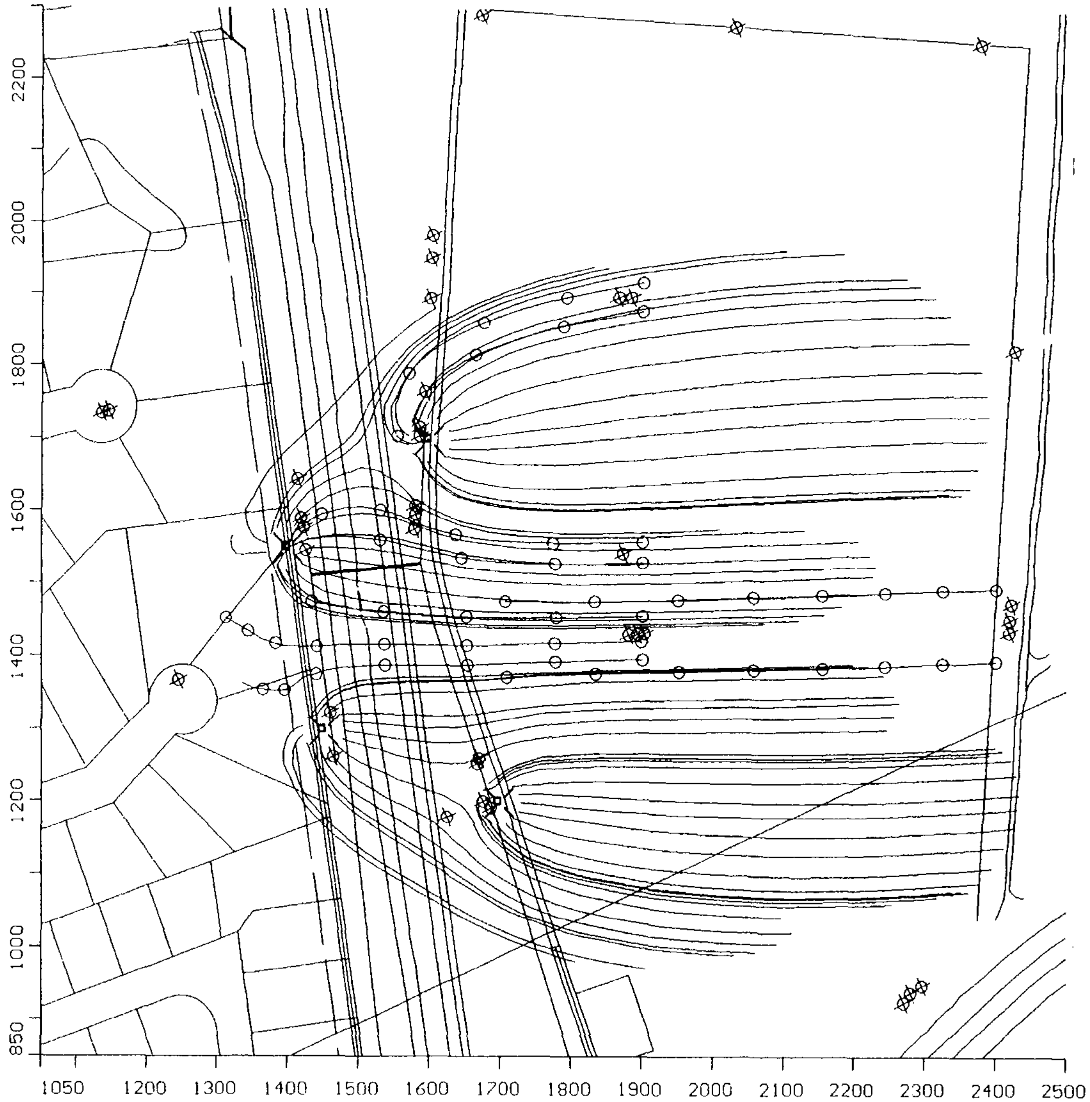
Units : [ft][day]

Data Set : S11C21



FLOWPATH 5.11

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Model Dimensions

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No. const. heads : 38
No. const. flux : 0
No. river nodes : 0
No. drain nodes : 0

Units : [ft][day]

Data Set : S11CZ1